Ephemeral wetlands and their turfs in New Zealand

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ABSTRACT

Ephemeral wetlands are widespread but localised in New Zealand, occurring mainly in surface depressions which have a marked seasonal alternation between being ponded during wet seasons but dry at other times. They typically support turf and sward vegetation having species-rich and distinctive biota. This report reviews current knowledge of ephemeral wetlands and their turf communities, describes their landform settings, vegetation processes and patterns, and flora, including threatened species. Threats, conservation issues, and future research needs are discussed. A classification of ephemeral wetlands is presented based on their association with different landforms (glacial, fluvial, coastal dunes, volcanic, bedrock depressions on schist and limestone, slumps, and man-made habitats). Turf habitats contain 419 native plant taxa (20.6% of native flowering plants) and 62 taxa (12.1%) of New Zealand's threatened or uncommon plants. These wetlands and their turfs are threatened by changes to major ecosystem processes (hydrology, soil nutrients), invasive weeds, and trampling and grazing by livestock.

Keywords: ephemeral, wetland, turf, sward, aquatic, conservation

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1. Introduction

Not all wetlands are permanently wet. One of the most poorly recognised types of wetland occurs where surface depressions in the land become ponded with water during wet seasons or wet years, yet are partially or wholly dry at other times. Inundation or substrate wetness is periodic and may be so infrequent that the wetland can be described as ephemeral. In extreme cases, the contrast between the states of ponding and drought can be so severe that the vegetation cover can be ephemeral, or else alternate between phases of aquatic and terrestrial plants.

The enigmatic nature of ephemeral wetlands is exemplified in a report titled 'When is a dryland a wetland?', wherein Ogle (1991) argues the case for the recognition and protection of ephemeral wetland habitats.

We consider ephemeral wetlands to be a distinctive wetland class, determined by a particular combination of landform, substrate, water regime, and nutrient factors. They are typically found in closed depressions lacking a surface outlet, in climates where seasonal variation in rainfall and evaporation encourages ponding in winter and spring, yet partial or complete drying in summer months or in dry years. Water source is groundwater or an adjacent water body. Substrates are usually wholly mineral, upon an impervious or slow-draining underlying horizon. Water flow is slow to nil, nutrient status moderate, and pH about neutral.

The geomorphological term 'closed depression' provides a generic term for land surface concavities having no watercourse outlet. Various terms have arisen in different parts of the world for depressions that are seasonally ponded. In the USA the term 'vernal pool' has been widely used (e.g. Zedler 1987), and Tiner (1999) uses 'depression wetland' for his wetland classification, but neither term has been adopted for this type of habitat in New Zealand.

In New Zealand, most ephemeral wetlands are found in closed depressions and these occur on a wide range of landforms and substrates, from coastal dunes to subalpine benches, on hummocky deposits of glacial, fluvial, or volcanic origin, and upon planar landforms of bedrock. In addition, ephemeral wetlands or their variants can occur beside larger bodies of water such as lakes and lagoons, beside man-made reservoirs or farm ponds, and sometimes in situations of hillside seepage.

Typically, in New Zealand, the vegetation of ephemeral wetlands has the stature of a turf. We define turf as a vegetation structural type of low stature (generally < 3 cm tall) of mainly herbaceous plants that are prostrate and tightly interlacing, forming a ground-hugging and often dense carpet of intertwined plants of numerous species. For vegetation of grasses or sedges having a somewhat taller stature and lawn-like structure we use the term sward. We consider both turf and sward to be a subset of the broader term herbfield. Most ephemeral wetlands display a strong pattern of zonation, correlated in some way with duration and periodicity of inundation. Zones of turf and sward communities often grade downslope to aquatic vegetation, and may merge upslope to rushland and sometimes scrub or forest.

Notwithstanding their localised distribution and small areal extent throughout New Zealand, ephemeral wetlands occur over a broad range of latitude and altitude. And despite the ephemeral habitat limiting the range of plant forms that can survive to mainly perennial, prostrate, small-leaved herbs, these comprise a very large diversity of often unrelated species having similar morphologies and life histories. Many of these plants are widespread, but others have disjunct or localised distributions, and some are nationally threatened.

It has long been known by botanists that ephemeral wetlands can be extremely rich and distinctive in terms of their vascular flora (e.g. Moore 1974). They also provide particular habitats for other plant forms (e.g. desmids; Flint & Williamson 1998, 1999), and for a unique invertebrate fauna (e.g. Burns et al 1984).

Biological study, conservation assessment, and management of New Zealand ephemeral wetlands have usually been carried out on a site-by-site basis, or within particular habitat types or regions. By considering ephemeral wetlands in a range of landform settings we have sought to gain an understanding of the hydrological, physical, and biotic features which all may have in common, and the conservation management principles which might therefore be applicable from one landform situation to another.

Ephemeral wetland ecosystems are threatened by alterations to the water regime, by physical modification of the landscape, by weed invasions, and by changes resulting from land development or intensification of productive land uses such as agriculture, horticulture, and forestry. The role of grazing and disturbance by livestock and other introduced animals needs to be considered, as these may favour the maintenance and domination by some plant species over others, and reduce, or increase, the risk of weed invasion in some circumstances. An understanding of natural processes and of anthropogenic (human-related) changes in turf communities is essential for management and conservation, including whether substrate disturbance may be required to maintain some communities.

This report provides an overview of New Zealand ephemeral wetlands, the turf vegetation and flora that characterises them, their processes, conservation management issues, and the needs for further research.

It should be noted that this account is not a nationwide survey of ephemeral wetlands, nor a systematic inventory of sites, nor an assessment of the adequacy of their conservation protection.

2. Objectives

- Review current scientific knowledge of ephemeral wetlands and their freshwater turf communities.
- Develop a classification framework for New Zealand ephemeral wetlands.
- Describe and illustrate examples of vegetation patterns and processes.

- Tabulate flora, highlighting threatened, uncommon, and characteristic species.
- Discuss threats and conservation management issues.
- Identify gaps in knowledge and needs for future research.

3. Methods

Our primary approach has been to collate existing information from vegetation survey reports, unpublished accounts, scientific literature, and from our own field observations over many years through the main islands of New Zealand. A limited amount of field study was undertaken, especially on landforms and in geographical regions that had been relatively unknown to us. Information has also been obtained from Department of Conservation regional scientists and other ecological colleagues.

In the field, our emphasis has been on observing and recording the range of variation of ephemeral wetland sites at each wetland system visited. Air photos were used to help interpret landforms and to gain some indication of seasonal water fluctuation patterns. Notes were made of wetland dimensions, morphologies, slopes, ponding depths, substrates, the general nature of soils, and other field clues to ecosystem functioning. The flora (principally of vascular plants) was recorded, along with an estimate of relative overall abundance of species.

A measure of vegetation zonation and composition was made at study sites selected as typifying the pattern at any one locality. For each zone of apparently consistent species composition an estimate was made of elevation range and horizontal extent upslope, together with a visual assessment of percent cover of plant species. These semi-quantitative data were collected as an indicative record of vegetation composition; we have not attempted to sample vegetation or analyse data towards any formal ordination and classification of turf types.

4. Scope of study

In this account we are focusing on an ecosystem and vegetation type characterised by four properties:

- Landform: some form of surface depression capable of holding a pond.
- Water regime: a general lack of through-flow water, and an alternation between being ponded and dried, the wetness and the wetland tending therefore to be ephemeral.
- Water chemistry: freshwater, not saline or brackish.
- Vegetation stature: a short and compact turf.

There are related habitats and vegetation types that are not considered as ephemeral wetlands in the strict sense. Many lakes have turf communities on their shores, but most lakes are fed and drained by streams and rivers, their size makes their shores subject to much wave action, while their depth and permanence account for many processes—such as stratification—that are typical of lakes. Accordingly, we have given less emphasis to lake-margin wetlands in this study, and to turf vegetation bordering permanent streams and rivers.

Almost all wetland types exhibit some fluctuations in water table level, but usually the contrast between being inundated and substantially dry is not sufficient for any peatland types—swamps, fens, and bogs—to be included within ephemeral wetlands.

By concentrating on freshwater wetlands we are not including turf vegetation that occurs in the saline or brackish conditions of coastal salt marshes, coastal lagoons, or inland saline sites. These habitats and their vegetation are relatively well described, e.g. by Partridge & Wilson (1988), Johnson & Partridge (1998), and Rogers et al. (1999). Nevertheless, we do include coastal dune hollows because these accumulate fresh water, despite their proximity to the coast.

Vegetation having the structure of turf can occur in many habitats other than strictly ephemeral wetlands, although generally in situations where some form of soil moisture variation is combined with other environmental stresses. Examples of these related habitats include coastal turfs (Rogers 1999), dwarf heaths, inland saline sites, certain bog margin communities, and snowbanks, and these will be discussed briefly in a later section.

5. Review of current knowledge

Most accounts of New Zealand ephemeral wetlands have been on a site-by-site basis, with documentation of the vascular plant flora and description of vegetation types. Some regional surveys have identified and described turf wetland sites, and there have been a few more detailed studies of zonation patterns, habitat processes, and impacts on water margin wetlands that include turf communities.

Ephemeral wetlands are sometimes overlooked as being wetlands and their lack of recognition has been elaborated on by Ogle (1991, 1994).

Kettle depressions of moraines provide an important habitat for ephemeral wetlands. Turfs of kettles through inland eastern South Island have been the subject of a suite of reports (Johnson 1978, 1980a, 1983, 1984, 1986a, 1990, 1991a, b, 1992a, b, 1994a; Johnson & Molloy 1988) describing their botany, biodiversity, and condition, often in the context of conservation questions on land use, land tenure review, reserve proposals, or assessment of waterbird habitats. Kettle turf in Canterbury has been described by Burrows (1977), Glenny et al. (1987), and in most detail for a single site at Cass in a thesis by Gilpin (1963).

Ephemeral wetlands with turf margins at various New Zealand sites are described in mainly unpublished botanical survey reports, e.g. for central North Island (Nicholls et al 1986), Hawke's Bay (Walls 1989), Northwest Nelson (Bartlett 1985; Courtney 1999), Otago (Johnson 1986b, 1993b; Johnson & Hewitt 1991; Wardle 1998), and Southland (Elliott & Ogle 1985; Johnson & Lee 1993). Many of the floristic lists of the late Tony Druce include coverage of turf wetland sites (e.g. Druce & Molloy 1991) and the disjunct distributions of many turf plants are outlined in Rogers (1989).

Protected Natural Area (PNA) surveys have not yet been completed for all of New Zealand's Ecological Districts or Ecological Regions, but the following published reports cover land areas where ephemeral wetlands are present: Eastern Hawke's Bay (Maxwell et al. 1993); Moawhango (Rogers 1993); Foxton (Ravine 1992); Balaclava, Sedgemere, and Dillon (Courtney & Arand 1994); Coleridge, Craigieburn, and Cass (Shanks et al. 1990); Mackenzie (Espie et al. 1984); Macraes (Bibby 1997); and Maniototo (Grove 1994).

For sandplain vegetation in the Manawatu, Esler (1969) provided an understanding of the distribution of turf plants relative to water table fluctuations. Ephemeral dune wetlands of the Manawatu–Wanganui coast have been further studied, e.g. by Ogle (1989a, 2000), partly in relation to management of threatened plant habitats. Studies by Singers (1997, 1998) at Tangimoana on this coast represent the first experiments on artificial disturbance of dune hollow substrates to encourage conservation of annual and threatened plants. Some New Zealand dune systems having interdune wetlands are identified in the inventories of Partridge (1992) and Johnson (1992c). For Northland dune lakes and wetlands there are the inventories of Cunningham et al. (1953) and Cunningham (1957). Impacts of sand movement are discussed by Ogle (1997), of plantation forestry by Collier (1996), and of cattle grazing by Tanner (1992).

Turfs of lake shores have received attention as part of studies related to management of lakes used for hydroelectricity generation, e.g. Lake Waikaremoana (Shaw 1998), Lakes Manapouri and Te Anau (Johnson 1972; Mark & Johnson 1985; Johnson & Burrows 2000), and Lake Monowai (Johnson 1991c). Other management issues of lake margin turfs, especially grazing and weed control, are covered by Champion & Shaw (2000), Champion (2000), and Champion et al. (2001). Because lake-margin turfs grade into permanently aquatic vegetation, descriptions of macrophyte communities are of relevance, e.g. Tanner et al. (1986).

Lake Wairarapa and its adjacent wetlands have been the location for several studies that illustrate the diversity of issues concerning ephemeral wetlands and freshwater turf vegetation. These include floristic accounts (Ogle & Moss 1984; Ogle et al. 1990), bird habitat study (Moore et al. 1984), water regime discussion (Ogle 1989b), monitoring of weedy and native grasses in an ephemeral wetland (Rebergen 2000), and plans for wetland management (Airey et al. 2000).

The biodiversity and scientific values of ephemeral wetlands extend beyond vascular plant vegetation. Kettle depressions, for example, have attracted studies on limnology and invertebrates (e.g. Burns et al. 1984), crustacea such as tadpole shrimp (Chapman & Lewis 1976), desmids (Flint & Williamson 1998, 1999), conservation of black stilts, and vegetation history (Burrows 1995).

6. Ecosystem properties

This section describes the general features of landform, climate, and hydrology that are common to all New Zealand ephemeral wetlands: these are the major environmental drivers for this system.

6.1 PHYSICAL GEOGRAPHY

Landforms containing closed depressions are those which tend to have a predominantly horizontal and gently undulating ground surface, a substrate sufficiently impervious to allow ponding of surface water, and an absence of permanent inflowing streams. The water body is principally fed by surface flow and subterranean seepage from the surrounding catchment. These landforms (described further in Section 7) may be underlain by either solid rock or unconsolidated materials. At any one location, not all depressions necessarily hold ponded water: some may be too shallow, have insufficient catchment, or have a pervious base. Depressions that do hold ponds generally have a silty base, often of loess, though some in high-rainfall districts or where the base is impervious will accumulate organic matter and become bogs or peat pools.

Regardless of landform setting and substrate, a typical closed depression is approximately circular or oval in shape, and some tens of metres or at most a few hundred metres across: usually not large or deep enough to have the character or processes of a lake. Depressions are often more elongated in shape when occupying an abandoned river meander or a dune hollow. Depth when fully ponded is usually in the order of 1–5 m, the shores of relatively gentle gradient, and the ground surface quite even and firm underfoot, the predominantly silty soil lacking any significant proportion of organic matter. Subsoils are typically gleyed, a feature which must help keep water tables perched and ponding sustained.

Vegetation of turf stature will generally cover most of a depression but may grade to a taller sward around the perimeter and to aquatic macrophytes or bared muddy substrates in the base. Some ephemeral wetlands have a predominant sward vegetation across their base, e.g. of sedges such as *Carex sinclairii* (Ogle 1994). Soil fertility levels are probably moderate: mesotrophic in wetland terminology. The absence of through-flow water and the loss of water mainly by evaporation may concentrate plant nutrients and soluble salts.

Most closed depressions, being smaller than lakes, are much less affected by large waves generated over long wind-fetches. Lakeshore sediments are subject to constant cycles of erosion, sorting, and redistribution. Associated turfs are eroded to miniature scarps along the contour, and to perpendicular runnels by the winnowing action of wavelets. Wave-sorted silts, sands, and gravels, along with organic debris, plant propagules and living rhizome fragments of plants, are redeposited upon and among the turf as thin veneers or else as hummocky storm ridges. The precise impact of each storm event is governed also by severity, season, the elevation of water level, and whether water level is falling or rising.

In closed depressions, these lake processes are less pronounced, but there are other dynamic ways in which sediments are moved around, and vegetation disturbed and nourished. For example, the base (compared with the margins of a depression) may have sediment that is finer, deeper, and softer; or loose accumulations of organic matter if regularly ponded; or cracked silt during a drought phase, if complete drying occurs.

In a closed depression, fine sediments are not lost downstream but can be stirred up in shallow waters and deposited as a skin over turf plant foliage, often to remain in a dried state after the water level has dropped. The regular evaporation of surface water in ephemeral wetlands associated with closed depressions often leaves a drying skin, partly algal or cyanobacterial, partly silt, upon drying ground and this can variously act as a smothering sheet upon turf, as a moisture-retentive mulch, or as a new surface for plant colonisation. Often it becomes flaky and either accumulates in mud cracks, or is blown away. Seasonal water fluctuations and the marked contrast between submerged and dry conditions result in a very strong alternation between aerobic and anaerobic conditions in the soil.

6.2 CLIMATE

Ephemeral wetlands occur over a very wide range of latitude (virtually the full spread of the North and South Islands) and altitude (sea level to alpine zone), and neither the habitat nor the turf vegetation is determined solely by temperature factors. Similarly, they occur across a range of rainfall zones from 350 mm per annum (Central Otago) to over 3000 mm per annum (western Fiordland). However, there is a tendency for ephemeral wetlands to be most common in districts having relatively high rainfall, as well as a pronounced dry season. Ephemeral wetlands appear to be least common in regions were rainfall is both high and relatively uniform throughout the year. In areas such as Westland, for example, where closed depressions tend to be constantly wet, bog vegetation usually develops upon accumulated peat.

Most ephemeral wetland turf communities grow exposed to full sunlight, although some also occur on shaded lake margins and in forested wet depressions. Some ephemeral wetlands occur where winter snow accumulates, and these must have reduced light levels over the winter months. Likewise, frost must be common in the same locations, and most wetland turf plants tolerate frost and the associated physical upheaval of the freeze / thaw process.

Wind is a factor in ephemeral wetland systems in open, exposed situations. Some depressions (deflation or ablation hollows) are created by wind excavation of unconsolidated sediment. The depth of wind-eroded depressions is limited by the position of the water table. Wind is also the main agent for inputs of fine sediment (as dust) to closed depressions, and wind must increase evaporation rates from ephemeral wetlands at both their ponded and dewatered phases.

Climate has an indirect control on the nature of ephemeral wetlands by determining the vegetation types on adjacent lands. Surrounding forest vegetation will tend to decrease the amount of groundwater available to a depression, compared with scrub or grassland.

6.3 HYDROLOGICAL TERMS AND FACTORS

Water bodies

Several terms can be applied to the water bodies of closed depressions and we have adopted the following usage. A 'pond' by dictionary definition is a small, usually artificial lake: very applicable to the typical New Zealand farm pond, and an appropriate term for a small (say < 200 m diameter) water body in a depression. The term 'pool' suggests a smaller body of still water, perhaps relatively more stable in level and with steeper sides, such as occurs within bogs, rather than in closed depressions. A 'puddle' is a small (muddy) pool; some ephemeral wetlands have a seasonal phase of having a mere basal puddle, occasionally no larger than 1–5 m diameter.

When does a 'pond' become a 'lake'? Perhaps when its widest part is 0.5 km or more—the criterion used by Irwin (1975) in his checklist of New Zealand lakes. Yet many smaller bodies of water, including some dune lakes, kettle lakes, and oxbow lakes of closed depressions, could be validly referred to as lakes on the basis of depth, permanence, or local custom. A 'tarn' is a small mountain lake: the term tends to bridge the gap between pond and lake, and is a useful one for upland situations. Of course, not all tarns are closed depressions with turf vegetation. A 'lagoon' is a shallow lake, especially one linked to a river, lake, or the sea. In New Zealand, the term 'lagoon' is most often used for coastal water impounded behind sand or gravel beach ridges or associated with river mouths, but the term is also used for inland examples, some of which are ephemeral wetlands.

Wetness

Degrees of wetness are important in understanding ephemeral wetlands. A substrate may be moist (i.e. slightly wet), saturated (fully charged with water so that the water table is close to the ground surface), or submerged (ponded or flooded). We prefer to restrict the term 'flooding' to describe inundation by storm runoff from adjacent land, overflow from a stream or river, or the rise in water associated with tidal inflow. We favour the term 'ponding' for water collecting in a closed depression (Tiner 1999).

Hydrological factors

The nature of ephemeral wetlands and their distinctive zones of turf vegetation are determined by particular combinations of the source and depth of water, and the duration, frequency, and timing of wetness.

Source and movement

Ephemeral wetlands of closed depressions are inflow systems, i.e. they are a sink for water flow, rather than being conduits of throughflow (like rivers and most lakes) or origins of outflow. Water inputs are from precipitation (direct rain, snow, or snowmelt), surface flow (during and soon after rain events), and subsurface flow related to general groundwater levels or to perched water tables. Ponding is governed by the general absence of an outlet stream (though some depressions may have a maximum ponding level determined by an impermanent surface outlet), by poorly permeable substrates, and by evaporation and transpiration.

Fluctuation regime

Most closed depressions have the capacity to hold ponded water to a depth of between 0.5 and 2 m, but sometimes up to several metres. The uppermost ponding level is usually indicated by a distinct contour line marked by the elevation to which the predominant terrestrial plants descend. Many depressions dry out completely; others retain a basal pond of permanent water. We have no quantitative data on rates of rise and fall of water level, but suspect that, in general, water levels rise rapidly in association with rain events, and then fall gradually. In any one system, the ponds of adjacent depressions can have either similar or different water fluctuation patterns. Duration of ponded and dry periods varies with elevation, but for most turf-vegetated depressions the periods would be in the order of weeks or months, thus providing substantial times of both aquatic and aerial environment. Most ephemeral wetlands tend to become ponded during winter and spring and the pond then gradually lowers in level through summer. Rainfall at any season will cause regular minor fluctuations upon this general annual pattern, but unusually heavy rains, wet seasons, or wet years can fully recharge some depressions, irrespective of time of year.

Periodicity

The following definitions, adapted from Tiner (1999), describe the conditions of ponding (or, conversely, of dryness) in different zones or different wetland sites:

- Episodic = ponded rarely (say once every few years)
- Intermittent = ponded in one or a series of wet years, but not every year
- Temporarily = ponded for two weeks or less during spring / summer
- Seasonally = ponded through part of spring / summer but dry by late summer
- Near-permanently = ponded throughout the growing seasons of most years
- Permanently = ponded always.

The condition of being saturated rather than ponded can also vary in periodicity, permanence and seasonality. Turf substrates can maintain varying degrees of saturation or moistness through being immediately upslope of a relatively stable pond level, or via localised seepage from upslope.

Four annual development stages, outlined by Zedler (1987) for vernal pools in California, are of relevance to ephemeral wetlands in general:

- Wetting phase: autumn rains encourage a turf of seedlings and resprouts before ponding occurs.
- Aquatic phase: aquatic plants and animals proliferate; non-aquatic species are subject to varying degrees of stress.
- Drying phase: begins as water level recedes, but high soil moisture ensures continued plant growth.
- Drought phase: plants brown off unless deep-rooted; drying cracks appear; summer rains may do little to stimulate growth.

7. Landform settings as a classification framework

In the absence of any quantitative classification and ordination of turf vegetation types based on a comprehensive data set, we have selected landform as a convenient basis for recognising, discriminating, and describing ephemeral wetland habitats. Landform features of importance include geology, geomorphology, landscape position, and substrate.

Ephemeral wetlands occur most commonly on particular landform types of diverse geological and geomorphological origin, and less commonly in association with other local site factors such as ground movements and particular permeability regimes of substrates. The main landform settings are outlined below in a sequence from those with permeable substrates associated with glaciers, lakes, rivers and streams, wind-deposited dune systems, and volcanic substrates; to bedrock substrates (especially schist and limestone); then situations created by earth movements such as faults and landslides; and man-made habitats. The figures referred to in the following text are gathered at the end of the report.

7.1 GLACIAL LANDFORMS

Moraines dumped by glaciers are typically hummocky, with bowl-shaped depressions commonly lacking surface drainage, and capable of holding water, either as permanent or ephemeral ponds. The term 'kettle' (or kettle-hole) is applied to depressions caused by the melting of stagnant ice in a retreating glacier. At the onset of a glacial retreat a valley glacier ceases to deliver its transported load of rocks, gravels, and silts to the former snout. Within the lowermost trunk of the glacier, as fissures, channels, and glacier lakes expand and deepen, rocks and stones tumble in from their steep sides to accumulate as basal heaps and lines. Final melting of the last detached blocks of stagnant ice lowers the former glacier surface to a level below that of the adjacent accumulated heaps, thus forming kettles.

Kettles are most common on terminal moraines (Figs 1E, 2A), but occur also on lateral moraines along the flanks of former glaciers (Fig. 2D).

Not all depressions in glacial deposits are strictly kettles. Some are the result of a complex deposition history of moraine hollows, bedrock hollows, meltwater channels or outwash plains partly enclosed by till or alluvium (Fig. 2C). Sediment linings of kettles can include former lake deposits and loess derived from the abundant dust supplies of glacial outwash riverbeds. Many kettles contain solitary, massive erratic boulders, often frost-shattered since their placement, or else lines or groups of boulders representing temporary glacier-surface or sub-surface stream channels from a time before final ablation of the disintegrating glacier. Some kettles have a central basal accumulation of boulders and rock fragments, loosely packed and with silt-free interstices that

suggest a free drainage pathway to underlying pervious till. These areas of shattered rock are often sorted to stone nets by frost boils, a phenomenon otherwise more typical of alpine fellfield (e.g. Mark & Bliss 1970).

Kettles containing ephemeral wetlands are best developed on the moraines of large valley glaciers along the eastern side of the Southern Alps, inland South Island, from Marborough to northern Southland. These kettles are in a generally montane zone (c. 300–1000 m altitude) and in the rainshadow of the Alps, such that their current vegetation setting is usually short tussock grassland. Some kettles never hold ponded water and have grassland uniformly distributed across their bases. Other examples are small lakes with permanent water and a relatively stable water level controlled by a surface outlet. In high rainfall areas, especially those to the west of the Southern Alps, moraines tend to be forested. Their kettles and other depressions have less permeable bases, either because an iron pan has formed or because of peat accumulation, so that bog or swamp vegetation has developed rather than turf (e.g. Stengs 1986).

Aside from glacial deposit landforms, glaciation also produces eroded depressions in bedrock, especially on benches and spurs. Depending on the rock type, these bedrock depressions tend to hold permanent ponds having very little water level fluctuation and minimal development of marginal turf zones. Many alpine tarns are like this.

7.2 LACUSTRINE HABITATS

Lakes occupy landforms of many origins, including all of those dealt with elsewhere in this section. Nevertheless, for convenience we give lakes a separate mention here because many lakes have marginal zones of turf communities, provided they have areas of gentle shores with unconsolidated substrates, and a regular (but not excessive) water fluctuation (Figs 6D–F). In one sense lakes are larger versions of depression wetlands, but are more permanent, usually deeper, and with inflowing and outlet streams or rivers.

In addition to lakes themselves having turf communities, lacustrine systems can provide conditions suitable for closed depressions, especially where the hollows between storm ridges have been left in an elevated position following a permanent lowering of lake level (Figs 1A–D).

7.3 FLUVIAL LANDFORMS

Turf vegetation often occurs as scattered patches or as a marginal strip alongside some permanent river and stream courses, but the fluvial landforms which best provide for turf are those watercourses which have been abandoned yet still act as water sinks during seasonally wet periods.

Almost every alluvial valley floor or floodplain exhibits small patches of dry wash where the soil is most silty, moist for longest, and the vegetation is most lush. At a larger scale and with a greater degree of soil moistness, it is usual to find a moist or marshy channel running along the inner margin of each river

terrace, nourished by seepage from the scarp of the next highest terrace. This sort of habitat goes part of the way towards encouraging conditions for ephemeral wetlands.

Closed depressions in fluvial systems are best developed in valley floors having extremely gentle gradients, where migrating streams or river systems have produced numerous meanders, many of which become wholly or partly cut off as oxbows or abandoned channels, progressively less prone to flushing by floods, and increasingly adopting the character of ephemeral ponds (Figs 6A, B).

7.4 COASTAL DUNE SYSTEMS

Dune and beach systems contain vegetated wetland hollows of various sizes and origins (Figs 3A–H). Dunes are composed of sand that has been sorted and blown by wind and deposited where movement has been slowed by vegetation or a lee slope. Beach ridges are mounds where storm waves have done most of the sediment placement and where gravel and shingle are the main substrate materials. Dune and beach systems are most extensive where sand supply is plentiful and the coast is advancing seawards (prograding), a process that is more pronounced where land has risen relative to sea level as a result of sea level drop or land uplift.

Various wetland types including turf can occur in the following range of dune habitats:

- dune hollows: any hollow of whatever shape; most dune hollows are relatively dry.
- deflation hollows: hollows eroded by wind down to a level where sand moistened by the water table is no longer prone to being blown away.
- dune slacks: small vegetated depressions between shore dunes or in a sandbank; especially those which periodically hold slack (i.e. scarcely flowing) water at times of highest tides.
- swales: long narrow depressions between beach ridges and aligned roughly parallel to the coast.
- sand plains: extensive areas of low-lying sand country among scattered or distant dunes.

The substrates of dune depressions are mostly sand, though alluvial or wind-blown silt may accumulate in the base of some hollows. Drainage through sand substrates is inherently good, but ponding occurs when the water table is high (fresh water may be perched above underlying brackish or salt water). Some dune wetlands are adjacent to or else grade into estuarine, tidal river, or coastal saltmarsh vegetation, but many can be considered as basically freshwater types, despite their proximity to the ocean.

Some dune depressions and their ponds are fed by surface streams; all are fed by groundwater, which may come from a considerable catchment inland, hence a constancy of water such that many dune depressions hold permanent small lakes, albeit with fluctuating levels and turfy margins (Fig. 3G).

7.5 VOLCANIC SUBSTRATES

Volcanism has produced the right conditions for closed depressions, especially in the central North Island (Figs 4A–H), where eruptions on a grand scale have deposited airfall beds of volcanic ash (tephra) and pyroclastic flow materials (ignimbrite) of welded (non-gaseous) or pumiceous (gaseous) material that has produced blanket or plateau topography. In addition, incremental accumulation of cold airfall ash showers has mantled the topography surrounding volcanic cones with thick veneers of unconsolidated ash. This process smoothes underlying relief, providing gently contoured depressions for water accumulation. Some of the depressions represent original undulations in the deposits; others have been created subsequently as deflation hollows, the ash being easily removed by wind. In some cases volcanic ejecta has blocked or partly blocked original drainage channels, thus promoting wetland conditions.

7.6 BEDROCK DEPRESSIONS: SCHIST

Substrates of hard rock, as opposed to those of unconsolidated materials, can support ephemeral wetlands, especially where the tectonic history of the rock has left relatively planar landforms. Our first of two examples is the Otago schist which, through much of central and eastern Otago, has strongly developed flat land surfaces resulting partly from its platy horizontal schistosity and partly from the persistence of a subdued landscape created by the ancient wearing down of the land surface to a peneplain (Fig. 5D). Despite uplift of broad ranges and ridges by folding and block-faulting, expanses of this old erosion surface are still present, and they contain depressions which may have formed via several processes. The schist surface may have been deformed by the weight of overlying sediments during marine transgression. Or, when again uplifted, localised chemical weathering could have created the depressions, either beneath a soil mantle or at the ground surface, perhaps through diverse climatic and weathering influences. Repeated and long-term cycles of wetting and drying on an exposed land surface could turn incipient puddles into deeper hollows, and wind deflation would contribute by removing dusty weathering products.

Whatever their origins, closed depressions in Otago schist tend to be relatively small (c. 5–30 m diameter), and to have a base that is partly bedrock and partly a veneer of silt (Fig. 5E). They can occur singly or in groups, and because they occur in a semi-arid climate they are ponded mainly in winter and early spring, and their drying phase is mainly a result of evaporation rather than subsurface slow drainage. Accumulation of salts in the semi-arid climate may influence turf composition.

7.7 BEDROCK: LIMESTONE

Karst landscapes—those composed of limestone, marble, or dolomite—often have nearly horizontal strata or land surfaces that favour the formation of surface depressions (Figs 5A–C). In addition, the solubility of carbonate rocks encourages the formation of underground streams and caves. When some of these collapse, surface depressions, termed sinkholes or dolines, may form. Underground drainage, if sufficiently restricted (including by overlying sediment), may result in intermittent ponding, or the formation of a karst lake (or polje). Lake Disappear (as illustrated by Williams 1992) is a polje.

Karst areas known to have ephemeral wetlands in closed depressions include the northwest Ruahine Range, and Northwest Nelson (at least three sites of note: Gouland Downs, Mt Arthur Tableland, and Matiri Plateau).

7.8 PONDING ASSOCIATED WITH EARTH MOVEMENT

Landslide surfaces are often dotted with semi-permanent ponds, especially where the heads of rotational slumps have parted company with hillsides. Landslide-dammed valleys produce ponds or lakes of many sizes (e.g. Lake Waikaremoana, at the large end of the scale). Landslide material is generally porous, so that drainage is usually partly or wholly subterranean. The wide amplitude of water levels that result from this variable inflow and drainage can sometimes be conducive to the formation of ephemeral wetlands. Landslide ponds may sometimes be quite deep—up to tens of metres—yet deep water usually occurs only for short periods separated by long intervals. In such cases the zone where ponding occurs may be distinguishable by vegetation of relatively reduced stature—say grassland or scrubland compared with forest above extreme maximum water level—but not with turf.

Sag ponds along faultlines are another form of closed depression found in New Zealand. Ponding of water is likely if one side of a fault trace is higher than the other. The crushed rock frequently found in fault zones is also conducive to the formation of depressions. It also provides the semi-permeable substrate that encourages water level fluctuation and the formation of turfs. Sag ponds often occur in lines along fault traces. Several New Zealand examples are illustrated by Aitken (1999), including the spectacular turf-margined examples along the Awatere Fault at Tarndale in Marlborough.

7.9 MAN-MADE HABITATS

Many artificial reservoirs constructed for irrigation, domestic water supply, or hydroelectricity take the form of small lakes, often as drowned river or stream valleys. The main shores and those bordering narrow arms tend to be relatively steep, with drowned terrestrial soils, but the more gentle bay-heads, often the site of fresh stream delta deposits, can provide ideal turf habitat, provided the water fluctuation regime is favourable (Figs 7E–G). Some reservoirs have water

level fluctuations too extreme for their shores to develop any form of stable vegetation (Fig. 7C). Likewise, some reservoirs, as well as natural lakes with controlled outlets used for hydroelectric storage, accumulate water during summer and experience drawdown during winter, when exposure of their shores does not coincide with the growing season.

Some farm ponds provide the right conditions for the growth of turf vegetation on their shores (Fig. 7B). More often, though, they have relatively stable water levels, shores composed of terrestrial soils, relatively high fertility, much disturbance from livestock trampling, and therefore a tendency to be vegetated with naturalised plants typical of damp agricultural habitats. Sewage ponds do not provide the right mix of conditions for turf.

Extraction pits (or borrow pits, to use their euphemistic name) can become ephemeral wetlands (Fig. 7A). Removal of gravel and similar materials, e.g. for road construction, can result in gently sloping excavations which descend below the level of a fluctuating water table, and where a small proportion of silt and a larger proportion of gravels serendipitously provide ideal conditions for turf plants (e.g. Mason 1969). Settling ponds, e.g. for stormwater, can be specifically designed to encourage the development of turf vegetation.

Turf greens as cultivated for bowls and croquet, and putting areas on golf courses, have many features in common with ephemeral wetland turfs. Their very short stature is initiated and maintained by mowing, and their component plant species are those tolerant of compaction. Many of the dominant plants of cultivated turfs have their natural origin in ephemeral wetland and lake-shore turfs. The same is true of many of the weed plants of playing turfs and also amenity lawns.

8. Flora

Considering the small land area they occupy in New Zealand, ephemeral wetland turfs contain a large number of native plant species. Most of the plants are illustrated by Johnson & Brooke (1989). Appendix 1 provides a preliminary list of plants for the general habitat type, tabulating presence and abundance for ten broad geographical regions of New Zealand for which data are available. The sites contributing to the lists for each region are all ephemeral wetland habitats, though records for larger lakes are included for three areas (Waikato, Wairarapa, Fiordland) to illustrate the similarity in flora between communities of ephemeral wetlands and lakes. Plant taxa listed are those occurring within or immediately adjacent to turf or sward vegetation types that are dominated by herbaceous plants. The only woody plants included are prostrate sub-shrubs which can be components of upper level turf zones.

A summary of the ephemeral wetland flora (Table 1) illustrates its size: 419 native and 171 naturalised plant taxa. We have assigned each taxon to various categories: is it of turf stature (< 10 cm tall), or else taller; is its occurrence obligate (almost restricted to) or facultative (not restricted to) turf communities? Among the native plants recorded in ephemeral wetland turf

communities, 70% are of turf stature (88 obligate, 207 facultative) whereas only 30% of the naturalised plants (1 obligate, 50 facultative) are of turf stature. Thus most weedy naturalised plants of ephemeral wetlands are taller growing than the native turf flora.

The species richness of the ephemeral wetland flora is shown by the comparison in Table 2 between numbers of named species of flowering plants found in ephemeral wetlands with figures for the total New Zealand flora (Wilton & Breitwieser 2000). Thus ephemeral wetlands contain 20.6% of native flowering plants, and an even higher proportion (29.3%) of monocots, and this despite the extremely limited area of ephemeral wetland habitat in New Zealand. Ephemeral wetlands hold a lesser proportion of total naturalised plants (9.9%), though the 170 taxa involved are a diverse group of invaders.

Freshwater turfs of ephemeral wetlands and lake shores can be considered as core habitat for the 88 taxa we consider to be obligate turf species and varieties. Many genera contribute a large number of species of turf stature to the native turf flora, notably *Carex* (17 taxa), *Epilobium* (14), *Ranunculus* (14), *Euchiton* (11), *Crassula* (9), *Isolepis* (8), *Hydrocotyle* (8), *Leptinella* (6), *Luzula* (6), *Gunnera* (5), *Mazus* (4), *Juncus* (4), *Plantago* (4), *Schoenus* (4), *Galium* (4), *Eleocharis* (3), *Glossostigma* (3), *Myriophyllum* (3), *Pratia* (3), and *Viola* (3).

TABLE 1. SUMMARY OF NEW ZEALAND EPHEMERAL WETLAND VASCULAR PLANT FLORA (DERIVED FROM APPENDIX 1) LISTING TOTAL NUMBERS OF NATIVE AND NATURALISED TAXA (i.e. BOTH SPECIES AND VARIETIES AND INCLUDING UNNAMED TAXA), AND NUMBERS OF TAXA WITHIN THE CATEGORIES OF PLANT STATURE AND FAITHFULNESS TO TURF HABITATS (SEE CATEGORIES BELOW).

	NATIVE				NATURALISED				
	TO	TF	XF	TOTAL	TO	TF	XF	TOTAL	TOTAL
Monocots	25	49	89	163	1	11	48	60	223
Dicot herbs	62	144	25	231		38	71	109	340
Dicot subshrubs		11	6	17					17
Ferns and allies	1	3	4	8		1	1	2	10
Total	88	207	124	419	1	50	120	171	590

TO: Turf stature (< 10 cm tall) / obligate presence in turf
TF: Turf stature / facultative presence in turf
XF: Larger than turf stature (> 10 cm tall) / facultative presence in turf

TABLE 2. COMPARISON OF NUMBERS OF NAMED SPECIES (i.e. EXCLUDING VARIETIES AND UNNAMED TAXA) OF NATIVE AND FULLY NATURALISED FLOWERING PLANTS IN EPHEMERAL WETLAND HABITATS WITH FIGURES FOR THE TOTAL NEW ZEALAND FLORA (WILTON & BREITWIESER 2000).

	TURF FLORA	NZ FLORA	% OF NZ TOTAL
Native monocots	162	552	29.3
Native dicots	225	1324	17.0
Total native flowering plants	387	1876	20.6
Naturalised monocots	60	433	13.5
Naturalised dicots	109	1271	8.6
Total naturalised flowering plants	169	1704	9.9

The native turf flora includes many plants that have interesting characteristics. The few ferns and fern allies found in turf communities include species of *Isoetes*, *Ophioglossum*, *Pilularia*, and *Azolla*; all having rather unusual morphology and growth habits. Freshwater turf provides a principal habitat for several plants that are represented in New Zealand by just a single species, e.g. those belonging to *Centella, Elatine, Hydatella, Iphigenia, Liparophyllum, Myosurus, Potentilla, Sebaea, Stackhousia*, and *Tetrachondra*. Turf is the principal habitat for all New Zealand taxa of *Hypsela* (2 taxa), *Lilaeopsis* (2), *Glossostigma* (3), *Gratiola* (2), and *Limosella* (?3).

Many genera are represented among turf plants by one or more distinctively small species, very often the tiniest New Zealand members of their genus, notably: *Acaena rorida, Agrostis muscosa, Brachyscome linearis, Cardamine* "tarn"*, Carex rubicunda, Centrolepis minima, Crassula multicaulis, C. peduncularis, C. sinclairii, Dichondra* cf. *brevifolia, Eleocharis pusilla, Epilobium angustum, E. komarovianum, Euchiton ensifer, E. paludosus, Galium* sp. cf. *perpusillum, Hydrocotyle hydrophila, H. sulcata, Hypericum japonicum, H.* sp. aff. *japonicum, Isolepis basilaris, I. caligenis, Juncus pusillus, Leptinella maniototo, Microtis oligantha, Myosotis pygmaea* vars., *Myriophyllum votschii, Ourisia modesta, Parahebe canescens, Plantago triandra, Poa lindsayi, Pratia perpusilla, Ranunculus limosella, R. recens* var. *lacustris, Rytidosperma australe, R. pumilum*, and *Schizeilema cockaynei*.

8.1 DISTRIBUTION PATTERNS

Just as ephemeral wetlands are widely but sporadically distributed throughout New Zealand, so too are many members of the turf flora. Nevertheless, there are examples of local endemism, and of sometimes strongly disjunct distribution patterns.

One approach to assessing distribution is to consider the proportions and numbers of turf plants that occur only in the northern or southern halves of New Zealand. Of the 88 obligate turf taxa, 8 occur only in the North Island while 15 occur only south of Cook Strait. Of the 207 facultative turf taxa, only 4 are restricted to the north, compared with 25 in the south.

Among the obligate turf plants, examples of North Island endemics are *Selliera rotundifolia* (Wanganui to western Wellington coast) and *Crassula manaia* (Taranaki coastal turfs). Through the eastern inland South Island a suite of distinctive endemics of ephemeral wetlands and lake-edge turf share a broadly similar pattern of distribution: *Cardamine* "tarn", *Epilobium angustum, Neopaxia linearifolia, Parahebe canescens*, and *Gnaphalium luteo-album* var. *compactum*. Restricted to the southern South Island are *Brachyscome linearis, Cardamine lacustris, Ranunculus recens* var. *lacustris*, and *Schizeilema cockaynei* (the last also found on Stewart Island).

A substantial number of turf plants exhibit a disjunct north/south distribution involving relatively localised presence in the central North Island, and a more widespread occurrence in the South Island. These are (Rogers 1989, C.C. Ogle, pers. comm.): *Carex berggrenii, C. capillacea, C. uncifolia, Drosera pygmaea, Euchiton delicatus, E. ensifer, Iphigenia novae-zelandiae, Ourisia modesta, Oreomyrrhis colensoi* var. *delicatula, Ranunculus ternatifolius*, and *Tetrachondra hamiltonii*.

8.2 NON-VASCULAR PLANTS

We have not set out to document the non-vascular flora of ephemeral wetlands, although certain elements of this flora are also characteristic of the habitat. However, many turf communities contain mosses (e.g. *Fissidens* spp.), and liverworts (e.g. *Fossombronia* spp.). Some liverworts can be important seasonal colonists on freshly exposed silty shores of ephemeral wetlands, notably *Riccia* spp. (Fig. 9A). Among algal groups, charophytes or stoneworts (especially *Chara* and *Nitella* spp.) are found in lower-elevation turfs, where they are sometimes exposed to the air at times of lowermost water levels. Filamentous algae can be prominent in summer ponds, and these are also a good habitat for desmids. Cyanobacteria can be present as blue-green or brownish, sometimes jelly-like globules or skins in submerged as well as on exposed shores subject to wetting and drying cycles. Few lichens occur in ephemeral wetlands, though one exception is small depressions in open country which pond only briefly and where species of *Siphula* and *Placopsis* may be present along with similarly drought-tolerant vascular turf plants.

8.3 LIFE STRATEGIES OF NATIVE AND NATURALISED TURF PLANTS

Tables 3 to 10 provide summary lists of turf plants grouped according to life strategies and ecological roles, and each species is annotated as to whether it occurs principally on relatively wet, moist, or dry substrates, these more-or-less equating with lower, middle, and upper zones of turf vegetation.

The 48 native plants which colonise bare ground in ephemeral wetlands (Table 3) are all able to colonise shore substrates that have bare soil, freshly exposed after physical disturbance, or following sediment deposition, or when a shore is exposed to the air as water level drops. These colonists are typically fast-growing, and while some can also be long-lived perennials, most are relatively short-lived; 37% of them (17 taxa) being annuals or short-lived perennials—quite a large number considering New Zealand's paucity of native annual plants. Examples of turf plants at a colonist phase are shown in Fig. 3H (a dune hollow) and Fig. 7H (a dewatered reservoir base).

The list of native long-lived perennial turf plants (Table 4) is large (96 taxa) and not exhaustive, but it illustrates the diversity of the commonest and most characteristic perennials of compact, stable turf vegetation. These are plants which tolerate competition from numerous cohabiting species (Figs 2G, H).

Twelve native turf species are summergreen (Table 5), most occurring in dry, upper-zone turfs. Most of these plants are tuberous orchids.

Native aquatic plants found in turf communities may be divided into two groups. Firstly, there is a group of 10 principally aquatic plants (Table 6), which can occur in the lowermost zones of turf vegetation, tolerating short periods of exposure to air, and tending then to lie prostrate on the substrate (e.g. *Myriophyllum* spp.) or to adopt a shorter stature than when deeply aquatic (e.g. *Isoetes kirkii*). Secondly, a group of 20 taxa (Table 7) are principally turf plants of alternately wet and dry habitats, yet are capable of growing where

TABLE 3. NATIVE TURF PLANTS THAT COLONISE BARED GROUND IN EPHEMERAL WETLANDS.

Agrostis muscosa	D	P	*I. habra*	M	P
Callitriche petriei	W	P	*Juncus antarcticus*	M	P
Cardamine debilis	D	A/P	*J. novae-zelandiae*	M	P
Cardamine lacustris	M	A/P	*J. planifolius*	W	P
C. "tarn"	M	A/P	*Lachnagrostis filiformis*	M	A/P
Centipeda minima	M	A	*L. striata*	M	P
Centrolepis minima	M	A	*Leptinella maniototo*	M	P
Cotula australis	D	A	*Lilaeopsis ruthiana*	W	P
Cotula coronopifolia	W	A/P	*Limosella lineata*	M	P
Crassula multicaulis	M	A/P	*Myosotis pygmaea*		
C. peduncularis	M	A	var. *minutiflora*	D	A
C. sinclairii	W	P	*Myosurus minimus*		
Elatine gratioloides	W	P	subsp. *novae-zelandiae*	M	A
Eleocharis neozelandica	M	P	*Myriophyllum pedunculatum*	W	P
Epilobium alsinoides	D	P	*M. propinquum*	W	P
E. brunnescens	D	P	*Neopaxia linearifolia*	W	P
Euchiton audax	D	P	*Parahebe canescens*	M	P
E. sphaericus	D	A	*Plantago triandra*	M	P
Gnaphalium luteo-album			*Poa lindsayi*	D	P
var. *compactum*	D	A/P	*Pseudognaphalium*		
Gonocarpus micranthus	D	P	*luteo-album*	D	A/P
Gratiola sexdentata	M	P	*Ranunculus acaulis*	M	P
Gunnera arenaria	M	P	*Rorippa palustris*	W	A/P
Isolepis aucklandica	M	P	*Schoenus maschalinus*	M	P
I. basilaris	M	P	*Sebaea ovata*	M	A
I. caligenis	M	P	*Triglochin striata*	W	P

Species are annotated as to their tendency to colonise substrates of different relative moisture status, as follows: W = wet, M = moist, D = dry; and whether they are: A = annual, B = biennial, P = perennial.

TABLE 4. COMMON NATIVE LONG-LIVED PERENNIAL TURF PLANTS OF EPHEMERAL WETLANDS.

Acaena inermis	D	*Juncus pusillus*	W
Anisotome aromatica	D	*Leptinella dioica*	M
Blechnum penna-marina	D	*L. maniototo*	M
Brachyscome linearis	D	*L. pusilla*	M
Carex berggrenii	D	*L. squalida*	M
C. decurtata	D	*Leucopogon fraseri*	D
C. flaviformis	M	*L. fraseri* var. *muscosus*	D
C. gaudichaudiana	M	*Lilaeopsis novae-zelandiae*	W
C. rubicunda	M	*L. ruthiana*	W
Celmisia gracilenta	D	*Limosella lineata*	M
Centella uniflora	D	*Liparophyllum gunnii*	M
Centrolepis ciliata	W	*Mazus* spp.	D
C. pallida	W	*Muehlenbeckia axillaris*	D
Dichondra brevifolia	D	*Myriophyllum pedunculatum*	M
Eleocharis acuta	M	*M. votschii*	M
E. gracilis	M	*Nertera balfouriana*	M
E. pusilla	W	*N. setulosa*	D
Epilobium angustum	D	*Ophioglossum coriaceum*	M
E. brunnescens	D	*Oreobolus pectinatus*	M
E. komarovianum	D	*Oreostylidium subulatum*	D
E. nerteroides	D	*Ourisia modesta*	M

Table 4 contd.

Euchiton delicatus	M	*Parahebe canescens*	M
E. lateralis	M	*Pilularia novae-zelandiae*	W
E. paludosus	M	*Pimelea oreophila*	D
E. traversii	D	*Plantago triandra*	M
Galium perpusillum	D	*Potentilla anserinoides*	M
Gaultheria depressa		*Pratia angulata*	D
var. *novae-zelandiae*	D	*P. arenaria*	M
Glossostigma elatinoides	W	*P. perpusilla*	M
Gonocarpus aggregatus	D	*Ranunculus foliosus*	D
G. micranthus	D	*R. glabrifolius*	M
Gratiola nana	M	*R. maculatus*	M
G. sexdentata	M	*R. recens* var. *lacustris*	M
Gunnera arenaria	M	*Raoulia subsericea*	D
G. dentata	M	*Rytidosperma australe*	D
G. monoica	M	*R. pumilum*	D
Helichrysum filicaule	D	*Schizeilema cockaynei*	M
Herpolirion novae-zelandiae	M	*S. nitens*	D
Hydrocotyle heteromeria	D	*Schoenus concinnus*	M
H. hydrophila	M	*S. maschalinus*	M
H. microphylla	M	*S. nitens*	M
H. moschata	D	*Selliera radicans*	M
H. novae-zeelandiae	W	*S. rotundifolia*	M
H. novae-zeelandiae		*Stackhousia minima*	D
var. *montana*	W	*Tetrachondra hamiltonii*	D
H. sulcata	M	*Utricularia novae-zelandiae*	W
Hypericum japonicum	M	*Viola cunninghamii*	M
Hypsela rivalis	M	*V. filicaulis*	D
Isolepis aucklandica	M	*V. lyallii*	M

Species are annotated as to their tendency to grow on substrates of different relative moisture status, as follows: W = wet, M = moist, D = dry.

TABLE 5. NATIVE SUMMERGREEN PERENNIALS OF TURFS OF EPHEMERAL WETLANDS.

Iphigenia novae-zelandiae	D	*P. nudum*	D
Microtis oligantha	D	*Spiranthes sinensis*	M
M. unifolia	D	*Thelymitra cyanea*	D
Ophioglossum coriaceum	D	*T. longifolia*	D
O. petiolatum	D	*T. pauciflora*	D
Prasophyllum colensoi	D	*T. pulchella*	D

Species are annotated as to their tendency to grow on substrates of different relative moisture status, as follows: M = moist, D = dry.

TABLE 6. NATIVE, PRINCIPALLY AQUATIC PLANTS THAT CAN OCCUR IN TURF OF EPHEMERAL WETLANDS.

Azolla filiculoides	*Myriophyllum pedunculatum*
Hydatella inconspicua	*M. propinquum*
Isoetes kirkii	*M. triphyllum*
Lemna minor	*Potamogeton cheesemanii*
Lepilaena bilocularis	*Zannichellia palustris*

permanently submerged, in which case many of them (e.g. *Callitriche petriei, Crassula ruamahanga, C. sinclairii, Elatine gratioloides, Pratia perpusilla*) adopt an aquatic growth form with elongated stems and narrow leaves.

Three groups of naturalised plants are listed as Tables 8, 9, and 10, these being the most common invaders of ephemeral wetlands. The proportion of short-lived plants to perennials is much higher among the naturalised flora than the native flora, e.g. 22 of 30 naturalised colonist species (73%) are annuals or biennials, compared with 33% of the native colonists. Sometimes the colonists appear along a shore contour where their seeds have been concentrated along a strand line and / or where the timing of water level drop coincides with their germination requirements (Fig. 8C).

The 15 species in Table 9 are naturalised plants that commonly occur among native plants in ephemeral wetlands, often within relatively dense turf vegetation, and without seeming to displace the native plants to any great degree.

By contrast, the 51 naturalised plants (12 annual or biennial, 39 strictly perennial) considered to be aggressive weeds (Table 10) are those which are able to achieve substantial cover and displace native plants, especially in upper-zone turf and sward vegetation (Figs 1C, 9B).

TABLE 7. NATIVE TURF PLANTS OF EPHEMERAL WETLANDS THAT CAN GROW AS PERMANENTLY SUBMERGED AQUATICS.

Callitriche petriei	*Isolepis inundata*
Crassula ruamahanga	*Juncus pusillus*
C. sinclairii	*Lilaeopsis novae-zelandiae*
Elatine gratioloides	*L. ruthiana*
Eleocharis pusilla	*Pilularia novae-zelandiae*
Glossostigma cleistanthum	*Pratia perpusilla*
G. elatinoides	*Ranunculus amphitrichus*
G. submersum	*R. limosella*
Hydrocotyle novae-zeelandiae	*Triglochin striata*
Isolepis fluitans	*Utricularia novae-zelandiae*

TABLE 8. NATURALISED PLANTS THAT COLONISE BARED GROUND OF EPHEMERAL WETLANDS.

Aira caryophyllea	Silvery hair grass	D	A/B
Anagallis arvensis	Scarlet pimpernel	D	A
Arenaria serpyllifolia	Sandwort	D	A
Callitriche stagnalis	Starwort	W	A/P
Centipeda cunninghamii	Sneezeweed	M	P
Cerastium fontanum	Mouse-ear chickweed	D	P
Chenopodium album	Fat hen	D	A
Cirsium arvense	Californian thistle	D	P
C. vulgare	Scotch thistle	D	B
Cyperus tenellus		M	A
Erodium cicutarium	Storksbill	D	A
Isolepis australiensis		M	A
I. marginata		M	A/P
I. setacea		M	A/P
Juncus articulatus	Jointed rush	M	P

Table 8 contd.

J. bufonius	Toad rush	M	A
J. tenuis	Track rush	M	P
Leontodon taraxacoides	Hawkbit	D	P
Lythrum portula	Water purslane	W	A
Myosotis discolor	Grassland forget-me-not	M	A
Poa annua	Annual poa	M	A/P
Polygonum persicaria	Willow weed	M	A
Polypogon monspeliensis	Beard grass	M	A
Ranunculus sceleratus	Celery-leaved buttercup	M	A
Sagina procumbens	Pearlwort	M	P
Sedum acre	Stonecrop	D	P
Spergula arvensis	Spurrey	D	A
Spergularia rubra	Sand spurrey	D	A/P
Verbascum thapsus	Woolly mullein	D	A/B
Veronica arvensis	Field speedwell	D	A
V. serpyllifolia	Turf speedwell	M	P
Vulpia bromoides	Vulpia hair grass	D	A

Species are annotated as to their tendency to colonise substrates of different relative moisture status, as follows: W = wet, M = moist, D = dry; and whether they are: A = annual, B = biennial, P = perennial.

TABLE 9. NATURALISED PLANTS THAT ARE COMMON AND PERSISTENT AMONG NATIVE PLANTS IN TURF VEGETATION OF EPHEMERAL WETLANDS.

Alopecurus geniculatus	Kneed foxtail	W	P
Centaurium erythraea	Centaury	M	A/B
Hieracium pilosella	Mouse-ear hawkweed	D	P
Hypochoeris radicata	Catsear	D	P
Juncus articulatus	Jointed rush	W	P
Leontodon taraxacoides	Hawkbit	D	P
Linum catharticum	Purging flax	M	A/P
Poa annua	Annual poa	D	A/P
Prunella vulgaris	Selfheal	M	P
Rumex acetosella	Sheep's sorrel	M	P
Sagina procumbens	Pearlwort	M	P
Sisyrinchium "blue"		M	P
Trifolium dubium	Suckling clover	M	A
T. repens	White clover	M	P
Veronica serpyllifolia	Turf speedwell	M	P

Species are annotated as to their tendency to grow on substrates of different relative moisture status, as follows: W = wet, M = moist, D = dry; and whether they are: A = annual, B = biennial, P = perennial.

TABLE 10. NATURALISED PLANTS THAT ARE COMMONLY AGGRESSIVE WEEDS IN TURF AND SWARD VEGETATION OF EPHEMERAL WETLANDS.

GRASSES:			
Agrostis stolonifera	Creeping bent	W	P
Alopecurus geniculatus	Kneed foxtail	W	P
Anthoxanthum odoratum	Sweet vernal	D	P
Axonopus fissifolius	Narrow-leaved carpet grass	M	A/P
Cynodon dactylon	Indian doab	M	P
Glyceria declinata	Floating sweetgrass	W	P
Holcus lanatus	Yorkshire fog	M	P
Paspalum distichum	Mercer grass	W	P
Poa pratensis	Meadow grass	M	P
Schedonorus phoenix	Tall fescue	D	P

Table 10 contd.

SEDGES AND RUSHES:			
Carex demissa	Yellow sedge	M	P
C. ovalis	Oval sedge	M	P
Cyperus congestus	Purple umbrella sedge	M	P
C. eragrostis	Umbrella sedge	M	P
Juncus acuminatus	Sharp-fruited rush	M	P
J. articulatus	Jointed rush	W	P
J. bulbosus	Bulbous rush	W	P
J. effusus	Soft rush	M	P
J. microcephalus	South American rush	W	P
J. tenuis	Track rush	D	P
DICOTYLEDONOUS HERBS:			
Aster subulatus	Sea aster	M	A/P
Bidens frondosa	Beggars' ticks	W	A
Cardamine pratensis	Cuckoo cress	M	P
Carduus tenuiflorus	Winged thistle	M	A/B
Conyza spp.	Fleabanes	D	A/B
Crepis capillaris	Hawksbeard	D	A/B
Epilobium ciliatum	Willowherb	W	A/P
Galium palustre	Marsh bedstraw	M	P
Lotus pedunculatus	Lotus	M	P
L. suaveolens	Hairy birdsfoot trefoil	M	P
Ludwigia palustris	Water purslane	W	P
Lycopus europaeus	Gypsywort	W	P
Lythrum hyssopifolia	Hyssop loosestrife	M	A
Mentha pulegium	Pennyroyal	M	P
Mimulus guttatus	Monkey musk	W	P
M. moschatus	Musk	W	P
Myosotis laxa subsp. *caespitosa*	Water forget-me-not	W	A/B
Nasturtium microphyllum	Watercress	W	P
Parentucellia viscosa	Tarweed	M	A
Plantago australis	Swamp plantain	M	P
P. lanceolata	Narrow-leaved plantain	D	P
P. major	Broad-leaved plantain	D	P
Polygonum hydropiper	Water pepper	W	A
Ranunculus flammula	Spearwort	W	P
R. repens	Creeping buttercup	M	P
Rumex conglomeratus	Clustered dock	M	P
R. crispus	Curled dock	M	P
R. obtusifolius	Broad-leaved dock	M	P
Senecio jacobaea	Ragwort	D	B/P
Stellaria alsine	Bog stitchwort	M	P
Taraxacum officinale	Dandelion	D	P

Species are annotated as to their tendency to grow on substrates of different relative moisture status, as follows: W = wet, M = moist, D = dry; and whether they are: A = annual, B = biennial, P = perennial.

9. Nationally threatened and uncommon plants

Appendix 2 lists ephemeral wetland plants that appear also in the current listing of New Zealand plant taxa regarded as being nationally threatened or uncommon (de Lange et al. 1999). Sixty-two taxa (31 obligate and 31 facultative turf plants) are threatened or uncommon. These form 12.1% of New Zealand's total number of threatened and uncommon plants (511 taxa). If the uncommon plants are excluded, and just those plants strictly categorised as threatened (Critically Endangered, Endangered, or Vulnerable) are considered, the numbers are 19 taxa compared with 107 for all New Zealand, i.e. 17.8%.

These relatively high numbers and proportions of uncommon and threatened plants in the turf flora are not surprising when we consider that ephemeral wetland turfs hold 20.6% of all the native flowering plants (Table 2). But what is most notable for both the total flora and the threatened / uncommon flora is that these plants occur in or are restricted to a habitat type that makes up an extremely small proportion of our total land area. Ephemeral wetlands are very important for many of our rare plants. Nine threatened and uncommon taxa are illustrated in Fig. 11.

10. Turf vegetation

10.1 PHYSIOGNOMY

Our definition of turf is of a vegetation structural type of low stature (generally < 3 cm tall) of mainly herbaceous vascular plants that are prostrate and tightly interlacing, forming a ground-hugging and often dense carpet of intertwined plants of numerous species.

This definition builds on that of Rogers (1999) who used turf as a 'term of convenience applied to a compositionally diverse range of vascular plant communities showing similar physiognomy', and provided a definition of coastal turfs.

Cockayne (1958) gave an appropriate description of turf features when he described coastal herb moor as having a plant-covering of 'an even turf of extreme density owing to the plants having their rosettes or leaves pressed close to the ground'.

Dictionary definitions of turf commonly describe a combination of grasses and matted roots upon (or removed from) a soil surface. These descriptions concur with our definition of turf vegetation as being a compact sandwich comprising foliage, prostrate surface stems and below-ground rhizomes, roots, underlying soil, and surface-trapped sediments.

Using the system of Atkinson (1985) for vegetation structural classes, our definition of turf fits into Atkinson's definition of 'herbfield', but is a distinguishable sub-set of that, especially because of the constantly low stature of turf vegetation.

Other terms which have been applied to semi-aquatic turf in New Zealand are 'amphibious sward' (Mason 1975), 'low mixed community' or 'mound community' (Chapman et al. 1971; Coffey & Clayton 1988).

10.2 GROWTH HABIT

Many ephemeral wetland turf plants fit the description by Wardle (1991, p. 33) of mat plants: 'creeping or rhizomatous herbs and dwarf shrubs in which the foliage presents a continuous flat surface.' Wardle makes further relevant observation of growth habit as he distinguishes mat from cushion plants: 'Mat plants growing among other vegetation have diffuse margins, but when colonising bare ground they develop circular outlines. Mats remain low because they continue to grow radially while central shoots scarcely grow at all, whereas in cushion plants central and marginal shoots grow at similar, albeit very slow rates.'

Turf vegetation can occasionally include plants of cushion habit (e.g. species of *Oreobolus*, *Centrolepis*, and *Gaimardia*. But most turf plants are herbs, dwarf sedges, grasses, or rushes, mostly rhizomatous but many of tufted habit, the latter often with rosettes of appressed leaves. Individual plants are evident for those species having a tufted habit, but seldom for those with creeping stems, except when they are growing alone as radially expanding colonist mats on ground that has been freshly disturbed or recently exposed after ponding (Fig. 4B).

The leaves of freshwater turf plants are typically tiny, and their shape tends to be either linear, pinnatifid, or spathulate: the 'knife-fork-and-spoon' plants of Johnson (1997). Leaves of any one species can vary in size and shape depending on whether they were produced under water or in an aerial environment. Thus *Myriophyllum propinquum* produces simple leaves when stranded on a shore, and pinnatifid leaves when submerged. *Leptinella maniototo* has linear leaves when submerged, usually early in the growing season, then more hairy, pinnatifid leaves when growing exposed to the air later in the season.

Turf plants with linear or spathulate leaves have the ability to produce much longer leaves with more pronounced paddle-tips when submerged, or for their existing leaves to elongate their petioles upon being submerged. In a shallow aquatic environment this enables photosynthetic leaf tips to be held above the level of loosely suspended litter and sediment on the pond floor. Two plants that illustrate this well are *Limosella lineata* and *Ranunculus limosella*, the latter species named for its similarity with the genus *Limosella*, as pointed out by Ogle & Moss (1984) who note also 'the names of the trio of *Glossostigma elatinoides, Elatine gratioloides,* and *Gratiola sexdentata*, the Latin ending *…oides* (meaning 'resembling something else') having been used because of the strong resemblances between genera.'

Most turf plants have ground-hugging leaves and stems when growing in full sunlight. These leaves or stems will elongate markedly or else raise themselves above ground level when shaded by a taller plant, or when having to seek light when growing out from under a stone or a log. Turf plants rapidly become etiolated when placed in the confines and shade of a plastic collecting bag. Rust fungi can make some turf plants grow taller, especially those rusts which attack *Galium perpusillum* and *Pratia perpusilla*. Affected stems have elongated internodes, their rust-induced greater height presumably being an advantage for dispersal of spores from the rust's orange pustules.

Subshrubs (low-growing semi-woody plants), e.g. species of *Coprosma*, *Leucopogon*, and *Pimelea*, can occur as < 3-cm-tall components of turf. Taller woody plants seldom occur within turf, except that on lake shores upper-turf zones may be studded with shrubs or partly shaded by shrubland, especially of the flood-tolerant and widespread manuka (*Leptospermum scoparium*) and mingimingi (*Coprosma propinqua*). Some turf communities of ephemeral wetlands have been invaded by naturalised species of willow and poplar, especially by small grey willow (*Salix cinerea*) and larger crack willow (*S. fragilis*) trees.

10.3 ZONATION

Zonation of turf vegetation in ephemeral wetlands is usually apparent as concentric bands of distinctive colour, tone, texture, or plant stature, reflecting the positions along the wet / dry gradient of either distinct communities or else the distribution limits of particular dominant or conspicuous plant species.

In many ephemeral wetlands and around most lake edges, turf grades downslope to aquatic beds or meadows of tall macrophytes, or to reedland emergent from the water. At the upper elevations of a zonation sequence, turf can often grade into what we term sward, where leafy sedges or rushes 10–20 cm tall are dominant. The uppermost zones of turf can sometimes intermingle with, or be replaced by, zones of sedgeland or rushland in the order of 0.5 to 1.5 m tall. But in many ephemeral wetlands there is no such gradual increase in plant height, and the uppermost turf zone rather abruptly abuts the lowermost boundary of the surrounding terrestrial vegetation.

At times of low water level, exposure of aquatics such as milfoils (*Myriophyllum* spp.) and pondweeds (*Potamogeton* spp.) results in the rotting back of their long shoots, then replacement by miniature 'strand forms' until ponding recurs. The water-repellant and floating foliage of aquatic grasses such as *Lachnagrostis* and *Alopecurus* is better able to persist when water level is low, their leaf blades lying prostrate on the ground. The floating fronds of *Azolla* spp. and duckweeds (e.g. *Lemna minor*) can be stranded yet continue to live on moist shore substrates even after water levels have receded.

10.4 REPRODUCTION

The marked alternation between wet and dry conditions, and the various types of physical disturbance that occur in ephemeral wetlands, give rise in turf plants to many strategies for persistence, regeneration and reproduction. Little detailed study has been undertaken on these topics, so the following comments should be taken as preliminary and generalised.

Many turf plants are either rhizomatous or else stoloniferous with frequent rooted nodes, and individual plants may extend over several tens of centimetres or even metres. Thus death of part of a plant does not usually lead to the demise of the whole individual. Regrowth onto eroded substrate or up through a surface deposit of sediment is straightforward. Vegetative reproduction often occurs in the unspecialised manner of viable fragments of stems being dislodged and redistributed. Wave-erosion on a turf shore usually involves the progressive upslope progression of a low scarp, the washing away of soil from the matted turf of roots and rhizomes, the breakage of stem fragments, and the water-carriage of these to new sites. Even gentle action by wind, currents, and wave action can leave the propagules spread through a freshly deposited veneer of silt and sand, or within an accumulation of flotsam on a strand line (Fig. 9C).

Most turf species can be found in flower at some time each growing season, and many appear to have flowering periods that span several months, or else flower after water levels have fallen, irrespective of the season. All the turf species of rushes, sedges, and grasses are wind-pollinated, as well as some of the dicotyledon genera, e.g. *Gunnera, Nertera, Plantago* and *Myriophyllum.* Some plants produce flowers while under water, where pollination is likely to be difficult. At least two genera (*Glossostigma* and *Viola*) are able to produce cleistogamic flowers: self-pollinated without the flowers opening. Many turf plants have obvious, showy flowers: small in absolute terms yet often large relative to their tiny vegetative parts, and often in great abundance (Figs 6G, H). When a turf is carpeted with flowers of genera such as *Hypsela, Pratia, Crassula, Galium, Parahebe, Ranunculus*, and *Stackhousia*, there are generally also many insect pollinators present. Such abundance of flowers suggests high production of seeds. A few turf plants have fleshy fruits but most have dry fruits with seeds presumably suited for dispersal by water. It is likely that sediment deposits in turf hold considerable seed banks.

Many turf plants have a tufted habit, and their contribution to total vegetation cover depends on their having numerous individuals. A larger number of turf plants are mat plants. When newly establishing on bared ground these can form dense radiating circular patches (e.g. *Callitriche petriei, Elatine gratioloides, Myriophyllum* spp.) or else lax patches where the plants seem to aim at maximising the expansion of their leading rhizomes rather than covering the ground with their foliage (e.g. the species of *Lilaeopsis, Limosella*, and *Pilularia*). In a dense, well-established turf of numerous interlacing species, it is sometimes possible to discern from foliage pattern or flower distribution what are probably individual plants of particular species (e.g. of *Eleocharis acuta, Schoenus concinnus, Utricularia novae-zelandiae* or *Gunnera dentata*), growing as patches 0.5 to perhaps 2 m across. But in most dense turf it is not possible to discern the extent of individual mat plants.

11. Zonation patterns and turf composition

Zonation patterns are so strong in turf vegetation of ephemeral wetlands that there seems little alternative to using zonation as the main basis for discussing diversity and variation in turf communities. At all field sites we have collected semi-quantitative data on plant composition within apparent vegetation zones or else within arbitrary segments upon the slope of a land / water interface. The tables in Appendix 3 have plant zonation and composition data collected from a variety of New Zealand ephemeral wetlands.

It is difficult to describe the composition of turf communities in simple terms because of the very great number of plant species, the fact that so many of them share dominance at any one place, and the lack of common names for most of them. In making summary comment on the tabulated data we shall refer to the least number of key plant species that enable a comparative story to be told.

The general zonation pattern in a kettle system

As a starting point, consider Table A3.1 in Appendix 3, which summarises plant composition data (Johnson 1994a) from a number of turfy kettle margins at Glenmore in Canterbury (Figs 1E, 2B). The table shows just the most common plants, their occurrence in five arbitrary zones and their generalised abundance on a 1–3 scale indicating maximum cover within one or more kettles. Some plant species span several zones while others are restricted to a single zone, this being especially the case in the uppermost zone. By choosing a few characteristic and abundant species from each zone we can build up a simplified zonation sequence as follows:

Zone A aquatic in permanent shallow water: *Potamogeton cheesemanii, Myriophyllum propinquum, Glossostigma elatinoides*.

Zone B muddy ground near kettle bases, exposed by late-season drop in water level: *Glossostigma elatinoides, Crassula sinclairii, Lilaeopsis ruthiana, Isolepis aucklandica, Myriophyllum pedunculatum.*

Zone C low-elevation zone of dense turf: *Isolepis aucklandica, Plantago triandra, Hydrocotyle hydrophila, Hypsela rivalis, Carex gaudichaudiana*.

Zone D middle zone of dense turf: *Galium perpusillum, Epilobium angustum, Pratia perpusilla, Selliera radicans.*

Zone E uppermost zone of dense turf, abutting onto tussock grassland: *Poa lindsayi, Polytrichum juniperinum, Agrostis capillaris, Gnaphalium luteo-album* var. *compactum, Leucopogon fraseri, Stackhousia minima*.

Kettles prone to drying

Part of Lake Lyndon, Canterbury (Table A3.2, Appendix 3; Fig. 10A; Johnson 1999) is a broad and gently sloping ephemeral wetland which dries completely in summer, and illustrates a type of kettle which lacks permanent aquatic vegetation in its base, has very broad vegetation zones which have gradually changing composition in the progression upslope, and where sharply drained substrate combined with long dry periods encourage a large proportion and sometimes substantial cover of naturalised plant species.

Kettles having little water fluctuation

In many kettle systems, and likewise also in other types of closed depressions on other landforms, it is not uncommon to find certain depressions which have a relatively constant water input from seepage, sometimes in combination with a surface outlet (Fig. 2E). Constant wetness can initiate peat accumulation and the consequent sealing-off of the formerly permeable floor. One such depression, a kettle in northern Southland (Johnson 1992a), located adjacent to more typical turf-zoned kettles, is illustrated by Table A3.3 in Appendix 3. The absence of much seasonal water fluctuation provides for a permanent basal pond with aquatic plants, a much-abbreviated sequence of zones in which bog plants are common (e.g. *Sphagnum, Oreobolus, Drosera*), then a moist marginal zone where more typical upper turf and mat plants merge with the surrounding hard tussock grassland.

Kettles having frequent, brief ponding

Some kettles and other depressions can become completely ponded after rain at all seasons of the year, but lose most of their water again over periods of a few days, so have no aquatic basal zone, and a marginal cover, which may or may not exhibit zones, where mosses are more abundant than vascular plants. Such short-duration ponds, often only a few metres across, can be common among upland tussock grasslands, and they are often dominated by *Polytrichum* mosses. A zoned example, from Glenmore, Canterbury, is shown in Fig. 2F.

Turf zonation on shores of large lakes

Table 3.4 in Appendix 3 is a generalised example of turf zonation from Lakes Manapouri and Te Anau, the two largest of the Fiordland lakes. These lakes have considerable water level fluctuations (4.6 m total fluctuation range at Lake Manapouri, 3.5 m at Lake Te Anau) which encourage well-developed turf zonations on those shores which have gentle slopes (Fig. 6E). Abundance of plant species within zoned communities is indicated in this example by relative frequencies, this being a simplification of a more detailed community analysis of 595 turf plots by Johnson & Burrows (2000).

This data set illustrates something of the complexity of a turf zonation pattern and how it arises in large part from the overlapping distributions of species, each having an individual elevation range relative to fluctuating water level.

Nineteen of the 61 plants listed span all four of the identified zones, the following plants being present at the highest frequencies: *Glossostigma* spp., *Myriophyllum pedunculatum, M. propinquum, Eleocharis acuta, Hypsela rivalis, Carex gaudichaudiana, Hydrocotyle hydrophila, Juncus articulatus*, and *Plantago triandra*. Broadly distributed species such as these are not especially helpful for characterising the zones.

Only a few species are restricted to just one of the four zones, and in this data set it is only the most frequently inundated Zone A which can be characterised in part by the sole occurrence of the following: *Pilularia novae-zelandiae, Centrolepis minima, Elatine gratioloides,* and *Isoetes kirkii.*

Otherwise, the general zonation pattern is perhaps most simply characterised by noting those species having the highest frequencies of occurrence within each of two pairs of zones:

Zones A and B: *Glossostigma* spp., *Myriophyllum pedunculatum, Triglochin striata, Juncus pusillus, Gratiola sexdentata, Leptinella maniototo, Lilaeopsis ruthiana, Alopecurus geniculatus, Centrolepis pallida, Ranunculus recens* var. *lacustris, Callitriche petriei*.

Zones C and D: Mosses, *Pratia angulata, Viola cunninghamii, Prunella vulgaris, Lotus pedunculatus*, *Schoenus pauciflorus, Lepidosperma australe, Nertera depressa, Hydrocotyle novae-zelandiae* var. *montana.*

A generally similar zonation pattern is described from Lake Wanaka, Otago by Johnson (1980b).

An ephemeral wetland adjacent to a South Island lake

A depression contained between old gravel storm ridges alongside Lake Wanaka (Figs 1A–1D) illustrates a situation where ponding is relatively shallow and brief (c. 3 months), such that zonation is not very pronounced, and where plants of turf stature occur within a predominant sward of grasses, sedges, and rushes, including a large number of naturalised species (Table A3.5 in Appendix 3).

An ephemeral wetland adjacent to a North Island lake

Among low-lying wetlands of the alluvial plain adjoining Lake Wairarapa is a depression that varies markedly in wetness between years (Appendix 3.6; Fig. 9B). Intermittently it can be completely dry and this can be followed by a period when plants of turf stature are common. During most years it retains an extensive pond, and turf species become subservient to dense swards of grasses, rushes, and robust herbs, many of them being naturalised weeds.

Zonation summary:

Zone A	main base: dense sward of Mercer grass (*Paspalum distichum*); *Potamogeton cheesemanii.*
Zone B	close to margin: dense mass of *Juncus articulatus, Myosotis laxa* subsp. *caespitosa, Ludwigia palustris, Polygonum salicifolium*.
Zone C	margin: tall clumps of *Cyperus ustulatus, Schedonorus phoenix*.

Ephemeral wetlands in coastal sand dunes

Moist depressions among sand dunes or on sand plains are usually flat-bottomed, and shallow when ponded, and have zonation patterns that are usually quite simple. Moist dune hollows have a considerable extent of bare sand substrate if the site is young or subject to continuing sand movement. The flora includes turf plants that are characteristic of the coast, and some (but not all) are found also as components of drier dune vegetation, salty or brackish salt marsh, and in the turfs of coastal terraces and headlands where wetness and ponding are not a habitat factor. Turf communities of dune ephemeral wetlands

are best developed where a moderate amount of disturbance occurs, including regular ponding and drying. Long periods of stability can lead to turf vegetation being partly or wholly replaced by rushland, especially of *Apodasmia similis*.

Figure 3A shows a dune hollow in Fiordland where ponding is too brief and infrequent for turf vegetation to develop. Figure 3B shows hollows on an Otago Peninsula sand flat where rushland of tall *Juncus* species emerges from shallow water in the most aquatic basal zone, and communities of turf stature occur in a perimeter zone which is subject to the most marked alternation between being ponded or substantially dry. By contrast, it is the turfy base of the Manawatu coastal hollow in Fig. 3C that has the strongest wet / dry contrast, and drier zones with *Isolepis nodosa* sedgeland and *Cortaderia* tussockland. A nearby Manawatu coastal hollow (Table A3.7 in Appendix 3) demonstrates a poorly defined zonation between the moist base and its *Apodasmia similis* rushland surrounds.

A second example of dune hollow turf (Table A3.8, Chatham Island, in Appendix 3) also shows a relatively simple zonation pattern. A few species with aquatic tolerance occupy the small lowest hollows. A dense turf (especially *Pratia arenaria, Myriophyllum pedunculatum* subsp. *novae-zelandiae, Selliera radicans,* and *Centella uniflora*) covers the extensive base, then a number of additional species help distinguish the marginal zone. Several of the turf plants in this table are Chatham Islands endemics. The 14 species of naturalised plants found in this Chatham ephemeral wetland are all, likewise, common components of inland South Island turf communities.

Ephemeral wetlands in open country on the Volcanic Plateau

In the midst of scrubby monoao 'frost flats' of the upper Rangitaiki catchment, a scattering of turfy wetlands in tephra-based depressions have a diversity of zonation patterns. An example of an ephemeral wetland shown in Fig. 4C has a zonation following the typical pattern of aquatic zone milfoils (*Myriophyllum* spp.) then *Eleocharis acuta*, then a sward of *Carex* spp. with grasses. A nearby example (Figs 4A, B; Table A3.9 in Appendix 3) is distinctly drier, even its deepest part turning to cracked mud during a drought phase. Its four main zones share many of the same dominants, but each zone is distinguishable by the lowermost elevation of certain turf plants:

Zone A *Lythrum portula, Lachnagrostis striata*
Zone B *Carex rubicunda* appears
Zone C *Carex dipsacea* and *Juncus gregiflorus* appear
Zone D *Leontodon taraxacoides* and *Prunella vulgaris* appear

An ephemeral wetland in tephra in a forest setting

Most depression wetlands in New Zealand occur in open country where they are surrounded by native grassland or low shrubland or by agricultural pasture. Many of these would have had a forest surrounding them in historic or prehistoric times. One extant example of a depression among native forest is Arahaki Lagoon, surrounded by tall kahikatea trees at Whirinaki Forest (Fig. 4H; Table A3.10 in Appendix 3). Turf communities occur in a strong zonation pattern, in summary as follows:

Zone A *Potamogeton cheesemanii, Myriophyllum propinquum*
Zone B *Eleocharis acuta* dominant, and only in this zone
Zone C *Eleocharis gracilis* and *Myriophyllum pedunculatum*
Zone D *Lilaeopsis ruthiana* and *Schoenus maschalinus*
Zone E *Pratia perpusilla, Baumea arthrophylla, Lachnagrostis* sp., and *Viola lyallii*
Zone F *Carex dipsacea* and *Centella uniflora*

Zonation in other habitats

Provided they have sufficient depth and amplitude of water fluctuation, ephemeral wetlands on any landform will show generally similar turf zonations to those described above. There is a tendency, however, for depressions upon bedrock (e.g. on limestone and schist, Fig. 5), those of river and stream meanders (Figs 6A, B), and those of alpine areas (Figs 8A, B) to be relatively shallow, often with little water level fluctuation, and for their turf zones to be abbreviated or compressed.

Some man-made depressions have turf communities with strongly developed zonation patterns (e.g. Fig. 7A), while others, especially reservoirs having large and irregular fluctuations, may have shores that are virtually bereft of vegetation (e.g. Fig 7C).

12. Other turf assemblages associated with ephemeral wetlands

In addition to the common turf communities of zoned systems summarised above from Appendix 3, several distinctive turf assemblages can be recognised as recurring in specific conditions of climate, substrate type and moisture, and shade.

Turf associations of dry climates and the margins of drought-prone depressions

Numerous turf species are characteristic of uppermost turf zones that experience the most brief or erratic periods of ponding. These are especially typical of kettles and other depressions in the dry climate areas of inland South Island: *Acaena inermis, Anisotome aromatica, Agrostis muscosa, Carex breviculmis, C. decurtata, Celmisia gracilenta, Colobanthus strictus, Coprosma perpusilla, C. petriei, Dichondra brevifolia, Epilobium angustum, Euchiton delicatus, E. lateralis, E. traversii, Gaultheria parvula, Hypericum japonicum, Kelleria dieffenbachii, Leucopogon fraseri, Myosotis pygmaea* var. *minutiflora, Nertera setulosa, Parahebe canescens, Pimelea oreophila, P. prostrata, Poa colensoi, P. lindsayi, Gnaphalium luteo-album* var. *compactum, Ranunculus foliosus, Rytidosperma australe, R. pumilum, Scleranthus uniflorus, Stackhousia minima, Stellaria gracilenta*.

Turf associations of gravel substrates

Some parts of ephemeral wetlands and lake margins have sparse turf vegetation on gravel substrates that are prone to wave disturbance. Characteristic plants include: *Cerastium fontanum, Cirsium* spp., *Epilobium* spp., *Euchiton audax, Helichrysum filicaule, Juncus novae-zelandiae, Lachnagrostis* spp., *Muehlenbeckia axillaris, Poa annua, Polygonum* spp., *Pseudognaphalium luteo-album, Raoulia* spp., *Sagina procumbens, Spergula arvensis, Trifolium* spp., *Verbascum* spp.

Turf plants characteristic of wet climates

In districts having high rainfall, depression bases do not necessarily dry out when pond level is low. Turf plants typical of these areas include *Centrolepis ciliata, C. pallida, Gratiola sexdentata, Gunnera dentata, G. monoica, Schizeilema cockaynei, Schoenus maschalinus, Tetrachondra hamiltonii,* and *Triglochin striata*.

Turf plants of boggy depression margins

Where upper zone turfs of depression margins retain some degree of subsurface moisture from adjoining land, often in combination with thin soils overlying bedrock or growing on other impervious ground, the turf can have a large component of plants more typical of bogs, e.g. *Carex echinata, Celmisia graminifolia, Euchiton mackayi, Gonocarpus micranthus, Herpolirion novae-zelandiae, Nertera balfouriana, Oreobolus pectinatus, Oreomyrrhis* sp. "bog", *Oreostylidium subulatum,* and *Plantago uniflora*.

Plants of upper zone turf and sward

Upper zones of ephemeral wetlands and lake margins can remain wet during periods of low water level either because of inflowing seepages and springs from land upslope or because the ground is gently sloping and pocked with water-holding puddles and runnels. Characteristic native plants found in these sites include: *Blechnum novae-zelandiae, Carex flaviformis, Epilobium chionanthum, Juncus gregiflorus, Polygonum salicifolium, Potentilla anserinoides, Ranunculus glabrifolius, Rumex flexuosus*. Common naturalised plants in similar sites are: *Carex demissa, C. ovalis, Epilobium ciliatum, Galium palustre, Juncus* spp., *Ludwigia* spp., *Lythrum hyssopifolia, Myosotis laxa* subsp. *caespitosa, Paspalum distichum, Polygonum* spp., *Ranunculus flammula, R. repens, Nasturtium microphyllum, Rumex* spp., *Stellaria alsine*.

Turf associations of sites shaded by woody vegetation

Upper zone turf which extends under scrub of forest has the following shade-tolerant turf plants: *Blechnum penna-marina, Brachyscome linearis, Centella uniflora, Epilobium nerteroides, E. nummulariifolium, Galium propinquum, Hydrocotyle heteromeria, H. moschata, H. novae-zeelandiae* var. *montana, Leptinella pusilla, L. squalida, Luzula picta, Mentha cunninghamii, Nertera depressa, Ourisia modesta, Pratia angulata, Ranunculus reflexus, Schizeilema nitens, Schoenus maschalinus, Tetrachondra hamiltonii, Viola filicaulis, V. lyallii.*

Turf plants of ephemeral wetlands in forest

A characteristic flora can occur as a sparse turf in small closed depressions within forest, as well as in forest floor puddly hollows or damp runnels: *Callitriche hamulata, C. petriei, Crassula ruamahanga, Gratiola nana, Isolepis habra, I. inundata, I. reticularis, Lilaeopsis ruthiana, Ourisia modesta, Potamogeton suboblongus*, and *Ranunculus ternatifolius*. A frequent dominant of forest floor moist hollows that are briefly ponded is the umbrella moss *Hypnodendron marginatum.*

13. Relationship of turf to other wetland types in New Zealand

How do ephemeral wetlands fit within the recently devised classification framework for New Zealand wetlands (Ward & Lambie 1999)? This hierarchical system has six levels of progressively finer detail, summarised as follows with comments as to the classification placement of ephemeral wetlands:

I. Hydrosystem (based mainly on broad hydrological setting): ephemeral wetlands are mainly located in palustrine (land-based) or lacustrine (lake-associated) hydrosystems, but may occur also in estuarine and inland saline hydrosystems.

IA. Sub-system (based on water regime): ephemeral wetlands are strongly characterised by a marked seasonal alternation between being ponded and dry.

II. Wetland Class (based on substrate, pH, chemistry): ephemeral wetlands could be classified within the wetland class of marsh, but in our opinion can validly be recognised as a distinctive class in their own right, characterised by the distinctive combination of mineral substrate, being fed mainly by groundwater, and having very marked water level fluctuation or seasonal periodicity. This treatment will be followed in a forthcoming publication on wetland types (Johnson & Gerbeaux, in press) wherein the nine wetland classes recognised will be bog, fen, swamp, marsh, shallow water, seepage, ephemeral wetland, pakihi and gumland, and saltmarsh.

IIA. Wetland Form (a category of descriptors of landforms which wetlands occupy and forms which they create or contain): ephemeral wetlands typically occur within closed depressions, but also in channels and basins.

III. Structural Class (vegetation structure or leading type of ground surface): ephemeral wetlands are usually vegetated with herbfield vegetation and, more specifically, with that subset of herbfield which we have defined as turf.

IV. Composition (dominant cover): ephemeral wetlands have great diversity of dominant plants.

How do the main turf communities of ephemeral wetlands compare with other wetland habitats and wetland types that are not of turf stature? The comparisons below are structured by *altering one or more environmental*

conditions or stresses, then considering the **resultant habitat**, its vegetation structure, and whether typical turf plants also occur there.

1. Permanent, *deep*, fresh water: → **lake beds** with aquatic meadows of macrophytes, charophytes, or bryophytes; few species of turf habit.
2. Permanent, fresh water *alternately deep or shallow*: → **lake margin** 'low mixed community'; this includes those aquatic-tolerant turf plants in Table 7.
3. *Permanent, shallow*, fresh, still water: → **lakes or rivers** having little fluctuation, and relatively sheltered margins with emergent reedland, rushland, or sedgeland; submerged turf plants may be present.
4. Fresh, *flowing* water: → **river banks**, variously unvegetated, eroded, freshly disturbed, or overhung with terrestrial vegetation; depending on flow regime, flood ferocity, sediment factors, and the absence of competing willow trees, freshwater turf vegetation may be present on suitable margins of rivers.
5. Permanent *or seasonal, brackish or variably fresh water near the coast*: → **coastal lagoons and tidal rivers**; zoned marginal vegetation often dominated by rushland or reedland; turf often present, variously comprising mixtures of salt marsh or freshwater turf species.
6. *Mineral soils rarely inundated but almost permanently moist*: → **marshes**; variously vegetation of sward or tussock habit: grassland, rushland, or sedgeland often with many naturalised plants; this vegetation can often abut on, merge with, or invade upper zones of turf; some turf species are often present on micro-habitats such as around pools or on the sides of rush or tussock pedestals.
7. *Mineral or peaty deep soils*, moderately fertile, the water table permanently high and sometimes a little above the ground surface: → **swamps and fens**, usually dominated by robust sedges, flax, ferns, shrubs, and sometimes trees; very few plants of turf stature occur in swamps.
8. *Peats, infertile because of lack of mineral soil materials or groundwater inflows, water table fairly constantly near ground surface*: → **bogs**; variously dominated by *Sphagnum* and other mosses, cushion plants, sedges, restiads, ferns, and shrubs. Bogs and turf wetlands share many species, notably *Carex gaudichaudiana* and *Isolepis aucklandica* that are common components of bog systems.
9. *Sloping peatlands or mineral substrates nourished by constant groundwater or by periodic surface water*: → **seepages and flushes**. Lowland seepages nourished by groundwater often have swards of grasses, rushes, and sedges, where some of the more vigorous, shade-tolerant, and nutrient-demanding turf species may also be present. In high rainfall areas, upland and alpine seepages which receive pulses of surface water are what we consider to be flushes. Because flushes experience regular but minor water level fluctuations, with alternations between being dry and shallowly submerged by sheetwash or terracette ponding (Fig. 8D), they verge on being ephemeral wetlands. Such flushes have characteristic floras (e.g. species of *Carpha, Gaimardia, Psychrophila, Abrotanella*, that are not found in turf) but they do also share a small portion of the turf flora of ephemeral wetlands and lake margins.

14. Relation to other turf habitats in New Zealand

In this section we consider habitats which also have vegetation of turf stature but which do not experience the factor of ponding alternating with extended dry times that is a strong determinant of ephemeral wetland turfs.

14.1 SALT MARSHES

Regular tidal fluctuation provides an alternation of submergence and emergence to salt marsh vegetation of estuaries, coastal lagoons that are open to the sea, and tidal rivers. In addition to zones of mangroves, shrubland, or rushland (especially *Juncus kraussii, Apodasmia similis*, *Schoenoplectus* spp.), salt marshes usually have a zone of predominantly short turf vegetation (Partridge & Wilson 1988) where most of the dominant plants are salt-tolerant herbs (e.g. *Sarcocornia quinqueflora, Samolus repens, Puccinellia* spp., *Isolepis cernua, Apium prostratum, Leptinella dioica*, and *Schoenus nitens*), which do not occur in freshwater turfs. Nevertheless, the salt marsh and freshwater turf floras do share a number of common turf plants e.g. *Selliera radicans* and *Triglochin striata*. Floristic distinctions between salt marsh and freshwater turfs become progressively less in coastal lagoons that are cut off from the sea and which receive freshwater inputs (e.g. Waituna Lagoon, Johnson & Partridge 1998), in tidal rivers towards the inland limit of tidal influence, and in marshes at the heads of enclosed fiord arms in Fiordland where the influence of marine salt water is much diluted by a buoyant overlying layer of fresh water derived from adjacent high-rainfall catchments (P.N. Johnson, unpubl. obs.).

14.2 COASTAL TURFS

Coastal turfs occupy headland crests, terraces, cliff ledges, and other slopes on very exposed coasts (Johnson 1993a; Rogers 1999). They include the coastal moor of Cockayne (1958) and the machair vegetation of Wilson et al. (1993). Rogers considers coastal turfs to be halophytic communities that occur away from their more traditional estuarine habitats, having been selected for by conditions of strong winds depositing high salt loads and creating mechanical buffeting which favours low-stature plants. Coastal turfs can occur on dry as well as wet substrates, and their extent has increased on headlands where forest has been removed and where grazing has reduced taller vegetation. Although the flora of coastal turf has its strongest linkage with that of estuarine salt marsh, it does include a number of coastal turf endemics (e.g. *Crassula manaia* and *Lepidium tenuicaule*), and shares with freshwater turfs a number of species that do not occur in intertidal salt marshes. Certainly, the compact habit and floristic diversity of coastal turfs makes them structurally very similar to freshwater turfs of ephemeral wetlands.

14.3 INLAND SALINE PATCHES

In the basins of semi-arid inland Otago, localised areas of saline soils are associated with knolls or aprons on terrace scarps, as salt pans of seasonally ponded abandoned river meanders or closed depressions and, in one instance, a small salt lake (Fig. 5F) (Johnson 1976; Allen & McIntosh 1997; Allen et al. 1997; Rogers et al. 1999). The flora includes turf plants typical of estuarine salt marshes (*Apium, Selliera, Sarcocornia, Samolus, Puccinellia* spp., *Plantago coronopus*), a suite of taller salt-tolerant herbs and grasses, both native and naturalised (especially species of *Atriplex, Chenopodium, Lepidium, Hordeum, Puccinellia,* and *Elymus*), but relatively few turf plants that link this habitat type with freshwater turfs of ephemeral wetlands.

14.4 DWARF HEATHS AND TURFS IN MONTANE TUSSOCK GRASSLANDS

In montane tussock grasslands, and certainly in inland Otago (Johnson 1994b, 1995a), there are at least two recurring micro-habitats which support considerable assemblages of turf and low-statured plants which are components also of the uppermost, most drought-prone turf zones in kettles and other inland South Island ephemeral wetlands. The first habitat is around rock tors on gentle spur crests where thin soils overlie a skirt of rock fragments: the soil is sharply drained and drought-prone, yet periodically well-watered by runoff from the tors during rain. The second—and very specific—situation is in rolling tussock land having shallow but numerous stream-dissections, where the above-stream slope meets the interfluve as a shoulder and where loess has accumulated. The turf banks found in these situations can be very steep. They are undoubtedly drought-prone in summer, especially those which face generally north into the sun. They may or may not be covered by snowbanks; indeed, those of northerly aspect may remain relatively snow-free over winter, but these sites may experience a long period of being charged with seepage water, especially at the time of spring snow melt. These two situations have saturated soil alternating with very dry soil, which may help explain the presence of dense and diverse turf and the localised absence or sparseness of tussock grasses compared with the immediately adjacent grassland.

The floristic composition of this turf represents an alliance of three elements. Firstly, there are numerous turf herbs which also occur in upper turf zones of ephemeral wetlands, e.g. *Agrostis muscosa, Colobanthus strictus*, *Leptinella squalida, Lycopodium fastigiatum, Geranium sessiliflorum, Helichrysum filicaule, Herpolirion novae-zelandiae, Oreostylidium subulatum, Ranunculus foliosus, Stackhousia minima,* and *Viola cunninghamii.* Secondly, the presence of abundant small-leaved but mat-forming subshrubs, e.g. *Coprosma petriei, C. perpusilla, Gaultheria* spp., *Leucopogon* spp., *Muehlenbeckia axillaris, Pentachondra pumila, Pimelea prostrata*, and *P. oreophila*, give this turf the character of an extremely dwarf heath. Thirdly, the presence of *Raoulia subsericea* and *Poa colensoi* is more typical of short dry tussockland.

14.5 ALPINE SNOWBANKS AND CUSHIONFIELDS

Snowbank communities (Fig. 8C) have plants of very low stature and they display zonation that reflects patterns of snow build-up and melt (Mark & Dickinson 1997). The outer edge of snowbanks (Mark & Bliss 1970) and, more specifically, snowbank communities of permanently moist sites (Talbot et al. 1992), share up to half of their floras with those of ephemeral wetlands.

Drier snowbank communities and alpine cushion fields which characterise the plateau summits of the south-central South Island have 'cushion, mat, and prostrate plants, generally less than 2 cm tall' (Mark & Dickinson 1997), the extreme dwarfism in this environment being ascribed by these authors to persistent strong winds, cold summers, and frequent freeze / thaw cycles. There is little floristic affinity between these alpine habitats and turfs of ephemeral wetlands at the level of plant species but, nevertheless, a large number of shared genera. Thus drier snowbanks and cushion fields contain a different assemblage of dwarf species of genera represented also in ephemeral wetlands, e.g. of *Agrostis, Anisotome, Carex, Celmisia, Colobanthus, Kelleria, Leptinella, Luzula, Neopaxia, Plantago,* and *Ranunculus*.

14.6 LAWNS AND PLAYING TURFS

A number of native turf plants, most notably *Leptinella dioica* and *L. maniototo,* are deliberately cultivated in the playing turfs used for bowling and croquet greens, and can also be found in golf course putting areas, in lawns, and in cemeteries where regular herbicide use can be a factor in maintaining a low-statured plant cover. Havell (1993) lists native plants that are common in bowling greens and lawns; in particular, species of *Colobanthus, Crassula, Dichondra, Hydrocotyle, Leptinella, Lilaeopsis, Mazus, Nertera, Oreomyrrhis, Oxalis, Plantago,* and *Pratia*. These plants are able to withstand foot and vehicle traffic, close mowing, soil compaction, animal pests such as *Porina* spp. caterpillars, and various diseases. Some of the native turf plants of lawns are considered to be weeds. Indeed, some nationally rare plants such as *Crassula* spp. and *Leptinella nana* have become weeds in regularly cultivated gardens.

15. Comparison with ephemeral wetlands overseas

Turf wetlands do not feature prominently in the international literature. Certainly, freshwater turf vegetation of similar structure to that described above for New Zealand occurs elsewhere in the temperate Southern Hemisphere, at least as evidenced by brief observations of lake edges in Tasmania and Argentina (P.N. Johnson, pers. obs.).

Ephemeral wetlands of many types occur in various parts of the world, especially in climates having marked alternations between wet and dry seasons, and landscapes conducive to ponding or to extended inundation by floodwaters. On a grand scale, the Pantanal of South America is a vast floodplain which is seasonally or intermittently flooded by up to several metres of water. The vegetation is a mosaic of forest, dryland, and aquatic types, but the latter, including ephemeral ponds, apparently have mainly tall communities of reedland, sedgeland, and robust herbs, rather than turf vegetation (Keddy 2000).

Australia is well endowed with ephemeral wetlands (Fleming 1991), and with various types of temporary ponds (Bayly & Williams 1973). Brock (1994) notes that fluctuations in water regime on various time scales are significant in Australian systems, yet the vegetation types of ephemeral wetlands such as intermittent floodplain lakes are mainly submerged aquatics, robust emergents, or woody plants; again, with no apparently marked zone of turf stature.

In Ireland, periodically inundated depressions upon limestone are known as turloughs. Coxon (1987a, b) provides inventory methods for description of their physical properties; these would be relevant for more detailed descriptions of New Zealand systems.

In North America, ephemeral wetlands of closed depressions are variously termed kettles, prairie potholes (both on glacial deposits), Carolina bays (in south-east USA; mainly with swamp forest), or vernal pools (Mitsch & Gosselink 2000). The term 'vernal pool' was originally applied to coastal terrace depressions in western USA, but has been used more widely by Zedler (1987) who provides a detailed account of the ecology of Californian vernal pools, and a brief discussion of the worldwide distribution of temporary pools. North American accounts of ephemeral wetlands note the strong zonation patterns, diversity of flora and fauna, and presence of characteristic and rare organisms in these habitats. While low-growing plants are present within these ephemeral wetlands, including representatives of genera that are found as turf plants in New Zealand, the predominant vegetation of all zones again appears to be of relatively robust plants, not of turf stature, but seemingly with growth forms and a size that more resemble those plants (mainly from the Northern Hemisphere) that are naturalised in New Zealand ephemeral wetlands.

16. Threats and impacts

16.1 WHAT IMPACTS DO EPHEMERAL WETLANDS AND THEIR TURFS ATTRACT?

Livestock such as cattle and sheep are attracted to wetland margins generally, for grazing and water. Because of their small size and localised nature within wider grazing areas, ephemeral wetlands can be subjected to concentrations of livestock. Rabbits prefer vegetation of very short stature; this they often achieve via their own intensive and tight cropping, but natural turf communities, especially those on firm and relatively dry substrates, provide precisely these

living conditions for rabbits. Many birds, especially waterbirds but also wading, migratory, and terrestrial birds, are attracted to places where land meets water, and especially to open expanses of turf, for grazing, resting, and congregating. Turf shores are often littered with bird droppings. The effects of grazing by birds are not often obvious in compact turf vegetation, but can be very evident on adjacent sward vegetation if it is reduced in stature by intensive bird grazing. Now extinct native birds which would have used these sites include species of duck, rail, goose, and swan. We do not know the impact of these birds compared with that of the modern avifauna which includes introduced water birds such as domestic goose, Canada goose, and black swan. These are all sizeable birds which can be present in large numbers in some areas.

Like other animals, people are also attracted to some ephemeral wetlands. People visit lakes and rivers for many forms of passive and active recreation; and often the most favoured sites—those which are accessible, sheltered, and have gently sloping shores and banks—are also the sites that have turf vegetation. Such sites—ideal for turf and access—frequently make up only a very small part of the total available 'edge' environment of lakes and rivers. Turf is generally very resistant to human foot traffic or to being sat or camped upon, but it is much less resisitant to wheeled vehicles. Upper turf zones of ephemeral wetlands often offer easy vehicle access for farm vehicles (Fig. 2C). Softer and muddier turf communities offer messy challenges for drivers of army training vehicles, and other 4WD vehicles or off-road bikes (Fig. 10F). The damage caused to these areas by vehicles can be severe.

16.2 HYDROLOGICAL ALTERATION

Turf communities of ephemeral wetlands obviously exist in fine balance with hydrological factors, especially the water fluctuation regime and water source. They are, therefore, likely to be sensitive to alterations of the hydrological regime, including those resulting from human activities, including artificial drainage, artificial inputs of water, or any land uses on adjacent or matrix land that would affect water yield; in particular, afforestation. To encourage waterfowl, some ephemeral wetlands, e.g. old dune hollows east of Lake Wairarapa (Moore et al. 1984), have been dug out and banked to hold more water.

16.3 ALTERATION TO SOIL AERATION

The regular alternation between dry and wet phases in ephemeral wetlands must be accompanied by marked alternations in availability of oxygen in the soils. Soil-weathering processes probably vary also with these cycles. Oxygen starvation during wet phases may well be a critical determinant of the turf stature of plants, of their shallow-rooting tendency, and may also act to prevent taller vegetation, including weedy plants, from establishing. Any changes to the magnitude, frequency, and seasonality of water fluctuation patterns could result in disruption of established long-term cycles of change in aeration and other soil properties.

16.4 SEDIMENTATION

Inputs of fine sediment (silt and mud) which might have been intercepted or stabilised when surrounding natural vegetation was intact, now have the potential to alter the permeability of the bases of ephemeral wetlands.

16.5 MINING AND OTHER FORMS OF MECHANICAL DISTURBANCE

Ephemeral wetland systems can be favoured sites for mining because they lack obstructing surface vegetation and because they are usually underlain by loose materials, e.g. sand in coastal dune systems. Historically, South Island kettles which occur close to roads have been used as sites for gravel extraction for roading materials. The terminal moraine landforms which hold kettles south of Lake Ohau were targeted at one time for removal of glacial erratic boulders for use in riverbank protection: the terminal moraine provided large, easily accessible boulders of solid rock without the need for quarrying. One method of rabbit control involves the laying of poisoned grain along the line of a rabbit-luring excavated furrow: kettle bases at their dry phase in inland Canterbury have been subjected to this treatment, presumably because their substrates are easily furrowed and their turf vegetation is favoured by rabbits.

16.6 NUTRIENT ENRICHMENT

The nutrient status of ephemeral wetlands can be artificially increased quite readily through topdressing, runoff, effluent discharge (e.g. Johnson 1995b; Fig. 10E), faecal matter from livestock and large waterfowl such as Canada geese and black swan, and animal carcasses (Fig. 10D). These processes arise mainly from intensification of agriculture (e.g. the current wave of dairy conversion towards high-energy farming), and of horticulture.

16.7 POLLUTANTS

Any depression in the land surface tends to represent an easy option for the disposal of rubbish and other waste material. Ephemeral wetlands, being water sinks and having little or no throughput of water, are susceptible to the effects of toxic material dumped or discharged into them. Ephemeral wetlands or ponds in the vicinity of intensive horticultural areas are also susceptible to spray drift.

16.8 TRAMPLING IMPACTS OF MAMMALS

Hoofed animals, both feral and farm livestock, can fracture, compact, and churn turf vegetation and soils. Native avifauna, including now-extinct birds species, would undoubtedly have congregated densely upon turf vegetation adjacent to water bodies, but their physical impacts on the substrate would have been

much less than those of introduced livestock. The impacts of large-hoofed animals, including horses (Fig. 4E), but especially sharp-hoofed cattle (Fig. 10B) and deer, include soil disturbance as described above. A flow-on effect of this disturbance is that it provides microsites suitable for germination and establishment of weeds. We know very little about the natural soil structures, profile morphology, soil chemistry and soil physics of turf environments, let alone how impacts such as compression of soil horizons that might accompany trampling would affect them.

16.9 WEEDS

Some naturalised plants that occur in ephemeral wetland turfs do not appear to usurp or threaten the native plants. But although they seem benign at present, such weeds could become threats following disturbance, nutrient enrichment, or changes in climate. Weeds of greatest concern are those which replace the natural dominants, fill the spaces needed by native annuals, are of taller, more shade-producing habit than the natives, are deeper-rooting, and which have the capacity to alter processes, e.g. in the way nutrients are cycled, energy captured, drainage filtered and intercepted, and sediment trapped. The upper zones of turf in ephemeral wetlands in grassland and pastoral settings are especially prone to invasion by grasses, notably browntop (*Agrostis capillaris*; Fig. 9D), creeping bent (*A. stolonifera*; Fig. 7D), and Chewing's fescue (*Festuca rubra*) which, in the absence of grazing, can overtop turf plants, create dense, litter-accumulating mats, and alter the moisture status of the substrate. Aquatic weeds are an issue in ephemeral wetlands that have permanent ponds. Weedy trees including willows (*Salix* spp.; Fig. 2C) and alder (*Alnus glutinosa*) are both an actual and a potential further threat to turf vegetation: these trees have no native counterpart capable of growing in turf. In river and lake margin turf they create a marked degree of shade during the growing season, they drop smothering deciduous leaves in autumn, their roots grow densely and close to the surface in turf vegetation, they increase the stability and rate of sediment accumulation of turf substrates, and they cause turf communities to become much less dense, more mossy, and with a predominance of shade-tolerant species.

16.10 INTRODUCED FISH AND OTHER AQUATIC ANIMALS

It is now rare to find any freshwater aquatic habitat, at least in New Zealand's lowland and montane zones, which lacks introduced fish, especially brown and rainbow trout. In their natural state, ephemeral wetlands which hold permanent or almost permanent ponds may be an important type of fish-free water body, because fish generally do not have access to them via any surface outlet channel. Notwithstanding natural impediments to access, trout have been introduced to (and survive in) some relatively small kettle lakes. Numerous other introduced fish species, including perch, mosquito fish, and types of carp, are also threats to closed depression pond systems which otherwise have the potential to remain free of introduced high-in-the-food-chain carnivores. Those ponds which lack any

fish, including native fishes, provide an opportunity for the conservation and study of native aquatic invertebrates in the absence of vertebrates. In many such ponds a patently high density of invertebrate life is visible. Native mudfish species occur in some ephemeral wetlands (e.g. Ling & Gleeson 2001); they may be threatened by introduced fishes.

17. Other conservation management issues

17.1 AWARENESS OF FRESHWATER TURF WETLANDS

Wetlands are, in general, poorly understood and largely undervalued in New Zealand. Ephemeral wetlands and their associated turf vegetation, as a subset of wetlands in general, have been almost completely overlooked, despite their being such a functionally distinctive ecosystem. Possibly the only community awareness of freshwater turfs would result from their amenity value in terms of places to fish, picnic, launch boats etc. Even amongst the conservation- and ecology-literate community, there is very little awareness of freshwater turfs and their biota—such knowledge is confined to a handful of amateur and specialist botanists and naturalists. There is a strong need to increase the profile of turf and ephemeral wetlands.

17.2 SCATTERED AND VARIABLE NATURE OF HABITATS

Ephemeral wetlands occur in widely scattered localities, sometimes singly but more often within landform systems that have many depressions of various sizes, in association with other wetland types (e.g. permanent lakes and ponds, stream margins, areas of seepage, marsh, or bog), located within a matrix of dryland vegetation. Land uses of this matrix and adjacent land can influence the whole wetland system, including both its surface and subsurface hydrology.

The localised nature, small size and, in some cases, narrow linear shapes of ephemeral wetland systems do not lend themselves to being readily or reliably identified by remote sensing or broad-scale mapping approaches. We emphasise that the variability of these systems is such that their recognition, description, and conservation assessment must rely on field knowledge and interpretation of their physical and biological features.

The 'island' nature of ephemeral wetland distribution is a feature to be borne in mind when considering the representativeness of sites being considered for protection and conservation management. Individual ephemeral wetlands are so inherently variable both within and between wetland systems that any one site can seldom be nominated as representative of the whole range of diversity of vegetation and biota.

17.3 AGRICULTURAL IMPACTS

Ephemeral wetlands in shallow depressions are vulnerable to land conversion by ploughing and discing. Large losses of ephemeral wetlands and turf ecosystems would have accompanied agricultural conversion of the lowlands of New Zealand.

17.4 LOSS OF BUFFER ZONES

Buffering of ephemeral wetlands against external pressures has been compromised, especially where natural surrounding vegetation such as forest, scrub, or tussock grassland has been modified to vegetation of shorter stature, including fully developed pasture land.

Ephemeral wetland systems which formerly were surrounded by woody vegetation, especially multi-tiered, high-biomass forest, would once have had a relatively higher input of organic matter. The change in inputs of both carbon and associated nutrients following the loss of surrounding forest could well have brought about changes to depression wetland turf communities and processes.

17.5 ARTIFICIAL STABILISATION OF HABITATS

Some ephemeral wetlands, especially those within sand dunes, are inherently unstable. Natural processes result in the substrate materials and their resultant landform features being in various development stages from freshly deposited to regularly disturbed, stabilised, eroded, or re-buried. Before human habitation of New Zealand, the biota of such systems survived in the long term by being able to colonise relevant microhabitats as and where these were created. A large area of habitat provides enough diversity of specific sites for populations to persist somewhere in the whole system. However, the artificial stabilisation of dunelands that is now common can effectively halt this dynamic process, especially where dunes have been stabilised with strong sand-binders such as the introduced marram grass (*Ammophila arenaria*), or by succeeding lupin scrub, wilding trees, or plantation forestry. Many of the threatened and uncommon taxa of dune hollows are early successional plants, e.g. *Eleocharis neozelandica, Isolepis basilaris, Sebaea ovata,* and *Selliera rotundifolia* that are dependent on a shifting mosaic of fresh dune hollows in dunes with mobile sands.

17.6 CLIMATE CHANGE

Increases in the incidence of extreme weather events, alteration to rainfall gradients, temperature change, sea-level rise, and hydrological changes associated with climate change can be expected to force latitudinal and altitudinal adjustments to biogeographical boundaries. Such changes will also affect ephemeral wetlands. We know little in detail about the reproductive

strategies of turf plants and about the successional responses of turf communities following major stress events; although, by and large, the majority of turf zones will be early successional in compositional nature because of the annual cycle of disturbance.

17.7 CATASTROPHIC AND GEOLOGICAL EVENTS

Compared with human time scales, most ephemeral wetland systems occupy landforms of some antiquity, dependent on processes that have a long periodicity. However, like all types of wetland, they come and go qiute quickly over geological time scales. One might need to take a very long-term conservation view in considering where and when future ephemeral wetland landforms will be created by tectonic uplift, glaciation or volcanism. Generally, the natural systems present today are likely to be all that will be present in human time scales. Nevertheless, there are some ongoing geological processes and more frequent catastrophic events which have the ability to quite rapidly produce new depression habitats. Retreating valley glaciers will continue to create new kettles. Landslides and fault movements will result in depressions and, ultimately, turf habitats where none may be present now. Coastal sand dune systems are the most labile of landforms that contain ephemeral wetlands. The vagaries of sand supply and wind patterns continually alter the distribution of dunes and their intervening damp hollows. Sea level change (most likely rise) will progressively impact upon all dune systems; tsunamis will inevitably cause major but one-off changes to localised dune areas. The natural onset of new areas of turf habitat and their subsequent development of turf communities is of scientific interest as representing the early stages of the long-term processes, and is, likewise, of conservation significance. New habitats for ephemeral wetlands will not necessarily occur within lands that are currently managed for conservation. How do we detect, then protect and manage incipient depressions wetland systems when they are not on conservation land? And whether on conservation land or not, the development of such systems is now likely to be severely impacted by human-related factors, such as the establishment of weeds. How do we assess and attempt to control such impacts?

17.8 ARTIFICIAL WETLANDS

Many artificial ponds and created lakes provide suitable habitats for turf communities. There is plenty of potential for enhancing development of turfs on such sites, for various purposes, including the conservation of rare plants, the provision of attractive, stable, resilient, and biodiverse vegetation cover on shores of man-made reservoirs and lakes utilised by wildlife or people, the restoration of gravel pits, or in the landscaping design of artificial wetlands used for the likes of stormwater settling. The main design requirements to encourage turf communities are gently sloping shores, suitable substrates, and appropriate water fluctuation regimes.

18. Conservation significance

Many aspects of ephemeral wetlands contribute to their importance in conservation. They comprise a distinctive class of wetlands, perhaps the most dynamic of wetland types in terms of experiencing seasonal extremes of wetness. The diverse landform types which they occupy are themselves of geomorphological interest, being the products of unusual combinations of geology, substrate deposition, earth movement, and erosion. Whereas most landforms and most wetlands are strongly influenced by fluvial processes, ephemeral wetland systems occur mainly on landforms governed by tectonic processes, glaciation, volcanism, and the wind-sculpting of sand dunes.

Today's ephemeral wetland systems are especially linked with landforms which have originated within the last several thousand years, but their high species richness indicates that suitable habitats have been present in New Zealand over much longer timescales, and through many different conditions of climate and land relief. The predominance and variety of plants having turf stature raises the question as to whether these evolved in response to grazing by birds, and might therefore represent part of the signature of New Zealand's flora having developed in the presence of a rich avifauna, yet without browsing mammals. New Zealand wetland turf plants and communities may be of high significance in a global context, for they appear to have no analogues in the Northern Hemisphere, where ephemeral wetlands are typically vegetated with plants of much taller stature.

Despite their scattered occurrence and their small total area in New Zealand, ephemeral wetlands are diverse in their plant communities, extremely rich in their flora, and clearly important as the sole or principal habitat for a high proportion of threatened plant taxa. Ephemeral wetlands have a distinctive fauna, especially because of the dynamic nature of the wetting and drying cycles, and because their ponds are usually isolated from streams, rivers, or larger water bodies. It is very likely that new faunal discoveries have yet to be made in ephemeral wetlands, just as it is known that these habitats contain distinctive plants which have yet to be named.

19. Future research needs

19.1 INVENTORY AND SURVEY

There is a need for both national inventory and regional survey of ephemeral wetland habitats. The habitats and geographical areas for which we have the least information include sand dune country (in particular, Northland), agricultural land, limestone areas, various areas of alluvial and plateau landforms, and the montane–subalpine zone. Inventory is most urgently needed in coastal areas, especially in the north of the North Island, and in the lower-

lying areas of the high country of the South Island where freeholding resulting from tenure review is opening up land for subdivision and more intensive development.

In practical terms, much of the future data gathering on ephemeral wetlands is likely to continue to occur in serendipitous fashion, when a biologist happens upon a turf wetland during the course of other studies or travels. For these as well as for more formal regional surveys we suggest that the botanical recording methods we have presented (vascular flora recorded with abundance estimates; semi-quantitative record of turf communities along any obvious zonation sequence; and documentation of physical features of site, landforms, and obvious hydrological features) will suffice as a relatively quick yet effective field assessment technique.

People carrying out conservation assessment and protection of ephemeral wetland systems should keep in mind their value as informative study sites for vegetation history research using pollen profiles and macrofossils.

19.2 BASIC RESEARCH QUESTIONS

Some of the research questions that arise in relation to ephemeral wetlands and their turfs may seem academic, but the answers will be important in underpinning the future development of management strategies that will be applicable to all ephemeral wetlands.

What causes turf? What environmental factors have encouraged so many different plants to evolve to a dwarf stature and to share many morphological features? Would taller plants be unable to withstand flattening by wave action or sediment deposition? Might the turf stature have something to do with wind, or with cold, or with being grazed heavily by water birds, at least during the evolution of turf plants? How do so many plants co-exist together in any given patch of turf? Competition for light would seem unlikely in turf habitats, which are mostly exposed to full sunlight. Most turf habitats have a reasonable constancy of soil moisture, and the water demands of tiny turf plants cannot be very great, but under drought conditions there may be periods of competition for water. What physiological and morphological responses are to be expected from alternately living under water and above it? Does the presence or availability of nutrients, oxygen, or toxins play a part in allowing plants to develop only a short stature? What about the reproductive biology of the plants? These questions, and the broader issue of why so many plants have adopted a prostrate habit in the profoundly alternating wet / dry habitat of ephemeral wetlands, are topics that have yet to be fully explored.

19.3 HOW SPECIAL IS TURF?

How specialised are freshwater turf plants and turf habitats to New Zealand? The convergence of growth form in turf species from so many diverse genera and families suggests that these habitats and their biota are very old and have existed in New Zealand for a very long time, probably through periods of very

different climate and land relief. Are turf habitats and biota better developed here than elsewhere in the world? If so, might they represent another situation akin to that of divaricating plants: a growth form and a natural phenomenon particular to New Zealand that it is our obligation to be good guardians of?

19.4 HYDROLOGICAL AND PHYSICAL FUNCTIONING

The most pressing research need for ephemeral wetlands and their turfs is to understand how they function. We have no long-term data on water fluctuation regimes: we know nothing about their seasonal cycles, how they are affected by extreme events, and whether they exhibit cyclical changes that might match the many cycles of climatic variability. Few hydrological studies have been made on the sources of water to ephemeral wetlands, the relative contributions of groundwater, surface flow, precipitation and so on, or on how and why pond levels drop. There is hardly any information on soils and substrates, and a basic starting point would be the collection of soil cores for analysis of total N, P, C, bulk density, and pH.

19.5 BOTANICAL STUDIES

We currently have a reasonable grasp of the vascular plant flora of ephemeral wetlands and their turfs (though there are known to be many undescribed taxa), some knowledge of the common patterns of turf plant zonation, and recorded examples of community composition. Ephemeral wetlands include a number of plant taxa generally recognised as being distinct, but which are still unnamed and undescribed. Future field studies and cultivation experiments can be expected to reveal further new plant taxa. There is considerable scope for a detailed ordination and classification of the diverse range of turf plant associations, and this would lead to the identification of distinctive plant community types which will be novel conservation candidates. Detailed zonation studies would reveal many more patterns, relationships to substrate types, and successional pathways than we are presently aware of. Our own botanical observations have scarcely touched on the contribution of bryophytes, algae, and cyanobacteria to these systems. The very large numbers of threatened and uncommon plant taxa which occur in ephemeral wetlands are an obvious reason for targeting this habitat type for detailed studies on the distribution, population trends, and habitat requirements of these specialised and unusual plants.

19.6 VEGETATION PROCESSES

In our descriptions of the physical and vegetation processes of ephemeral wetlands we have recorded mainly qualitative observations, or hinted at processes which we have inferred. Obviously, ephemeral wetlands offer much opportunity for studies of their vegetation changes (plant successions) over

both short- and long-term periods. Compared with the natural vegetation processes of native plants, what are the processes of spread, establishment, invasion, or replacement of naturalised plants? And how are these vegetation processes affected by erosion, sediment deposition, nutrient changes, birds, trampling, or livestock grazing? There is need not only for research on these topics, but for development of monitoring methodologies appropriate to the habitat and the questions.

19.7 INVERTEBRATE STUDIES

There is little information on the invertebrates of ephemeral wetlands, but it is likely that there is as great a diversity of invertebrate life as there is of vascular turf plants.

19.8 STRATEGIC RESEARCH QUESTIONS

Five research topics stand out as especially important in addressing currently known management issues with respect to ephemeral wetlands and their turfs. These are:

Grazing

What are the impacts of grazing mammals on turf vegetation, substrates, and processes? These impacts will include the consumption of herbage and the deposition of faecal matter. A corollary to this question is an assessment of the possible benefits of appropriate intensity and timing of sheep grazing (and rabbit grazing) as a management tool to minimise the competitive impact of naturalised weedy plants capable of overtopping and replacing native turf plants.

Trampling

What are the impacts of trampling by sharp-hoofed animals such as cattle, sheep, and deer on ephemeral wetlands? This issue often arises in discussions, negotiations, and hearings about the condition, management, and protection of wetlands in general. The need for more knowledge on this topic is especially relevant for ephemeral wetlands, because their small size, shallow water, and soft basal sediments mean they are generally very accessible and particularly vulnerable, especially to concentrations of cattle.

Habitat disturbance

To what extent can ephemeral wetlands at a weedy or advanced successional stage be restored by disturbance or removal of vegetation? The initial experimental work of Singers (1997, 1998) and of Jim Campbell (Colin Ogle, pers. comm.) with excavated scrapes in dune wetlands on the Wanganui coast indicate that early successional turf plants can be encouraged by disturbance. The technique warrants more widespread testing at other sites.

Afforestation

What are the hydrological impacts of plantation forestry upon water yield to ephemeral wetlands in the various landform types where they occur?

Buffering

What are the buffering roles of different vegetation types surrounding ephemeral wetlands, and how might information on them be used to determine the desirability of restoring surrounding vegetation to something approaching its natural condition?

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Appendix 1

FLORA OF VASCULAR PLANTS OF EPHEMERAL WETLANDS IN SELECTED REGIONS OF NEW ZEALAND

Lists based on observations by the authors augmented by records from other sources, as noted. Annotations are tabulated on growth form, faithfulness (obligate or facultative) to turf habitats, and regional abundance for each taxon. Plant taxa included are those that occur in habitats that are alternately inundated and exposed, within or immediately adjacent to turf or sward vegetation types that are dominated by herbaceous plants.

Abbreviations:

* Naturalised (not native)

Growth form (column 1):

T: Species having turf habit, i.e. prostrate or of stature < c. 10 cm tall.

X: Species of larger stature that can occur in turf vegetation.

Habitat faithfulness (column 2):

O: Obligate taxa of freshwater wetland turfs; almost restricted to these habitats.

F: Facultative taxa of freshwater wetland turfs; found also in other communities.

Regions:

A: Waikato Lakes: Lakes Whangape and Waahi (additional records from Champion et al. 2001).

B: Central North Island: Rangitaiki River head (additional records from Nicholls et al. 1986); Kaimanawa Range, Moawhango wetlands (Rogers 1989); Whirinaki Forest, Arahaki Lagoon; Hawke's Bay, Maungaharuru Range (G.Y. Walls pers. comm.).

C: Manawatu and Taranaki; principally Whitiau Scientific Reserve and Tangimoana (additional records from Ogle 2000).

D: Wellington area; principally Lake Wairarapa shore and near Boggy Pond (additional records from Ogle et al. 1990).

E: Marlborough and Nelson; principally Sedgemere and Lake Tennyson areas (additional records from Druce & Molloy (1991); and Farewell Spit (from Courtney 1999).

F: Canterbury to North Otago morainic kettles.

G: Otago; principally schist peneplain sites (Emerald Stream, Sutton, Greenland, Flat Top Hill).

H: Southland; principally northern Southland (Oreti, Von, and Mararoa valleys, and Countess Range).

I: Fiordland lake shores (Lakes Te Anau, Manapouri, Monowai, Hauroko, Poteriteri, and Hakapoua; Johnson et al. 1997).

J: Chatham Islands (Maunganui Beach, Tennants Lake, Ocean Mail, Hapupu, and Pitt Island).

Abundance:

a = abundant

f = frequent

o = occasional

r = rare

\+ = record based on published or unpublished lists for the area concerned

			REGIONS:									
	1	2	A	B	C	D	E	F	G	H	I	J
MONOCOTYLEDONS												
Apodasmia similis	X	F			a	+				a	a	
* *Agrostis capillaris*	X	F	o	+		+	a	f	o	f	o	f
A. muscosa	T	F		+			o	f	f	f	r	
A. pallescens	X	F		+				o				
A. personata	X	F						r		r		
* *A. stolonifera*	X	F	a		+	f	o	o	f	o	f	
* *Aira caryophyllea*	T	F	+					o		r	o	
* *A. praecox*	T	F								r		
* *Alisma lanceolata*	X	F				o						
* *Alopecurus geniculatus*	X	F	o			o		f	a	o	a	
Amphibromus fluitans	T	F	+	+		o						
* *Anthoxanthum odoratum*	X	F	f	f			f	f	f	f	o	o
* *Aponogeton distachyus*	X	F				+						
* *Axonopus fissifolius*	T	F	a									
Baumea arthrophylla	X	F	f	o								
B. articulata	X	F	+									
B. juncea	X	F	+									
B. rubiginosa	X	F	+	o		+		r				
B. tenax	X	F	+	+		+			r			
B. teretifolia	X	F	+									
Bolboschoenus caldwellii	X	F				+						
B. fluviatilis	X	F	+			+						
B. medianus	X	F	+									
* *Bromus willdenowii*	X	F	+			+						
Bulbinella angustifolia	X	F						r	r			
Carex berggrenii	T	F		+			o	a	f	f		
C. breviculmis	T	F		+			o	a	o			
C. buchananii	X	F				+	r	o		o		
C. capillacea	T	F		r			+	+	+			
C. carsei	T	F					+					
C. cirrhosa	T	O	+			+						
C. colensoi	T	F					r	o	r			
C. comans	X	F		+					r			
C. coriacea	X	F		+			f	f	f	o	o	
C. decurtata	T	F						o	+	r		
* *C. demissa*	X	F		+					r			
C. diandra	X	F						o	o	o		
C. dipsacea	X	F	o	f		+		r	r	o	r	
C. dissita	X	F	+					+	o			
C. echinata	T	F		+			f	f	o	f		
C. edgariae	T	F							+			
C. flagellifera	X	F	+				r					

Appendix 1 contd.

		REGIONS:											
		1	2	A	B	C	D	E	F	G	H	I	J
	C. flaviformis	T	O					o	f	o	o		
	C. gaudichaudiana	T	F	a	f			a	a	a	a	a	
	C. geminata	X	F		+		+		+				
	C. kaloides	X	F					f	r	+	o		
	C. lachenalii	T	F						r				
	C. lessoniana	X	F	+			+						
	C. maorica	X	F	o	r		+		o		o		
	C. muelleri	X	F					+	r				
*	*C. otrubae*	X	F				+						
*	*C. ovalis*	X	F	+	o			f	f	o	r	r	
	Carex petriei	X	F		+				r	r			
	C. pumila	T	F			f	+						
	C. resectans	T	F					+	r	r			
	C. rubicunda	T	O		f								
	C. secta	X	F	+	o		+	o	f	r	o		
	C. sinclairii	X	F		f		o	f	f	+	o	r	
	C. subdola	X	F	f									
	C. tenuiculmis	X	F						r	+	r		
	C. traversii	T	F					+					
	C. uncifolia	T	F		+					r			
	C. virgata	X	F	+	o		+		o		f		
	C. wakatipu	X	F						r				
	Carpha alpina	X	F		+			o	o	o			
	Centrolepis ciliata	T	F					o	r	r	o		
	C. minima	T	O						r	o	r		
	C. pallida	T	F							o	f		
	Chionochloa conspicua	X	F							r			
	C. rubra	X	F					f	f	o	r	r	
	Cortaderia fulvida	X	F	+									
	C. richardii	X	F						o	o	o		
*	*C. selloana*	X	F			o							
	C. toetoe	X	F			o	+						
*	*Critesion murinum*	X	F				+						
*	*Cynodon dactylon*	X	F	a		o							
*	*Cynosurus cristatus*	X	F	+			+		+				
*	*Cyperus congestus*	X	F			o							
*	*C. eragrostis*	X	F	o		o	o						
*	*C. tenellus*	T	F	f									
	C. ustulatus	X	F	o		+	a						
*	*Dactylis glomerata*	X	F	+			+		o		r		
	Deschampsia cespitosa	X	F		+				r	r	o		
	D. chapmanii	T	O					o	f	o	r	o	
	Deyeuxia avenoides	X	F	+							o		
	D. lacustris	T	O					+					
	D. quadriseta	X	F		+								
	Eleocharis acuta	X	F	a	f	+	f	o	a	a	f	a	a
	E. gracilis	T	O	f	a	+	+	f	f	o	f	f	o
	E. neozelandica	T	O			r		+					
	E. pusilla	T	O				+	o	f		f		
	E. sphacelata	X	F	f	r		+			r			
*	*Elodea canadensis*	X	F				+	o	f		f		
*	*Elytrigia repens*	X	F				+						
	Empodisma minus	X	F	+	+					r	r		

Appendix 1 contd.

				REGIONS:									
		1	2	A	B	C	D	E	F	G	H	I	J
	Festuca novae-zelandiae	X	F		+				f	o	r		
*	*F. rubra*	X	F				+				o		
	Fimbristylis squarrosa	X	F	o									
*	*Glyceria declinata*	X	F	+			o		f	f	r		
*	*G. fluitans*	X	F	+									
*	*G. maxima*	X	F	+									
	Herpolirion novae-zelandiae	T	F		o			+	f	f	r		
	Hierochloe redolens	X	F		o				r				
*	*Holcus lanatus*	X	F	f	a	a	a	f	a	f	o	o	a
	Hydatella inconspicua	T	F							r			
	Iphigenia novae-zelandiae	T	O		+				r	r			
*	*Iris pseudacorus*	X	F				+						
	Isachne globosa	X	F	+			+						
	Isolepis aucklandica	T	F					r	a	a	o	a	f
*	*I. australiensis*	T	O					o	o		r		
	I. basilaris	T	O			f		o	f	f	o	r	
	I. caligenis	T	O		+			o	r	r			
	I. cernua	T	F			o	+				o		
	I. crassiuscula	T	O		+								
	I. distigmatosa	X	F		+								
	I. fluitans	T	F		+					r			
	I. habra	T	F		r				r	r	o		
	I. inundata	T	F	+			+			r			
*	*I. marginata*	T	F	+		o							
	I. nodosa	X	F	+		a	+				f		
	I. prolifer	X	F			o	o			r			
	I. reticularis	T	O	+	+		+				o		
*	*I. setacea*	T	F		+				r	o			
	I. subtillissima	T	O		+								
*	*Juncus acuminatus*	X	F	+	+								
*	*J. acutiflorus*	X	F							r			
	J. antarcticus	T	O					o	f	o	o	r	r
*	*J. articulatus*	X	F	+	a	a	a	f	a	a	o	a	a
	J. australis	X	F	+		+	+			r			
*	*J. bufonius*	T	F	+	o	o	o	o	f	f	r	o	f
*	*J. bulbosus*	X	F	+	o			r	r		o		
	J. caespiticius	T	F			o	+						
*	*J. canadensis*	X	F						r				
	J. conglomeratus	X	F					r	f	f	f		
*	*J. dichotomus*	X	F				f						
	J. distegus	X	F				+		o	o	r		
*	*J. effusus*	X	F	+	+		+	a	a	f	r	o	
*	*J. fockei*	X	F			+							
	J. gregiflorus	X	F	+	o	o	f		o	f	o	a	o
	J. holoschoenus	X	F	+	+								
	J. kraussii subsp. *australiensis*	X	F			o							
*	*J. microcephalus*	X	F	+			+						
	J. novae-zelandiae	T	O					o	f	o	o		
	J. pallidus	X	F			o	+						
	J. planifolius	X	F	+	+	o	+			r	o		
	J. pusillus	T	O		+		+	f	f	o	f	f	
	J. sarophorus	X	F	+		o	r		o				

Appendix 1 contd.

			REGIONS:									
	1	2	A	B	C	D	E	F	G	H	I	J
* *J. squarrosus*	T	F					o					
* *J. tenuis*	X	F	+			+	r	f	r	r		
Lachnagrostis billardierei	X	F			o							
L. filiformis	T	F	+	o	f	+		o	o	o		
L. lyallii	T	F							o	r		
L. striata	T	F	+	o			f	f	f	r	f	
Lemna minor	T	F	+	+		o	r	o		r		
Lepidosperma australe	X	F	+	o				r		o	o	
Lepilaena bilocularis	T	F				o						
Libertia ixioides	X	F							r			
L. peregrinans	X	F			o							
* *Lolium perenne*	X	F	+			+			r			
Luzula celata	T	F						r				
* *L. congesta*	X	F							o			
L. crinita	X	F					r	r				
L. decipiens	T	O		+								
L. leptophylla	T	O					+	o	r			
L. picta	T	F		+			o	o	o	o		
L. rufa	T	F					+	f	o	r	r	
L. rufa var. *albicomans*	T	F		+				r				
L. ulophylla	T	F						o				
Microtis oligantha	T	O		+				f	r	r		
M. unifolia	T	F	o	+	+	+		o	r	o	r	
Oreobolus pectinatus	T	F		o			f	f	o	o		
O. strictus	T	F						r	o	r		
* *Paspalum dilatatum*	X	F	+		+	+						
* *P. distichum*	X	F	+			a						
* *Phleum pratense*	X	F				+		o	+	r		
Phormium cookianum	X	F							o			
P. tenax	X	F	+		o	+			o			
* *Poa annua*	T	F	+			+	f	f	o	r	o	f
P. cita	X	F		+				o	r	o		
P. colensoi	X	F					o	f	f	r		
P. lindsayi	T	F					+	f	o	o		
* *P. pratensis*	X	F		+	+		f	f	o	r	r	
* *P. trivialis*	X	F	+			+						
* *Polypogon monspeliensis*	X	F	+		o							
Potamogeton cheesemanii	X	F	+	f		a	f	a	o	f	a	
* *P. crispus*	X	F	+			r						
P. ochreatus	X	F				+	o	f	r	o		
P. pectinatus	X	F				+						
P. suboblongus	T	F		+			r	o		o		
Prasophyllum colensoi	T	F		+				o	o	r	r	
P. nudum	T	F		+								
Puccinellia walkeri subsp. *chathamica*	T	F								o		
Ruppia polycarpa	X	F				+		r		r	f	
Rytidosperma australe	T	F					r	f	r			
R. buchananii	X	F							r			
R. gracile	X	F		r				o	r	o		
* *R. racemosum*	X	F	+			+						
R. pumilum	T	F		+			o	f	r			
* *Schedonorus phoenix*	X	F	f		a	a			o			

Appendix 1 contd.

		REGIONS:										
		1	2	A	B	C	D	E	F	G	H	I	J
	Schoenoplectus pungens	X	F			f	a				f		
	S. tabernaemontani	X	F	f		o	o						
	Schoenus concinnus	T	O		+		+		f	r	o		
	S. fluitans	T	F		o								
	S. maschalinus	T	O	+	f		+				f	o	
	S. nitens	T	O			a		+			f		
	Schoenus pauciflorus	X	F		+			a	f	o	f	f	
*	*Sisyrinchium* "blue"	T	F			f	o						
	Spiranthes sinensis	X	F		+	r							
*	*Spirodela punctata*	T	F	+			+						
*	*Sporobolus africanus*	X	F	+		o							
	Thelymitra cyanea	X	F		+								
	T. longifolia	X	F	+	+								
	T. pauciflora	X	F		+	+							
	T. pulchella	X	F		+								
	Triglochin palustris	X	F						r				
	T. striata	T	F	+	+	f	+	+		f	a		
	Typha orientalis	X	F	+	r	r	+	o	f				
	Uncinia rubra	X	F		+				r	o			
	U. strictissima	X	F		+					+			
	U. uncinata	X	F	+						o			
*	*Vulpia bromoides*	X	F	+						r	r		
	Zannichellia palustris	T	O			+	o						
	Zoysia minima	T	F			+							
	HERBACEOUS DICOTYLEDONS												
	Acaena anserinifolia	T	F	+		+				o	o		
	A. buchananii	T	F						r				
	A. caesiiglauca	T	F						o	r			
	A. fissistipula	T	F						r	r			
	A. inermis	T	F					o	f	o	o		
	A. microphylla	T	F		+					r			
	A. rorida	T	O		+								
*	*Achillea millefolium*	X	F	+			+		r	o		o	
*	*Alternanthera sessilis*	X	F	r									
*	*Amaranthus retroflexus*	X	F				+						
*	*Anagallis arvensis*	T	F	+		o	+		r		f		
	Anaphalioides bellidioides	T	F							o			
	Anisotome aromatica	T	F					r	o	+	o		
*	*Anthemis cotula*	X	F	+			+						
*	*Aphanes arvensis*	T	F						r				
*	*Arenaria serpyllifolia*	T	F						o				
*	*Aster subulatus*	X	F	f		o							
*	*Bidens frondosa*	X	F	+	o		r						
	Brachyscome linearis	T	O							r	r		
	Callitriche hamulata	T	O	+	+								
	C. petriei subsp. *petriei*	T	O	+			f	o	f	f	o	a	
	C. petriei subsp. *chathamensis*	T	O								f		
*	*C. stagnalis*	T	F	+	+	+	+		r	o	r		
	Calystegia sepium	X	F	f			f						
	Cardamine corymbosa	T	F	+				+	r				
	C. debilis agg.	T	F	+	+		+		o	+	r	o	

Appendix 1 contd.

		REGIONS:										
		1	2	A	B	C	D	E	F	G	H	I	J
*	*C. hirsuta*	T	F	+			+						
	C. lacustris	T	O							r	r		
*	*C. pratensis*	T	F	+						r			
	C. "tarn"	T	O					+	r	r	r		
*	*Carduus tenuiflorus*	X	F	+			+						
	Celmisia alpina	T	F					o					
	C. glandulosa	T	F							r	r		
	Celmisia gracilenta	T	F					o	f	o	r		
	C. graminifolia	T	F						f	o			
	C. setacea	X	F		+								
*	*Centaurium erythraea*	T	F	+	o	a		r	f		r		
	Centella uniflora	T	F	a	f	o	+		o		f	f	
	Centipeda aotearoana	T	O	+		+	+		r	+			
*	*C. cunninghamii*	T	F	+			+	+					
	C. elatinoides	T	O	+			+						
	C. minima subsp. *minima*	T	O		r	+	+						
*	*Cerastium fontanum*	T	F				+	o	f	o	r	o	o
*	*Chenopodium album*	X	F	+			+						
*	*C. murale*	X	F				+						
*	*C. pumilio*	T	F				+						
	C. pusillum	T	F		+								
*	*Ciclospermum leptophyllum*	X	F				+						
*	*Cirsium arvense*	X	F	o			+	o	o	o	o	r	
*	*C. vulgare*	X	F	o	r		+	r	o	o	r	r	r
	Colobanthus apetalus	T	F				+	+	r	+	r		
	C. strictus	T	F					r	o	+	r	r	
*	*Conium maculatum*	X	F	+			+						
*	*Conyza bilbaoana*	X	F	+			+						
	Cotula australis	T	F	+			+						
	C. coronopifolia	X	F	+		+	o				f		
	Craspedia uniflora	T	F					o	o	r			
	C. "Lake Heron"	T	O						+				
	C. "tarn"	T	O					+					
	Crassula helmsii	T	O					+					
	C. hunua	T	F				+						
	C. kirkii	T	F								o		
	C. manaia	T	F			+							
	C. mataikona	T	F			+	+		+				
	C. multicaulis	T	O					o	r	r			
	C. peduncularis	T	O						r	r			
	C. ruamahanga	T	F				+			r			
	C. sinclairii	T	O				a	a	a	a	f	a	
*	*Crepis capillaris*	T	F	+	+	+	+	r	f	f	o		
	Dichondra brevifolia	T	F						f	o			
	D. sp. aff. *brevifolia*	T	O	+	o		+				f		
	Drosera arcturi	T	F					o	o	f			
	D. binata	X	F	+	+					r			
	D. pygmaea	T	F		+								
	D. spathulata	T	F		+					o			
	Elatine gratioloides	T	O	r	o	r	+	f	f	+	+	f	
	Epilobium alsinoides	T	F	+	+			f	f	f			
	E. atriplicifolium	T	F		+			o	o		o		

Appendix 1 contd.

				REGIONS:									
		1	2	A	B	C	D	E	F	G	H	I	J
	E. angustum	T	O					r	a	o	r	r	
	E. billardiereanum	T	F			o					o		
	E. brunnescens	T	F						f	+	o	o	
	E. brunnescens subsp. *minutifolium*	T	F						o				
	E. chionanthum	X	F		o		+		f	r	o		
*	*E. ciliatum*	X	F	+	+	r	+	o	f	r	r		
	E. cinereum	X	F							r			
	E. chlorifolium	X	F						r				
	Epilobium hectorii	T	F						r	r			
	E. komarovianum	T	O				+	f	f	+	o	f	
	E. melanocaulon	T	F							r			
	E. microphyllum	T	F						r	r			
	E. nerteroides	T	F	+	+	+	+	f					
	E. nummulariifolium	T	F	+		+	+						
	E. pallidiflorum	X	F	+	+		+		r				
	E. pedunculare	X	F							r			
	E. pernitens	T	F							o			
	E. tenuipes	T	F		+				r				
*	*Erodium cicutarium*	T	F				+		r				
*	*Erophila verna*	T	F						r				
	Eryngium vesiculosum	T	F				+						
	Euchiton audax	T	F	+	+	o		f	f	o	+	o	
	E. delicatus	T	F		o				f	r			
	E. ensifer	T	O		+					+			
	E. involucratus	X	F	+	+		+						
	E. lateralis	T	F		r		+	+	o	o	+		
	E. limosus	T	O	+	+		+		o	r			
	E. mackayi	T	F						o	r			
	E. paludosus	T	O		+				o	o			
	E. polylepis	T	F		+			o	o				
	E. ruahinicus	T	F						o	o	r		
	E. sphaericus	X	F	+			+	r					
	E. traversii	T	F		+			f	a	o	f		
	Euphrasia zelandica	T	F						o	r			
*	*Foeniculum vulgare*	X	F				+						
*	*Galium aparine*	X	F	+			+			r			
*	*G. palustre*	X	F	a	f	+	a		r		f		
	G. perpusillum	T	F					o	a	o	r	o	
	G. sp. cf. *perpusillum*	T	O		o		+	+	o	f			
	G. propinquum	T	F	+			+		+	r			
	G. trilobum	T	F				+		r				
	Gentiana cf. *bellidifolia*	X	F					o					
	G. corymbifera	X	F					o	r				
	G. grisebachii	T	F		+			o	o	r	o		
	Geranium microphyllum	T	F						o	r	r		
*	*G. molle*	T	F	+			+						
	G. sessiliflorum	T	F		+			o	f	o	r		
	Geum leiospermum	T	F						r	r			
	Gingidia decipiens	T	F						r				
	Glossostigma cleistanthum	T	O	+			+		o				
	G. elatinoides	T	O	+	a	+	a	a	a	f	o	a	
	G. submersum	T	O	+	a		+	a	a	r	f		

Appendix 1 contd.

		REGIONS:										
		1	2	A	B	C	D	E	F	G	H	I	J
	Gnaphalium luteo-album var. *compactum*	T	O					f	o				
	Gonocarpus aggregatus	T	F	+	+			o	f	o	o		
	G. micranthus	T	F	+	a			f	a	f	o	f	
	Gratiola nana	T	O						r	f			
	G. sexdentata	T	O	f	f	+	f	+	o		f		
	Gunnera arenaria	T	O			f							
	G. densiflora	T	F					+	+				
	G. dentata	T	F						r		f		
	G. monoica	T	F				+		r		o		
	Gunnera prorepens	T	F		+		+						
	Helichrysum filicaule	T	F		+				f	o	r	r	
*	*Hieracium pilosella*	T	F		o			o	a	f	o	r	
*	*H. praealtum*	X	F					r	f				
	Hydrocotyle heteromeria	T	F	+				r	r		o	r	
	H. hydrophila	T	O	+	o	o	f		a	f	r	a	
	H. microphylla	T	F					o	f	o	o	o	
	H. moschata	T	F	+			+			o			
	H. novae-zeelandiae	T	F	+	o	+	+		o		r		
	H. novae-zeelandiae var. *montana*	T	F		+			+	a	o	o	o	r
	H. pterocarpa	T	F	+	+		+						
	H. sulcata	T	O		o			f	a	o	f		
	Hypericum gramineum	T	F		o				r				
	H. japonicum	T	O	+	f		+	r	f	o			
	H. sp. aff. *japonicum*	T	O		f				o				
*	*Hypochoeris radicata*	T	F	+	o	o	o	o	f	o	o	r	
	Hypsela rivalis	T	O		o		+	f	f	f	o	a	
	Hypsela aff. *rivalis* "Burgoo"	T	O					+					
	Kelleria dieffenbachii	T	F						o	r			
	K. laxa	T	F						r	r			
	K. paludosa	T	F						r				
	Lagenifera cuneata	T	F							r			
	L. petiolata	T	F							o	r		
	L. pumila	T	F		+					o			
*	*Lapsana communis*	X	F	+			+						
*	*Leontodon taraxacoides*	T	F	+	f	a	+		o	+	o	f	
	Leptinella dioica	T	F					o	o				
	L. dispersa subsp. *dispersa*	T	O				+						
	L. maniototo	T	O				+		a	f	a	a	
	L. potentillina	T	F								f		
	L. pusilla	T	F					+	f		f		
	L. squalida	T	F				o	f	o	o	o	a	
	Lilaeopsis novae-zelandiae	T	O	+		f	+		+		a		
	L. ruthiana	T	O		f		a	f	a	f	o	a	
	Limosella lineata	T	O	+	+	o	a	a	a	f	o	a	a
	*L. "*Opunake"	T	O			+							
	L. "Manutahi"	T	O			+							
*	*Linum catharticum*	T	F		+	o		f	a	o	o		
	Liparophyllum gunnii	T	F							r			
	Lobelia anceps	T	F	+		f	+				o		
	Logania depressa	T	?O		?								

Appendix 1 contd.

		REGIONS:										
		1	2	A	B	C	D	E	F	G	H	I	J
*	*Logfia minima*	T	F						r				
*	*Lotus pedunculatus*	X	F	a	f	a	a		r	o	f		
*	*L. suaveolens*	X	F	+		+							
*	*Ludwigia palustris*	X	F	a	f		a						
*	*L. peploides* subsp. *montevidensis*	X	F	a									
*	*Lupinus polyphyllus*	X	F							o			
*	*Lycopus europaeus*	X	F	a									
*	*Lysimachia nummularia*	T	F	f									
*	*Lythrum hyssopifolia*	X	F	+		f	f						
*	*L. portula*	X	F		f				r	r			
*	*Matricaria dioscoidea*	X	F	+			+						
	Mazus arenarius	T	F							+			
	Mazus novae-zelandiae subsp. *impolitus*	T	F			o			+				
	M. novae-zelandiae subsp. *novae-zelandiae*	T	F			+	+						
	M. radicans	T	F					r		r			
*	*Melilotus indicus*	X	F	+		o							
	Mentha cunninghamii	T	F					o	o	r	r	r	
*	*M. pulegium*	T	F	a			f	a					
*	*M. spicata*	X	F				+		r				
	Microseris scapigera	T	F		+			o	o	o			
*	*Mimulus guttatus*	X	F				+		o		o		
*	*M. moschatus*	X	F	+				r	o	+	r	r	
	M. repens	T	F				+	+					
*	*Modiola caroliniana*	T	F	+			+						
	Montia fontana	T	F		+			r	f	o	r	r	
*	*Mycelis muralis*	X	F	+					r		r		
*	*Myosotis discolor*	T	F						o	o			
*	*M. laxa* subsp. *caespitosa*	X	F		o	+	a	f	a	o	r	o	o
	M. pygmaea var. *drucei*	T	F								r		
	M. pygmaea var. *minutiflora*	T	F						o				
	M. aff. *pygmaea* "Volcanic Plateau"	T	O		+								
	M. uniflora	T	F						r				
	Myosurus minimus subsp. *novae-zelandiae*	T	O						f				
*	*Myriophyllum aquaticum*	X	F	f									
	M. pedunculatum subsp. *novae-zelandiae*	T	O		a	o	f	a	a	f	f	a	f
	M. propinquum	X	F	+	a		a	a	a	a	f	a	
	M. triphyllum	X	F	a	+		+	f	f	o	o	a	f
	M. votschii	T	O			a	+	f	r		f	f	
*	*Nasturtium microphyllum*	X	F		+	+			o	+	r		
*	*N. officinale*	X	F	+									
	Neopaxia linearifolia	T	O						f	o	r	o	
	Nertera balfouriana	T	F					r	o	r	r		
	N. ciliata	T	F		+								
	N. depressa	T	F	+					r	+	f	o	
	N. scapanioides	T	F	+	+								
	N. setulosa	T	O		+		+	f	f				
	Oreomyrrhis sp. "bog"	T	F					o	o	r			

Appendix 1 contd.

		REGIONS:											
		1	2	A	B	C	D	E	F	G	H	I	J
	O. colensoi var. *colensoi*	T	F								o		
	O. colensoi var. *delicatula*	T	F					+		r			
	O. ramosa	X	F					r	o	r			
	O. rigida	T	F						r				
	Oreostylidium subulatum	T	F						r	o	r		
*	*Ornithopus perpusillus*	T	F						r				
	Ourisia modesta	T	O		+			+		+			
	Oxalis exilis	T	F	+		+	+	+	f	r			
	O. magellanica	T	F							r			
	Parahebe canescens	T	O						f	o	r		
*	*Parentucellia viscosa*	X	F	+	f	f	o		r		r		
*	*Plantago australis*	X	F	+	+						o		
*	*P. lanceolata*	X	F	+	+	+	+		o		r		
*	*Plantago major*	X	F	+	+	o	+		o		r	o	
	P. raoulii	T	F					r		r			
	P. spathulata	T	F						o				
	P. triandra	T	O		+			f	a	f	r	a	
	P. uniflora	T	F					r	o	r			
*	*Polygonum hydropiper*	X	F	+	+	+	+						
*	*P. persicaria*	X	F	+					r		r		
	P. plebeium	T	F		+								
	P. salicifolium	X	F	a			a			r			
	Potentilla anserinoides	T	F	+	o	o	+	o	a	o	o	f	f
	Pratia angulata	T	F	o	f	+	+	f	a	o	o	f	
	P. arenaria	T	F								a		
	P. perpusilla	T	O	o	f		o	o	a	f	f		
	P. angulata x *perpusilla*	T	O	a									
*	*Prunella vulgaris*	T	F	+	o	f	+	f	a	r	f	r	
	Pseudognaphalium luteo-album	T	F	+	+	o	+	f	f	f	r	o	o
	Ranunculus acaulis	T	F			o							
	R. amphitrichus	T	F	+	o		o	o	o				
	R. brevis	T	F					r	r				
	R. cheesemanii	T	F						o	r	r		
*	*R. flammula*	X	F	a	f		+		r		f		
	R. foliosus	T	F					o	o	o	r		
	R. glabrifolius	T	F		o			+	f	o	o	o	r
	R. gracilipes	T	F							o			
	R. limosella	T	O				+	o	f		o		
	R. macropus	T	F				+		r				
	R. maculatus	T	F							o	r		
	R. multiscapus	T	F						r	o			
	R. reflexus	X	F	+					r		o		
	R. recens var. *lacustris*	T	O							f			
*	*R. repens*	X	F	f			f		f		r	f	
	R. royi	T	F								r		
*	*R. sceleratus*	X	F				+		o	o			
	R. ternatifolius	T	O		+				r	r	+	r	
*	*R. trichophyllus*	X	F				r		o		r		
	Raoulia glabra	T	F							r			
	R. hookeri	T	F					o					
	R. monroi	T	F						r				
	R. subsericea	T	F					o	o	r	r		

Appendix 1 contd.

		REGIONS:										
		1	2	A	B	C	D	E	F	G	H	I	J
	R. tenuicaulis	T	F						r		r		
*	*Reseda luteola*	X	F						r				
	Rorippa palustris	X	F	+			+	+	f	r	r	o	
*	*Rumex acetosella*	T	F	+			+	f	a	f	o	r	o
*	*R. conglomeratus*	X	F	f			+						
*	*R. crispus*	X	F	+			o		f	o	f	f	
	R. flexuosus	X	F					o	f	+	r	r	
*	*R. obtusifolius*	X	F	o			+		o		r		
*	*Sagina apetala*	T	F							r			
*	*Sagina procumbens*	T	F	+				f	a	f	o	o	o
	Samolus repens	T	F			o							
	Schizeilema cockaynei	T	O						r	o	f		
	S. nitens	T	O					f	o	o	o		
	Scleranthus brockiei	T	F					+	r				
	S. uniflorus	T	F						o	o			
	Sebaea ovata	T	O			r							
*	*Sedum acre*	T	F				+		r	r			
	Selliera radicans	T	F		o	o	+		f	r	a	a	
	S. rotundifolia	T	O			a							
	Senecio biserratus	X	F						r		r		
*	*S. jacobaea*	X	F	+			+		r		r		
	S. minimus	X	F	+						o			
*	*Sisymbrium officinale*	X	F	+			+						
	Solanum americanum	X	F	+			+						
*	*S. nigrum*	X	F	+			+						
*	*S. physalifolium*	X	F				+						
*	*Sonchus asper*	X	F	+			+			r			
*	*S. oleraceus*	X	F	+			+			r	o		
*	*Spergula arvensis*	X	F	+			+		r				
*	*Spergularia rubra*	T	F	+					r	+			
	Stackhousia minima	T	F		+			o	a	r			
*	*Stellaria alsine*	X	F	+				r	f	o	o	o	
	S. gracilenta	T	F						o	o			
*	*S. graminea*	X	F				+	r	+	r			
*	*S. media*	X	F	+			+			r			
*	*Taraxacum officinale*	X	F	+		+	+		o	+	r		
	T. magellanicum	T	F								r		
	Tetrachondra hamiltonii	T	F		+				r	o			
*	*Trifolium arvense*	X	F						r				
*	*T. dubium*	T	F		+	o	+	o	a	f	r	r	o
*	*T. fragiferum*	T	F			f	+						
*	*T. pratense*	X	F	+			+		o		r		
*	*T. repens*	T	F	+	+	r	o	f	a	f	f	o	f
*	*T. subterraneum*	T	F				+						
*	*Tripleurospermum inodorum*	X	F						r				
	Utricularia novae-zelandiae	T	F		+			r	f	f	f		
	Urtica australis	X	F								o		
	U. linearifolia	X	F				+						
*	*U. urens*	X	F				+						
*	*Verbascum thapsus*	X	F	+					f				
*	*V. virgatum*	X	F						r				
*	*Veronica anagallis-aquatica*	X	F				+						
*	*V. arvensis*	T	F	+					o	+	r		

Appendix 1 contd.

			REGIONS:									
	1	2	A	B	C	D	E	F	G	H	I	J
* *V. scutellata*	T	F				+						
* *V. serpyllifolia*	T	F	+	o			f	a	o	r	o	
* *Vicia hirsuta*	X	F				+						
* *V. sativa*	X	F				+		r				
Viola cunninghamii	T	F		o			f	a	f	r	f	
V. filicaulis	T	F							o			
V. lyallii	T	F		o		+	o	o		o		
* *V. tricolor*	T	F						r				
Wahlenbergia albomarginata	T	F						o	o	r		
W. gracilis	T	F							r			
SUBSHRUBS												
Androstoma empetrifolia	X	F					o	r	r	r		
Coprosma atropurpurea	T	F					f	f	f			
C. perpusilla	T	F						o	o			
C. petriei	T	F						f	o			
C. talbrockiei	T	F					+					
Gaultheria depressa	T	F						r				
G. sp. (= *depressa* var. *novae-zelandiae*)	T	F					r	o		o		
G. macrostigma	X	F						o	o	o		
G. parvula	T	F						f	f	r		
Haloragis erecta	X	F				+						
Leucopogon colensoi	X	F					+	o	r			
L. fraseri	T	F					o	a	o	o	o	
L. fraseri var. *muscosus*	T	F					+	f	o			
Muehlenbeckia axillaris	T	F				+	f	a	f	f		
Pentachondra pumila	T	F					o	o	o	r		
Pimelea oreophila	X	F					o	o	o			
P. prostrata	X	F						o				
P. "Turakina"	X	F			+							
FERNS AND FERN ALLIES												
Azolla filiculoides	T	F	+	o		f		r	o	r		
* *A. pinnata*	T	F	+									
Blechnum novae-zelandiae	X	F	+	o		+		r		a		
B. penna-marina	X	F		o		+	o	f	+	f		
Isoetes kirkii	X	F				+	a	a	+	a		
Lycopodium fastigiatum	X	F					o	r	+			
Ophioglossum coriaceum	T	F		+			+	f	o	+	a	r
O. petiolatum	T	F			+							
* *Osmunda regalis*	X	F	o									
Pilularia novae-zelandiae	T	O				+	f	f		f		

Appendix 2

THREATENED AND UNCOMMON PLANTS

Plant taxa listed by de Lange et al. (1999) that occur in New Zealand ephemeral wetland habitats, their threat categories, growth form, and faithfulness (obligate or facultative) to turf habitats.

Abbreviations:

Threat categories:

Ex: Presumed extinct (1 taxon)

C: Critically Endangered (3 taxa)

E: Endangered (5 taxa)

V: Vulnerable (11 taxa)

D: Declining (5 taxa)

S: Naturally Uncommon, Sparse (15 taxa)

Vag: Naturally Uncommon, Vagrant (1 taxon)

RR: Naturally Uncommon, Range Restricted (9 taxa)

IK: Insufficiently Known (3 taxa)

TIC: Taxonomically indeterminate, Critically Endangered (2 taxa)

TIE: Taxonomically indeterminate, Endangered (2 taxa)

TIV: Taxonomically indeterminate, Vulnerable (2 taxa)

TIRR: Taxonomically indeterminate, Range Restricted (1 taxon)

TIIK: Taxonomically indeterminate, Insufficiently known (2 taxa)

Growth form:

T: Species having turf habit, i.e. prostrate or of stature < c. 10 cm tall.

X: Species of larger stature that can occur in turf vegetation.

Habitat faithfulness:

O: Obligate taxa of freshwater wetland turfs; almost restricted to these habitats.

F: Facultative taxa of freshwater wetland turfs; found widely also in other communities.

	FAMILY	THREAT CATEGORY	GROWTH FORM	HABITAT FAITH-FULNESS
Acaena rorida	Rosaceae	C	T	O
Amphibromus fluitans	Poaceae	C	T	O
Brachyscome linearis	Asteraceae	RR	T	O
Cardamine (a) (CHR 312947; "tarn")	Brassicaceae	TIE	T	O
Cardamine lacustris *(= Iti lacustris)*	Brassicaceae	RR	T	O
Carex capillacea	Cyperaceae	S	T	F
C. cirrhosa	Cyperaceae	S	T	O
C. edgariae	Cyperaceae	S	T	F
C. tenuiculmis	Cyperaceae	V	X	F
C. traversii	Cyperaceae	RR	T	F
C. uncifolia	Cyperaceae	S	T	F
Centipeda minima subsp. *minima*	Asteraceae	S	T	O
Centrolepis minima	Centrolepidaceae	RR	T	O
Coprosma talbrockiei	Rubiaceae	RR	T	F
Craspedia (e) (CHR 514391; "tarn")	Asteraceae	TIE	T	O
Craspedia (j) (CHR 516302; Lake Heron)	Asteraceae	TIIK	T	O
Crassula hunua	Crassulaceae	E	T	F
C. manaia	Crassulaceae	RR	T	F
C. mataikona	Crassulaceae	IK	T	F
C. multicaulis	Crassulaceae	S	T	O
C. peduncularis	Crassulaceae	E	T	O
C. ruamahanga	Crassulaceae	S	T	F
Deschampsia cespitosa	Poaceae	V	X	F
Deyeuxia lacustris	Poaceae	IK	T	O
Drosera pygmaea	Droseraceae	S	T	F
Eleocharis neozelandica	Cyperaceae	D	T	O
Euchiton ensifer	Asteraceae	S	T	O
Gnaphalium luteo-album var. *compactum* *(= Pseudognaphalium* sp.)	Asteraceae	S	T	O
Gratiola nana	Scrophulariaceae	V	T	O
G. pedunculata	Scrophulariaceae	Vag	X	O
Gunnera densiflora (CHR 90309)	Gunneraceae	TIIK	T	F
Hydatella inconspicua	Hydatellaceae	D	T	F
Hypsela aff. *rivalis* (369981; Burgoo Stream)	Lobeliaceae	TIV	T	O
Iphigenia novae-zelandiae	Colchicaceae	V	T	F
Isolepis basilaris	Cyperaceae	V	T	O
I. fluitans	Cyperaceae	D	T	F
Lepilaena bilocularis	Zannichelliaceae	S	T	F
Libertia peregrinans	Iridaceae	D	X	F
Limosella (a) (CHR 222625; Opunake)	Scrophulariaceae	TIC	T	O
Limosella (b) (CHR 515038; Manutahi)	Scrophulariaceae	TIRR	T	O
Logania depressa	Loganiaceae	Ex	T	O?

Appendix 2 contd.

	FAMILY	THREAT CATEGORY	GROWTH FORM	HABITAT FAITH-FULNESS
Luzula celata	Juncaceae	E	T	F
Mazus arenarius	Scrophulariaceae	V	T	F
M. novaezeelandiae subsp. *impolitus* f. *impolitus*	Scrophulariaceae	V	T	F
M. novaezeelandiae subsp. *novaezeelandiae*	Scrophulariaceae	E	T	F
Myosotis aff. *pygmaea* (CHR 244566; Volcanic Plateau)	Boraginaceae	TIV	T	O
Myosurus minimus subsp. *novae-zelandiae*	Ranunculaceae	D	T	O
Ophioglossum petiolatum	Ophioglossaceae	V	T	F
Oreomyrrhis colensoi var. *delicatula*	Apiaceae	S	T	F
Ourisia modesta	Scrophulariaceae	S	T	O
Pimelea (a) (CHR 495025; Turakina)	Thymelaeaceae	TIC	X	F
Polygonum plebeium	Polygonaceae	IK	T	F
Ranunculus brevis	Ranunculaceae	RR	T	F
R. macropus	Ranunculaceae	S	T	F
R. maculatus	Ranunculaceae	RR	T	F
R. recens var. *lacustris*	Ranunculaceae	RR	T	O
R. ternatifolius	Ranunculaceae	V	T	O
Sebaea ovata	Gentianaceae	C	T	O
Selliera rotundifolia	Goodeniaceae	V	T	O
Tetrachondra hamiltonii	Tetrachondraceae	S	T	F
Triglochin palustris	Juncaginaceae	E	X	F
Uncinia strictissima	Cyperaceae	V	X	F

Appendix 3

PLANT ZONATION TABLES

Examples of composition in concentric zones of turf vegetation on the margins of ephemeral wetlands and lakes at a selection of New Zealand sites. Map references are to Topographic Map Series NZMS 260. In each table, abundance of plant species is listed for vegetation zones as they occur from low on the shore to the upslope margin. The symbol + indicates presence at < 1% cover. Naturalised plants are indicated by *.

Key to Appendix 3 sites:

Table A3.1—Glenmore, Tekapo, Canterbury.

Table A3.2—Lake Lyndon, Canterbury.

Table A3.3—Oreti Valley, Southland.

Table A3.4—Lakes Manapouri and Te Anau, Fiordland.

Table A3.5—Near Lake Wanaka, Otago.

Table A3.6—Near Boggy Pond, Wairarapa.

Table A3.7—Whitiau, Wanganui coast.

Table A3.8—Maungonui Beach, Chatham Island.

Table A3.9—Rangitaiki, Volcanic Plateau.

Table A3.10—Arahaki Lagoon, Whirinaki.

Key to vegetation zones:

A = Aquatic in permanent shallow water

B = Muddy ground near kettle bases, exposed by late-season drop in water level

C = Low elevation zone of dense turf

D = Middle zone of dense turf

E = Uppermost zone of dense turf, abutting onto tussock grassland

Key to generalised plant abundance values:

1 = 1–5% maximum cover

2 = 5–15 % maximum cover

3 = Over 15% maximum cover

TABLE A3.1. GLENMORE, WEST OF LAKE TEKAPO, CANTERBURY.

Generalised zonation pattern of principal plant species on margins of kettles at Boundary and Cluster Tarns, Glenmore moraines. Area centred on map reference I37/020970; altitude 900 m. Date of observations: December 1993. See Fig. 1E. Reference: Johnson 1994a.

	VEGETATION ZONE				
	(BASE)A	B	C	D	E (MARGIN)
Potamogeton cheesemanii	3	2			
Myriophyllum propinquum	3	2			
Glossostigma elatinoides	2	3			
Crassula sinclairii	2	3	1		
Ranunculus limosella	2	2			
Glossostigma submersum	2	1			
* *Alopecurus geniculatus*	1	2			
Callitriche petriei	1	2			
Lilaeopsis ruthiana	1	3	1		
Eleocharis acuta	1	2	1	1	
Pilularia novae-zelandiae	1	2	1		
Eleocharis pusilla	1	1	1		
Elatine gratioloides	1	1			
Isolepis aucklandica		3	3	2	1
Myriophyllum pedunculatum		3	1		
Limosella lineata		2	1		
* *Agrostis stolonifera*		2	1		
Plantago triandra		1	3	2	
Hydrocotyle hydrophila		1	3	2	
Hypsela rivalis		1	3	2	
Leptinella maniototo		1	2	1	
Utricularia novae-zelandiae		1	2		
Neopaxia linearifolia		1	2		
Isolepis basilaris		1	1		
Rorippa palustris		1	1		
* *Juncus articulatus*		1	1		
Carex gaudichaudiana			3	2	1
Parahebe canescens			2		
Galium perpusillum			2	3	3
Juncus pusillus			2	1	
Epilobium angustum			1	3	3
Pratia perpusilla			1	3	
Poa lindsayi			1	2	3
Gonocarpus micranthus			1	2	2
Agrostis muscosa			1	2	1
Agrostis pallescens			1	2	1
Carex berggrenii			1	2	1
Hypericum japonicum			1	1	
Myosotis pygmaea var. *minutiflora*			1	1	
Euchiton delicatus			1	1	
Hydrocotyle microphylla			1	1	
Euchiton lateralis			1	1	1
Viola cunninghamii			1	1	1
Selliera radicans			2	3	
Hydrocotyle novae-zeelandiae var. *montana*			2	2	
Euchiton traversii			2	2	
Deschampsia chapmanii			2	1	
Schoenus concinnus				2	1
Polytrichum juniperinum				1	3

Table A3.1 contd.

		VEGETATION ZONE				
		(BASE)A	B	C	D	E (MARGIN)
	Dichondra brevifolia				1	2
*	*Hieracium pilosella*				1	2
*	*Rumex acetosella*				1	2
	Scleranthus uniflorus				1	2
	Stellaria gracilenta				1	1
	Lachnagrostis striata				1	1
	Carex decurtata				1	1
	Luzula rufa				1	1
	Microtis oligantha				1	1
*	*Agrostis capillaris*					3
	Gnaphalium luteo-album var. *compactum*					3
	Leucopogon fraseri					3
	Stackhousia minima					3
	Carex breviculmis					2
	Geranium sessiliflorum					2
	Acaena inermis					2
	Poa colensoi					2
	Muehlenbeckia axillaris					2
	Oreomyrrhis colensoi					2
	Gaultheria parvula					2
	Pimelea prostrata					2
	Leptinella pusilla					1
*	*Linum catharticum*					1
	Coprosma perpusilla					1
	Colobanthus strictus					1
	Pratia angulata					1
	Ranunculus foliosus					1
*	*Trifolium repens*					1
	Wahlenbergia albomarginata					1

TABLE A3.2. LAKE LYNDON, WEST OF PORTERS PASS, CANTERBURY.

Estimated percentage cover of turf plants in six zones of its northern lobe (c. 600 × 300 m and c. 2.5 m deep), which dries completely in summer. Map reference K35/ 050680; altitude 840 m. Date of observation: 7 December 1998. See Fig. 10A. Reference: Johnson 1999.

	VEGETATION ZONE					
	(BASE) A	B	C	D	E	F (MARGIN)
Width of zone (m)	40	40	15	20	80	30
Bare ground	25	2	15	90	0	0
Lilaeopsis ruthiana	20	15				
Eleocharis pusilla	15					
Crassula sinclairii	20	10	10			
Pratia perpusilla	20	20				
Juncus pusillus		30	10			
Eleocharis acuta		5				
Potamogeton cheesemanii		2				
Leptinella maniototo		10	5		25	
* *Alopecurus geniculatus*		5	20			
Neopaxia linearifolia			15			
* *Trifolium repens*			5		20	10
Epilobium angustum			5	2	10	2
Agrostis muscosa			5	2		
* *Sagina procumbens*			5			
Gnaphalium luteo-album var. *compactum*			2			
* *Spergularia rubra*			2	2		
* *Rumex acetosella*				2	5	
* *Cerastium fontanum*				1		
Poa lindsayi				1		
Epilobium microphyllum				1		
Galium perpusillum					25	5
* *Juncus tenuis*					10	
* *Trifolium dubium*					2	10
* *Anthoxanthum odoratum*					2	25
* *Hypochoeris radicata*						25
* *Cirsium arvense*						5
* *Hieracium pilosella*						5
* *Taraxacum officinale*						5
Rumex flexuosus						5

TABLE A3.3. ORETI–VON CATCHMENTS, WEST OF LAKE WAKATIPU, NORTHERN SOUTHLAND.

Estimated percentage cover of turf plants in five zones of a kettle 20 × 5 m having a pond with boggy margins and scarcely any water fluctuation. Map reference E42/ 407409; altitude 700 m. Date of observation: 27 February 1991. Reference: Johnson 1992a.

	VEGETATION ZONE				
	(BASE) A	B	C	D	E (MARGIN)
Width of zone (m)	8	1	4	1	5
Myriophyllum pedunculatum	80				
Potamogeton cheesemanii	10				
Eleocharis acuta	10				
* *Juncus effusus*		10			
Carex echinata		40	10		
Sphagnum falcatulum		50			
Sphagnum cristatum			50	5	
Oreobolus pectinatus			10	70	
Breutelia pendula			10		
Drosera arcturi			5		
Gonocarpus micranthus			5	20	
* *Agrostis capillaris*			2	2	15
Plantago uniflora			2		
Celmisia graminifolia			2	2	5
Lachnagrostis lyallii			2		
Carex coriacea			2		
Festuca novae-zelandiae					50
* *Anthoxanthum odoratum*					10
Ranunculus foliosus					5
Muehlenbeckia axillaris					5
Coprosma perpusilla					5
Pimelea oreophila					5

TABLE A3.4. LAKES MANAPOURI AND TE ANAU, FIORDLAND.

Principal turf species at four elevations of the lake shores. These four zones represent a simplification, by combining adjacent pairs of eight turf communities derived from TWINSPAN analysis of 595 plots of 0.5 × 0.5 m (Johnson & Burrows 2000).

Key to % frequency of occurrence in plots:

1 = 1–4% 2 = 5–10 % 3 = 11–25% 4 = 26–50% 5 = > 50%

	VEGETATION ZONE			
	A	B	C	D
Mean altitude of zone (m.a.s.l.):				
Lake Manapouri	177.5	178.0	179.1	179.9
Lake Te Anau	202.0	202.3	203.1	204.0
Number of Plots	139	78	181	197
Pilularia novae-zelandiae	4			
Centrolepis minima	3			
Elatine gratioloides	2			
Isoetes kirkii	1			
Juncus pusillus	4	3		
Myriophyllum propinquum	4	1		
Limosella lineata	3	2		

Table A3.4 contd.

	VEGETATION ZONE			
	A	B	C	D
Crassula sinclairii	3	1		
Potamogeton cheesemanii	1	1		
Glossostigma spp.	5	4	1	
Myriophyllum pedunculatum	5	4	1	
Triglochin striata	4	4	1	
Gratiola sexdentata	4	3	1	
Leptinella maniototo	4	3	1	
Lilaeopsis ruthiana	4	2	1	
* *Alopecurus geniculatus*	3	3	1	
Centrolepis pallida	3	3	1	
Isolepis aucklandica	3	2	1	
Ranunculus recens var. *lacustris*	2	4	1	
Eleocharis gracilis	2	3	2	
Eleocharis pusilla	1	3	1	
Myriophyllum votschii	1	3	1	
Pratia perpusilla	1	3	1	
Carex berggrenii	1	2	1	
Eleocharis acuta	5	5	4	1
Hypsela rivalis	4	4	1	1
Carex gaudichaudiana	3	5	4	1
Hydrocotyle hydrophila	3	5	3	1
Callitriche petriei	3	3	1	1
* *Juncus articulatus*	3	3	3	1
Plantago triandra	2	5	2	1
Centella uniflora	2	3	3	1
Schizeilema cockaynei	2	3	1	1
Hydrocotyle sulcata	2	3	1	1
Isolepis habra	2	2	2	1
Selliera radicans	1	4	2	1
Mosses	1	3	5	5
Lachnagrostis spp.	1	3	3	1
Viola cunninghamii	1	2	4	2
* *Lotus pedunculatus*	1	2	3	2
* *Prunella vulgaris*	1	2	3	2
Tetrachondra hamiltonii	1	2	1	1
Centrolepis ciliata	1	2	1	1
Leptinella pusilla		4	2	
Gonocarpus micranthus		2	3	
Gonocarpus aggregatus		1	2	
Pratia angulata		2	3	3
Leptinella squalida		2	1	1
Galium perpusillum		2	1	1
Schoenus maschalinus		2	1	1
Schoenus pauciflorus		1	4	1
Nertera depressa		1	3	1
Lepidosperma australe		1	3	1
Gentiana grisebachii		1	2	2
Ranunculus reflexus		1	1	1
Hydrocotyle novae-zeelandiae var. *montana*			2	2
Muehlenbeckia axillaris			2	1
Gunnera dentata			2	1
Anaphalioides bellidioides			1	1
Lagenifera petiolata			1	1
Viola filicaulis				1

TABLE A3.5. DUBLIN BAY, LAKE WANAKA, OTAGO.

Estimated percentage cover of turf plants in four zones in a depression upon gravels behind a lake shore storm beach. This depression, c. 40 × 20 m across and 0.4 m total depth, has a base which dries completely, and is situated among short grassland and woodland of kanuka (*Kunzea ericoides*), matagouri (*Discaria toumatou*), sweet brier (*Rosa rubiginosa*), and *Coprosma propinqua*. Map reference F40/ 061103; altitude 280 m. Date of vegetation record: 12 February 2000. See Figs 1A, B, C, D.

	VEGETATION ZONE			
	(BASE) A	B	C (MARGIN)	D (SURROUNDS)
Width of zone (m)	1	8	1–2	
Bare ground	10			
Glossostigma elatinoides	30	1		
Limosella lineata	20	+		
Elatine gratioloides	10	+		
Galium perpusillum	10	30	3	
Lachnagrostis filiformis	10	15	15	
* *Juncus articulatus*	10	15	5	
Eleocharis acuta		10		
* *Agrostis stolonifera*		10	10	
Carex gaudichaudiana		10		
Epilobium angustum		5	5	
Juncus pusillus		1		
* *Centaurium erythraea*		1	+	+
* *Hieracium pilosella*		+		+
Gonocarpus micranthus		1	3	
Dichondra brevifolia		+		
* *Carex ovalis*		1	20	
* *Juncus effusus*			15	
* *Ranunculus repens*			20	10
* *Rumex acetosella*			2	
* *Juncus bufonius*			1	
Hypericum japonicum			+	
Carex resectans			+	
Ophioglossum coriaceum			+	
* *Prunella vulgaris*			+	
Euchiton audax			+	+
* *Hieracium lepidulum*				10
* *Trifolium pratense*				5
* *Agrostis capillaris*				50
* *Anthoxanthum odoratum*				15
* *Holcus lanatus*				10
Leucopogon fraseri				+
Geranium sessiliflorum				+

TABLE A3.6. WAIRARAPA, NEAR BOGGY POND, EAST SIDE OF LAKE WAIRARAPA.

Estimated percentage cover of turf plants in three zones in a depression upon alluvium, impounded behind lake-margin dunes, with surrounding marshy wetlands (e.g. of *Cyperus ustulatus*) and remnant forest of kahikatea (*Dacrycarpus dacrydioides*). Map reference S27/ 994928; altitude c. 5 m. This depression is c. 100 × 100 m across and c. 1-m deep when fully ponded; ponded for much of the year but intermittently completely dry. Date of observation: 19 January 2000. See Figs 9B, 11A. General reference: Rebergen 2000.

	VEGETATION ZONE		
	(BASE) A	B	C (MARGIN)
Width of zone (m)	80	5	4
* *Paspalum distichum*	60		
Potamogeton cheesemanii	20		
Drepanocladus sp.	10	10	
Myriophyllum propinquum	5	+	
Azolla filiculoides	2		
Callitriche petriei	1	+	
Gratiola sexdentata	1		
* *Potamogeton crispus*	+		
* *Ranunculus trichophyllus*	+		
Pratia perpusilla	+	+	
* *Juncus articulatus*	+	25	
* *Myosotis laxa* subsp. *caespitosa*		15	
* *Ludwigia palustris*		15	
Polygonum salicifolium		10	10
* *Agrostis stolonifera*		5	
Juncus gregiflorus		5	
* *Mentha pulegium*		5	
* *Lotus pedunculatus*		5	10
Ranunculus amphitrichus		2	
* *Alisma lanceolata*		1	
* *Alopecurus geniculatus*		1	
Amphibromus fluitans		1	
* *Bidens frondosa*		+	
Cotula coronopifolia		+	
Eleocharis acuta		+	
* *Glyceria declinata*		+	
Isolepis prolifer		+	
Juncus sarophorus		+	
Lemna minor		+	
* *Lythrum hyssopifolia*		+	
* *Rumex crispus*		+	
Schoenoplectus tabernaemontani		+	
* *Galium palustre*		+	5
Cyperus ustulatus			50
* *Schedonorus phoenix*			15
Calystegia sepium			10

TABLE A3.7. WHITIAU SCIENTIFIC RESERVE, WANGANUI COAST AT WHANGAEHU RIVER MOUTH.

Estimated percentage cover of turf plants in the base and surrounds of a dune hollow with jointed wire rush (*Apodasmia similis*) among hind-dunes with marram grass (*Ammophila arenaria*). Map reference R23/ 892282; altitude c. 5 m. A depression c. 40 × 8 m across and 0.4 m total ponding depth. Date of observation: 18 January 2000. See Figs 3D, E. Floristic reference: Ogle 2000. In the third column, composition is listed also for an adjacent hollow (5 × 2 m) which contains the rare plant *Sebaea ovata*. (Fig. 3F).

	VEGETATION ZONE		
	BASE	SURROUND	(*Sebaea* HABITAT)
Width of zone (m)	4	4–20	
Bare silt and sand	25		
Schoenus nitens	25	15	30
Gunnera arenaria	10	10	30
Bryophytes	10	10	
* *Leontodon taraxacoides*	10	10	5
Selliera rotundifolia	5		10
Apodasmia similis	5	25	5
* *Juncus articulatus*	5		
Lobelia anceps	1		1
* *Lythrum hyssopifolia*	1		
Isolepis cernua	1		
Triglochin striata	1		
* *Schedonorus phoenix*	1	10	10
* *Lotus pedunculatus*		10	
* *Holcus lanatus*		5	
Isolepis nodosa		5	
* *Prunella vulgaris*		+	1
Coprosma acerosa		+	
Phormium tenax		+	
* *Centaurium erythraea*		+	
Juncus kraussii subsp. *australiensis*			+
Cortaderia toetoe		+	
* *Sporobolus africanus*			2
Epilobium billardiereanum			1
* *Plantago major*			1
* *Trifolium fragiferum*			+
Sebaea ovata			+

TABLE A3.8 CHATHAM ISLAND, MAUNGONUI BEACH.

Estimated percentage cover of turf plants in three zones of a broad shallow depression c. 2 × 0.3 km between sand dunes, and dry at the time of study. Map reference Chatham Sheet 1/ 310756; altitude c. 3 m. Date of observation: 30 March 2000.

	VEGETATION ZONE		
	A	B	C
Zone position	lowest hollows	main base	margin
Width of zone (m)	2–10	150	20
Lilaeopsis novae-zelandiae	20	1	
Myriophyllum pedunculatum subsp. *novae-zelandiae*	15	15	2
Selliera radicans	15	10	15
Triglochin striata	10	1	
Myriophyllum votschii	10		
Cotula coronopifolia	10		
Limosella lineata	10		
* *Poa annua*	5	1	
Callitriche petriei subsp. *chathamensis*	5		
Pratia arenaria		25	5
Centella uniflora		10	
Isolepis cernua		5	
Leptinella squalida		5	15
Puccinellia walkeri subsp. *chathamica*		5	
Dichondra sp. aff. *brevifolia*		5	5
Bryophytes		5	
* *Trifolium repens*		3	10
* *Trifolium dubium*		2	
Oreomyrrhis colensoi		2	2
Schoenus nitens		2	10
Schoenus maschalinus		1	
Lobelia anceps		1	
Lagenifera petiolata		1	2
* *Agrostis capillaris*			15
* *Holcus lanatus*			5
* *Anthoxanthum odoratum*			2
* *Vulpia bromoides*			2
Taraxacum magellanicum			1
Ranunculus royi			1
* *Sagina procumbens*			1
* *Rumex acetosella*			1
* *Hypochoeris radicata*			1
* *Cerastium fontanum*			1
Hydrocotyle novae-zeelandiae var. *montana*			1
* *Prunella vulgaris*			1
Helichrysum filicaule			1
Hydrocotyle heteromeria			1
* *Juncus articulatus*			+
Juncus antarcticus			+
* *Cirsium vulgare*			+
Ophioglossum coriaceum			+

TABLE A3.9. UPPER RANGITAIKI CATCHMENT, SOUTH-EAST OF TAUPO, VOLCANIC PLATEAU.

Estimated percentage cover of turf plants in five zones of a relatively dry turf depression upon tephra in a broad 'frost flat' basin among monoao (*Dracophyllum subulatum*) scrub. Map reference U19/ 051462; altitude 730 m. A depression c. 200 × 50 m across and 0.4 m total depth, with a base which dries completely. Date of observation: 17 January 2000. See Figs 4A, B, D. General reference: Nicholls et al. 1986.

	VEGETATION ZONE				
	(BASE) A	B	C	D	E (MARGIN)
Width of zone (m)	20	10	6	4	2
Bare silt	33	20	15	20	
* *Lythrum portula*	25	15	10		
Lachnagrostis striata	25	20	5	2	
Glossostigma spp.	15	15	5	3	
Centipeda minima subsp. *minima*	1				
* *Juncus bufonius*	1				
* *Veronica serpyllifolia*	1				
Carex rubicunda		20	20	25	
Lilaeopsis ruthiana		5	20		
Euchiton delicatus		2			
Hypsela rivalis		1	2		
Carex dipsacea			15		
Juncus gregiflorus			5		
* *Juncus articulatus*			3		
* *Leontodon taraxacoides*				20	
* *Prunella vulgaris*				15	
Lepidosperma australe				5	
Hypericum sp. aff. *japonicum*				5	
Hypericum japonicum				2	
Hypericum gramineum				1	
Dichondra sp. aff. *brevifolia*				1	
Euchiton lateralis				1	
* *Holcus lanatus*					50
* *Anthoxanthum odoratum*					50

TABLE A3.10. ARAHAKI LAGOON, WHIRINAKI FOREST, WEST OF HUIARAU RANGE.

Estimated percentage cover of turf plants in six zones of a seasonally wet hollow upon tephra, surrounded by forest of kahikatea (*Dacrycarpus dacrydioides*). Map reference V18/ 285737; altitude 490 m. A depression 400 × 100 m across, c. 2-m deep when fully ponded. Date of observation: 3 December 2000. See Fig. 4H.

	VEGETATION ZONE					
	(BASE) A	B	C	D	E	F (MARGIN)
Width of zone (m)	10	5	5	20	20	10
Water	40					
Mud		15	20			
Potamogeton cheesemanii	30					
Myriophyllum propinquum	30	15	20			
Eleocharis acuta		60				
Glossostigma elatinoides		10	20	10	2	1
Eleocharis gracilis			20	25	20	5
Myriophyllum pedunculatum			10	20	10	2
* *Juncus articulatus*			5			
Gratiola sexdentata			5	15	15	1
Lilaeopsis ruthiana				20	5	2
Schoenus maschalinus				10	10	15
Pratia perpusilla					15	15
Baumea arthrophylla						10
Lachnagrostis sp.					5	2
Viola lyallii					4	4
Hydrocotyle hydrophila					2	2
Carex gaudichaudiana					2	4
Carex dipsacea						10
Centella uniflora						10
Hydrocotyle novae-zeelandiae						5
Euchiton delicatus						5
Pratia angulata						4
Juncus gregiflorus						2
Hypericum japonicum						2
* *Parentucellia viscosa*						2
* *Galium palustre*						2
* *Centaurium erythraea*						1
Sphagnum novo-zelandicum						1
* *Cirsium vulgare*						1
Carex virgata						1
Ranunculus glabrifolius						1

Summary of zones: A = basal pond, 10 cm deep; B = *Eleocharis acuta* 40 cm tall; C = green muddy turf; D = orange turf mainly *Eleocharis gracilis*; E = ditto with scattered 2–6-m-diameter clumps of the tall sedge *Baumea arthrophylla*; F = upper turf with scattered tussocks of *Carex dipsacea*. Surrounding the turf zones are further zones of woody vegetation: G = manuka (*Leptospermum scoparium*) shrubs to 5 m tall as an interrupted zone to 4 m wide; H = kahikatea (*Dacrycarpus dacrydioides*) forest as a complete surrounding perimeter zone some 20–30 m wide, periodically inundated, with trees 20–25 m tall, over understorey shrubs of *Coprosma rotundifolia*, *C. rigida*, and *Neomyrtus pedunculata*; I = taller kahikatea (to 35 m) over tiers of tawa (*Beilschmiedia tawa*, *Dicksonia fibrosa* tree ferns, and shrubs of pepper tree (*Pseudowintera colorata*) on ground beyond the apparent upper level reached by ponded water.

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