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Assessment of Trophic State Change in Selected lakes of the Auckland Region Based on Rotifer Assemblages

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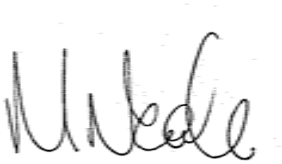

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Assessment of Trophic State Change in Selected Lakes of the Auckland Region based on Rotifer Assemblages: 2005-2008

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Contents

1 Executive Summary

We assessed the trophic state of seven Auckland Regional Council lakes from quarterly samples collected between 2005 and late 2008. In addition, the privately owned Lake Kawaupaku was monitored monthly throughout 2008. Trophic state was assessed based on the composition of rotifer assemblages collected during monitoring.

Inferred trophic states of the lakes were generally ranked in a similar manner over time; Lake Ototoa had the best inferred water quality (generally oligotrophic), while Lake Spectacle had the poorest (hypertrophic to supertrophic). The remaining lakes were generally assessed as being on the mesotrophic to eutrophic boundary (e.g., Lakes Wainamu, Pupuke and Kuwakatai), and were relatively stable through time. Lake Tomarata, however, began the study with an inferred trophic state of oligotrophic /mesotrophic, but was assessed as mesotrophic/eutrophic by the end of the study. Lake Kereta also began the study as mesotrophic/eutrophic, but ended as eutrophic /supertrophic. This indicates that these two lakes may have had declines in water quality during this study period. Lake Spectacle, on the other hand, was widely variable, but the inferred trophic state at the end of the study (supertrophic) was better than at the start (hypertrophic). Lake Kawaupaku was assessed as eutrophic.

2 Introduction

Lake trophic state is typically assessed by monthly sampling of a variety of physical and chemical indicators. Such regular monitoring can be time consuming and expensive. Often neglected are bioindicator approaches, using the responses of organisms to aid in evaluations of trophic state. Such bioindicators integrate biological, physical and chemical properties in the environment over time. Trophic state was found to be a major determinant of rotifer distribution among North Island lakes by Duggan *et al.* (2001a, b), and a quantitative bioindicator index was developed using rotifer community composition to infer Trophic Lake Index (TLI) values (sensu Burns *et al.* 1999). This method is increasingly being used in North Island lakes, particularly to infer trophic state in situations where lakes cannot be sampled regularly (e.g., Environment Waikato lakes; Duggan 2007; Duggan 2008). Rotifers appear to be particularly useful indicators as they are species rich, they are often the numerically dominant zooplankton, and are sensitive to environmental change (e.g., Duggan *et al.* 2001b).

The Auckland Regional Council (ARC) conducts routine water quality monitoring of seven lakes in the Auckland region; Lakes Ototoa, Tomarata, Wainamu, Pupuke, Kuwakatai, Spectacle and Kereta. Changes in the trophic states of these lakes were assessed using rotifer communities collected at quarterly intervals between late-2001 and late-2004 (ARC 2005). In 2008, ARC monitored the privately owned Lake Kawaupaku at more regular intervals.

In this report, the Rotifer Community Index of Duggan *et al.* (2001b) is used to infer trophic state changes from zooplankton samples collected from the ARC lakes between January 2005 and August 2008. This information will be used by ARC to complement trophic state assessments based on traditional methods.

3 Method

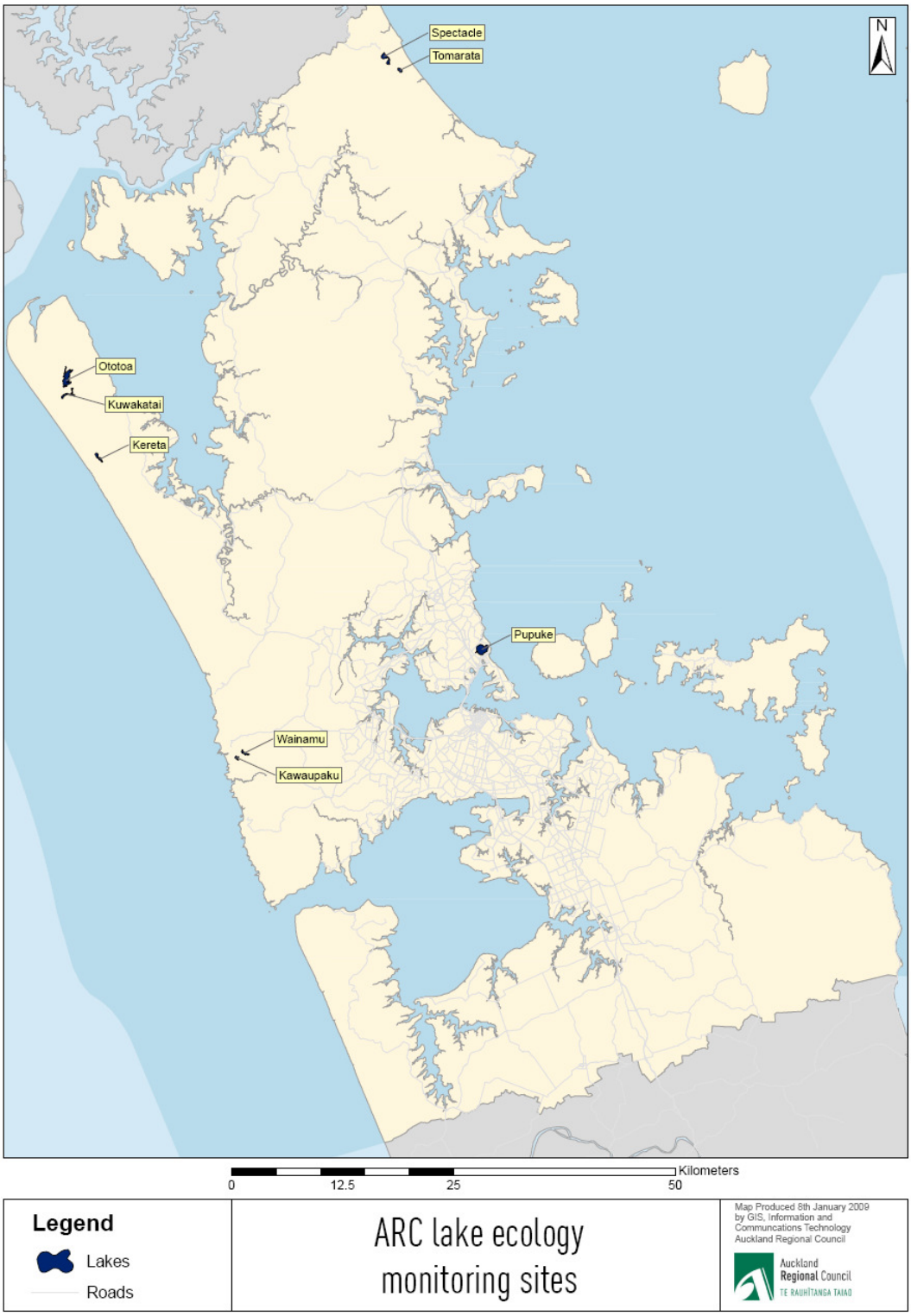
Seven of the eight lakes (Figure 1) monitored by the ARC during this study were sampled approximately quarterly between September 2004 and August 2008 (Lakes Ototoa, Kereta, Tomarata, Wainamu, Pupuke, Spectacle and Kuwakatai). Lake Kawaupaku has been sampled once or twice monthly from November 2007 to July 2008. Zooplankton were sampled using a 72 µm mesh net (0.2 m diameter) through the top 5 m of the water column. Samples were preserved with ~10% formalin (see ARC (2005) for further description of sampling methods).

Trophic state monitoring is best assessed by rotifers so these were enumerated and identified until at least 300 individuals of rotifer indicator taxa were counted, or until the whole sample was completed if fewer species were found. Crustacea have not been included in this study as they are of little or no value for assessing lake water quality.

Trophic state was assessed using the bioindicator scheme of Duggan *et al.* (2001b), where it was recommended that four quarterly samples should be taken in a year and averaged to obtain trophic state. This has been done where possible, although some samples were not usable. For example, samples taken in 2005 were largely devoid of zooplankton, or associated phytoplankton and detritus, which suggests collection problems and/or a lack of preservation. Additionally, all samples collected in May 2008 had few (if any) species, while some contained animals that were still live, indicating a lack of preservation of many samples on this occasion. In this report we calculated TLI values for samples if they had any rotifer indicator taxa present in the samples, rather than using the >25 individual limit employed in ARC (2005), so as to avoid large gaps in the data. Despite still missing some samples due to a lack of indicator taxa, based on the results of the current study we believe that the use of two or three samples in a year (with few individuals) is moderately robust, as we generally did not observe great variability in inferred values over time (see Results section).

TLI values were inferred for any one date as an average of data collected on that sampling date, and from the previous data taken up to one year before. TLI values are therefore provided as a moving average of inferred TLI for each lake over time. For the first sampling dates of the current study, we used data from ARC (2005) in our calculations.

Figure 1.
The location of the eight lakes sampled during this study



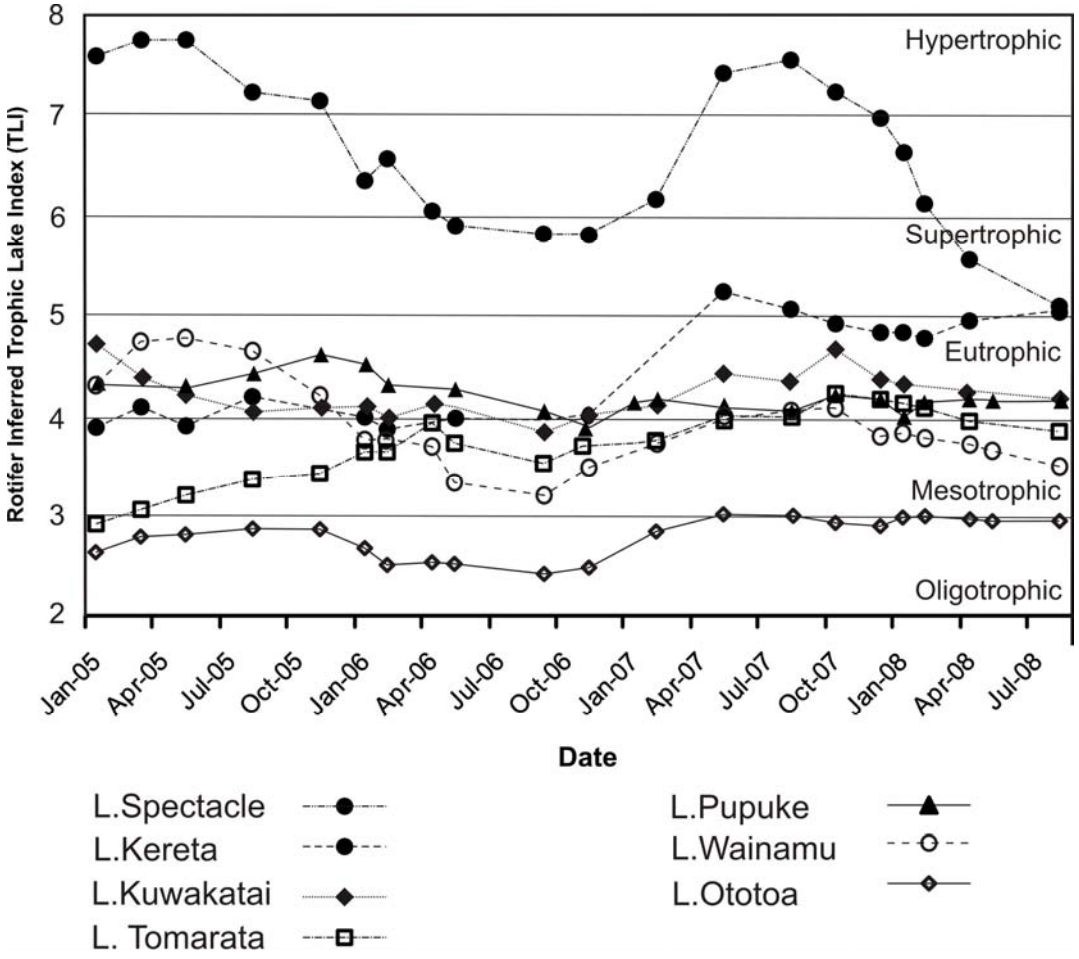
4 Results and Discussion

4.1 Overall Trends among Lakes

A wide variety of rotifer species were recorded during this survey (Appendix 1). Overall lake trophic state was assessed to be the best in Lake Ototoa, which was typically oligotrophic, but bordered on mesotrophic from mid-2007 until the end of the study (Figure 2). TLI values in Lake Tomarata generally increased throughout the study, beginning as oligo-mesotrophic, gradually increasing to eutrophic in late 2007, but ending the study on the meso-eutrophic boundary. Lake Wainamu was initially inferred to be eutrophic but shifted to the mesotrophic range in 2006. Although this lake was assessed to have become mildly eutrophic again, it ended the study as mesotrophic. Lakes Pupuke and Kuwakatai were typically on the mesotrophic/eutrophic boundary throughout the study, and reasonably stable over time. Lake Kereta began the study on the mesotrophic/eutrophic boundary, but trophic state was inferred to decrease such that it was on the boundary of eutrophic to supertrophic at the end of the study. Lake Spectacle was highly variable, but consistently had the poorest water quality. Initially Lake Spectacle was inferred to be hypertrophic, decreased to supertrophic from mid-2006, but then increased again in 2007 to hypertrophic. Finally, the lake was assessed to decrease to its lowest point at the end of the study at the eutrophic/supertrophic boundary (Figure 2). Data for inferred TLI values for this study, and that of ARC (2005), are given in Appendix 2.

Lake Kawaupaku was assessed as eutrophic by averaging the 12 samples collected between November 2007 and June 2008 (inferred TLI = 4.61; Appendix 3).

Figure 2.
Assessed trophic state (TLI) of seven lakes in the Auckland region between January 2005 and August 2008. Data points represent a moving average TLI assessment for each lake, using the average of samples collected from that month and from samples collected within the year prior to that sample.



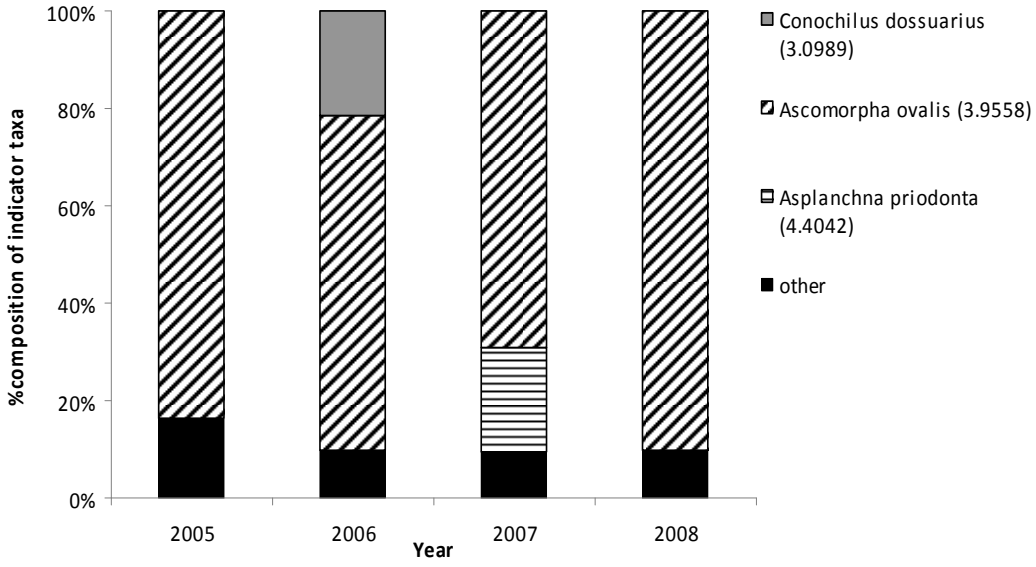
4.2 Species Occurrences and Temporal Changes of Indicator Taxa

All species recorded in the current study were also found in the study of ARC (2005), except for the presence of *Euchlanis calpidia* in Lake Kereta. This is a common littoral and benthic species (as were many of the taxa recorded in Lake Kereta), and is probably widely distributed in New Zealand. The typically saline species *Hexarthra fennica*, an unusual occurrence recorded in Lake Pupuke in the ARC (2005) study, was not recorded again in this study. To determine which rotifer species are primarily responsible for the changes in TLI values assessed over time, the relative abundances of indicator taxa for each lake are presented here as an annual average.

4.2.1 Lake Ototoa

Rotifers indicative of lower trophic states dominated the species composition of Lake Ototoa (e.g., *Conochilus dossuarius* and *Ascomorpha ovalis*; Figure 3). Species composition, and therefore inferred TLI values, changed little over time. However, TLI was assessed at its lowest for this lake in 2006, when *Conochilus dossuarius* was present in good numbers. This species has the lowest TLI optima of all indicator taxa provided by Duggan *et al.* (2001b), but was typically less common in Lake Ototoa in this study than in the 2001-2004 period (ARC 2005).

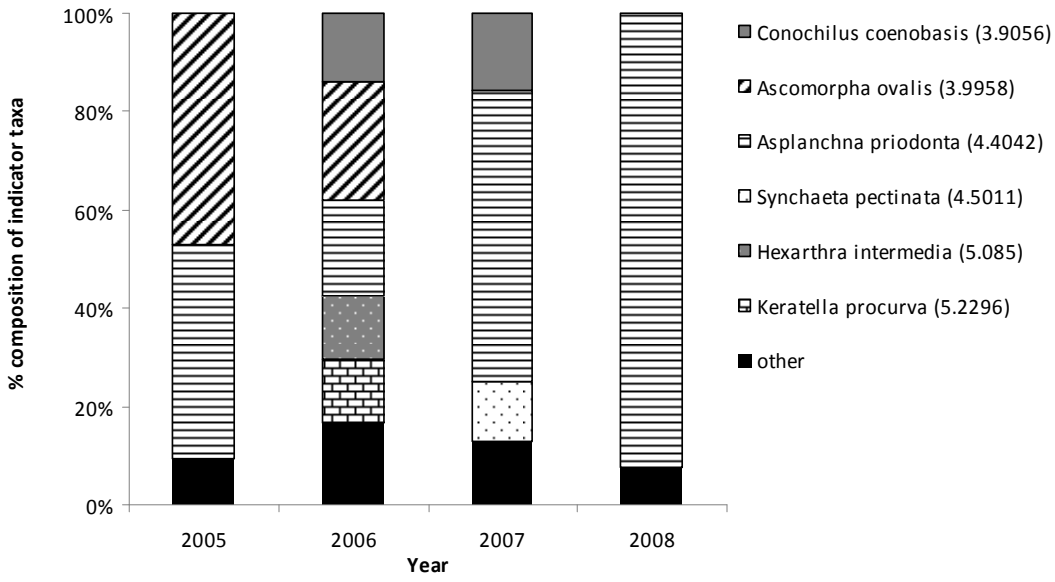
Figure 3.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Ototoa. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



4.2.2 Lake Tomarata

Lake Tomarata was typically inferred as mesotrophic during the study, but overall the inferred TLI values increased through time (Figure 4). This can be attributed to a decrease in species with low TLI optima during the study (*Ascomorpha ovalis* and *Conochilus coenobasis*), and an associated increase in importance of species with TLI optima greater than 4 (especially *Asplanchna priodonta*). Species composition was far less dominated by *Conochilus coenobasis* in this survey than in the 2001-2004 period, suggesting water quality has become poorer since this time.

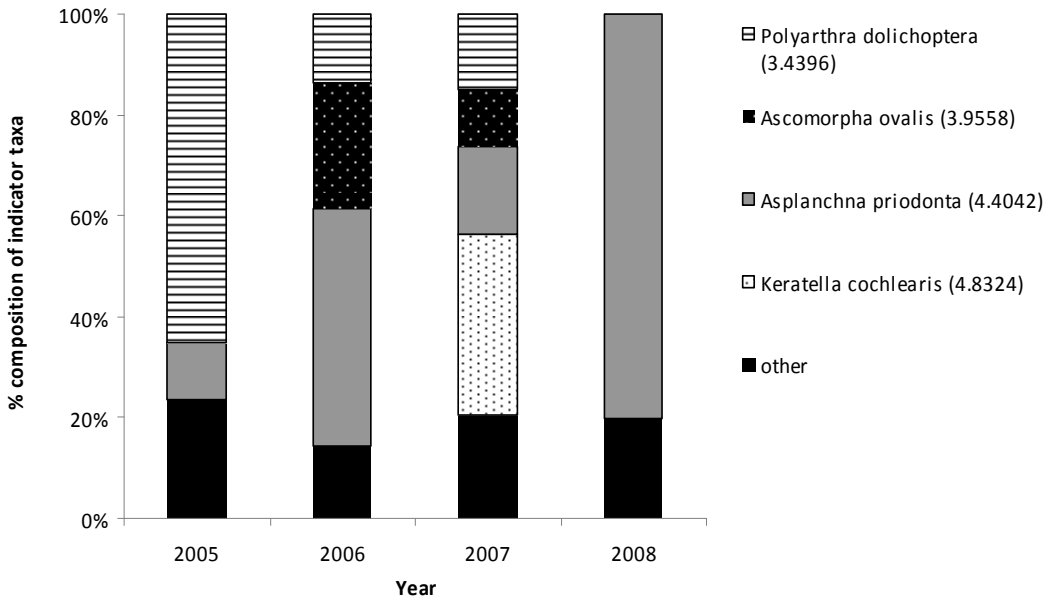
Figure 4.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Tomarata. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



4.2.3 Lake Wainamu

Lake Wainamu was assessed as being eutrophic to mesotrophic throughout this study period. Species composition was dominated by taxa with TLI optima of <5 throughout the study period (Figure 5). However, fewer taxa were assessed as being dominant in this study than in the 2001-2004 period. Greater proportions of *Keratella cochlearis* and *Asplanchna priodonta* were found in the current study, which have higher TLI optima than species that dominated in the 2001-2004 study (ARC 2005), and as such the inferred TLI values were commonly higher in this study.

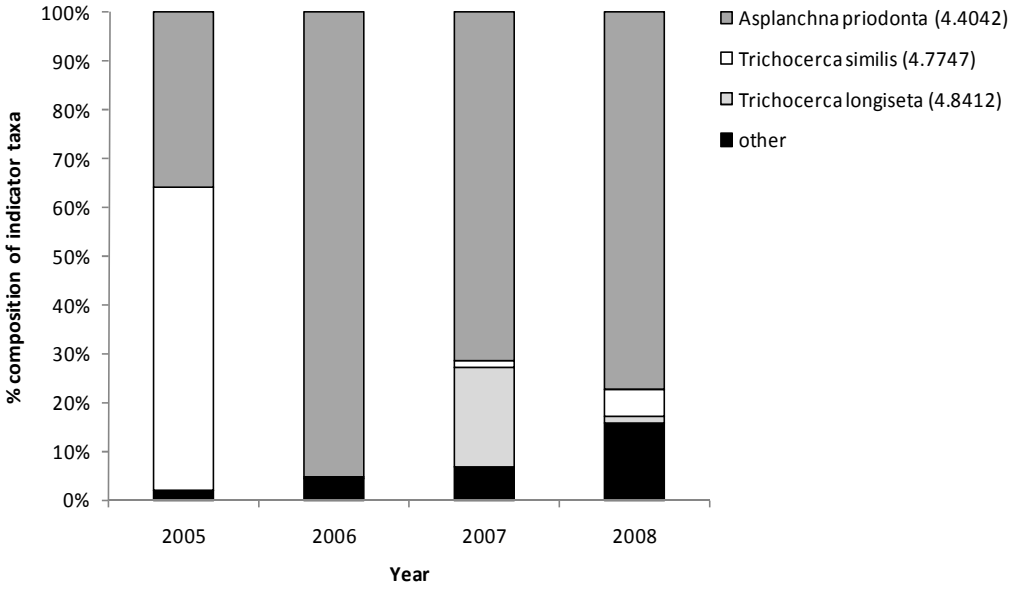
Figure 5.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Wainamu. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



4.2.4 Lake Pupuke

Lake Pupuke was fairly stable on the mesotrophic to eutrophic boundary throughout the current study period (Figure 6). This result was similar to the 2001 to 2004 study, with *Asplanchna priodonta* and *Trichocerca similis* generally being amongst the dominant species (both have TLI optima ~4.5). *Trichocerca longiseta* was common in 2007, but has otherwise only been a rare component of the lake fauna.

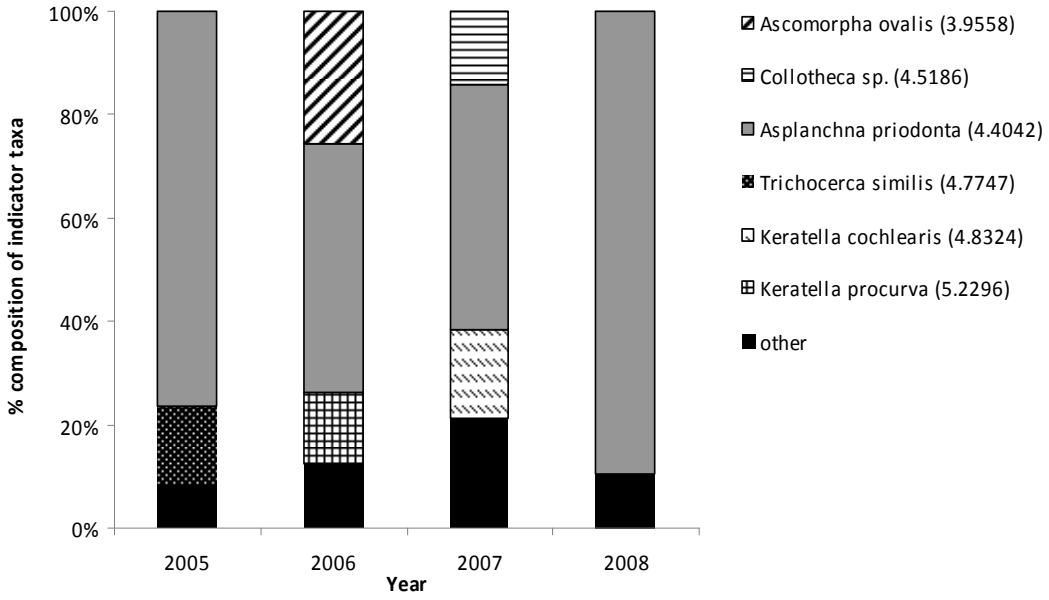
Figure 6.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Pupuke. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



4.2.5 Lake Kuwakatai

As with Lake Pupuke, *Asplanchna priodonta* dominated the species composition of Lake Kuwakatai, and the lake was therefore generally assessed in the eutrophic range throughout (Figure 7). Species dominance was similar to that in the 2001-2004 study, and the inferred trophic states were also similar between studies (ARC 2005).

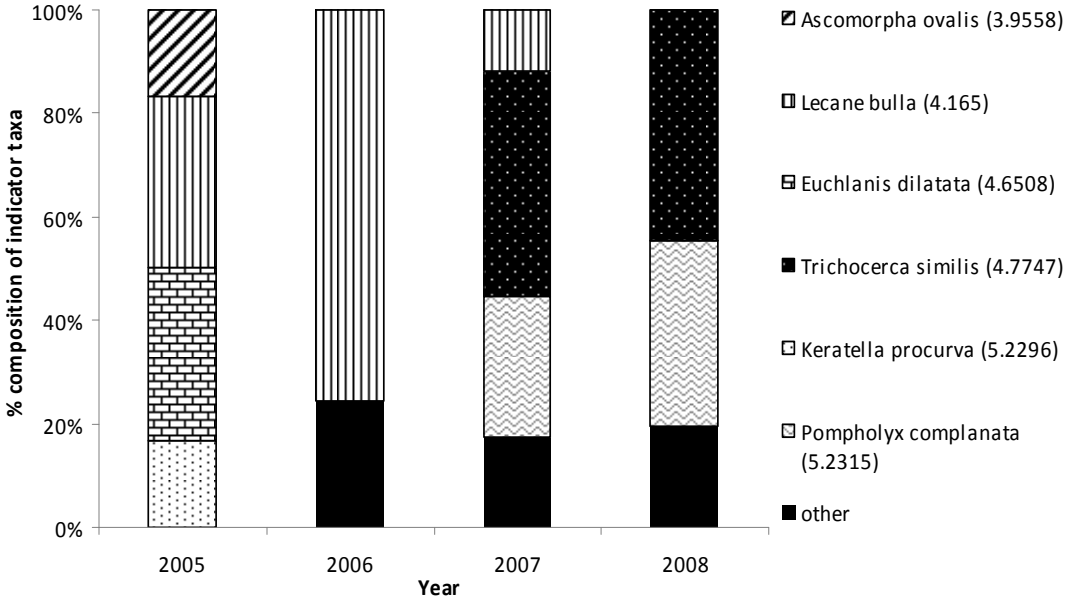
Figure 7.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Kuwakatai. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



4.2.6 Lake Kereta

The variability of inferred trophic state in Lake Kereta over time is reflected in the changes in rotifer species dominance (Figure 8). In 2005 and 2006 Lake Kereta was inferred to be eutrophic, and species with lower TLI optima dominated during this time (e.g., *Lecane bulla*, *Ascomorpha ovalis* and *Euchlanis dilatata*). In 2007 and 2008, an increase in inferred TLI was associated with increases in the proportions of *Trichocerca similis* and *Pompholyx complanata*, species with higher TLI optima than those found to dominate previously.

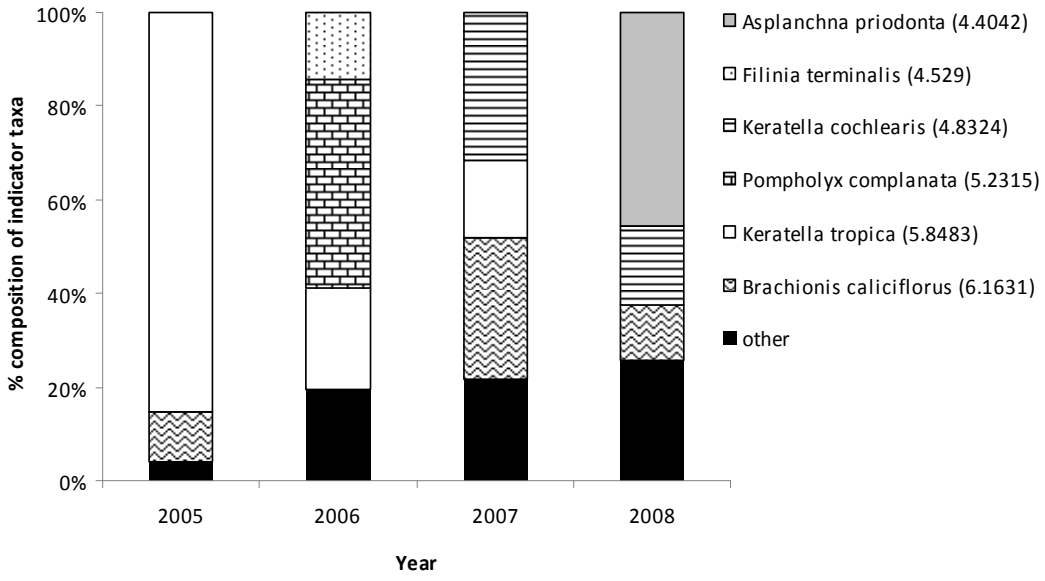
Figure 8.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Kereta. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



4.2.7 Lake Spectacle

The Lake Spectacle rotifer fauna was highly variable throughout the study, reflecting the variability in inferred TLI values (Figure 9). *Brachionus calyciflorus* and *Keratella* species – taxa indicative of eutrophic waters globally - dominated in 2005 and 2007 when TLI was inferred as being at its greatest. *Asplanchna priodonta* dominated samples collected in 2008, when the TLI was inferred to decrease to supertrophic.

Figure 9.
Comparison of percent composition of dominant (comprising > 10% of assemblage in any year) rotifer indicator species from Lake Spectacle. Taxa are ordered from lowest TLI optima (top) to highest TLI optima (bottom).



5 General Conclusions

The rotifer inferred trophic states of the monitored lakes in this study were ranked in a broadly similar manner as they were in the 2001-2004 study (ARC 2005). However, overall it was less easy to give clear rankings of the lakes due to overlapping distributions. However, Lake Ototoa was inferred as the lake with the best water quality (oligotrophic to oligo-mesotrophic), while Lake Spectacle had the poorest (hypertrophic to supertrophic). At the beginning of the study Lake Tomarata had the greatest water quality of the remaining lakes (oligo-mesotrophic), but the water quality was inferred to decline to mesotrophic/eutrophic by the end of the study. Lake Kereta, on the other hand, began as mesotrophic/eutrophic and declined to eutrophic/supertrophic (Appendix 1). Lakes Wainamu, Pupuke and Kuwakatai were assessed as broadly similar throughout the study (all ~mesotrophic/eutrophic), and their inferred trophic states remained relatively stable throughout the study.

Relative to the 2001-2004 study (ARC 2005) the average inferred TLI values appear to be similar. However, of greatest concern must be Lake Tomarata, which had inferred TLI values 1 TLI unit higher by the end of this study than at any time in the previous study. Lake Wainamu may also be slightly worse (~0.5 TLI units) on average than in the previous study, but did end the current study with similar inferred values than in 2001-2004. Lake Spectacle, on the other hand, was inferred to have an improved water quality at the end of the study than at any time since 2002, although this lake has been highly variable throughout. Despite also showing some variability, Lake Kereta was far more stable in this study than in 2001-2004, but may have declined in water quality slightly during this study.

Lake Kawaupaku was inferred to be eutrophic, similar to the majority of the ARC lakes monitored during this study.

Acknowledgements

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Appendix 1

List of ''indicator'' and ''other'' rotifer species recorded during the study. Indicator taxa are ordred based on the TLI optima from lowest to highest. Lakes ordered from approximately lowest to highest TLI (except Lake Kawaupaku).

	TLI optima	Ototoa	Tomarata	Wainamu	Pupuke	Kuwakatai	Kereta	Spectacle	Kawaupaku
Indicator taxa									
Conochilus dossuaruis	3.0989	x							x
Synchaeta longipes	3.3232	x							
Polyarthra dolichoptera	3.4396			x	x		x		
Trichocerca stylata	3.7553		x			x			
Conochilus coenobasis	3.9056		x	x					
Ascomorpha ovalis	3.9558	x	x	x	x	x	x		x
Lecane bulla	4.1650	x		x	x	x	x		x
Testudinella patina	4.3055					x			
Synchaeta oblonga	4.3875			x				x	
Asplanchna priondonta	4.4042	x	x	x	x	x		x	x
Synchaeta pectinata	4.5011		x	x					
Collotheca sp.	4.5186	x		x	x	x	x		
Filinia pejleri	4.5193		x	x				x	
Filinia terminalis	4.5290							x	
Hexarthra mira	4.6060			x					
Euchlanis dilatata	4.6850						x	x	
Asplanchna brightwelli	4.6949				x			x	x
Trichocera similis	4.7747	x	x	x	x	x	x	x	x
Trichocerca longiseta	4.8412				x				
Keratella cochlearis	4.8324		x	x	x	x		x	
Filinia novaezealandiae	4.8392	x							x
Hexarthra intermedia	5.0850	x	x	x			x	x	x
Keratella procurva	5.2296	x	x	x	x	x	x		x
Pompholyx complanata	5.2315		x	x		x	x	x	x
Asplanchna seiboldi	5.6245		x	x					
Keratella tropica	5.8483							x	
Brachionus calyciflorus	6.1631						x	x	
Filinia longiseta	6.3957			x	x		x	x	

	Ototoa	Tomarata	Wainamu	Pupuke	Kuwakatai	Kereta	Spectacle	Kawaupaku
Other rotifers								
Bdelloids	x	x	x	x	x	x	x	x
Brachionus angularis	x					x	x	
Dicranophorus epicharis						x		
Dicranophorus grandis						x		
Euchlanis calpidia						x		
Euchlanis meneta						x		
Euchlanis pyriformis			x					
Lecane luna		x				x		
Lecane lunaris					x	x	x	
Lepidella accuminata						x		
Macrochaetus collinsi						x		
Mytilina ventralis						x		
Platyais quadricornis		x					x	
Proales sp.						x		x
Testudinella mucronata						x		
Trichocerca rattus						x		

Appendix 2

Rotifer inferred TLI values for each of the long-term monitored ARC lakes for the current study and from ARC (2005). Asterisks (*) indicate that insufficient numbers of indicator taxa were collected to calculate TLI; for 2002-2004 data this was considered as <25 indicator taxa (see ARC 2005), while for the 2005-2008 study this indicates no indicator taxa were recorded. Values are bolded for any samples enumerated during the current study (including two older Lake Pupuke samples) where TLI was inferred from <25 indicator taxa. Blank areas indicate that no sample was collected and/or received for that month.

	Ototoa	Tomarata	Wainamu	Pupuke	Kuwakatai	Spectacle	Kereta
Feb-02	2.62	2.72	3.15	4.47	4.27	6.10	4.14
May-02	2.66	2.70	3.29	4.39	4.23	6.24	4.28
Aug-02	2.96	3.04	3.71	4.16	*	6.58	4.44
Mar-03	2.93	3.59	3.91	4.18	4.50	6.92	*
May-03	3.20	3.80		4.20	4.67	7.14	5.10
Sep-03	3.17	3.62		4.29	4.73	7.62	5.17
Nov-03	3.07		3.76				4.36
Feb-04	2.81	3.05		4.27	4.82	7.51	3.95
May-04	2.61	3.07	*	*	*	*	*
Aug-04	*	*	*	*	*	7.38	*
Sep-04				**3.93**			
Oct-04				**4.21**			
Nov-04		2.87	3.63	*		7.23	3.66
Dec-04				4.21			
Jan-05	**2.61**	**2.88**	**4.29**	**4.34**	**4.71**	**7.58**	**3.87**
Mar-05	**2.77**	**3.04**	**4.73**	*	**4.38**	**7.75**	**4.07**
May-05	**2.80**	**3.19**	**4.76**	**4.29**	**4.19**	**7.75**	**3.89**
Aug-05	**2.86**	**3.35**	**4.63**	**4.40**	**4.05**	7.22	**4.17**
Nov-05	**2.85**	3.40	4.19	**4.59**	4.10	7.15	*
Jan-06	2.66	**3.62**	3.75	**4.51**	4.08	**6.35**	3.97
Feb-06	2.48	3.63	3.79	4.31	3.99	6.57	**3.85**
Apr-06	2.51	**3.92**	**3.68**		**4.12**	6.05	*
May-06	2.49	**3.72**	3.32	4.25	4.08	5.91	**3.98**
Sep-06	**2.39**	**3.52**	3.19	4.05	3.86	**5.82**	*
Nov-06	2.45	3.76	3.47	3.88	4.00	5.82	**3.99**
Jan-07				4.12			
Feb-07	**2.83**	3.77	3.69	4.15	4.11	6.17	*
May-07	3.00	3.98	3.97	4.13	4.40	7.41	**5.23**
Aug-07	**2.95**	3.98	4.06	**4.25**	4.34	7.55	**5.04**
Oct-07	2.91	4.22	4.06	4.25	**4.62**	7.22	4.91
Dec-07	2.88	4.15	3.78	4.25	4.36	6.97	4.82
Jan-08	**2.97**	4.12	**3.81**	4.06	**4.29**	6.64	4.82
Feb-08	2.98	4.08	3.76	4.16	*	6.12	4.77
Apr-08	2.95	**3.94**	3.70	4.20	4.24	**5.54**	4.94
May-08	**2.93**	*	*	**4.19**	*	*	*
Aug-08	2.93	3.83	**3.48**	4.15	4.14	5.09	**5.03**

Appendix 3

Rotifer inferred TLI values for Lake Kawaupaku for each sampling date.

Date	Inferred TLI
28/11/2007	5.89
19/12/2007	5.52
09/01/2008	4.84
30/01/2008	3.14
20/02/2008	3.07
12/03/2008	5.11
01/04/2008	4.74
22/04/2008	4.53
14/05/2008	5.26
05/06/2008	4.97
26/06/2008	4.08