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Regional Council
Kaunihera Taiao ki Waitaha

Te Waihora/Lake Ellesmere Catchment. Functional Significance and Sensitivity of Groundwater Fauna

Report No. R13/113

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TE WAIHORA/LAKE ELLESMERE CATCHMENT

Functional Significance and Sensitivity of Groundwater Fauna

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REPORT

Golder Associates

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1.0 BACKGROUND

As part of the flow and limit setting consultation process for the Selwyn/Te Waihora catchment Canterbury Regional Council (CRC) staff have received a request for information about groundwater fauna and their sensitivity to nitrates and other effects of land and water use development. In this report[1] Golder has provided a brief summary of this topic using information sourced from the latest New Zealand and overseas scientific literature. Golder begin by defining aquifer systems as one of three groundwater dependent ecosystems present in the Selwyn/Te Waihora catchment, and the least considered from a management perspective. This report then describes the current state of knowledge and potential ecosystems services provided by life in the groundwaters. Finally, pressures and impacts that may impair those ecosystem services are reviewed.

2.0 GROUNDWATER DEPENDANT ECOSYSTEMS

In a catchment such as the Selwyn/Te Waihora the hydrological systems, ground and surface water, are highly connected and interdependent. Therefore, management of these systems must consider the integrity of each component in relation to the whole. While the flow, flora and fauna of surface streams in the Selwyn/Te Waihora catchment have long been the subject of investigation and the quality and quantity of groundwater flowing to those stream is being considered currently, there has been no consideration for or the role of life in the aquifers. Golder suggest that a useful framework for a holistic view of the groundwater part of Selwyn/Te Waihora hydrological system would be to use the definition of a Groundwater Dependant Ecosystem (GDE) developed by Tomlinson et al. (2008). GDE can be broadly separated into three classes,

- Ecosystems dependent on the subsurface presence of groundwater, for example where vegetation has roots accessing groundwater
- Ecosystems dependant on the surface expression of groundwater, for example spring streams and wetlands
- Ecosystems within aquifers

Each of these GDE types can be found in the Selwyn/Te Waihora catchment and are being variably considered in the water quality and quantity limit setting process by CRC. For example lowland stream ecological health, which is a priority outcome in the process, is dependent on groundwater quantity and quality (Williams 2008). However, the groundwaters themselves are currently considered as a resource, but not an ecosystem, which represents a gap in the understanding of and potential for effective management of the overall hydrological system. Consideration of all GDE and specifically groundwater ecosystems alongside the more obvious surface ecological systems would aid more holistic management of the Selwyn/Te Waihora catchment.

3.0 GROUNDWATER BIODIVERSITY

The groundwater beneath the Canterbury plains supports a diverse, but poorly understood fauna with an unknown role in the maintenance of aquifer porosity and ground and spring water quality. This knowledge gap is particularly surprising given that groundwater and in particular clean groundwater comprises up to 80% of the inland freshwater in New Zealand (White 2001), provides the basis for much irrigated agriculture and baseflows back to rivers and streams.

[1] This Report is subject to the Report Limitations described in Appendix A

Figure 1: Phreatogammarus fragilis a common groundwater amphipod species. Max length 15 mm. (Provided by Nelson Bousted, NIWA.).

The existence of a significant groundwater fauna in New Zealand was first revealed in 1882 when Charles Chilton collected several new species from wells located in the Canterbury plains (Figure 1). Groundwater invertebrate communities in New Zealand are now known to be dominated by species of water mites, but also include amphipods, isopods, Syncaridae, molluscs, Oligochaeta, flat worms and copepods to name but a few. Although generally small and lacking pigment the more enigmatic members of the fauna include amphipods up to 15 mm in length (Figure 1) and large predatory flatworms (Figure 2). As of 2003 (Scarsbrook et al. 2003) there were 102 formally described groundwater-dwelling species in New Zealand and there are expected to be many more awaiting discovery and description.

Chilton's findings constituted the first such records in the southern hemisphere. However, research and field sampling has since been sporadic and New Zealand has subsequently fallen behind the rest of the world in recognising the biodiversity of groundwater for its intrinsic values and role in the maintenance of the groundwater resource upon which our economies and environmental values are reliant (Boulton et al. 2008).

In particular there is a growing global awareness of the vast array of microbial life in groundwater (Griebler & Leuders 2008) with enormous potential to process materials (such as nutrients and organic matter), but research on the functional role and community structure of these organisms in New Zealand is very limited.

In the Selwyn/Te Waihora catchment flow in the lowland streams and water for irrigation is primarily derived from groundwater and the environmental and economic values in the catchment depend partially on the little known processes within the aquifers.

Figure 2: Prorhynchus putealis a large predatory flatworm found in well samples from beneath the Canterbury Plains. Max length 70 mm. (Provided by Michelle Greenwood).

4.0 ECOSYSTEM SERVICES PROVIDED BY GROUNDWATER FAUNA

Ecosystem services are the conditions and processes by which natural ecosystems and their species sustain and fulfil human life (Daily 1997). In the context of the Selwyn/Te Waihora catchment this means the maintenance of sufficient, clean groundwater for potable supplies, irrigation and environmental values. Although there is little New Zealand specific, evidence of the effects of various landuse impacts on groundwater ecosystems and their services (Scarsbrook et al. 2003, Boulton et al. 2008) conclusions can be drawn by applying fundamental ecological principles to the information that is available and the findings from studies overseas.

Tomlinson & Boulton (2008) reviewed the ecosystem services provided by groundwater (Table 1). Of particular importance to the Selwyn/Te Waihora catchment is the potential for groundwater fauna to bio-remediate organic pollution, such as sewage (Sinton 1984), and sustain linked ecosystems. These ecosystem services are likely to derive from the breakdown of organic matter and maintenance of interstitial space, or aquifer porosity, through movement and feeding of groundwater fauna. Groundwater invertebrates might also be used as bio-indicators of ecosystem health in the same way that they are used in surface streams.

Table 1: Main categories of ecosystem services provided by groundwater.

Type of service	Example
Provisioning	Water for drinking, irrigation, stock and industrial uses
Supporting	Bioremediation, ecosystems engineering, nutrient cycling, sustaining linked ecosystems, providing refugia
Regulating	Flood control and erosion prevention
Cultural	Cultural, social and scientific values, tourism

Notes: – categories devised by the Millenium Ecosystems Assessment (2005)

Investigations of terrestrial and stream ecological systems comparing ecosystem function, for example the breakdown of organic matter, to biodiversity (essentially the number of species), have generally found a negative relationship. Therein, as the number of species falls the ecosystem loses the ability to function. A loss of function is interpreted as a loss of ecosystem service if the desired service is aligned with that function, i.e., processing organic waste discharged to land (Boulton et al. 2008). Thus, as species are lost or the composition of a community changes due to increases or decreases in resources or contaminants it is likely that ecosystem services will eventually decline. The precise relationship between biodiversity and service is unknown for the majority of ecological systems, especially groundwater.

Two potential patterns based on a range of theoretical, experimental and field studies are shown in Figure 3 (Boulton et al. 2008). The green dashed line shows a linear relationship where for every loss of biodiversity there is a constant proportional decline in service. A more likely scenario is shown by the red line. When the system is relatively intact and biodiversity high, ecosystem function is resilient to disturbance and some taxa are effectively redundant. However, there will be a tipping point at which ecosystem function will decline dramatically. Whatever the precise relationship, it is safe to assume that with increasing impacts upon the groundwater ecosystem will come increasing risk of a loss of service. A specific example of ecosystem function decline in a Canterbury aquifer is described in Section 5.0.

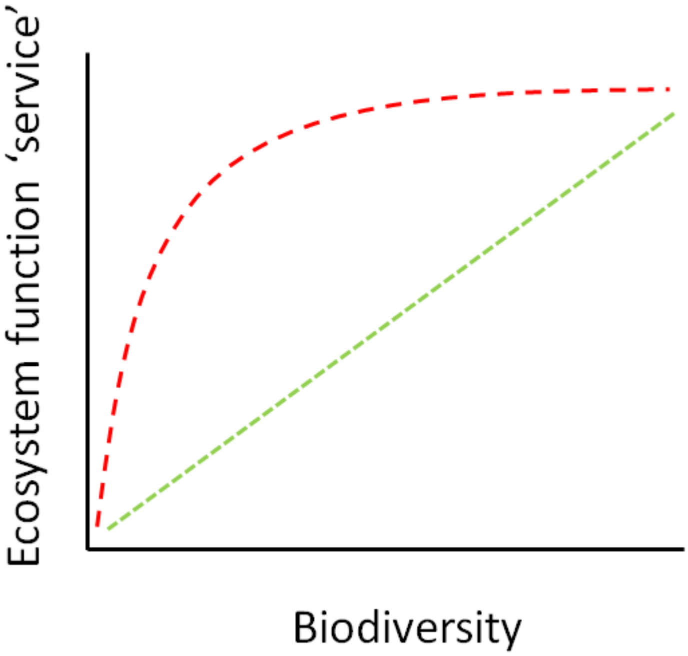

Figure 3: Potential relationships between biodiversity and ecosystem services.

5.0 PRESSURES AND IMPACTS

Groundwaters in Canterbury and the rest of New Zealand are under increasing pressure from water abstraction and various contaminants, including organic and inorganic toxic compounds (e.g. pesticides and heavy metals), nitrogen and organic matter from effluent disposal (Scarsbrook et al. 2003). These impacts all have potential to effect groundwater biodiversity and ecosystem services.

Because of the complete lack of light within groundwater systems there is no photosynthesis and biota are completely reliant on organic carbon coming from the surface. The abundance of life in groundwaters is often highly correlated with the supply of organic matter, but excessive additions of material may saturate the ecosystem (Boulton et al. 2008). Intensive farming and effluent disposal to land can elevate levels of organic matter in groundwater. Sinton (1984) collected samples of groundwater taxa 'downstream' of a sewage irrigation area on the Canterbury plains. Invertebrates, mainly amphipods and isopods (Figure 4), were consuming sewage and reached unusually high abundances compared to non-sewage irrigated areas, up to 2000 individuals per m^3 in contaminated wells. However, in the more contaminated wells the groundwater community was unable to process the organic matter, many individuals died and the organic matter remained in the groundwater system.

Nutrient levels particularly nitrate, in Canterbury aquifers have become elevated and may exceed accepted drinking water standards (Hayward & Hansen 2004). In a recent review of nitrate toxicity for stream ecosystems it was found that several invertebrate groups were particularly sensitive to nitrate, including amphipods (Hickey & Martin 2009). Although there is little data available for New Zealand taxa there are consistent results from around the globe on which Hickey & Martin (2009) based their conclusions. Hickey & Martin (2009) suggest that an upper limit to nitrate concentrations of 3.6 mg/L in streams would protect 80 % of aquatic biodiversity. However, this concentration of 3.6 mg/L of nitrate is regularly exceeded in groundwaters in the Te Waihora/Lake Ellesmere catchment. Thus, in the groundwater community some taxa may thrive, while others decline and some disappear; the entire community and its function changes. Although currently there is very little New Zealand specific information it is highly likely that elevated nitrate in groundwaters increases the risk of biodiversity loss and a decline in ecosystem services. Management of nitrate losses from agricultural land needs to consider the direct receiving environment, groundwater, as well as the lowland streams and lakes.

Other substances which are known to impact upon stream communities and are present in groundwaters are heavy metals, pesticides, fungicides, herbicides and antibiotics, the effects of which we know very little. In additional to the general standard list of contaminants there is an emerging threat from pharmaceutical and personal care products (PPCPs) (USEPA 2012). Globally investigations of the impact of heavy metals on animals living in the saturated gravels beneath rivers have shown marked reductions in groundwater taxa, including the elimination of amphipods (Notenboom et al 1994). Soluble organic compounds (SOCs) such as pesticides have been detected in a significant number of wells in New Zealand (Close 2004), particularly in Canterbury (Smith 1993). Although the overall effects of these pollutions on the function of groundwater ecosystems is not clear, the sensitivity of crustaceans generally to contaminants suggests negative impacts are likely.

Figure 4: Cruregens fontanus a common isopod in the groundwaters beneath the Canterbury Plains. Max Length ~10 mm. Nelson Bousted, NIWA.

Finally, the intensive development and use of the groundwater resource in Canterbury has an impact upon groundwater level fluctuations relative to the natural change in the system (Williams 2008). Although the larger invertebrates such as isopods and amphipods (Figure 4) are good runners and swimmers, stranding during rapid drawdown or dramatic changes in water levels may occur. On the other hand, microbial communities are attached to the substrate and cannot move. A recent study has suggested that attached microbial communities are quite resilient to fluctuations in water levels (Zhou et al. 2012). This study occurred in a pristine alpine aquifer undergoing natural fluctuations and found that microbial communities changed little with changing water level. The applicability of these results to the groundwater ecosystems of Canterbury is unknown, but prolonged, unnatural, changes in water level may impact negatively upon microbial biofilms.

6.0 SUMMARY

In summation, groundwater invertebrate and microbial communities are expected to play an important role in maintaining the water quantity and quality of Canterbury's groundwater. However, there is currently insufficient science to quantify that role. The intrinsic values and ecosystem services provided by these communities are not currently acknowledged in the management of groundwater resources in the Selwyn/Te Waihora catchment. Although the precise relationship between the provision of ecosystem services and biodiversity in groundwaters is unknown, basic ecological principles suggest that a reduction in biodiversity increases the risk of a decline in ecosystem function and services. The primary negative impacts upon the biodiversity of groundwater ecosystems are from contamination by organic and inorganic substances from agricultural, industrial and domestic discharges. The impact of unnatural water level change on groundwater ecosystems remains unknown.

7.0 RECOMMENDATION

In order to safeguard the ecosystem services and intrinsic biodiversity values of groundwater communities in the Selwyn/Te Waihora catchment groundwaters should be considered as an ecosystem as well as a resource. In practise the requirements for flow and low nitrates (as well as other contaminants) in the lowland streams align closely with the needs of the groundwater ecosystem. However, explicit recognition of groundwater as an ecosystem is required to sustainably manage that resource.

8.0 REFERENCES

Boulton AJ, Fenwick GD, Hancock PJ, Harvey MS 2008. Biodiversity, functional roles and ecosystem services of groundwater invertebrates. Invertebrate Systematics 22: 103-116.

Brunke M, Gonser T 1997. The ecological significance of exchange processes between rivers and groundwater. Freshwater Biology 37:1-33.

Close ME, Flintoft MJ 2004. National survey of pesticides in groundwater in New Zealand – 2002. New Zealand Journal of Marine and Freshwater Research 38: 289-299.

Daily GC 1997. Introduction: what are ecosystem services? In Daily GC (ed) Nature's Services: Societal Dependence on Natural Ecosystems. Island Press: Washington, DC, USA pp. 1–10.

Griebler C, Leuders T 2008. Microbial diversity in groundwater ecosystems. Freshwater Biology 54:649-677.

Hayward SA, Hanson CR 2004. Nitrate contamination of groundwater in the Ashburton-Rakaia plains. Canterbury Regional Council, Report No. R04/9.

Hickey CW, Martin ML 2009. A review of nitrate toxicity to freshwater aquatic species. Prepared for the Canterbury Regional Council by NIWA.

Millennium Ecosystem Assessment 2005. Ecosystems and Human Well-being: Synthesis, Island Press, Washington, DC.

Notenboom J, Plenet S, Turquin MJ 1994. Groundwater contamination and its impact upon groundwater animals and ecosystems. In Gibert J, Danielpol DL, Stanford JA eds. Groundwater ecology Academic Press, San Diego. pp 477-507.

Scarsbrook MR, Fenwick GD, Duggan IC, Hasse M 2003. A guide to the groundwater invertebrates of New Zealand. NIWA science and technology series No. 51.

Sinton LW 1984 The macroinvertebrates of a sewage polluted aquifer. Hydrobiologia 119: 161-169.

Smith VR 1993. Groundwater contamination by triazine pesticides, Levels Plain, Canterbury. Canterbury Regional Council Report 93: 1-45.

Tomlinson M, Boulton A 2008. Subsurface groundwater dependent ecosystems: a review of their biodiversity, ecological processes and ecosystem services. Waterlines occasional paper No. 8. Australian National Water Commission.

USEPA 2012. http://www.epa.gov/ppcp/. Accessed 16.8.2012.

White PA 2001. Groundwater resources of New Zealand. In Rosen MR, White PA, eds. Groundwaters of New Zealand, New Zealand Hydrological Society, Wellington. Pp 45-47.

Williams HR 2008. Groundwater and the 'living lake'. In Hughey KFD, Taylor KJW *eds.* Te Waihora/Lake Ellesmere: status of the lake and future management. Lincoln University, New Zealand. Pp. 9-20.

Zhou Y, Kellerman C, Griebler C 2012. Spatio-temporal patterns of microbial communities in a hydrologically dynamic pristine aquifer. FEMS Microbiology Ecology 81: 230-242.

APPENDIX A

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