Zooplankton composition and a water quality assessment of seventeen Waikato lakes using rotifer community composition

CBER Contract Report 80

Client report prepared for
Environment Waikato

by

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May 2008

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Acknowledgements

The author wishes to thank the Environment Waikato staff for collection and delivery of the samples, and helpful correspondence, during and after their monitoring of these lakes.

Contents

Executive Summary

Zooplankton species composition was documented from 17 Waikato lakes from net haul samples collected in late 2007 (summer) and early 2008 (autumn). The lakes examined were Harihari, Mangahia, Maratoto, Ngahewa, Ohinewai, Okowhao, Parangi, Rotokawau, Rotomanuka, Serpentine East, Serpentine North, Serpentine South, Taharoa, Tutaeinanga, Waahi, Waikare and Whangape.

A variety of species was observed during the study, including 41 rotifer, 5 cladoceran and 3 copepod taxa, mites and mysid shrimps. Most taxa recorded were typical inhabitants of New Zealand lakes. However, there appears to be a growing non-indigenous component to the zooplankton, with the freshwater jellyfish *Craspedacusta sowerbyi* (2 lakes), the rotifer *Conochilus exiguus* (1 lake) and two *Daphnia* species (*D. dentifera* and an apparently new invader; widespread) recorded during this study.

Rotifer-inferred TLI estimates ranked the lakes from best to poorest in the following order: Lake Serpentine East (3.38), Maratoto (3.43), Serpentine South (3.76), Harihari (4.74), Ngahewa (4.93), Parangi (5.00), Mangahia (5.03), Serperntine North (5.10), Rotomanuka (5.32), Taharoa (5.68), Okowhao (6.11), Tutaeinanga (6.15), Ohinewai (6.67), Waikare (6.79), Rotokawau (7.46), Whangape (7.66) and Waahi (7.88). This ranking is comparable to assessments made using different methods elsewhere. In a previous Waikato lake study, the rotifer-inferred TLI value from Lake Taharoa samples collected in late 2006 was 2.7 (i.e., oligotrophic). A higher value in the current study may indicate that the rotifer community had a delayed response to a recent decline in water quality in this lake. Alternatively, it strengthens the supposition that accurate assessments using this method should be made when several (i.e., quarterly) samples are taken throughout the year. Nevertheless, the maximum difference in inferred TLI values between summer and autumn samples from a single lake in the current study was 2.0.

Introduction

In late 2007 and early 2008, Environment Waikato conducted surveys of 17 lakes in the Waikato region: Lakes Harihari, Mangahia, Maratoto, Ngahewa, Ohinewai, Okowhao, Parangi, Rotokawau, Rotomanuka, Serpentine East, Serpentine North, Serpentine South, Taharoa, Tutaeinanga, Waahi, Waikare and Whangape. Most of these lakes have little historic data relating to their water quality or biology. Additionally, some sites have limited access possibilities, further precluding the collection of long term water quality data. The inference of lake trophic state and other water quality characteristics typically relies on monthly sampling of a variety of indicators, but for lakes that are isolated or have difficult access such fine-scale monitoring is difficult or unfeasible. Biotic indices are commonly used in such circumstances as they integrate biological, physical and chemical factors over time, allowing for less fine-scale monitoring than traditional methods. Duggan et al. (2001a, b) found that trophic state was the major determinant of rotifer distribution among North Island lakes, 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). This approach was used for ten Waikato lakes using single samples collected in late 2006 (see Duggan 2007). However, although rotifer-inferred TLI values ranked lakes similarly to an order predetermined by Environment Waikato, there were some discrepancies. One possible reason for these problems was that only single samples were used, as opposed to the quarterly sampling recommended by Duggan et al. (2001a).

In this report, zooplankton community composition was documented from plankton hauls from fourteen lakes sampled in late 2007 (summer) and early 2008 (autumn)(i.e., two samples from each lake). From the resulting species datasets, the Rotifer Community Index of Duggan et al. (2001a) was used to infer lake water quality.

Methods

Seventeen lakes were sampled by Environment Waikato staff for this study. Zooplankton were sampled from a central (or deep) position in each lake in late 2007 and early 2008, using vertical hauls through the entire water column with a plankton net (40µm mesh size; haul speed ~1 $m.s^{-1}$). Samples were immediately preserved using ethanol.

In the laboratory, preserved samples were examined for zooplankton community composition. As rotifers are the zooplankton group most useful for water quality monitoring, samples were enumerated until a total of at least 200 individuals of "indicator species" were recorded; i.e., species that have an assigned TLI optima and tolerance score given by Duggan et al. (2001a). Based on the resulting lists, the bioindicator scheme of Duggan et al. (2001a) was used to infer trophic state. All identifications were made to species level wherever possible.

Results and Discussion

Community composition

A wide variety of zooplankton taxa were recorded during the study. Forty one rotifer, five cladoceran and three copepod taxa were distinguished, as well as planktonic mites, mysid shrimps and the freshwater jellyfish *Craspedacusta sowerbyi* (Table 1). Most taxa were fairly typical North Island lake inhabitants. All of the rotifers recorded in this survey were also found in the North Island survey of Duggan et al. (2001a, 2002) except for *Brachionus lyratus* and *Polyarthra vulgaris*. Both of these species were recorded in the previous study of ten Waikato lakes by Duggan (2007), and are therefore not unusual. In this report I have not differentiated the records of *Brachionus lyratus* from *B. angularis* as they appeared morphologically very similar, and to form a gradient in morphology that made it difficult to confidently assign these specimens to one or the

other taxon. However, both are present in the Waikato lakes. *Conochilus exiguus* was recorded from Lake Serpentine East. This species is interesting in that it has only been recorded previously from Lakes Rotomanuka and Rotomanuka South in New Zealand, and outside of New Zealand only from North America, prompting Duggan et al. (2002, 2006) to suggest that this may constitute a non-indigenous species to New Zealand. Given the three New Zealand records to date are from a restricted geographical area this contention seemingly still holds.

Crustacean species recorded were generally also typical inhabitants of North Island lakes, and were similar to those recorded in the previous survey of Duggan (2007). The copepods *Boeckella delicata*, *Calamoecia lucasi* and *Mesocyclops leuckarti* were common representatives in the lakes, and are common components of the zooplankton in New Zealand more broadly (Chapman & Lewis 1976). Of the cladocerans, two *Ceriodaphnia* species were recorded that were not found in the previous Waikato lakes survey. However, both have previously been recorded as common in the Waikato lakes (Greenwood et al. 1991). In this survey I have grouped the *Daphnia* species as one taxon. *Daphnia dentifera*, a recently discovered North American non-indigenous species (Duggan et al. 2006), likely makes up a number of these records. However, a second morphologically similar, but larger, *Daphnia* species was also present in some lakes, which appears to constitute a new and previously unrecognised non-indigenous species. Further research is required to confidently assign a species name to this species, and to accurately differentiate it from *D. dentifera* in the samples. The mysid shrimp *Tenagomysis chiltoni* was recorded in Lakes Waahi and Waikare, where it has been recorded previously in great numbers (Chapman et al. 1991). Finally, the freshwater jellyfish *Craspedacusta sowerbyi*, a probable invader from China, was

Table 1. Zooplankton species present in the net hauls from seventeen Waikato lakes. Lakes are ordered alphabetically.

	Harihari	Harihari	Mangahia	Mangahia	Maratoto	Maratoto	Ngahewa	Ngahewa	Okawhao	Okawhao	Ohinewai	Ohinewai	Parangi	Parangi	Rotokawau	Rotokawau	Rotomanuka	Rotomanuka
	14-Dec-07	12-Mar-08	10-Dec-07	07-Mar-08	10-Dec-07	20-Mar-08	18-Dec-07	12-Mar-08	11-Dec-07	10-Mar-08	11-Dec-07	10-Mar-08	14-Dec-07	17-Mar-08	11-Dec-07	16-Apr-08	20-Dec-07	26-Mar-08
ROTIFERA																		
Anuraeopsis fissa	X														X	X	X	X
Ascomorpha ovalis	X	X			X							X	X				X	X
Asplanchna brightwelli			X	X	X		X	X				X	X	X	X	X	X	
Asplanchna priodonta									X	X								X
Brachionus angularis/lyratus							X	X						X				
Brachionus budapestinensis															X			
Brachionus caliciflorus				X							X				X			
Brachionus quadridentatus														X	X			
Cephalodella gibba													X					
Collotheca sp.							X	X		X		X		X	X			
Conochilus coenobasis					X	X												
Conochilus dossuarius								X										
Conochilus exiguus																		
Conochilus unicornis																		
Epiphanes macrourus							X							X				
Filinia novaezealandiae			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Filinia pejleri																	X	
Flinia longiseta					X						X				X		X	
Hexarthra intermedia		X										X	X	X	X	X		X
Hexarthra mira	X		X	X			X	X		X							X	
Keratella cochlearis	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Keratella procurva	X					X			X									
Keratella slacki			X						X									
Keratella tecta				X	X						X	X		X	X	X	X	X
Keratella tropica			X	X	X	X	X	X	X	X	X	X			X	X		
Lecane bulla							X					X	X	X				
Lecane flexilis								X										
Lecane lunaris	X																	
Monommata sp.																		
Polyarthra dolichoptera	X	X	X		X		X			X		X			X	X	X	X
Polyarthra vulgaris				X														
Pompholyx sp.	X		X					X	X	X	X	X	X		X		X	X
Synchaeta longipes																		
Synchaeta oblonga			X					X										
Synchaeta pectinata	X	X	X															
Trichocerca pusilla			X				X					X	X	X			X	X
Trichocerca similis		X	X		X	X	X	X	X		X	X					X	X
Trichocerca stylata																		
Trichocerca tenuior									X									
Bdelloids															X	X		
ARTHROPODA																		
Cladoceans																		
Bosmina meridionalis			X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Ceriodaphnia cf. *puchella*						X												
Ceriodaphnia dubia								X										X
Chydorus sp.											X	X	X					
Daphnia spp.			X					X	X	X	X	X	X		X	X		
Copepods																		
Boeckella delicata			X						X									X
Calamoecia lucasi	X	X		X	X	X	X	X			X	X	X	X	X		X	X
Mesocyclops leuckarti	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
nauplii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mites																		
Mysid shrimp: *Tenagomysis chiltoni*																		
CNIDARIA: *Craspedacusta sowerbyi*																		

Table 1 (cont). Zooplankton species present in the net hauls from seventeen Waikato lakes. Lakes are ordered alphabetically.

	Serp. East 12-Dec-07	Serp. East 26-Mar-08	Serp. Nth 12-Dec-07	Serp. Nth 03-Apr-08	Serp. Sth 12-Dec-07	Serp. Sth 26-Mar-08	Taharoa 14-Dec-07	Taharoa 12-Mar-08	Tutaeinagna 18-Dec-07	Tutaeinagna 12-Mar-08	Waahi 19-Dec-07	Waahi 31-Mar-08	Waikare 19-Dec-07	Waikare 02-Apr-08	Whangape 19-Dec-07	Whangape 31-Mar-08
ROTIFERA																
Anuraeopsis fissa	X	X	X	X	X			X						X	X	X
Ascomorpha ovalis	X	X	X	X												
Asplanchna brightwelli						X		X								
Asplanchna priodonta			X		X		X									
Brachionus angularis/lyratus						X			X	X	X	X	X		X	
Brachionus budapestinensis																
Brachionus caliciflorus						X						X				
Brachionus quadridentatus																X
Cephalodella gibba																
Collotheca sp.					X	X		X								
Conochilus coenobasis																
Conochilus dossuarius																
Conochilus exiguus	X	X														
Conochilus unicornis		X														
Epiphanes macrourus	X	X	X													
Filinia novaezealandiae	X	X	X	X	X		X	X	X	X	X		X	X	X	X
Filinia pejleri	X				X											
Flinia longiseta																
Hexarthra intermedia							X							X		
Hexarthra mira		X		X	X	X										
Keratella cochlearis	X		X	X	X	X		X	X	X	X				X	
Keratella procurva																
Keratella slacki								X		X						
Keratella tecta	X	X		X		X	X	X		X	X	X	X	X	X	X
Keratella tropica	X		X						X		X	X		X		X
Lecane bulla								X								
Lecane flexilis						X										
Lecane lunaris			X													
Monommata sp.	X															
Polyarthra dolichoptera	X	X	X	X	X	X	X	X								
Polyarthra vulgaris																
Pompholyx sp.			X	X	X		X	X	X		X					
Synchaeta longipes	X		X													
Synchaeta oblonga																
Synchaeta pectinata					X	X										
Trichocerca pusilla							X	X			X			X	X	
Trichocerca similis							X	X	X			X				
Trichocerca stylata																X
Trichocerca tenuior		X														
Bdelloids					X							X				
ARTHROPODA																
Cladoceans																
Bosmina meridionalis	X	X	X	X	X	X	X	X	X	X				X	X	X
Ceriodaphnia cf. *puchella*				X	X											
Ceriodaphnia dubia								X								
Chydorus sp.																
Daphnia spp.		X							X			X	X	X		
Copepods																
Boeckella delicata																
Calamoecia lucasi	X	X	X	X	X	X	X	X	X	X	X	X	X		X	
Mesocyclops leuckarti	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
nauplii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mites							X									
Mysid shrimp: *Tenagomysis chiltoni*											X		X	X		
CNIDARIA: *Craspedacusta sowerbyi*		X	X													

recorded from Lake Serpentine East and Lake Serpentine North. Individuals recorded were very small, so it is unclear whether they formed a significant summer bloom. It is not known whether this species has been previously observed in these lakes, but it has been recorded widely through a number of Waikato lakes in the past (Boothroyd et al. 2002). Overall, with the presence of *Craspedacusta sowerbyi*, *Conochilus exiguus*, and now potentially two non-indigenous *Daphnia* species, the Waikato lakes appear to have a high, and growing, representation of non-indigenous zooplankton species.

Trophic state assessment

Based on rotifer inferred TLI values, Lake Serpentine East had the best water quality, followed by Lakes Maratoto and Serpentine South (all mesotrophic; Table 1; Figure 1). Lakes Harihari and Ngahewa were assessed as eutrophic, while Lakes Parangi, Mangahia, Serpentine North, Rotomanuka and Taharoa were all assessed as supertrophic. All other lakes were assessed as hypertrophic, with Lakes Rotokawau, Whangape and Waahi all inferred to possess the poorest water quality (inferred TLIs >7: Figure 1). Although monitored data does not exist for most of these lakes to compare the rotifer inferred TLI results, the assessed rankings calculated here do not seem unreasonable. For example, lake order here was similar to that provided by Edwards et al. (2007) using the LakeSPI index, with Lake Serpentine East and South at the top of their assessment, and Lakes Whangape and Waahi at the bottom.

In the previous study of ten Waikato lakes by Duggan (2007), Lake Taharoa was assessed by the rotifer inferred TLI method as having good water quality (inferred TLI = 2.7), not in accordance with the lakes marked decline in water quality over the previous

Table 1. Rotifer inferred TLI values for 17 Waikato lakes from late 2007 (summer), early 2008 (autumn) samples, and an average of these values. Lakes are ordered from lowest to highest inferred TLI values.

Lake	Date	Rotifer Inferred TLI	Rotifer Inferred TLI (average)
Serpentine East	12-Dec-07	2.68	
Serpentine East	26-Mar-08	4.07	3.38
Maratoto	10-Dec-07	3.96	
Maratoto	20-Mar-08	2.90	3.43
Serpentine South	12-Dec-07	3.94	
Serpentine South	26-Mar-08	3.57	3.76
Harihari	14-Dec-07	4.54	
Harihari	12-Mar-08	4.93	4.74
Ngahewa	18-Dec-07	4.73	
Ngahewa	12-Mar-08	5.13	4.93
Parangi	14-Dec-07	4.67	
Parangi	17-Mar-08	5.34	5.00
Mangahia	10-Dec-07	4.69	
Mangahia	07-Mar-08	5.38	5.03
Serpentine North	12-Dec-07	4.25	
Serpentine North	03-Apr-08	5.95	5.10
Rotomanuka	20-Dec-07	5.60	
Rotomanuka	26-Mar-08	5.05	5.32
Taharoa	14-Dec-07	5.25	
Taharoa	12-Mar-08	6.11	5.68
Okowhao	11-Dec-07	6.25	
Okowhao	10-Mar-08	5.96	6.11
Tutaeinanga	18-Dec-07	6.89	
Tutaeinanga	12-Mar-08	5.40	6.15
Ohinewai	11-Dec-07	7.27	
Ohinewai	10-Mar-08	6.07	6.67
Waikare	19-Dec-07	7.81	
Waikare	02-Apr-08	5.77	6.79
Rotokawau	11-Dec-07	8.02	
Rotokawau	16-Apr-08	6.89	7.46
Whangape	19-Dec-07	7.72	
Whangape	31-Mar-08	7.61	7.66
Waahi	19-Dec-07	7.37	
Waahi	31-Mar-08	8.38	7.88

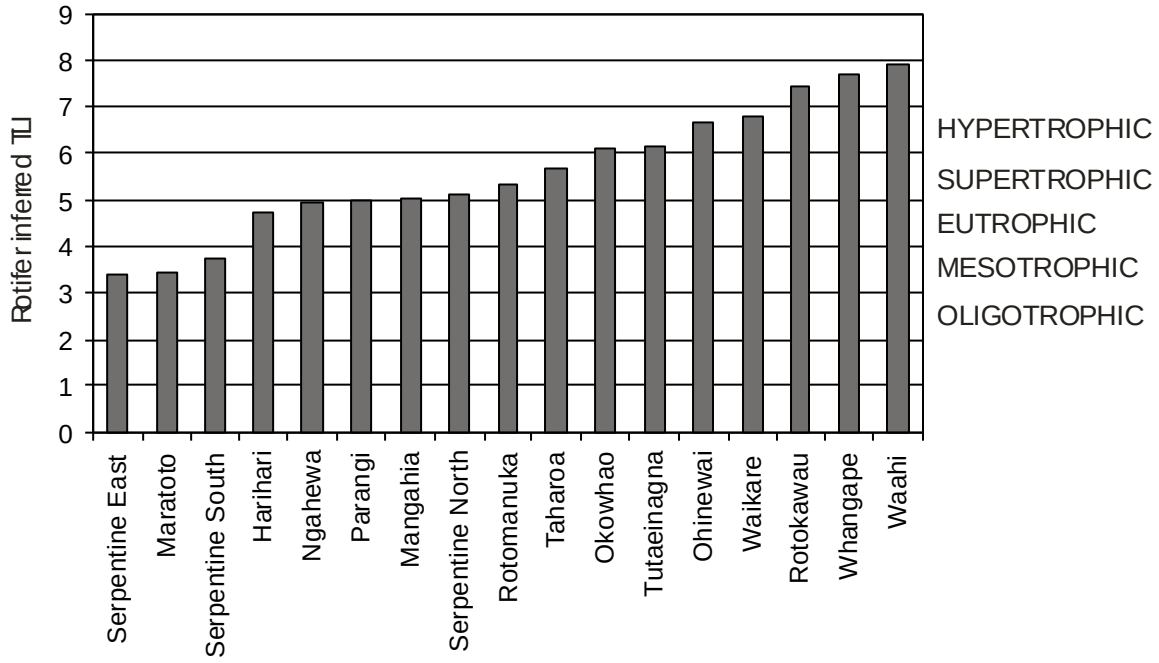

Figure 1: Averaged rotifer inferred TLI values from samples collected in late 2007 and early 2008 from seventeen Waikato Lakes. Lakes are ordered from lowest to highest inferred TLI values.

two years (pers. comm., Keri Neilson, Environment Waikato). However, the rotifer inferred TLI value from the current survey indicates that the water quality of Lake Taharoa is far worse than was assessed previously (average TLI = 5.7). Such a result would have more accurately reflected the rankings of lakes determined by Environment Waikato in the previous study. This may indicate that the zooplankton community composition may not have immediately responded to the change in water quality. Alternatively, the variance in assessed TLI values may have been a result of the need to obtain several samples from different times of the year to accurately infer lake trophic state. It was recommended by Duggan et al. (2001a) that four quarterly plankton samples be collected over a year and these be averaged to obtain an accurate trophic state assessment, as assessments made from single samples sometimes show wide variability (i.e., up to 4 TLI units for some samples; Duggan 1999). In the current study, the average

difference in inferred TLI values between summer and autumn samples was 0.9 across all lakes, with a maximum difference of 2.0 for Lake Waikare.

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Appendix 1

List of "indicator" rotifer species recorded during this survey as a percentage of all indicator taxa. Indicator taxa are ordered based on TLI optima from lowest to highest.

	TLI optima	Harihari 14-Dec-07	Harihari 12-Mar-08	Mangahia 10-Dec-07	Mangahia 07-Mar-08	Maratoto 10-Dec-07	Maratoto 20-Mar-08	Ngahewa 18-Dec-07	Ngahewa 12-Mar-08	Okawhao 11-Dec-07	Okawhao 10-Mar-08	Ohinewai 11-Dec-07	Ohinewai 10-Mar-08	Parangi 14-Dec-07	Parangi 17-Mar-08	Rotokawau 11-Dec-07	Rotokawau 16-Apr-08	Rotomanuka 20-Dec-07	Rotomanuka 26-Mar-08
ROTIFERA																			
Conochilus dossuarius	3.0989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synchaeta longipes	3.3232	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polyarthra dolichoptera	3.4396	2.9	0.6	7.9	0.0	1.0	0.0	10.5	0.0	0.0	9.4	0.0	0.9	0.0	0.0	2.1	8.2	4.0	3.0
Conochilus unicornis	3.8036	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conochilus coenobasis	3.9056	0.0	0.0	0.0	0.0	30.0	80.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ascomorpha ovalis	3.9558	11.3	8.6	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.0	0.0	0.0	3.1	1.4
Lecane bulla	4.165	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.3	16.4	6.3	0.0	0.0	0.0	0.0
Synchaeta oblonga	4.3875	0.0	0.0	2.6	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asplanchna priodonta	4.4042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9
Synchaeta pectinata	4.5011	0.6	0.3	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Collotheca sp.	4.5186	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.0	0.3	0.0	0.3	0.0	0.3	0.3	0.0	0.0	0.0
Filinia pejleri	4.5193	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Hexarthra mira	4.606	9.5	0.0	53.2	7.1	0.0	0.0	7.6	0.6	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0
Asplanchna brightwelli	4.6949	0.0	0.0	1.8	1.9	0.6	0.0	4.6	2.6	0.0	0.0	0.0	6.8	2.7	2.5	2.1	3.8	1.2	0.0
Trichocerca tenuior	4.6982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichocerca similis	4.7747	0.0	1.4	1.2	0.0	60.7	14.2	1.3	26.6	6.9	0.0	3.5	7.7	0.0	0.0	0.0	0.0	1.5	1.6
Anuraeopsis fissa	4.8205	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	5.2	1.9
Keratella cochlearis	4.8324	72.3	36.4	6.5	5.9	0.3	0.0	0.4	21.3	24.9	2.9	24.8	8.0	4.4	13.4	15.5	0.3	11.1	18.4
Filinia novaezealandiae	4.8392	0.0	0.0	1.8	80.2	0.3	0.6	63.9	37.4	0.4	1.0	1.5	11.9	3.7	1.0	9.5	23.5	52.8	38.6
Trichocerca pusilla	4.8556	0.0	0.0	0.3	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	1.2	3.4	1.3	0.0	0.0	10.5	0.3
Hexarthra intermedia	5.085	0.0	52.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.9	68.5	70.1	3.0	0.3	0.0	25.5
Keratella procurva	5.2296	0.3	0.0	0.0	0.0	0.0	2.5	0.0	0.0	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pompholyx sp.	5.2315	0.9	0.0	2.9	0.0	0.0	0.0	0.0	5.0	1.2	61.0	6.9	16.6	0.5	0.0	4.3	0.0	1.5	0.3
Keratella tropica	5.8483	0.0	0.0	10.3	0.9	3.2	1.9	2.1	2.9	5.7	16.5	59.9	24.6	0.0	0.0	32.0	62.1	0.0	0.0
Brachionus quadridentatus	5.92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.0	0.0	0.0
Keratella slacki	5.9414	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	44.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Keratella tecta	6.0166	0.0	0.0	0.0	3.4	1.6	0.0	0.0	0.0	0.0	0.0	0.5	1.2	0.0	4.6	16.5	1.6	0.3	1.1
Brachionus caliciflorus	6.1631	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Flinia longiseta	6.3957	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	6.7	0.0	6.8	0.0
Brachionus budapestinensis	6.5324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0
Inferred TLI		4.54	4.93	4.69	5.38	3.96	2.9	4.73	5.13	6.43	5.96	7.2	6.07	4.67	5.34	8.02	6.89	5.6	5.05
Average Lake TLI			4.74		5.03		3.43		4.93		6.2		6.64		5		7.46		5.32

Appendix 1 (cont)

List of "indicator" rotifer species recorded during this survey as a percentage of all indicator taxa. Indicator taxa are ordered based on TLI optima from lowest to highest.

	TLI optima	Serp. East 12-Dec-07	Serp. East 26-Mar-08	Serp. Nth 12-Dec-07	Serp. Nth 03-Apr-08	Serp. Sth 12-Dec-07	Serp. Sth 26-Mar-08	Taharoa 14-Dec-07	Taharoa 12-Mar-08	Tutaeinagna 18-Dec-07	Tutaeinagna 12-Mar-08	Waahi 19-Dec-07	Waahi 31-Mar-08	Waikare 19-Dec-07	Waikare 02-Apr-08	Whangape 19-Dec-07	Whangape 31-Mar-08
ROTIFERA																	
Conochilus dossuarius	3.0989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synchaeta longipes	3.3232	0.8	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polyarthra dolichoptera	3.4396	72.4	0.3	17.9	16.7	25.9	64.0	19.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conochilus unicornis	3.8036	0.0	39.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conochilus coenobasis	3.9056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ascomorpha ovalis	3.9558	0.5	1.6	3.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lecane bulla	4.165	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synchaeta oblonga	4.3875	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asplanchna priodonta	4.4042	0.0	0.0	11.5	0.0	0.3	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synchaeta pectinata	4.5011	0.0	0.0	0.0	0.0	14.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Collotheca sp.	4.5186	0.0	0.0	0.0	0.0	6.6	1.9	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filinia pejleri	4.5193	0.5	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hexarthra mira	4.606	0.0	54.0	0.0	0.3	2.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asplanchna brightwelli	4.6949	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichocerca tenuior	4.6982	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichocerca similis	4.7747	0.0	0.0	0.0	0.0	0.0	0.0	6.9	17.8	3.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Anuraeopsis fissa	4.8205	17.1	1.0	10.5	20.1	0.6	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	37.8	2.2	9.7
Keratella cochlearis	4.8324	0.3	0.0	54.0	23.0	4.4	30.5	0.0	17.3	24.9	92.5	26.1	0.0	0.0	0.0	4.6	0.0
Filinia novaezealandiae	4.8392	2.7	2.5	1.6	0.3	40.6	0.0	1.6	15.1	2.3	0.7	0.7	0.0	25.3	45.4	18.6	1.9
Trichocerca pusilla	4.8556	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.8	0.0	0.0	2.8	0.0	0.0	0.6	0.3	0.0
Hexarthra intermedia	5.085	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Keratella procurva	5.2296	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pompholyx sp.	5.2315	0.0	0.0	0.6	3.7	0.6	0.0	66.7	14.0	13.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Keratella tropica	5.8483	5.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	56.5	0.0	2.1	1.2	0.0	0.6	0.0	84.3
Brachionus quadridentatus	5.92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Keratella slacki	5.9414	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0
Keratella tecta	6.0166	0.3	0.6	0.0	35.8	0.0	0.3	0.3	29.3	0.0	2.3	67.2	94.4	74.7	15.2	74.3	3.8
Brachionus caliciflorus	6.1631	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0
Flinia longiseta	6.3957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brachionus budapestinensis	6.5324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inferred TLI		2.68	4.07	4.25	5.95	3.94	3.57	5.25	6.11	6.89	5.4	7.37	8.38	7.81	5.77	7.72	7.61
Average Lake TLI			3.38		5.1		3.76		5.68		6.15		7.88		6.79		7.66