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Zooplankton Communities, and TLI and Lake Health Assessments, of Selected Lakes in the Wellington region

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Brachionus plicitilis from Waimanu Lagoon. Photos: Ian Duggan.

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EXECUTIVE SUMMARY

Zooplankton were collected from ten lakes in the Wellington Region in 2022, with a further three historic samples collected from 2019 (including one unique lake). These were used to explore community composition of these lakes, as well as trends in rotifer inferred TLI assessments, the proportions of native versus non-native zooplankton, and crustaceans versus rotifers.

Based on these results, lakes can be ranked in the following order, from lowest to highest rotifer inferred TLI values; Lake Ngarara (1.8; oligotrophic), Lake Waitawa (3.9), Barton's Lagoon (3.9; both mesotrophic), Turner's Lagoon (4.0), Boggy Pond, (4.2), Waimanu Lagoon (4.5; all eutrophic), Lake Pounui (5.0), Lake Kohangatera (5.1), Matthew's Lagoon (5.3; all supertrophic), Lake Waiorongomai (8.0) and Lake Nganoke (8.3; both hypertrophic). The Matthew's Lagoon (both 5.3) and Lake Waitawa results (3.3 and 4.5) were averages of samples from two years. Nevertheless, these results should be treated with caution, due to being calculated from single samples, or samples from different years, rather than the recommended multiple samples collected over different seasons.

Most of the lakes were devoid of non-native species. Nevertheless, Lakes Pounui and Waitawa both had populations of the introduced *Daphnia galeata*, which is native to northern hemisphere temperate regions (i.e., Holarctic), while Lake Waitawa also possessed a population of the Australian copepod *Boeckella minuta*. The latter record is interesting in that it is otherwise only known from constructed waters in New Zealand, including the Karori Reservoirs and Waikato Hydroelectricity Lakes. As such, this is the first record of this species established in a natural lake in New Zealand.

The zooplankton community of Lake Pounui (98.7%), Lake Waitawa in 2019 (89.9%), Lake Waitawa in 2022 (76.7%) and Boggy Pond (73.1%) were heavily crustacean dominated, while Lake Kohangatera (5.9% crustaceans), Matthews Lagoon (23.5%), Lake Ngarara (27.9%), Lake Waiorongomai (28.6%), Barton's Lagoon (30.5%), Lake Nganoke (32.6%) and Turner's Lagoon (34.7%) were heavily rotifer dominated. Matthew's Lagoon (52.1%) and Waimanu Lagoon (40.4%) had similar proportions of crustacean and rotifer zooplankton. The size distributions of zooplankton in Lakes Pounui and Waitawa are likely influenced by the crustacean invaders in these lakes. Different degrees of top-down control by zooplanktivorous fish, removing larger crustacean zooplankton, may influence the variability among the remaining waterbodies, though longer-term data and knowledge of fish communities is required to better determine this.

Besides *B. minuta*, the waterbodies sampled included some unusual species. A *Brachionus* rotifer, with affinities to *B. caudatus*, was recoded from Lake Kohangatera and Boggy Pond; this seemingly represents an undescribed species. The typically estuarine copepod *Gladioferens pectinatus* and saline rotifer *Brachionus plicatilis* were recorded in Waimanu Lagoon, reflecting a probable marine influence in this lagoon. *Gladioferens pectinatus* was also recorded in Matthews Lagoon, representing a rare occurrence for this species in a freshwater lake.

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1. INTRODUCTION

Traditional inference of lake trophic state typically relies on monthly sampling of a variety of indicators (e.g., Secchi transparency, chlorophyll a concentrations, nutrients), but for lakes that are isolated or have difficult access such fine-scale monitoring is difficult or unfeasible. Also, in areas with at least moderate numbers of lakes, regular monitoring of many water bodies is commonly not possible from a financial perspective. Biotic indices are often used in such circumstances, as they integrate biological, physical and chemical factors over time, allowing for less fine-scale monitoring than traditional methods. Further, biotic indices provide information on the life within the lake ecosystems, ignored in traditional water quality monitoring.

A number of studies globally have found good relationships between zooplankton communities and trophic state, and the potential utility or actual development of bioindicator schemes using zooplankton is increasing (e.g., Ejsmont-Karabin 2012; Haberman & Haldna 2014; May et al. 2014). Duggan et al. (2001a, b) found that trophic state was the major determinant of rotifer distribution among lakes in North Island, New Zealand, and based on these responses developed a quantitative bioindicator index using rotifer community composition for inferring Trophic Lake Index (TLI) values (sensu Burns et al. 1999). In New Zealand, Waikato Regional Council and Auckland Council have undertaken the only long-term water quality monitoring programs of lakes utilising zooplankton globally, based in part on the Rotifer inferred TLI of Duggan et al. (2001) (see Duggan et al. 2021; Duggan & Hussain 2021).

Beyond nutrients, zooplankton may provide further measures of ecosystem health, in particular with respect to non-native species. For example, lake health is compromised when non-native species are present or dominating biotic assemblages. In New Zealand, the rate of invasions by zooplankton species is increasing, with a number of non-native cladoceran and copepod species identified over the last 20 years (e.g., Duggan et al. 2006; Duggan et al. 2012; Duggan et al. 2014), some of which have come to dominate the invaded communities (Balvert et al. 2009; Duggan et al. 2012; Duggan et al. 2014). Further, zooplankton community composition can also be altered by the presence of non-native fish. For example, the removal of brown trout from Upper Karori Reservoir shifted community composition from one dominated by large, efficient filter-feeding crustaceans to smaller, less efficient rotifer (Duggan et al. 2015).

This report aims to:

1) Examine the community composition of zooplankton in selected lakes in the Wellington Region.
2) Examine rotifer inferred TLI assessments for these lakes.
3) Examine the proportions of native versus non-native zooplankton species, and crustacean versus rotifers.

2. METHODS

Zooplankton samples were collected from ten lakes in the Wellington Region in 2022; Barton's Lagoon, Lake Nganoke, Lake Pounui, Turner's Lagoon, Matthew's Lagoon, Boggy Pond, Lake Ngarara, Waimanu Lagoon, Lake Waiorongomai, and Lake Waitawa. Three further samples were examined from 2019; from Lake Kohangatera, with additional samples from Lake Waitawa and Matthew's Lagoon. Samples were collected using 10 m horizontal tows with a plankton net (40 µm mesh size; 0.22 m diameter; haul speed ~1 m.s-1), giving an approximate filtered volume of 380 litres. Samples were immediately preserved using isopropyl alcohol. In the laboratory, preserved samples were examined for zooplankton community composition. Where possible, samples were counted until at least 300 individuals in total were counted. As rotifers are the zooplankton group most useful for water quality monitoring, it was also ensured that, where possible, samples were enumerated until a total of at least 100 individuals of rotifer 'indicator species' were recorded, where possible; i.e., species that have an assigned TLI optima and tolerance score given by Duggan et al. (2001). Based on the resulting lists, the bioindicator scheme of Duggan et al. (2001) was used to infer lake trophic state. All identifications were made to species level wherever possible. The proportions of native versus non-native species, and of crustaceans versus rotifers, were also examined.

3. RESULTS AND DISCUSSION

Zooplankton Composition among Lakes

A diverse array of zooplankton species was recorded in the samples, including 54 rotifer taxa, 6 cladoceran and at least 7 copepod taxa (Table 1a, b). Among these, a *Brachionus* rotifer, with affinities to *B. caudatus*, was recoded in Lake Kohangatera and Boggy Pond (Fig 1); this species seemingly represents an undescribed species. It appears similar to a specimen recorded by Duggan (1999) collected from Lake Wairarapa. The typically estuarine copepod *Gladioferens pectinatus* was recorded in Matthews Lagoon and Waimanu Lagoon, and the saline rotifer *Brachionus plicatilis* in Waimanu Lagoon (Fig 2). For Waimanu Lagoon, the presence of these species reflects a likely marine influence in the waterbody. However, Matthew's Lagoon is not influenced by the ocean (Perrie & Royal 2022). While uncommon to be recorded in freshwaters, Bayly (1963) notes that *Gladioferens* populations have been found in Australian lakes up to 60 km from the coast; Matthew's Lagoon is less than 20 km from the nearest coast. A number of brachionid rotifer species (*Brachionus* spp., *Keratella* spp.) were recorded, which are commonly associated with more eutrophic conditions, while no *Conochilus* species were recorded, which are typical components of oligotrophic conditions (Duggan et al. 2001). Another unusual finding included the presence of trematode cercariae in the Turner's Lagoon sample, which may have emerged from snails that were also present in the sample (Figure 3).

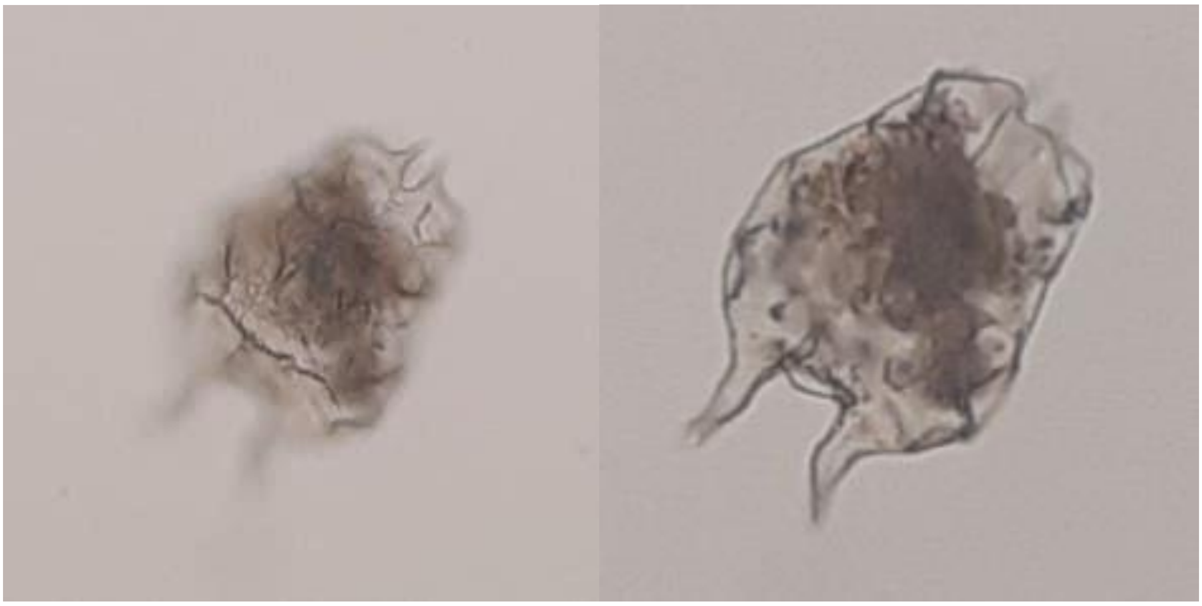

Figure 1. *Brachionus* cf. *caudatus*, presented in two focal planes.

Figure 2. *Brachionus plicitilis* from Waimanu Lagoon.

Figure 3. Trematode cercariae from Turner's Lagoon.

Table 1a. List of rotifer species recorded during this survey.

	Bartons Lagoon 31/03/2022	Boggy Pond 31/03/2022	Lake Kohangatera 10/04/2019	Lake Ngarara 21/03/2022	Matthews Lagoon 4/01/2019	Matthews Lagoon 24/03/2022	Lake Nganoke 24/03/2022	Turners Lagoon 24/03/2022	Lake Pounui 23/03/2022	Waimanu Lagoon 21/03/2022	Lake Waiorongomai 22/03/2022	Lake Waitawa 30/04/2019	Lake Waitawa 22/03/2022
Rotifers													
Anuraeopsis fissa						X	X						
Ascomorphella volvocicola	X			X									
Asplanchna brightwelli					X								
Asplanchna priodonta												X	
Asplanchna sieboldi													X
Bdelloid rotifers	X	X	X	X	X		X	X			X		X
Brachionus angularis					X	X	X						X
Brachionus budapestinensis					X	X	X						
Brachionus caliciflorus					X								
Brachionus cf. *caudatus*		X	X										
Brachionus plicatilis										X			
Brachionus quadridentatus			X		X	X	X			X	X		
Brachionus urceolaris										X			
Cephalodella forficula								X					X
Cephalodella gibba								X					
Cephalodella ventripes		X											X
Collurella uncinata	X	X											
Dicranophorus epicharis							X						
Euchlanis dilatata								X				X	
Euchlanis pyriformis								X					
Euchlanis meneta								X	X				
Filinia longiseta				X	X								
Filinia novaezealandiae			X			X	X						
Gastropus hyptopus						X							
Hexarthra intermedia		X											
Hexarthra mira										X			
Keratella cochlearis		X	X	X					X				
Keratella procurva												X	X
Keratella slacki						X	X						
Keratella tecta		X		X			X						
Keratella tropica				X			X			X			
Lecane bulla		X	X	X								X	X
Lecane closterocerca	X	X	X										
Lecane flexilis			X										
Lecane luna		X		X				X	X				
Lecane lunaris	X	X	X				X	X					
Lepadella accuminata		X		X									
Lepadella ovalis			X					X					
Monommata sp.	X	X	X					X					
Mytilina mucronata								X					
Notommata alantois								X					
Platyias quadricornis		X	X										
Polyarthra dolichoptera		X		X	X	X	X			X	X		X
Scaridium longicaudatum	X												
Synchaeta oblonga	X	X	X	X				X					
Synchaeta pectinata			X										
Synchaeta stylata												X	X
Testudinella patina			X					X					
Trichocerca brachyura	X	X	X	X			X				X		X
Trichocerca longiseta		X											X
Trichocerca porcellus													X
Trichocerca pusilla						X	X						X
Trichocerca similis		X							X			X	X
Trichocerca teniour		X						X					

Table 1b. List of cladoceran and copepod species recorded during this survey.

	Bartons Lagoon 31/03/2022	Boggy Pond 31/03/2022	Lake Kohangatera 10/04/2019	Lake Ngarara 21/03/2022	Matthews Lagoon 4/01/2019	Matthews Lagoon 24/03/2022	Lake Nganoke 24/03/2022	Turners Lagoon 24/03/2022	Lake Pounui 23/03/2022	Waimanu Lagoon 21/03/2022	Lake Waiorongomai 22/03/2022	Lake Waitawa 30/04/2019	Lake Waitawa 22/03/2022
Cladocera													
Alona sp.		X				X	X	X	X			X	
Bosmina meridionalis	X			X					X		X		X
Camptocercus australis								X					
Chydorus sp.		X	X			X			X		X	X	X
Daphnia galeata									X			X	X
Simocephalus elizabethae		X				X							
Copepods													
Boeckella hamata									X				
Boeckella minuta												X	X
Calamoecia lucasi									X				
Elaphoidella bidens									X				
Eucyclops serrulatus			X										
Gladioferens pectinatus						X				X			
Mesocyclops australiensis	X	X	X		X	X	X	X	X		X	X	X
Indeterminate harpacticoid copepods			X										
Copepod nauplii	X	X	X	X	X	X	X	X	X	X	X	X	X
Ostracods		X				X	X		X		X		X
Mysids											X		

Trophic State Assessments

Based on these results, lakes can be ranked in the following order, from lowest to highest rotifer inferred TLI values; Lake Ngarara (1.8; oligotrophic), Lake Waitawa (3.9), Barton's Lagoon (3.9; both mesotrophic), Turner's Lagoon (4.0), Boggy Pond, (4.2), Waimanu Lagoon (4.5; all eutrophic), Lake Pounui (5.0), Lake Kohangatera (5.1), Matthew's Lagoon (5.3; all supertrophic), Lake Waiorongomai (8.0) and Lake Nganoke (8.3; both hypertrophic). All of these assessments were made on single samples, except Matthew's Lagoon and Lake Waitawa, which were calculated as the averages of two samples from 2019 and 2022. Nevertheless, these results should be treated as indicative only, as for trophic state assessments using the bioindicator scheme of Duggan et al. (2001b), it is recommended that four quarterly samples be taken in a year and averaged to obtain trophic state, due to high variability among seasons.

Trends in the proportions of non-native species

Detection of non-native species provides further information of lake health, which would otherwise have been missed without the zooplankton monitoring programme. Most of the lakes were devoid of non-native species, which is remarkable when comparing them to other North Island lakes (see for example, the widespread occurrence and common dominance of non-native zooplankton taxa in Waikato and Auckland lakes; Duggan et al. 2021; Duggan & Hussain 2021). Nevertheless, Lakes Pounui and Waitawa both had populations of the introduced holarctic *Daphnia galeata*, a taxon widespread throughout the North Island and present also in some South Island lakes. Further, Lake Waitawa also possessed a population of the Australian copepod *Boeckella minuta*. This record is notable, in that it is otherwise known only from constructed waters in New Zealand, including the Upper and Lower Karori Reservoirs (Wellington) and Waikato Hydroelectric Lakes (Banks & Duggan 2009). As such, this is the first record of this species in a natural lake in New Zealand.

Overall, the effects that non-native zooplankton species are having on New Zealand lake ecosystems are not well appreciated. However, changes in zooplankton species composition have been noted following invasions. For example, in Lake Kereta, Auckland, the invasion of the nonindigenous copepod *Skistodiaptomus pallidus* led to the apparent extirpation of the native *Calamoecia lucasi* for a number of years (Duggan et al. 2014), while in Lake Puketirini, Huntly, rotifers were greatly reduced in numbers following the establishment of *Daphnia galeata* (Balvert et al. 2009). While *Daphnia* species are highly efficient feeders of algae, more so than the native zooplankton species, their relative susceptibilities to higher trophic levels such as fish are unknown. On one hand, the non-native species may be less susceptible to native fish species through having superior escape responses (copepods) or behavioural adaptations such as diel vertical migrations (*Daphnia*). Alternatively, being larger crustacean species, non-native cladocerans and copepods may provide a superior food resource for fish, enhancing their populations, though the relative benefits to native and non-native fish species may differ. With their pivotal position in aquatic food webs as primary consumers, changes in zooplankton species composition are likely to result in ecosystem-level effects that influences top-down and bottom-up dynamics; further research is required to determine these broader ecosystem-level effects.

Proportions of crustacean versus rotifer species abundances

The zooplankton community of Lake Pounui (98.7%), Lake Waitawa in 2019 (89.9%), Lake Waitawa in 2022 (76.7%) and Boggy Pond (73.1) were heavily crustacean dominated, while Lake Kohangatera (5.9% crustaceans), Matthew’s Lagoon (23.5%), Lake Ngarara (27.9), Lake Waiorongomai (28.6%), Barton’s Lagoon (30.5%), Lake Nganoke (32.6%) and Turner’s Lagoon (34.7%) were heavily rotifer dominated. Matthews Lagoon (52.1%) and Waimanu Lagoon (40.4%) had similar proportions of crustacean and rotifer zooplankton. Nevertheless, these results provide only a snapshot of the communities at one time, and whether these results represent longer-term trends in crustacean and rotifer dominance among these lakes is unclear. However, that Lake Pounui and the two samples from Lake Waitawa were the most strongly dominated by crustaceans, likely reflects that these are the two lakes that have been invaded by non-indigenous crustacean zooplankton. In Lake Waitawa, in particular, 75.3% of individuals collected in 2019, and 23.3% of individuals in 2022, represented non-indigenous species. Without long-term zooplankton monitoring and data of fish composition, it is difficult to make firm conclusions. However, we might expect those with greater proportions of larger crustaceans (i.e., Lake Pounui, Lake Waitawa and Boggy Pond) to have a lower influence of zooplanktivorous fish species than those that were dominated by smaller rotifers (i.e., Lake Kohangatera, Matthew's Lagoon, Lake Ngarara and Lake Waiorongomai) (e.g., Duggan et al. 2015).

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