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Zooplankton monitoring for TLI and lake health assessment of the Waikato lakes: 2016-2017

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Executive summary

Zooplankton were examined from ten regularly sampled Waikato Regional Council lakes in 2016 and early 2017, to explore trends in rotifer inferred TLI assessments through time, as well as changes in the proportions of native versus non-native zooplankton, and crustacean versus rotifers. Additionally, three data-deficient geothermally influenced lakes were examined less intensively (usually single samples on a single date).

Based on the complete 2016 results, lakes with regular monitoring can be ranked in the following order, from lowest to highest rotifer inferred TLI (RTLI) values; Harihari (2.7; oligotrophic), Serpentine South (3.9; mesotrophic), Areare (4.5), Hakanoa (4.8), Waahi (4.9), Waikare (4.9; all eutrophic), Ruatuna (5.0), Waiwhakareke (5.1), Mangakaware (5.1; all supertophic), and Whangape (6.5; hypertrophic). While most of these results are consistent with monitoring results from previous years, Lake Waahi's assessment was lower than any previous assessments, typically being assessed as supertrophic or hypertrophic.

Lakes Harihari and Serpentine South continued to have consistently low proportions of non-native zooplankton species, likely due to being the most isolated and least accessible lakes in this study. Lakes Areare, Hakanoa and Mangakaware were more greatly affected, commonly with non-native species comprising up to around 20% of their communities. Lake Waahi was the most compromised, with non-native species comprising >70% of the community in 2015, though the proportion of non-native individuals was generally reduced in 2016 and 2017. The combined TLI assessments and proportion of non-native species in Lake Waahi indicated this lake was the most poor with respect to lake health in 2015, but has improved on both metrics over the last year.

Clear-cut patterns in crustacean or rotifer dominance were not evident for most lakes. However, Lake Waahi was heavily crustacean dominated in the current study, primarily due to high proportions of the Australian copepod *Boeckella symmetrica* and North American cladoceran *Daphnia galeata*.

For the one-off samples, from geothermal sites Lakes Rotowhero, Lake Orutu and Whangioterangi (Echo Lake), TLI assessments could not be made due to low numbers of individuals collected, the unusual composition, and lack of indicator species encountered. Lake Orutu was dominated by New Zealand geothermal specialists, the copepod *Paracyclops waiariki* and rotifer *Lecane* cf. *rhytida*. No zooplankton were found in the remaining lakes.

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 likely not possible from a financial perspective. 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.

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 on the Rotifer inferred TLI of Duggan et al. (2001).

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 rotifer inferred TLI assessments for 2016 and early 2017 for the Waikato Regional Council lakes, and compare these to assessments made previously.
2) Examine changes in the proportions of native versus non-native zooplankton species, and crustacean versus rotifers, in 2016 and early 2017 relative to earlier monitoring.
3) Examine the zooplankton of three geothermally influenced lakes, which have limited data.

2 Methods

Zooplankton samples were collected regularly from ten shallow (<15m deep) Waikato Regional Council in 2016 and 2017; Areare, Hakanoa, Harihari, Mangakaware, Ruatuna, Serpentine South, Waahi, Waikare, Waiwhakareke and Whangape. Each lake has had a different history with respect to the timing and intensity of monitoring. For example, Lakes Harihari, Serpentine South and Waahi have been monitored regularly since 2007, while Lake Ruatuna has only been sampled since mid-2015. Additionally, single samples were collected from several geothermal lakes; Lake Rotowhero (15 May 2017), Lake Orutu (16 May 2017) and Whangioterangi (Echo Lake; 25 May 2017). Samples were collected using vertical hauls through the entire water column with a plankton net (40 µm mesh size; 0.2 m diameter; haul speed ~1 $m.s^{-1}$). Samples were immediately preserved using ethanol. 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 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. For calculations of rotifer inferred TLI, data were only used if >100 individuals of indicator taxa were able to be counted. Trends in the proportions of native versus non-native species, and of crustaceans versus rotifers, were also examined for the regularly sampled lakes.

3 Results and discussion

Average rotifer inferred TLI (RTLI) values were calculated for the 2016 results, as well as for the start of 2017. As less than half of the samples for 2017 have been sampled or analysed to date, much change may be seen in the inferred assessments once the full year of samples are collected and analysed, as assessments are preferably made as an average of samples from all seasons (Duggan et al. 2001). As such, I place little confidence in the apparent changes observed in the data for 2017 at this stage. Based on the complete 2016 results, lakes with regular monitoring were ranked in the following order from lowest to highest inferred TLI; Harihari (2.7; oligotrophic), Serpentine South (3.9; mesotrophic), Areare (4.5), Hakanoa (4.8), Waahi (4.9), Waikare (4.9; all eutrophic), Ruatuna (5.0), Waiwhakareke (5.1), Mangakaware (5.1; all supertrophic), and Whangape (6.5; hypertrophic).

In 2016 Lake Areare was assessed using the rotifer inferred TLI (RTLI) as eutrophic (4.5), highly consistent with results since 2010 (Figure 1a & b). Lake Hakanoa was assessed as eutrophic (4.8; 2016) with RTLI, on the boundary of supertrophic, also consistent with the previous four years of sampling. Lake Harihari was assessed as oligo- to mesotrophic in 2016 (2.7); although results have been highly variable for this lake in the past, assessments have been fairly consistent since 2014. Lake Mangakaware was assessed as supertrophic in 2016 (5.1), again consistent with results since 2014. Lake Ruatuna was assessed as eutrophic (5.0); although this assessment is worse that that in 2015, this lake has been monitored for too short a time to determine trends. Lake Serpentine South was assessed as mesotrophic using RTLI in 2016 (3.9), which is fairly consistent with that assessed based on rotifers over the last 10 years. Lake Waahi was assessed as eutrophic in 2016 (4.9), and continued a trend in improving water quality through time; again, little confidence can be placed on the high 2017 assessment for Lake Waahi at this point, as it is based on a small number of samples. Lake Waikare was assessed as eutrophic (4.9), consistent with past assessments, with some evidence of a slight improvement through time. Lake Whangape was assessed as hypertrophic (6.5), the worst of the lakes in the dataset, in common with all previous assessments except 2014, when it was assessed as supertrophic (Figure 1b). For Lake Waiwhakareke, the inferred RTLI was 5.0, on the eutrophic-supertrophic boundary, consistent with assessments in 2014 and 2015.

For the geothermally influenced lakes sampled, no species were found in the Lake Rotowhero or Whangioterangi samples. In Lake Orutu, a number of individuals of the copepod *Paracyclops waiariki* and rotifer *Lecane* cf. *rhytida* were recorded, as well as some unidentifiable bdelloid rotifers and a single individual of a *Cephalodella* species. The dominant species identified in Lake Orutu were similar to that found in geothermally influenced lakes of the central North Island previously (Duggan & Boothroyd 2002). For example, *Lecane* cf. *rhytida* has been recorded from Lake Rotowhero previously by James (1995) and Duggan & Boothroyd (2002), while *P. waiariki* was described from Lake Rotowhero (Lewis 1974), and has been recorded at several other sites within the Waiotapu geothermal field (Duggan & Boothroyd 2002). Sampling of Lake Rotowhero by the author at various times over a number of years have shown that abundances of species in the lake are typically extremely low, and variable. As such, it may be unsurprising that no individuals were recorded here on this particular occasion.

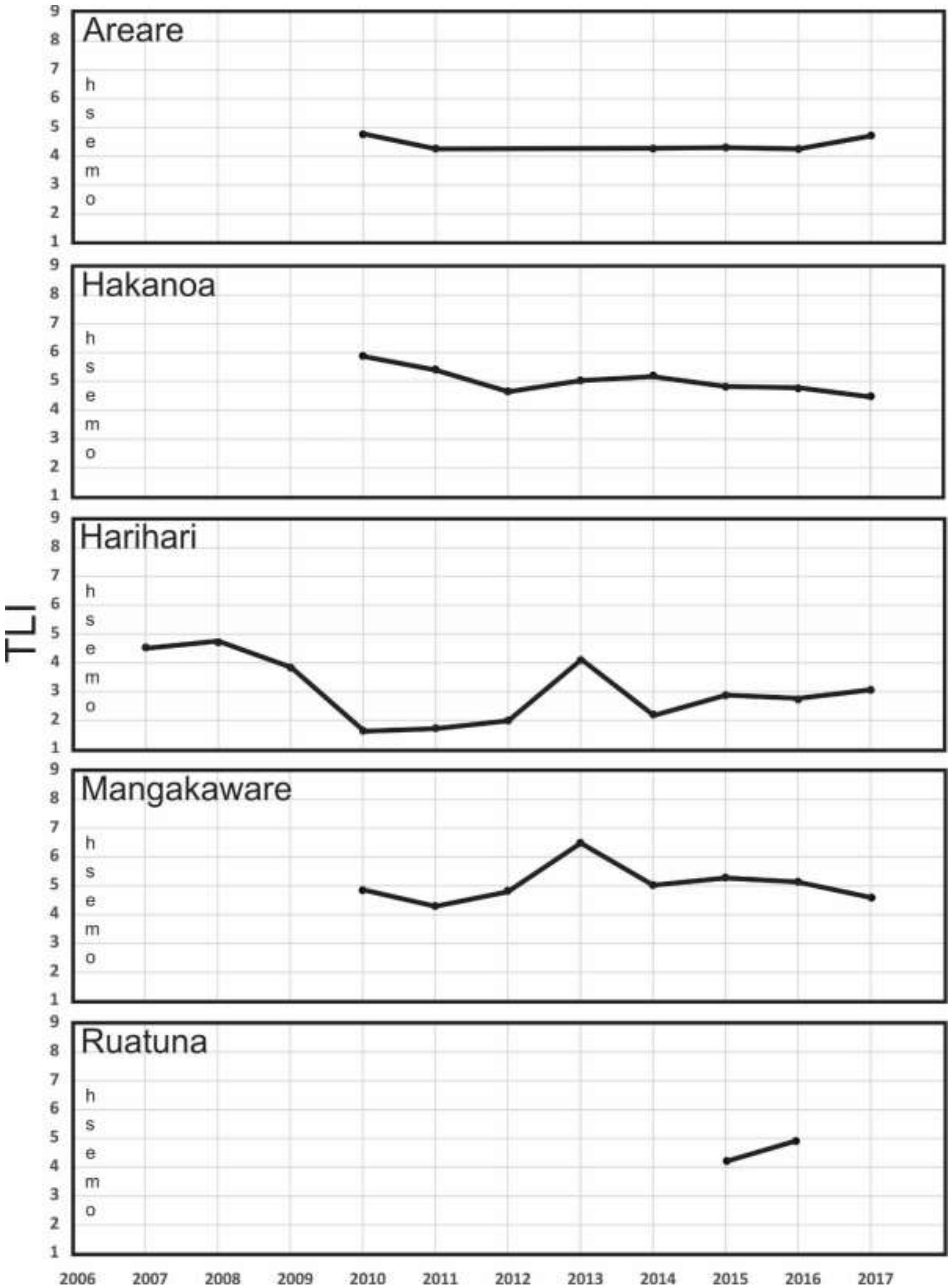

Figure 1a. Long-term trends in rotifer inferred TLI (RTLI) values from Waikato Regional Council lakes between 2007 and 2017. h = hypertrophic, s = supertrophic, e = eutrophic, m = mesotrophic, o = oligotrophic.

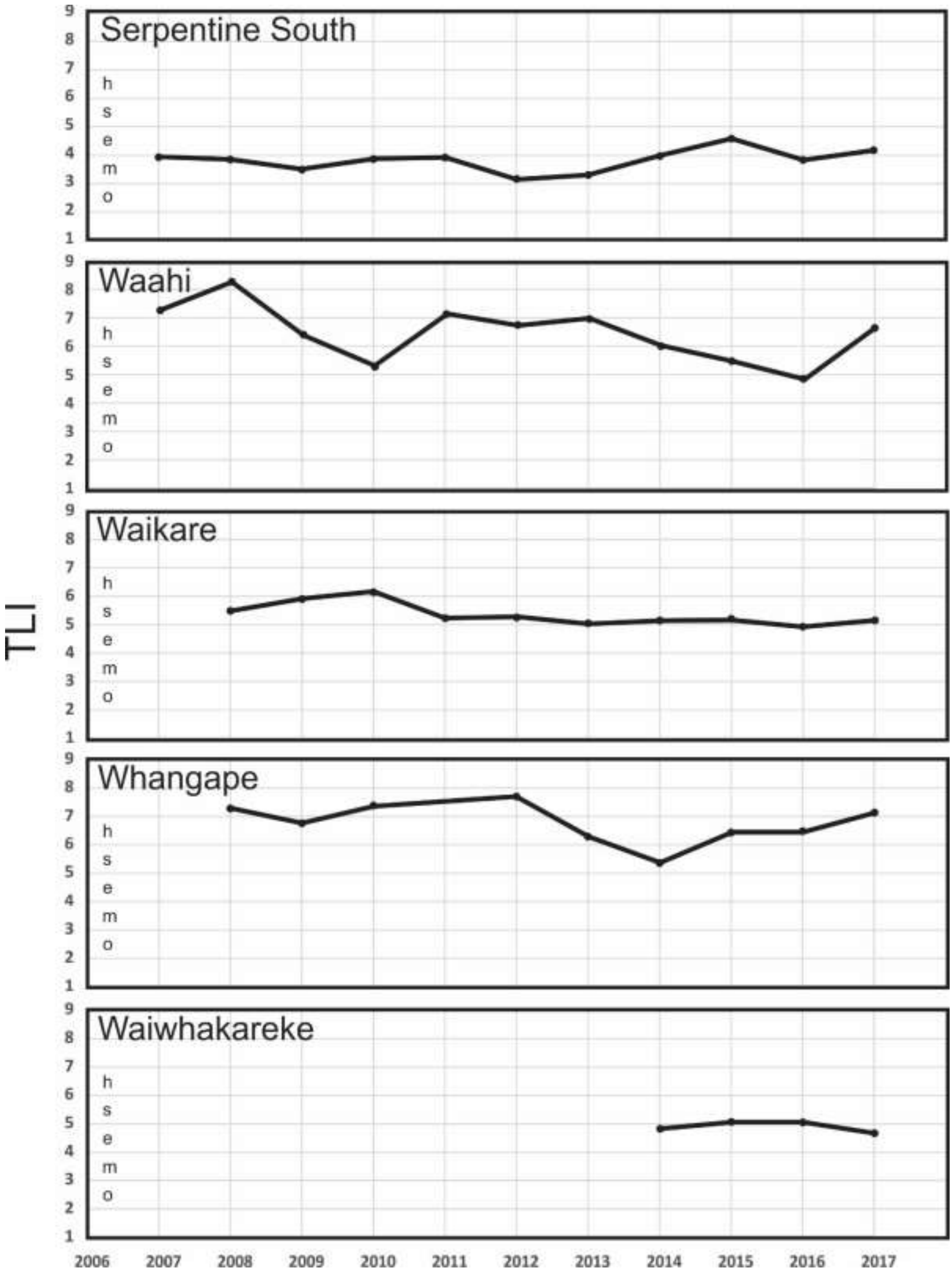

Figure 1b. Long-term trends in rotifer inferred TLI (RTLI) values from Waikato Regional Council lakes between 2007 and 2017. For Lake Waahi in 2014, RTLI was calculated from two samples with rotifer numbers between 50 and 100, as none of the six samples met the >100 individuals requirement. h = hypertrophic, s = supertrophic, e = eutrophic, m = mesotrophic, o = oligotrophic.

3.1 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. Lakes Harihari and Serpentine South were least affected by non-native zooplankton species, with only very small proportions found at any time (Figure 2a and b). These lakes are among the most isolated and least accessible lakes in this study, indicating such species may have fewer opportunities to establish new populations. Lakes Waikare and Whangape typically had low proportions of non-native species (<10%), although each had short-term peaks where non-native species comprised >20% of the community. Although there are apparently greater opportunities for establishment of non-indigenous species in these lakes, the poor water quality (and associated unsuitability of food items; e.g., cyanobacteria), may keep the relative abundances of these species low here. Lakes Areare, Hakanoa and Mangakaware commonly had non-native species comprising up to around 20% of their communities, while Lakes Waiwhakareke (up to 40%) and Ruatuna (up to 60%) had greater proportions. Overall, Lake Waahi was the most compromised, with non-native species commonly comprising >20% of the community since the beginning of the study. Between late 2014 and late-2015, samples all comprised >70% non-native species. Nevertheless, three of the four samples collected in 2016-2017 comprised 70% native species. The dominant non-native species' in this lake were the Australian calanoid copepod *Boeckella symmetrica* and North American cladoceran *Daphnia galeata*; the importance (at least in terms of numerical abundance) of *B. symmetrica*, in particular, has been reduced in recent samples, suggesting this species may have gone through a boom-and-bust cycle following invasion of the lake, which is commonly observed in such situations. For example, this pattern is similar to that seen for the North American *Skistodiaptomus pallidus* in Lake Kereta, Auckland (Duggan et al. 2014). The combined TLI assessments and proportion of non-native species in Lake Waahi indicates this lake has improved with respect to lake health since 2015, albeit may still be regarded as moderately impaired.

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 of the Waikato lowland lakes, 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 work is required to determine these broader ecosystem-level effects.

3.2 Proportions of crustacean versus rotifer species abundances

Clear-cut trends in crustacean and rotifer dominance were not evident across all lakes (Figure 3a & b). For example, whether a lake was dominated by rotifers or crustaceans (i.e., copepods and cladocerans) was highly variable in Lakes Areare, Hakanoa, Harihari, Mangakaware, Ruatuna and Serpentine South through time. Lake Whangape was the most consistent, with rotifers typically dominating community composition, although on two occasions became crustacean dominated during the current study period. Lake Waahi showed similar trends, being generally rotifer dominated until late 2013, after which time crustaceans greatly dominated, including all but one of the most recent samples; this was largely due to the recent invasion of the Australian copepod *Boeckella symmetrica* into the lake. On the other hand, all nine samples collected from Lake Waiwhakareke to date have been crustacean dominated, indicating that the influence of planktiviorous fish on zooplankton may not be strong in this lake.

Despite shifts between crustacean and rotifer dominance being fairly clear in response to the addition or removal of stressors in some studies (e.g., Duggan et al. 2014; Duggan et al. 2015), dominance was in general highly variable in the current study. However, with long-term monitoring and with shifts in fish composition (such as through new introductions or removals), dominance is likely to shift to new, more obvious equilibria.

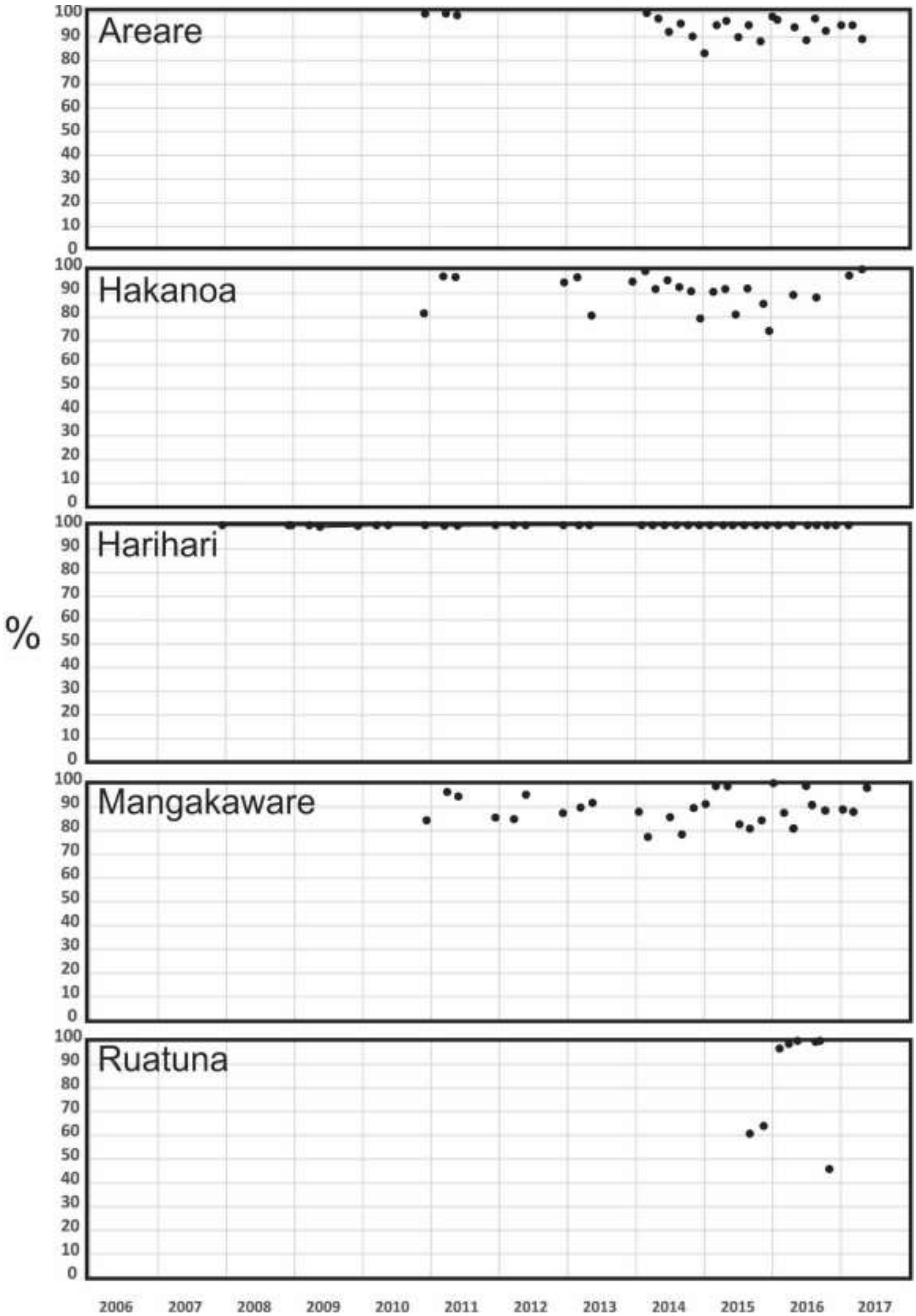

Figure 2a. Long-term trends in the proportion of native zooplankton abundances relative to non-native species in Waikato Regional Council lakes between 2007 and 2017.

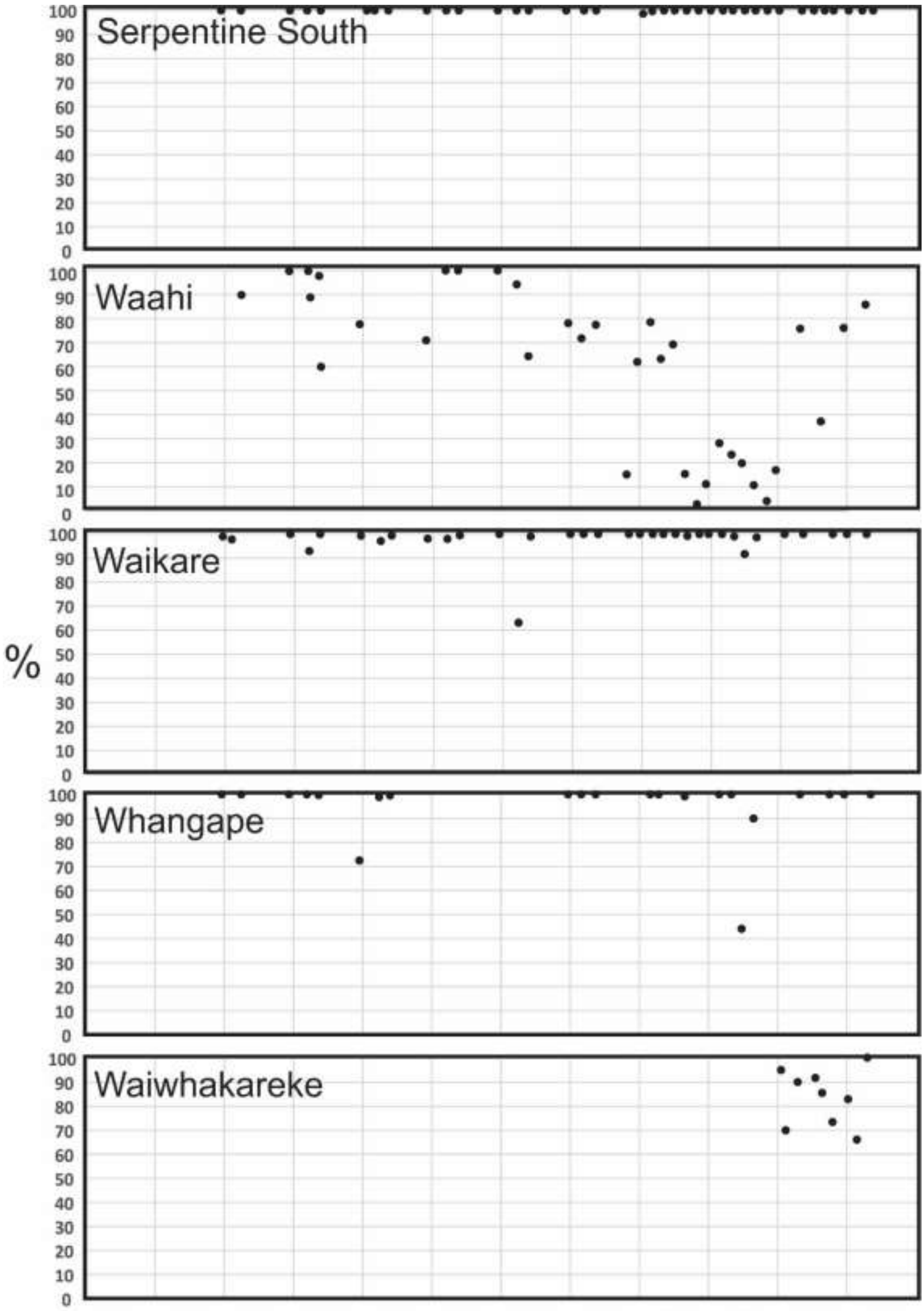

Figure 2b. Long-term trends in the proportion of native zooplankton abundances relative to non-native species in Waikato Regional Council lakes between 2007 and 2017.

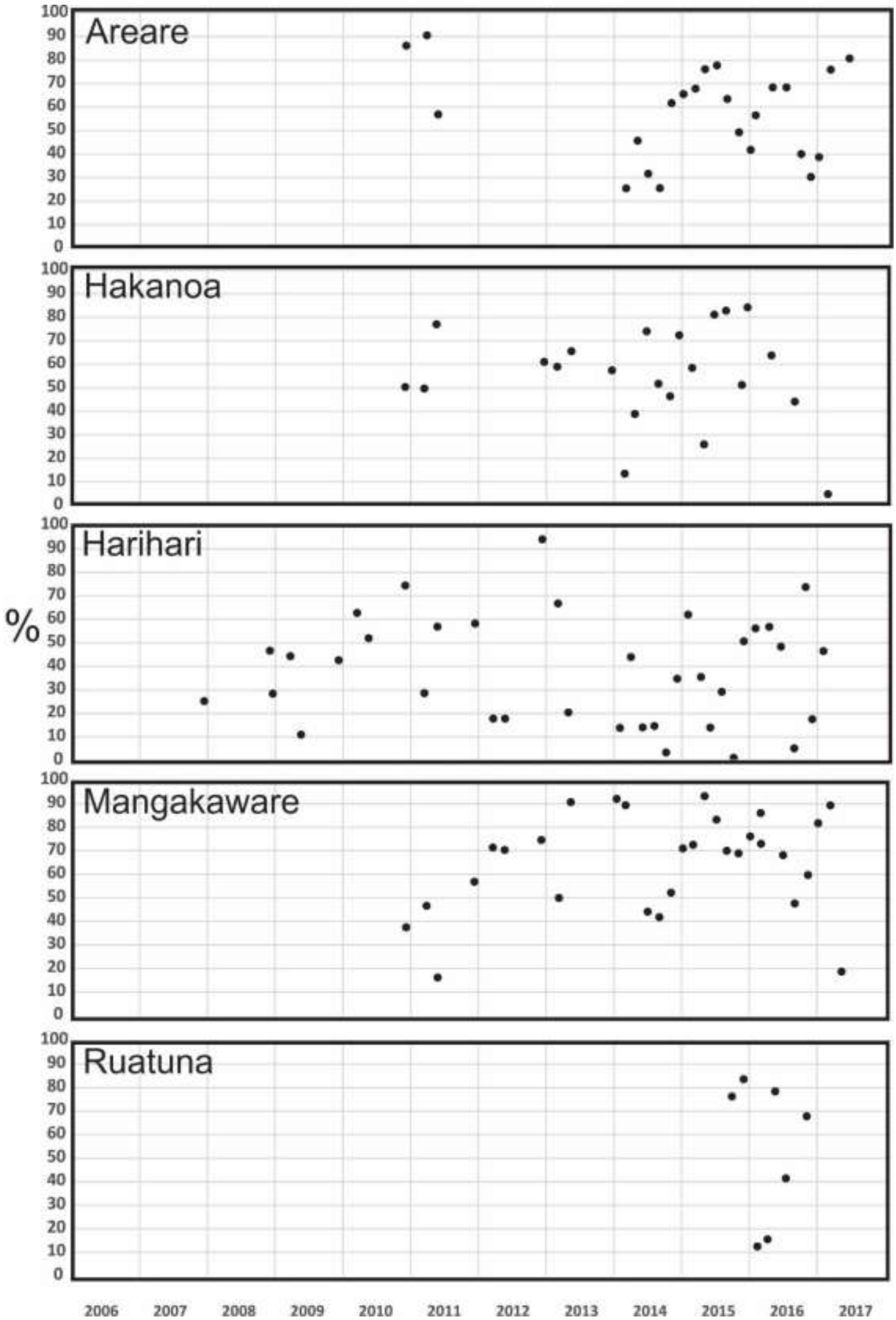

Figure 3a. Long-term trends in the proportion of crustacean zooplankton abundances relative to rotifers in Waikato Regional Council lakes between 2007 and 2017.

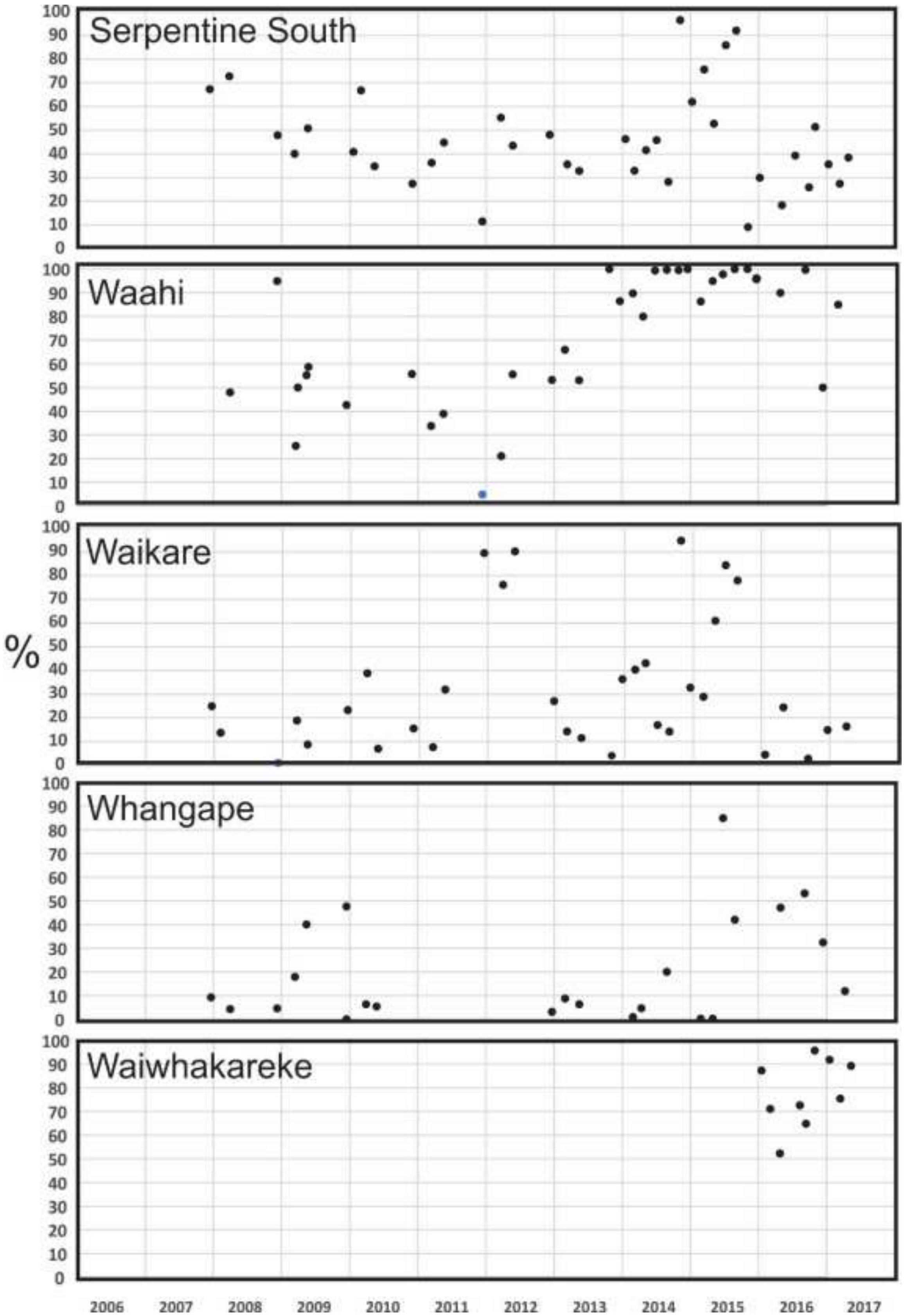

Figure 3b. Long-term trends in the proportion of crustacean zooplankton abundances relative to rotifers in Waikato Regional Council lakes between 2007 and 2017.

References

Balvert SF, Duggan IC, Hogg ID 2009. Zooplankton seasonal dynamics in a recently filled mine pit lake: the effect of non-indigenous Daphnia establishment. Aquatic Ecology 43: 403–413.

Burns NM, Rutherford JC, Clayton JC 1999. A monitoring and classification system for New Zealand lakes and reservoirs. Journal of Lake and Reservoir Management 15: 255-271.

Duggan IC, Boothroyd I 2002. The distribution of biota from some geothermally influenced standing waters in the Taupo Volcanic Zone. NIWA Client Report EVW02226.

Duggan IC, Green JD, Burger DF 2006. First New Zealand records of three non-indigenous zooplankton species: *Skistodiaptomus pallidus*, *Sinodiaptomus valkanovi* and *Daphnia dentifera*. New Zealand Journal of Marine and Freshwater Research 40: 561-569.

Duggan IC, Green, JD, Shiel RJ 2001. Distribution of rotifers in North Island, New Zealand, and their potential use as bioindicators of lake trophic state. Hydrobiologia 446/447: 155-164.

Duggan IC, Green JD, Shiel RJ 2002. Distribution of rotifer assemblages in North Island, New Zealand, lakes: relationships to environmental and historical factors. Freshwater Biology 47: 195-206.

Duggan IC, Neale MW, Robinson KV, Verburg P, Watson NTN 2014. *Skistodiaptomus pallidus* (Copepoda: Diaptomidae) establishment in New Zealand natural lakes, and its effects on zooplankton community composition. Aquatic Invasions 9: 195-202.

Duggan IC, Robinson KV, Burns CW, Banks JC, Hogg, ID 2012. Identifying invertebrate invasions using morphological and molecular analyses: North American *Daphnia 'pulex'* in New Zealand fresh waters. Aquatic Invasions 7: 585-590.

Duggan IC, Wood SA, West DW 2015. Brown trout (*Salmo trutta*) removal by rotenone alters zooplankton and phytoplankton community composition in a shallow mesotrophic reservoir. New Zealand Journal of Marine and Freshwater Research 49: 356-365.

Ejsmont-Karabin J 2012. The usefulness of zooplankton as lake ecosystem indicators: rotifer trophic state index. Polish Journal of Ecology 60: 339–350

Haberman J, Haldna M 2014. Indices of zooplankton community as valuable tools in assessing the trophic state and water quality of eutrophic lakes: long term study of Lake Võrtsjärv. Journal of Limnology 73: 263-273.

James MR 1995. A comparison of microzooplankton in aquatic foodwebs with special emphasis on ciliates. Unpublished PhD thesis. The University of Otago. 234pp.

Lewis ML 1974. *Paracyclops waiariki* n. sp. (Copepoda: Cyclopoida) from thermal waters in Rotorua. New Zealand Journal of Marine and Freshwater Research 8: 275-281.

May L, Spears BM, Dudley BJ, Gunn ADM 2014. The response of the rotifer community in Loch Leven, UK, to changes associated with a 60% reduction in phosphorus inputs from the catchment. International Review of Hydrobiology 99: 65-71.