2.3.4 Estuarine

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

2.3.5 Marine

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

2.3.6 Inland saline

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

2.3.7 Plutonic

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

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

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

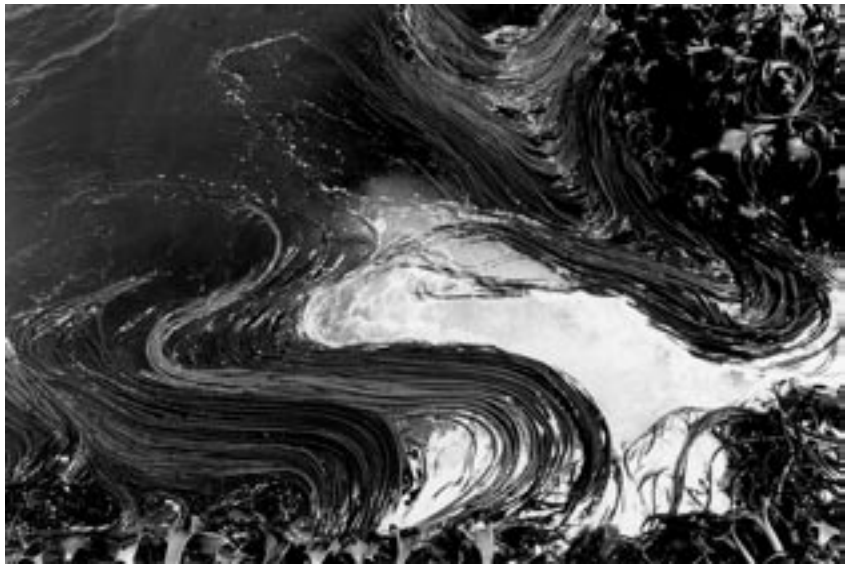

Fig. 7 Marine hydrosystem: surge through kelp beds, Catlins coast, Otago.

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

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

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

Fig. 11 Nival hydrosystem: snowfields at the head of the Whitbourn Glacier, Otago.

2.3.8 Geothermal

A hydrosystem where the dominant function is geothermal water (heated by volcanic activity to 30°C or more); geothermal wetlands may have water temperatures below this, yet be influenced by chemicals from current or former inputs of geothermal-derived water. Geothermal wetlands occur predominantly in the central North Island and include volcanically active habitats of fumarole margins, hot surface waters, heated soils that are permanently or intermittently wet, and shallow water at land margins. Details of this hydrosystem are not further considered in this book.

2.3.9 Nival

Snowfields and glaciers constitute a common though mostly frozen hydrosystem of the mountains, not generally thought of as a wetland habitat, but acknowledged here because snow and ice are indeed a habitat of algal communities, and because of the importance of melting snow and ice in nourishing vegetated wetlands.

Key to hydrosystems

1 Salinity 5‰ (5 parts per thousand) or more 2
Salinity less than 5‰ 4

2 Water regime not influenced by tidal water; situated in inland basins where salinity results from localised areas of saline soils associated with semi-arid climate . . . . . **inland saline**
Water regime influenced by tidal water, and salinity due to marine-derived salt . . . 3

3 Partly enclosed by land but open to the sea, with evident tidal effects, or coastal land markedly affected by marine salt; salinity 5–35‰ . . . . . **estuarine**
Little or no obstruction to open sea; salinity about 35‰ . . . . . **marine**

4 Water regime affected by extreme temperatures (cold or hot) 5
Water regime not affected by extreme temperatures 6

5 Water mostly frozen . . . . . **nival**
Water regime and chemistry influenced by geothermal activity with water being 30°C or more, or else affected by chemicals from current or former inputs of geothermally derived water . . . . . **geothermal**

6 Water regime and chemistry associated with waterways and water bodies that run through cave systems formed mainly but not exclusively on limestone . . . . . **plutonic**
Water regime not associated with waterways and water bodies that run through cave systems. 7

7 Water regime not subject to surface inundation; wetland not immediately adjacent to flowing water or along the margins and shores of a lake; situated in topographically flat or in slightly concave, often not easily defined depressions, or in depressions at the edge of escarpments, or on slopes; sometimes occupying groundwater discharge zones . . . . . **palustrine**
Water regime subject to surface inundation and resulting from marked water-level fluctuations; wetland immediately adjacent to flowing water or along the margins and shores of a lake 8

8 Situated in river or stream channels, or immediately adjacent to water courses; influenced by continuous or intermittently flowing water. . . . . **riverine**
Not confined to channels or adjacent to water courses but situated in topographically defined depressions that retain inflowing surface runoff and groundwater originating from surrounding catchments or upslope sources; with presence of permanent non-flowing deep water 9

9 Major dimension of water body 0.5 km or more . . . . . **lacustrine**
Major dimension of water body less than 0.5 km 10

10 Influenced by characteristic lake processes such as fluctuating water level and wave action. . . . . **lacustrine**
Not influenced by any lake process . . . . . **palustrine**

2.4 Subsystems

The subsystem is the second, and less formal, level of classification, allowing for attention to be drawn to particular descriptors of water regime (water source, movement, drainage, fluctuation, and periodicity of wetness) as outlined in Section 4.1 on hydrology. These water regime factors, considered in combination, and in conjunction with other wetland functions, give rise to the formulation of the wetland classes that follow. Note that the usefulness of particular water regime descriptors varies between hydrosystems. In the estuarine hydrosystem, tidal fluctuation is a predominant factor. In the riverine hydrosystem, rate and stability of water flow are important. In the lacustrine hydrosystem, fluctuation period and lake water stratification are strong descriptors.

2.5 Wetland classes

Wetland classes are governed by distinctive combinations of substrate factors, water regime, and the consequent factors of nutrient status and pH. Nine wetland classes are recognised: bog, fen, swamp, marsh, seepage, shallow water, ephemeral wetland, pakihi and gumland, and saltmarsh.

This third level of wetland classification is the most important one for the practical business of assigning a name to a functional wetland unit. Table 2 lists the characters of water regime, substrate, and chemistry. Note that there is much overlap of shared character states between wetland classes. Accordingly, each class is circumscribed by a particular combination of character states that are most distinctive to it.

Being based upon function – the ways in which wetlands work – wetland classes are not differentiated by the situations they occupy or the vegetation they contain. Nevertheless, particular landforms, vegetation structural classes, and plants are associated with each wetland class (Table 3 on p. 39). Note, however, that so far as the classification method is concerned, these features are secondary to the factors of physical and chemical environment which primarily delimit wetland classes.

Wetland classes fit beneath hydrosystems (Table 1). Most wetland classes can occur within more than one hydrosystem, and indeed some will actually span a hydrosystem boundary at particular sites. The wetland classes are described below in no particular order.

Fig. 12 Bog: a cushion bog with tussocks, a pool, and surrounding shrub and tree bog, Gorge Plateau, south Westland.

2.5.1 Bog

A peatland which receives its water supply only from precipitation, receiving neither groundwater nor any nutrients from adjacent or underlying mineral soils. Bogs are oligotrophic (nutrient-poor), poorly aerated, and usually markedly acid. Bog peat is poorly drained, having almost no water movement, and the water table is generally close to or just above the ground surface, and relatively constant.

Bogs occur most often on relatively level or very gently sloping ground, including hill crests, basins, terraces, and within other wetland types. Their vegetation types are very wide-ranging, dominants including mosses, lichens, cushion plants, sedges, grasses, restiads, ferns, shrubs, and trees.

Fig. 13 Fen: a gently sloping fen with a mixture of wire rushland, tussockland, and flaxland at National Park, Mt Ruapehu, Volcanic Plateau.

2.5.2 Fen

A wetland with a predominantly peat substrate that receives inputs of groundwater and nutrients from adjacent mineral soils. The water table is usually close to or just below the peat surface, and relatively constant. Water flow is slow to moderate. Fens have low to moderate acidity and are oligotrophic to mesotrophic.

Fens have slightly higher nutrient status than bogs, often because they occupy slight slopes, such as fans or the toes of hillsides (see Fig. 24) where they may grade downslope to swamp. Fens also occur on level ground where relatively shallow peat has not accumulated much above the influence of underlying mineral substrate, including situations around the margins of domed bogs. Fen vegetation is often composed of sedges, restiads, ferns, tall herbs, tussock grasses, or scrub.

Fig. 14 Swamp: a flax (*Phormium tenax*) - *Coprosma propinqua* / *Carex geminata* sedge swamp with leads of open water and indications of a fluctuating water level, Maher Swamp, Westland.

2.5.3 Swamp

A wetland that receives a relatively rich supply of nutrients and often also sediment via surface runoff and groundwater from adjacent land. Swamps usually have a combination of mineral and peat substrates. Leads of standing water or surface channels are often present, with gentle permanent or periodic internal flow, and the water table is usually permanently above some of the ground surface, or periodically above much of it.

Swamps usually occur in basins, and on valley floors, deltas, and plains. Vegetation cover is often sedge, rush, reed, flax, tall herb, or scrub types, often intermingled, and also forest.

2.5.4 Marsh

A mainly mineral wetland, having moderate to good drainage, fed by groundwater or surface water of slow to moderate flow, and characterised by moderate to great fluctuation of water table or water level. Marshes are often periodically inundated by standing or slowly moving water. They

Fig. 15 Marsh: a valley floor marsh with rush clumps, grasses, and herbfield, near Waihi Beach, Bay of Plenty.

are usually mesotrophic to eutrophic, and slightly acid to neutral in pH. Marshes differ from swamps by having better drainage, a generally lower water table, a usually more mineral substrate, and a higher pH.

Marshes occur mainly on slight to moderate slopes, especially on valley margins, valley floors, and alongside water bodies such as rivers and lakes. Vegetation is most often rushland, grassland, sedgeland, or herbfield.

2.5.5 Seepage

An area on a slope which carries a moderate to steady flow of groundwater, often also surface water, including water that has percolated to the land surface, the volume being less than that which would be considered as a stream or spring. Substrate ranges all the way from raw or well-developed mineral soil to peat; nutrient status and pH range from low to high; and the water table varies from just above the ground surface to a slight depth below. Seepages are located primarily where groundwater diffuses to the surface, especially at a change of slope, or where an impermeable basement raises the water table.

Fig. 16 Seepage: the toe-slope of a hillside with grazed sedgeland on a seepage carrying a moderate flow of groundwater and surface water, Greenstone Valley, Otago.

Flushes are considered here as falling within the wetland class of seepage. Flushing occurs when a periodic pulse of water, usually associated with rain (or seasonally with snow-melt), produces a sheet-flow of surface water, providing nutrients from higher ground, replenishing oxygen, and sometimes scouring the ground surface. Surface wetness is not always constant. Flushes are usually elongated downhill. The term flush has been commonly used in New Zealand for sloping wetlands in the mountains; it could validly be considered as a distinct wetland class.

Seepages (including flushes) are often relatively small and localised but occur both as stand-alone wetlands and as features which feed, drain, or are contained within other wetland classes. They intergrade with bogs and fens, but differ partly on the basis of their size and slope: seepages occupy sites of active water movement having enhanced aeration and nutrient supply. Vegetation is usually of low stature: moss, cushion, or sedge types; sometimes scrub or forest.

Fig. 17 Shallow water: a gently flowing river channel through a lowland swamp with submerged, bottom-rooted aquatic plants of pondweed (*Potamogeton pectinatus*) and starwort (*Callitriche petriei*), plus marginal floating foliage of giant sweetgrass (*Glyceria maxima*), Waipori River, Otago.

2.5.6 Shallow water

Aquatic habitats, generally less than a few metres deep, having standing water for most of the time. This wetland class accommodates the margins of lakes, rivers, and estuary waters, in which case the term 'shallow open water' is sometimes used to acknowledge the presence of an open body of water further from the shore. This wetland class also encompasses bodies of water that are not sufficiently large or lake-like in character to warrant lacustrine classification, yet of greater significance than just as water body forms contained within a wetland. The dominant unifying determinant is the presence of standing water. Nutrient and water chemistry factors are basically those of the water, rather than the substrate. In practice, the shallow water wetland class provides for habitats that 'land-based' wetland workers would meet with at land / water margins. For purposes of mapping or categorising fully aquatic habitats of lacustrine or riverine hydrosystems, the term 'deep open water' is available as an additional wetland class.

Fig. 18 Ephemeral wetland: the summer-drying phase of Julian's Pond, Taranaki.

2.5.7 Ephemeral wetland

A distinctive class most frequently found in closed depressions lacking a surface outlet, in climates where seasonal variation in rainfall and evaporation leads to ponding in winter and spring, and with fluctuation so pronounced that it can lead to complete drying in summer months or in dry years (Johnson & Rogers 2003). Water source is groundwater or an adjacent water body. Substrates are usually wholly mineral, upon an impervious underlying horizon. Water flow is slow to nil, nutrient status moderate, and pH neutral. Closed depressions occur especially on moraines, bedrock, dunes, and tephra. Vegetation is a characteristic marginal zone of turf and sward, and sometimes also rushland and scrub. Extreme cases of ephemeral wetland alternate between aquatic and terrestrial plants at different seasons.

2.5.8 Pakihi and gumland

Characterised by mature or skeletal soils of very low fertility and low pH, wholly mineral or sometimes with peat, rain-fed and with poor ability to transport water, frequently saturated but seasonally dry. Usually on level to rolling or sloping land in districts of high rainfall, the soils are old and severely leached of most nutrients.

This problematical wetland class embraces a medley of habitats including some, but not all, of the West Coast pakihi (Mew 1983) and Northland gumlands (e.g. Esler & Rumball 1975), but can extend also to sites having soils of extreme infertility because of their skeletal nature or lack of nutrients from inhospitable substrates such as ultramafic rock. Many of the peaty sites that have traditionally been referred to as pakihi can be classified as bog or fen. Nevertheless, the wetland class of pakihi and gumland is needed to accommodate habitats which may completely lack peat, and where wetness, sufficient for them to be regarded as a type of wetland, results in frequent soil waterlogging, even though this may alternate with periods when soils are relatively dry.

The wetland class pakihi and gumland is admittedly difficult to circumscribe on the basis of substrate and water regime. No simple and embracing name suggests itself for this wetland class and we are loath to confuse the issue by suggesting one. 'Wet heath' (e.g. Wardle 1991) might be a contender, but the vegetation connotation does not sit well with the wetland class level of the present classification system.

Despite these problems, the pakihi and gumland wetland class nevertheless has the unifying factors of a flora typical of wetlands, and vegetation that is usually heathland (shrubland in combination with restiads, sedges, and ferns; a mix of several vegetation structural classes, see Section 2.7). Such heathland, often fire-induced, poses difficulties for wetland classification because it can extend also to relatively dry habitats and also to blanket peatlands.

2.5.9 Saltmarsh

A wetland class embracing estuarine habitats of mainly mineral substrate in the intertidal and subtidal zones, but also including those habitats in the supratidal zone (such as wet coastal platforms) and in the inland saline

Fig. 19 Pakihi and gumland: represented here by the pakihi on German Terrace, near Westport, Buller, having typical fire-affected scrub of manuka (*Leptospermum scoparium*), and resprouting sedges and tangle fern (*Gleichenia dicarpa*).

Fig. 20 Saltmarsh intertidal zones of mangrove (*Avicennia marina* subsp. *australasica*) scrub, and rushlands of sea rush (*Juncus kraussii* subsp. *australiensis*) and oioi (*Apodasmia similis*), Whitianga, Coromandel Peninsula.

hydrosystem, which although non-tidal have similar saline substrates and constancy of soil moisture. Water source is from groundwater and adjacent saline or brackish estuary waters. The saltmarsh wetland class includes non-vegetated habitats such as mudflats, and the full range of vegetation types typical of the intertidal zone, from herbfield to rushland, scrub, and mangrove scrub or low forest.

2.5.10 Other wetland classes

The nine wetland classes outlined above should accommodate most of the broad level variants of palustrine, estuarine, and inland saline hydrosystems, along with those habitats associated with land / water margins of the riverine and lacustrine hydrosystems. Wetland workers may find the need to erect additional wetland classes, and this is valid as long as they are able to be circumscribed on the basis of distinctive combinations of substrate factors, water regime, nutrient status, and pH. It should be noted that our circumscription of the saltmarsh wetland class is a broader one than that outlined by Ward & Lambie (1999b). Their table 2 includes several additional wetland classes for the estuarine hydrosystem, such as seagrass meadow and algalflat: units which we treat as able to be described at the subsequent classification levels of structural class and composition of vegetation.

Although this book does not attempt to give any detailed coverage of wetland classes of lacustrine and riverine open waters, a draft classification of these is included in table 4 of Ward & Lambie (1999b). In summary, however, it can be noted that their lacustrine wetland classes are based upon combinations of two sets of descriptors, the first being nutrient status (oligotrophic, mesotrophic, eutrophic, dystrophic) and the second being the nature of lake stratification (monomictic, amictic, polymictic). These terms are discussed in Sections 2.6.3 and 4.2. For naming riverine wetland classes Ward & Lambie use descriptors concerned with the two factors of water flow (stable, variable, flashy) and channel gradient (steepland, midland, lowland). These terms are discussed in Section 4.1.2.

Ward and Lambie (1999b) also provide draft structures for classifying wetland classes in the geothermal, plutonic, and marine hydrosystems.

Key to wetland classes

1 Wetland ecosystem characterised by an accumulation of peat 2
(peatland)

Wetland ecosystem characterised by minimal or no peat accumulation, though layers of muck and a mix of mineral and organic muck may be present 4

2 Peatland often combining mineral and peat substrates; with moderate water flow and fluctuation and often the presence of leads of standing water or surface channels; water usually moderately acid (pH 4.8–6.3) and relatively rich in dissolved minerals . . **swamp**

Peatland with peat exclusively 3

3 Peatland with a surface raised or level with surrounding terrain; receiving water exclusively from precipitation and not influenced by groundwater or runoff water; water table generally at or slightly below the surface; water usually markedly acid (pH < 4.8) and low in dissolved minerals . . . . . **bog**

Peatland receiving inputs of water and nutrients from adjacent mineral soils, with water flow on the surface and through the subsurface; fluctuating water table may at times be a few centimetres above or below the surface but under normal conditions is level with the land surface; water usually moderately acid (pH 4–6) and moderately rich in dissolved minerals . . . . . **fen**

4 Mineral wetland on a slope which carries a moderate to steady flow of groundwater, often also surface water; located primarily where groundwater diffuses to the surface . . . . . **seepage**

Mineral wetland not fitting above description 5

5 Water table persisting above or near ground surface for all or most of the year 6

Water table often below ground surface, and surface prone to temporary drying . . . 8

6 Surface water near-permanent, to c. 2 m depth; tidal or not tidal. . . . . **shallow water**

Surface water slight or tidal 7

7 Influenced by tidal water and / or where high soil salinity is a strong factor . . **saltmarsh**

Having low or nil soil salinity; often along the margins of lacustrine and riverine systems; sometimes in areas influenced by supratidal water in estuarine systems . . . . . **swamp**

8 Wetland that lacks a permanent surface outlet and has a marked seasonal alternation between being ponded and dry . . . . . **ephemeral wetland**

Wetland without marked seasonal alternation between being ponded and dry 9

9 Wetland characterised by ultra-infertile acidic soils with an impervious horizon, prone to temporary drought. . . . . **pakihi and gumland**

Wetland with moderate to much water fluctuation, often on slight to moderate slope, or along the margins of lacustrine and riverine systems . . . . . **marsh**

Continue to next file: WetlandsBWb.pdf

Table 2 Distinguishing features of New Zealand wetland classes

Wetland Class	Water origin (predominant)	Water flow	Drainage	Water table position cf. ground	Water fluctuation	Periodicity	Substrate	Nutrient status	pH
Bog	rain only	almost nil	poor	near surface	slight	wetness permanent	peat	low or very low	3–4.8
Fen	rain + groundwater	slow to moderate	poor	near surface	slight to moderate	wetness near-permanent	mainly peat	low to moderate	4–6
Swamp	mainly surface water + groundwater	moderate	poor	usually above surface in places	moderate to high	wetness permanent	peat and/or mineral	moderate to high	4.8–6.3
Marsh	groundwater + surface water	slow to moderate	moderate to good	usually below surface	moderate to high	may have temporary wetness or dryness	usually mineral	moderate to high	6–7
Seepage	surface water and/or groundwater	moderate to fast	moderate to good	slightly above to below surface	nil to moderate	permanent wetness to temporary dryness	peat, mineral, or rock	low to high	4–7
Shallow water	lake, river, etc., or adjacent groundwater	nil to fast	nil to good	well above surface: inundated	nil to high	wetness almost permanent	usually mineral	moderate	4–7
Ephemeral wetland	groundwater + rain	nil to slow	moderate to good	well above to well below surface	marked wet/dry alternation	seasonal, sometimes temporary wetness/dryness	mineral	moderate	5.5–7
Pakihi and gumland	mainly rain	almost nil	poor	below surface	slight to moderate	wetness near-permanent but prone to temporary drought	mineral or peat	very low to low	4.1–5
Saltmarsh	seawater, brackish water, salt spray, groundwater from land	moderate to slow	good	closely below surface between tides	tidal, or slight in supratidal zone	mainly tidal	mainly mineral	moderate	4.9–8

Table 3 Landforms, vegetation, and key indicator plants associated with wetland classes in New Zealand

Wetland Class	Predominant landforms	Common vegetation structural classes	Some key indicator plants
Bog	usually almost level ground, including hill crests, basins, terraces	wide range including moss, lichen, cushion, sedge, grass, restiad, fern, shrub, and forest types	*Sphagnum, Oreobolus, Baumea tenax, Sporadanthus, Empodisma, Dracophyllum, Epacris, Leptospermum, Halocarpus*
Fen	slight slopes of bog margins, swamp perimeters, hillside toe slopes, alluvial fans	usually sedge, restiad, rush, fern, tall herb, or scrub types	*Schoenus pauciflorus, S. brevifolius, Empodisma, Chionochloa rubra, Hebe odora, Baumea teretifolia, Leptospermum*
Swamp	mainly on valley floors, plains, deltas	usually sedge, rush, reed, tall herb, and scrub types, often intermingled, and including forest	*Phormium, Carex, Coprosma, Gahnia, Typha, Cordyline, Dacrycarpus, Laurelia, Syzygium*
Marsh	slight to moderate slopes, valley margins, edges of water bodies	typically rush, grass, sedge, or shrub types	*Juncus, Carex, Agrostis, Cortaderia*
Seepage	moderate to steep hill slopes, scarps; heads and sides of water courses	usually low-stature moss, cushion, or sedge types; sometimes scrub or forest	*Carpha alpina, Montia*, mosses
Shallow water	ponds, pools, streams; margins of lakes, lagoons, rivers	submerged, floating, or emergent aquatics	*Myriophyllum, Potamogeton, Azolla, Bolboschoenus, Baumea, Ruppia, Schoenoplectus, Isolepis*
Ephemeral wetland	closed depressions especially on moraines, bedrock, dunes, tephra	marginal zones of turf and sedge sward, sometimes rushland and scrub	*Glossostigma, Lilaeopsis, Myriophyllum, Pratia, Isolepis, Carex gaudichaudiana, Eleocharis*
Pakihi and gumland	level to rolling or sloping land having impervious soils, including pakihi, gumland, and formerly forested land	mixtures of heaths and other small-leaved woody plants with restiads, ferns, sedges, lichens, mosses	*Empodisma, Baumea tenax, Gleichenia, Schoenus, Leptospermum, Dracophyllum, Nothofagus, Dacrydium*
Saltmarsh	margins of estuaries; wet coastal platforms	seagrass meadow, turf, herbfield, rushland, scrub, mangroves	*Zostera, Sarcocornia, Samolus, Apodasmia, Plagianthus divaricatus, Avicennia*