Aquatic invertebrate communities of lowland wetlands in New Zealand

Characterising spatial, temporal and geographic distribution patterns

SCIENCE FOR CONSERVATION 305

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Cover: Open water leads at Drummond Wetland, Southland.
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A B S T R A C T

This report documents the aquatic invertebrate communities of lowland wetlands throughout New Zealand. It addresses three questions: how do communities vary within and between wetlands; to what extent do communities vary temporally; and how are communities affected by environmental variables? Invertebrate collections from 40 wetlands showed that the fauna was dominated by midges (Chironomidae), aquatic mites (Acarina), Copepoda, Nematoda and Ostracoda. The mud snail *Potamopyrgus antipodarum* and the damselfly *Xanthocnemis zealandica* were also common. A detailed survey of the open-water habitats of two acidic fens and two swamps showed that invertebrate communities varied more between wetlands than they did within wetlands, presumably reflecting differences in water chemistry between fens and swamps. Thus, it may not be necessary to sample specific habitats or plants within wetlands to accurately characterise their invertebrate communities, as long as the range of habitat types is covered. Similarly, analysis of annual data collected at one wetland and of seasonal data collected at two wetlands showed that although invertebrate communities varied temporally, the degree of this variation was small compared with differences within or between wetlands. Thus, wetland invertebrate surveys may not be particularly sensitive to the time of sampling, as community composition is driven by large-scale factors that influence water chemistry and that override temporal changes in the relative abundance of some taxa. Finally, a survey of 40 wetlands throughout the country showed that invertebrate communities are controlled mainly by biogeography, followed by water chemistry—particularly pH. This finding has management implications, as regionally based conservation goals may need to be considered instead of setting goals for specific wetland types.

Keywords: wetlands, invertebrates, swamps, fens, bogs, temporal variation, spatial variation, sampling protocols

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1. Introduction

High biodiversity value is frequently cited as an important justification for wetland conservation (Mitsch & Gosselink 2000; Junk et al. 2006). Many wetlands are 'ecotones'—transitional habitats between terrestrial and aquatic ecosystems, which have high biological diversity as a result of their diverse mixture of habitats derived from both ecosystems (Decamps & Naiman 1990; Tiner 1999). The blending of deep and shallow aquatic environments within wetlands offers potential habitat for both terrestrial and aquatic flora and fauna. Wetlands with the highest conservation values are often recognised to be those where a range of water regimes and fertilities maximise species diversity (Keddy 2000; Junk et al. 2006). Accurate determination and protection of the biodiversity value of wetlands therefore requires information about aquatic as well as terrestrial biota, including their biogeographic variation and habitat requirements.

Much of the biodiversity value of New Zealand wetlands is poorly understood. Although the vascular plant flora has been described in some detail (Johnson & Brooke 1998; Johnson & Gerbeaux 2004), there is still very little understanding of the physical and chemical drivers of plant species composition. The importance of wetlands for fish and bird habitat is well-documented (Sorrell & Gerbeaux 2004; Williams 2004), but the factors controlling fish and bird productivity in New Zealand wetlands are uncertain, as are the distributions of these organisms throughout the country. Other groups of organisms, such as aquatic invertebrates and algae, have received relatively little attention.

Recent assessments have confirmed that approximately 90% of the original wetland cover of New Zealand has been lost (Ausseil et al. 2008). Furthermore, there has been a disproportionate loss of wetlands of certain types and in certain areas, with particularly heavy losses of lowland systems, and higher losses in eastern and northern regions of the country. In pre-European times (prior to the early 1800s), wetland cover included a diverse range of wetland types, almost all of which offered some open-water habitat (Johnson & Gerbeaux 2004). Given the ongoing pressure on wetlands and their continued loss, coupled with potential nutrient enrichment arising from catchment land-use (Clarkson et al. 2003), assessments of the aquatic habitats and invertebrate communities within New Zealand wetlands are long overdue.

Aquatic invertebrates are found in all freshwater ecosystems, including rivers, lakes and wetlands. They live on or in the bottom substrate, swim in the water column, or live on the surface of the water. There are four major groups of freshwater invertebrates:

- Arthropods, including insects (e.g. mayflies (Ephemeroptera), caddisflies (Trichoptera), stoneflies (Plecoptera), dragonflies (Odonata), and true flies (Diptera), including chironomid midges and blackflies), crustacea (such as freshwater shrimp (e.g. *Paratya*) and amphipods (e.g. *Paraleptamphopus*), as well as zooplankton such as Cladocera (*Daphnia*), ostracods and copepods), and aquatic mites (Acarina).

- Molluscs, such as snails (especially *Potamopyrgus*) and filter-feeding bivalves (e.g. fingernail clams (*Sphaerium* and *Pisidium*) and freshwater mussels (e.g. *Hyridella menziesi* (kākahi), *Cucumerunio websteri*).
- Oligochaetes, typified by a number of different worm species that live in muddy streambeds.
- Nematodes, which are very small, cylindrical, 'worm-like' animals with smooth cuticles.

For convenience, freshwater ecologists have arbitrarily divided aquatic invertebrates into two groups: macroinvertebrates, which are those that are large enough to be retained by a sieve with a mesh size of 500 μm, and meiofauna, which are those that pass through a 500-μm sieve but are retained on a 64-μm sieve (Robertson et al. 2000). This latter group includes recently hatched insect larvae, microcrustacea (such as copepods, ostracods (pea shrimp) and daphnia (water fleas)), as well as animals such as nematodes.

Freshwater invertebrates play a vital role in transferring plant-based organic carbon derived from terrestrial sources (e.g. leaves or woody debris) or aquatic sources (e.g. algae or macrophytes) into animal-based organic carbon, which is then available to predators such as fish and birds. Freshwater invertebrates also have intrinsic biodiversity and ecological values: almost all are native to New Zealand, and many are endemic (i.e. they are not found anywhere else in the world).

1.1 OBJECTIVES

This report describes the first stage of a research programme that aims to document the aquatic invertebrate biodiversity values of lowland wetlands in New Zealand and to present information on variation in community composition in near-pristine wetlands. We selected wetlands mostly with minimal human impacts, with one exception: the Bullock Creek wetland, on the South Island's West Coast. Parts of this wetland had been converted into pasture by 19th-century settlers, with a network of drains dug during the first half of the 20th century. However, grazing had ceased in this wetland approximately 20 years ago, and the site is being managed to restore it to a more natural state (Sorrell et al. 2007). This wetland is also surrounded by undisturbed native bush, so pressures from the surrounding catchment are minimal. This site was part of a restoration programme run collaboratively by the Department of Conservation (DOC), Landcare Research and the National Institute of Water & Atmospheric Research (NIWA), and regular monitoring of the invertebrate communities in this wetland to assess the effect of hydraulic restoration allowed us to examine temporal variability of the invertebrate communities there (see section 3). Selection of mostly unimpacted wetlands was necessary to first obtain knowledge of invertebrate biodiversity, and the factors influencing invertebrate distributions in the absence of anthropogenic disturbances. Identification of the underlying drivers of invertebrate community composition allows evaluation of potential effects of human activities that might influence these drivers.

The aims of the present project were to document:

- The nature of the invertebrate community within wetlands
- The degree of variation in aquatic invertebrate community composition within wetlands versus variation between wetlands
- The amount of temporal variability in wetland aquatic invertebrate communities
- Patterns of natural biogeographic variation in invertebrate species composition across New Zealand, and identification of factors controlling invertebrate species composition in wetlands

The study has the following management goals:

1. The findings will help identify any rare taxa or taxonomic groups, and help us begin to understand more about the spatial distribution of freshwater invertebrates. All data obtained from the wetland work to date will be placed on NIWA's Freshwater Biodata Information System (FBIS: (https://secure.niwa.co.nz/fbis/index.do) as part of what is hoped will become a central repository of wetland invertebrate data.
2. Examination and description of the invertebrate communities of wetlands throughout the country will allow us to identify any regions of particularly high invertebrate biodiversity. Such information will enable DOC and other land managers (such as regional or district councils) to prioritise conservation efforts for different wetlands based on their aquatic biodiversity values. Furthermore, the Dairying & Clean Stream Accord (2003) requires regionally significant wetlands to be defined, in order for farmers to take subsequent action to protect them.
3. Characterisation of the invertebrate communities within wetlands will also provide us with an opportunity to compare the biodiversity of this habitat with that of rivers and lakes. Within New Zealand, most attention to freshwater biodiversity has traditionally been focused on invertebrate communities in running waters or lakes; yet wetlands may support equally high or higher biodiversity, as has been found in Europe (Davies et al. 2008).
4. By understanding how invertebrate communities are controlled by environmental variables in pristine wetlands, and by seeing how these variables are altered by land-use changes, it may be possible to predict the effect of wetland degradation on invertebrate biodiversity. This information has obvious relevance if the adverse impacts of land-use change, nutrient run-off, and changes to hydrological regimes in wetlands are to be minimised. Minimising adverse effects of land-use changes on wetlands is important, not only to ensure maintenance of invertebrate biodiversity in wetlands, but also to ensure that other components of these ecosystems (e.g. fish and wading birds) are unaffected by loss of potential food sources caused by unsustainable land-use activities.
5. The information obtained from studying the aquatic invertebrate communities in pristine wetlands will be a fundamental part of creating a Wetland Macroinvertebrate Community Index score (WMCI score). The WMCI score will be similar to the commonly used MCI score (Stark 1985), which was developed to assess organic pollution in stony-bottomed streams or, more recently, in soft-bottomed streams (Stark & Maxted 2007). It is possible that

separate WMCI scores will need to be developed for swamps and bogs/fens, or for different regions of the country. This score will allow managers to assess the ecological health of particular wetlands based on their invertebrate communities. Its foundation lies in quantifying how invertebrate communities change between pristine wetlands, and wetlands that are subject to increasing degrees of anthropogenic disturbance, and assigning tolerance scores to each taxa depending on their response to distrubance. This latter goal is currently being undertaken as part of a DOC-funded Terrestrial and Freshwater Biodata Information System (TFBIS) programme.

6. A better understanding of aquatic invertebrate biodiversity values of wetlands is considered a requisite step for the completion of the Waters of National Importance (WONI) project, the objective of which is to identify water bodies that require protection to ensure that a full range of freshwater biodiversity is protected throughout the country.

2. General concepts and methodologies

2.1 WETLAND CLASSIFICATION

Wetlands exist in areas of poor drainage where water can accumulate. They can be permanently to intermittently wet, generally have shallow water, and have land margins that support ecosystems of plants and animals that are adapted to wet conditions (Johnson & Gerbeaux 2004). Johnson & Gerbeaux (2004) grouped wetlands using a semi-hierarchical system with four levels:

1. Level 1 is based on differences in hydrosystems (i.e. the broad hydrological and landform setting, and salinity and temperature regimes)
2. Level 2 is based on wetland classes, circumscribed by different combinations of substrate, water regime, nutrients and pH
3. Level 3 deals with structural classes of the vegetation (e.g. forest, rush land, herbfield) or ground surface (rockfield or mudflat)
4. Level 4 deals with species composition of the vegetation

Levels 1 & 2 are mainly concerned with large-scale differences in hydrology and water chemistry between wetlands, while Levels 3 & 4 deal with smaller-scale differences within a wetland that describe the ground surface and vegetation.

There are three main freshwater hydrosystems within New Zealand: Palustrine (swamp, marsh), Riverine, and Lacustrine (lake) (Johnson & Gerbeaux 2004). Although other minor freshwater hydrosystems exist that are of local or restricted significance (e.g. geothermal and nival/ice-sourced), these were not included in the present study, which focused on palustrine wetlands in lowland areas (less than 250 m a.s.l.). Palustrine wetlands are characterised by shallow aquatic environments in which the dominant feature is attached or rooted vegetation, which is emergent permanently or seasonally above freshwater, non-tidal surface water or groundwater (Johnson & Gerbeaux 2004).

New Zealand's wetland classification scheme (Johnson & Gerbeaux 2004) recognises at least nine classes of palustrine wetlands, of which four (bogs, fens, swamps and marshes) are covered in this study. These classes cover most of the palustrine wetlands of New Zealand. Ephemeral wetlands, seepages, pakihi and gumland, and saltmarsh areas were not considered. The four classes being considered broadly follow a hydrological gradient from the dominant water source being precipitation (bogs), to inputs being dominated by surface flow (marshes). Associated with the hydrological gradient are gradients in soil type (from more peaty, organic soils in bogs through to predominantly mineral soils in marshes), chemistry (from low pH in bogs to high pH in swamps and marshes), and fertility (generally increasing from bogs through to swamps). For a complete assessment of wetland invertebrate communities, future sampling > 250 m above sea level, and from the full range of wetland classes is required.

When documenting the invertebrate biodiversity values of pristine wetlands in New Zealand, it is important to note the uneven loss of different wetland classes since European colonisation. Ausseil et al. (2008) documented that swamps and marshes have been most heavily reduced (with 6% and 8% of original cover remaining, respectively, compared with 26% and 19% remaining for bogs and fens, respectively).

2.2 ANTHROPOGENIC EFFECTS ON WETLANDS

Wetlands are faced with a multitude of different pressures from human activities, including alterations of nutrient budgets and hydrological regimes, sedimentation, fire, vegetation clearance, soil disturbance, and biotic invasions from both terrestrial and aquatic organisms (e.g. exotic fish, weedy plant species, stock grazing, and both vertebrate and invertebrate pest species). Some of these pressures may affect only a small portion of a wetland, while others may affect the entire wetland. The threat from biotic invasions by exotic organisms is of particular concern, as this can occur even in wetlands surrounded by unmodified catchments. These pressures may lead to a loss of wetland biodiversity, structure and function. Taken to the extreme, such activities can result in an entire wetland being lost from the landscape. Less extreme results are seen in remnant wetland areas, which can range from simple drainage ditches across what were once waterlogged soils, to small areas of isolated ponds surrounded by highly modified agricultural or urban landscapes. At the other end of the scale, some wetlands still remain in highly unmodified landscapes, where they most likely exist and function as they always have.

In New Zealand, two methods have been developed to assess the degree of human disturbance (and associated pressures) on wetlands (Table 1). The first method (Clarkson et al. 2003) calculates a wetland condition index (WCI), based on changes to five specific indicators, each of which contains a number of indicator components. This method was developed for use in the field by non-experts with a relatively limited amount of training. The second method (Ausseil et al. 2008) calculates a wetland's 'index of ecological integrity' (IEI). This combines six spatial indicators of human activities that degrade wetland biodiversity and function: loss of natural cover; human-made impervious cover; introduced fish; introduced woody weeds; artificial drainage; and nitrate leaching risk. Values of these indicators are derived from a number of GIS databases, allowing national assessments of wetland condition to be made.

TABLE 1. SPECIFIC INDICATORS AND INDICATOR COMPONENTS USED TO ASSESS WETLAND CONDITION (CLARKSON ET AL. 2003), OR ECOLOGICAL INTEGRITY (AUSSIEL ET AL. 2008).

INDEX	INDICATOR	COMPONENTS
Wetland condition	Change in hydrological integrity	• Impact of man-made structures • Water table depth • Dryland plant invasion
	Change in physicochemical parameters	• Fire damage • Degree of sedimentation/erosion • Nutrient levels • Von Post index
	Change in ecosystem intactness	• Loss in area of original wetland • Conductivity barriers
	Change in browsing, predation and harvesting regimes	• Damaged by domestic or feral animals • Introduced predator impacts on wildlife • Harvesting levels
	Change in dominance of native plants	• Introduced plant canopy cover • Introduced plant cover
Ecological integrity	Naturalness of catchment cover Artificial impervious cover (urbanisation, roading) Nutrient enrichment Introduced fish Woody weeds Drainage and disturbance	

This study endeavoured to sample wetlands that were in good condition. Wetlands were first selected with the help of experienced local ecologists who confirmed sites to be amongst those in the best condition in each region. Their overall condition was subsequently confirmed by examination of the IEI from Ausseil et al. (2008). Wetland condition was better in bogs and fens (especially in the South Island) than in swamps and marshes. This imbalance was reflected in this study, with many of the sites being bogs and fens, and only a few swamps and marshes. There have also been strong geographic patterns in loss of wetland habitat, with losses being particularly high in low-lying areas of the North Island, and on the east coast of the South Island. Consequently, no east-coast South Island wetlands were sampled for the work presented in this report, and many of the wetlands that were sampled in the North Island would only have had a moderate ecological integrity (despite representing the best wetlands in the area), as they were exposed to a number of different pressures. They were still included for analysis in this report for the sake of good geographic coverage.

2.3 TYPES OF AQUATIC HABITATS

Sampling was restricted to permanent water bodies in wetlands, which we identified by the presence of macrophytes (water-loving plants). Ephemeral habitats often display marked changes in their invertebrate communities (e.g. Brooks 2000; Fuentes et al. 2005; Strehlow et al. 2005) as different taxa become dominant during the drying–filling cycle. For the purposes of this study, we recognised five types of open-water habitat that occurred in palustrine wetlands (Fig. 1), although not all are necessarily found in any one wetland:

- 'Main channels'—wide, deep, open-water areas flowing slowly through wetlands. Wetland vegetation is generally restricted to the edges of these channels.
- 'Leads'—smaller than channels, and are characterised by shallower, less-open water, and dense wetland vegetation growing in the water. Leads consist of either standing or very slow-moving water and, unlike ponds, have ill-defined margins. Leads are particularly common in flax swamps, where open water is found at the base of each plant.
- 'Large ponds'—arbitrarily defined as being greater than 10 m in diameter, and often fringed with emergent macrophytes. However, the majority of their water surface is open to the sky.
- 'Small ponds'—arbitrarily defined as being < 10 m in diameter, and have discrete margins. They are also often completely fringed with wetland vegetation, which often grows fairly extensively through the pond.
- 'Drains'—obviously man-made. Typified by their straightness, and often have smooth banks. Spoil mounds from the drain are often piled up along the edges. This habitat type was only found at the Bullock Creek wetland.

Depending on its size and class, an individual wetland may support one, some or all of these open-water habitat types. These habitats may or may not support different biological assemblages—something that needs to be considered when designing a sampling or monitoring protocol.

2.4 SAMPLING INVERTEBRATE COMMUNITIES

2.4.1 Sampling technique

The most common methods for collecting aquatic invertebrates from wetlands involve the use of corers, nets or traps (see Batzer et al. 2001). Each method has its own advantages and disadvantages.

Corers

Corers can be used to sample either the animals living in the bottom sediment (i.e. the benthos), or the benthos plus any animals in the water column enclosed within the core. For the former technique, the corer (usually some sort of steel or plastic cylinder of a known diameter) is simply driven into the wetland substrate and then pulled out again, along with the 'plug' of wetland sediment. All inorganic matter is then separated from invertebrates by sieving. The second technique involves stirring the water and underlying substrate into a slurry, which is then collected using buckets or nets (see Sanders 2000). A refinement of this technique

Figure 1. Examples of the different open-water habitats found in wetlands throughout New Zealand:
A. A main channel at Birchfield Swamp, Westland
B. A lead at Groves Swamp, Westland
C. A large pond at Maori Lakes, Westland
D. A small pond at Ruggedy Flats, Stewart Island/Rakiura
E. A man-made drain at Bog Burn, Southland

was successfully used in the Waitaki River catchment (Stark & Suren 2002), where wetlands were sampled using a corer (300-mm diameter by 450-mm high) placed on the bottom of each wetland. The bottom substrate, water column and any aquatic plants enclosed within the corer were agitated into a slurry, and a commercial 'wet dry' vacuum cleaner (run from a 240-V generator) was then used to suck all this material into the large collecting chamber of the vacuum. The corer was sealed at its base with a 50-mm-thick foam flange that ensured a good seal, so that all the water within the corer was removed and collected in the vacuum cleaner. The collected material was then emptied through a

250-µm-mesh sieve to collect all invertebrates and organic matter. The advantage of this method over traditional coring methods is that even fast-swimming taxa are collected in the vacuum cleaner, which is able to quickly remove all the water and stirred-up slurry from the core.

Core samples can also be collected from macrophyte beds. This is relatively easy where the macrophytes are not dense and the corer can be placed quickly around selected stems of plants. However, this is more problematic in dense macrophyte beds, as it is difficult to place the corer quickly over the plants and onto the bottom of the wetland, as the plants become jammed between the corer and the bottom.

The main advantage of core sampling is that a known surface area of the bottom of the wetland, or a known volume of water column and substrate is sampled, allowing quantitative information to be obtained.

A disadvantage of core sampling is that samples can only be taken in water that is shallower than the corer, unless some sort of sleeve is placed over the top of the corer to prevent animals swimming into or out of the corer. In addition, only a relatively small area of each wetland can be sampled, meaning only a small proportion of the overall invertebrate community will be sampled. Although this disadvantage can be minimised by collecting replicate samples, it must be remembered that core samples, in particular, can contain large quantities of organic matter and mud, meaning that samples can take a long time to process (up to 3–4 hours). This can constrain the number of replicates that can be processed when time and money are limiting. Given the close relationship between species richness and area sampled, the collection of only a few core samples may result in the taxonomic richness of a particular wetland being underestimated.

Sweep nets

Sweep nets can be moved through the water column or rapidly pushed (or jabbed) into macrophyte beds and into the substrate to collect invertebrate samples. When using nets, care must be taken to minimise the risk of excessive organic matter clogging the collecting net and reducing sampling efficiency. This can be achieved by regularly emptying the net into sample bottles. The optimal mesh size for the sweep net is a compromise between being too small, in which case the net will very quickly clog, and being too large, in which case some of the smaller invertebrates will not be adequately collected. In practice, most sweep nets have a mesh size of between 250 µm and 1000 µm, with 250-µm nets and 500-µm nets being the most common. It has been reported that this method is more efficient at capturing invertebrates than core sampling (Cheal et al. 1993; Turner & Trexler 1997). It also allows a wide variety of habitats to be sampled.

The disadvantage of the sweep-net method is that it is hard to quantify the amount of habitat sampled so, at best, only percentage abundances of taxa can be determined. However, it is possible to sample for specific time periods (e.g. 2 minutes) or to make a known number of discrete 'jabs' with the net in each habitat, to provide uniformity in the sampling effort. This allows invertebrate abundances to be compared between different wetlands, although possibly not with the same degree of accuracy as if a known surface area had been sampled.

Traps

There are a number of designs of small traps that can be placed in the water column to capture swimming invertebrates (see Radar et al. 2001). These traps are usually deployed for a known period of time, so that comparative quantitative information can be collected between different habitats or wetlands.

The big advantage of this technique is that most of the samples collected will be free of organic matter and contain only those invertebrates of interest. The disadvantages are that traps target only a small proportion of the invertebrate community, and each wetland must be visited on two occasions, once to deploy the traps and once to retrieve them.

Sampling technique used in this study

Since we wanted to characterise the invertebrate communities in a wide variety of wetland habitats and individual wetlands in this study, we decided to use a sweep net (300-µm mesh) to collect invertebrates. Selection of a 300-µm mesh sweep net was a compromise between the mesh size being small enough to collect smaller invertebrates such as microcrustacea, and yet big enough to allow fine silts and detritus to drain through the mesh to minimise clogging. Using the sweep-net meant forfeiting the advantage of collecting quantitative data (as could have been achieved through the use of corers) and, instead, collecting semi-quantitative data. Each sample was collected for 2 minutes to provide some standardisation of sampling effort. This enabled us to estimate relative invertebrate abundances between the different wetlands sampled.

2.4.2 Sample preservation and storage

Once samples have been collected, they can either be processed alive in the field or preserved and processed at a later date in the laboratory. If samples are to be preserved, this needs to be done as soon as possible following collection, most often using 100% isopropanol (IPA). It is important to ensure that sufficient IPA is placed in the sample container to ensure that all the material is properly preserved, and does not start to decompose. This concern is probably more relevant for wetland samples then for river samples, as there is usually much more organic material present in wetland samples.

In this study, we used 750–1000-mL sample containers, which were half to two-thirds (at most) filled with the sample. The container was then filled to the top with IPA, giving a final IPA concentration of at least 60% to minimise the chance of samples decomposing. Identification labels (written on waterproof paper) were placed inside each sample container, and also attached to the outside of each container. All samples were entered into a central sample register spreadsheet as part of NIWA's sample tracking and processing protocol. It is a good idea to follow some sort of sample tracking and registration protocol, especially when large numbers of samples are collected, to ensure that all samples are tracked through all stages of collection, processing and data entry (e.g. see Stark et al. 2001).

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