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Zooplankton monitoring for TLI and lake health assessment of the Waikato lakes: 2015-2016

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Table of contents

Executive summary

Zooplankton were examined from nine regularly sampled Waikato Regional Council lakes in 2015 and early 2016, 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, seven lakes were examined less intensively (usually single samples) from lakes less frequently, or not previously, sampled.

Based on the complete 2015 results, lakes with regular monitoring can be ranked in the following order from lowest to highest rotifer inferred TLI (RTLI) values; Harihari (2.9; oligotrophic), Areare (4.3), Serpentine South (4.6), Hakanoa (4.8; all eutrophic), Waiwhakareke (5.0), Waikare (5.2), Mangakaware (5.3), Waahi (5.6; all supertophic) and Whangape (6.4; hypertrophic). While most of these results are consistent with monitoring results from previous years, Lake Serpentine South's eutrophic assessment was higher than any previous assessments, typically being on the mesotrophic boundary between 2010 and 2012. Despite Lake Waahi being assessed as supertrophic, the inferred TLI values for this lake appear to be improving through time.

For lakes that are less regularly monitored, Lake Ruatuna had an average RTLI of 4.9 (eutrophic) across 4 samples collected in late 2015 and early 2016. For the one-off samples, Lake Puketi was assessed as mesotrophic (3.1), Ngapouri (4.1) and Rotoiti (4.5) as eutrophic, Parkinsons (5.2) and Ngahewa (5.6) as supertrophic, and Lake Serpentine North (6.2) as hypertrophic.

Lakes Harihari and Serpentine South had 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 among the most affected, commonly with non-native species comprising up to around 20% of their communities. Lake Waahi is the most compromised, with non-native species comprising >70% of the community in 2015. The combined TLI assessments and proportion of non-native species in Lake Waahi indicate this lake is the most poor with respect to lake health.

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 propotions of the Australian copepod *Boeckella symmetrica* and North American cladoceran *Daphnia galeata*.

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, invasions of zooplankton are increasing in importance, with a number of non-native cladocerans and copepods increasing in number and distribution over the last 20 years (e.g., Duggan et al. 2006; Duggan et al. 2012; Duggan et al. 2014), and can commonly dominate the invaded communities (Balvert et al. 2009; Duggan et al. 2014). 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 large crustacean to small rotifer dominance (Duggan et al. 2015).

This report aims to:

1. Examine rotifer inferred TLI assessments for 2015 and early 2016 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 2015 and early 2016 relative to earlier monitoring.

Methods

Zooplankton samples were collected regularly from nine shallow (<15m deep) Waikato Regional Council in 2015 and 2016; Areare, Hakanoa, Harihari, Mangakaware, 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 Waiwakareke has only been sampled since 2014. Additionally, four samples were collected from Lake Ruatuna, and single samples were collected from Lakes Ngahewa, Ngapouri, Parkinsons, Puketi, Rotoiti and Serpentine North. 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. As rotifers are the zooplankton group most useful for water quality monitoring, samples were enumerated where possible until a total of at least 100 individuals of rotifer 'indicator species' were recorded; 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.

Results and Discussion

Average rotifer inferred TLI (RTLI) values were calculated for the 2015 results, as well as for the first half of 2016. As only half of the samples for 2016 have been analysed to date, some change may be seen in this data once the full year of samples are collected and analysed, as assessments are preferably made from samples from all seasons (Duggan et al. 2001). Based on the complete 2015 results, lakes with regular monitoring were ranked in the following order from lowest to highest inferred TLI; Harihari (2.9; oligotrophic), Areare (4.3), Serpentine South (4.6), Hakanoa (4.8; all eutrophic), Waiwhakareke (5.0), Waikare (5.2), Mangakaware (5.3), Waahi (5.6; all supertophic) and Whangape (6.4; hypertrophic).

In 2015 and 2016 Lake Areare was assessed using the rotifer inferred TLI (RTLI) as eutrophic (4.3 and 4.7), consistent with results from 2010, 2011 and 2014 (Figure 1a & b). Lake Hakanoa was assessed as eutrophic (4.8; 2015) to supertrophic (5.3; 2016) with RTLI, also consistent with the previous three years of sampling. Lake Harihari was assessed as oligo- to mesotrophic in 2015 (2.9), and eutrophic to date in 2016 (4.5); these results are highly variable, but consistent with previous changeable assessments for this lake, which have ranged from oligotrophic to eutrophic since 2007. Nevertheless, the 2016 results are not yet complete. Lake Mangakaware was assessed as supertrophic in 2015 (5.3) and 2016 (5.9), both of which are higher than the eutrophic assessments made in 2010, 2011 and 2012, indicating a possible decline in water quality in this lake; however, these are lower than the 2013 assessment of supertrophic. Lake Serpentine South was assessed as eutrophic using RTLI in 2015 (4.6) and 2016 (4.4), which are both higher than any previous assessments, being on the mesotrophic boundary between 2010 and 2012. Lake Waahi was assessed as supertrophic in 2015 (5.6), and despite being high appears to be generally improving through time. Lake Waikare was assessed as supertrophic (5.2 and 5.9), consistent with past assessments. Lake Whangape was assessed as hypertrophic (6.4 and 7.4), in common with all previous assessments except 2014, when it was assessed as supertrophic (Figure 1). For Lake Waiwhakareke, the inferred RTLI was 5.0 and 5.1, on the eutrophic-supertrophic boundary, consistent with the only previous assessment in 2014 (not figured).

For the remaining lakes, Lake Ruatuna had an average RTLI assessment of eutrophic (4.9) across the four samples. For the one-off samples, Lake Puketi was assessed as mesotrophic (3.1), Ngapouri (4.1), and Rotoiti (4.5) as eutrophic, Parkinsons (5.2) and Ngahewa (5.6) as supertrophic, and Lake Serpentine North (6.2) as hypertrophic.

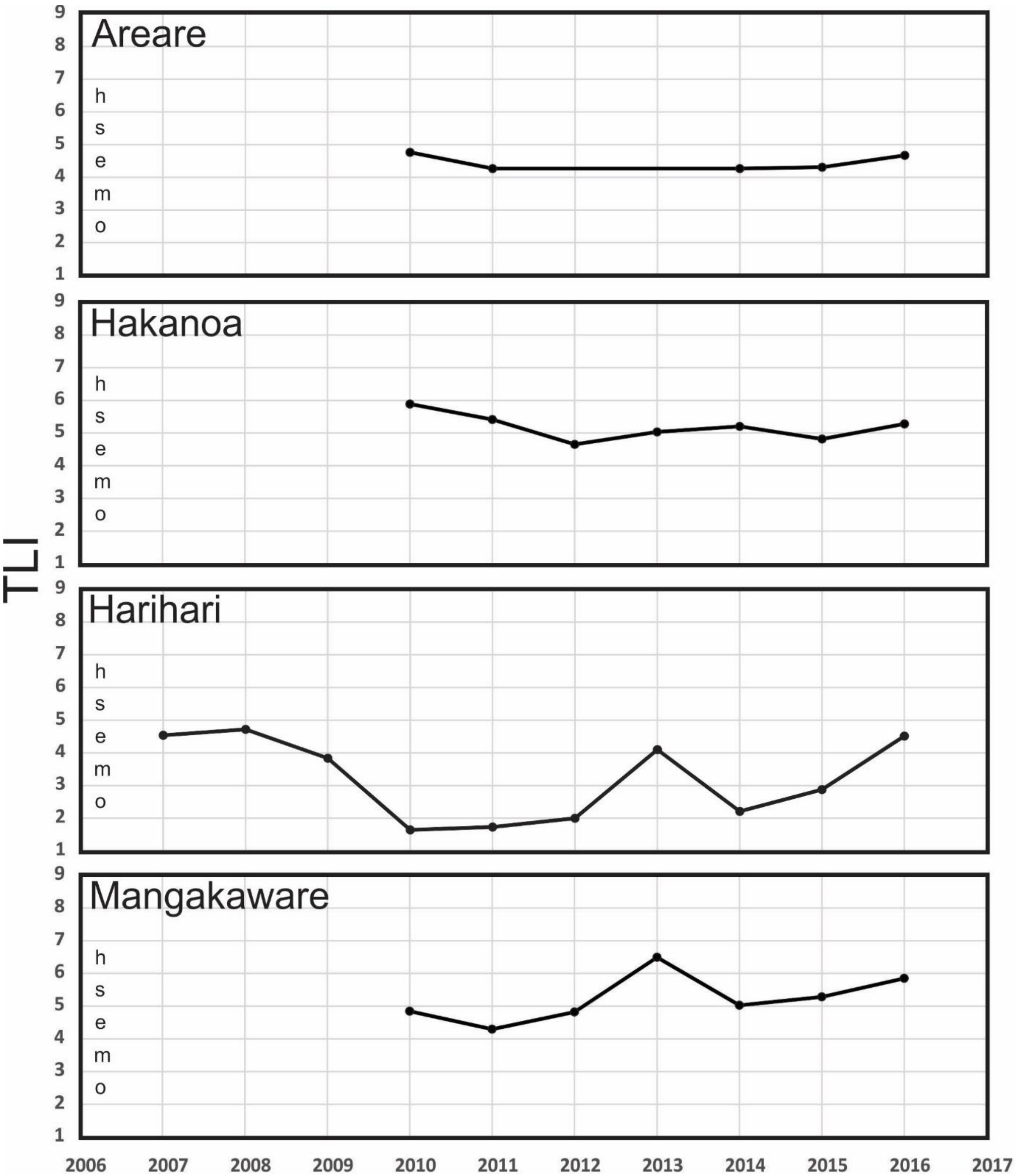

Figure 1a. **Long-term trends in rotifer inferred TLI (RTLI) values from Waikato Regional Council lakes between 2007 and 2016. h = hypertrophic, s = supertrophic, e = eutrophic, m = mesotrophic, o = oligotrophic.**

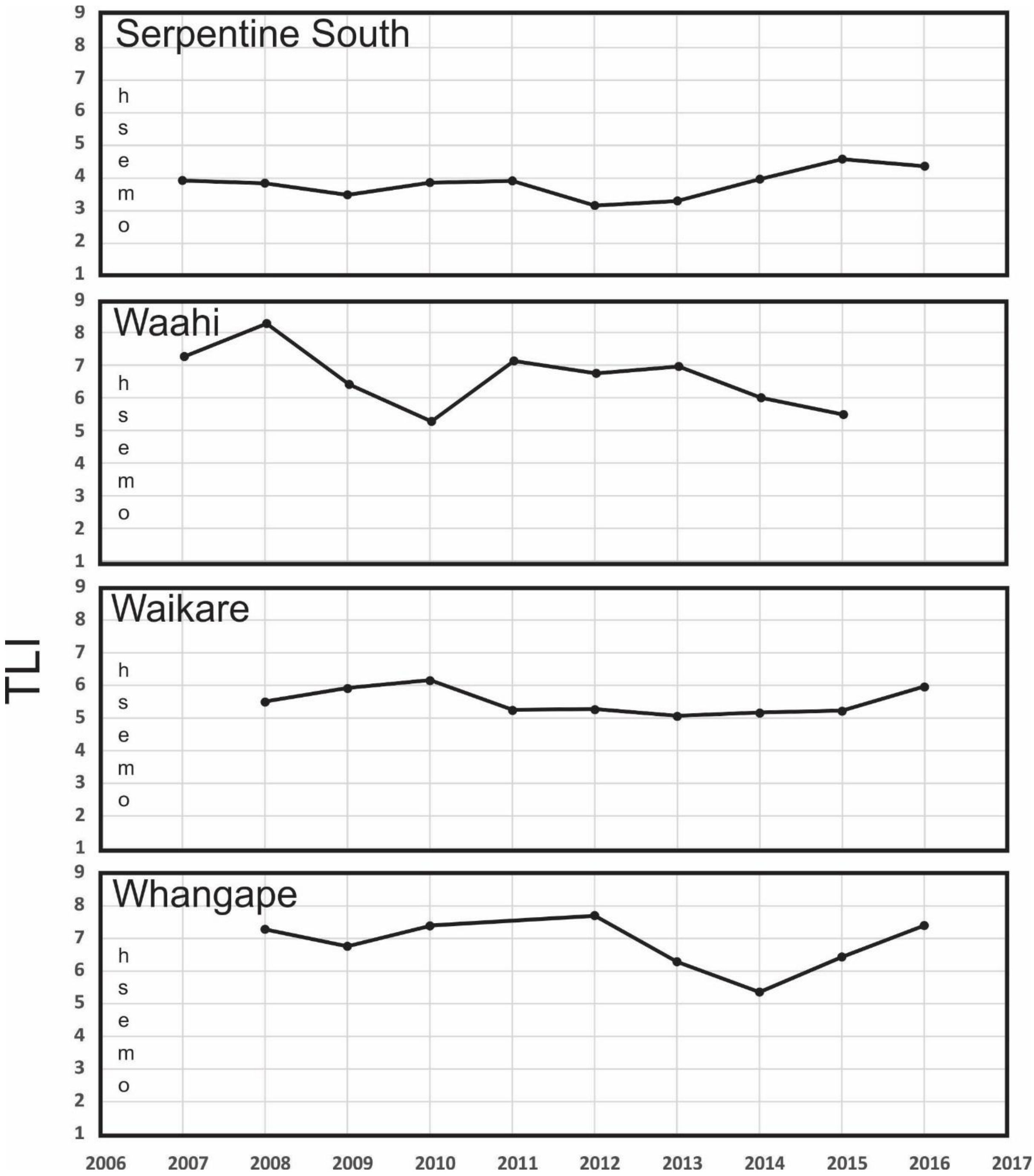

Figure 1b. **Long-term trends in rotifer inferred TLI (RTLI) values from Waikato Regional Council lakes between 2007 and 2016. For Lake Waahi in 2014 was calculated from two samples with rotifer numbers between 50 and 100, as none of the six samples met the >100 individuals requirement. h = hypertrophic, s = supertrophic, e = eutrophic, m = mesotrophic, o = oligotrophic.**

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. Combined with TLI assessments, these lakes can be deemed as the healthiest of lakes among the dataset. 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. Lakes Areare, Hakanoa and Mangakaware commonly had non-native species comprising up to around 20% of their communities. Overall, Lake Waahi was the most compromised, with non-native species having commonly comprised >20% of the community since the beginning of the study. Since late 2014, samples have all comprised >70% non-native species, except for the final sample collected in 2016, which was greater than 70% native. The dominant non-native species' in this lake were the Australian calanoid copepod *Boeckella symmetrica* and North American cladoceran *Daphnia galeata*. The combined TLI assessments and proportion of non-native species in Lake Waahi indicate this lake is the most poor with respect to lake health.

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. Further work is required to determine these broader ecosystem-level effects.

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 and Serpentine South through time. Lake Whangape was the most consistent, with rotifers typically dominating community composition, although on one occasion became crustacean dominated in the current study period. The same was true for Lake Waahi until late 2013, after which time crustaceans greatly dominated, including in the most recent samples; this was largely due to the recent invasion of the Australian copepod *Boeckella symmetrica* into the 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.

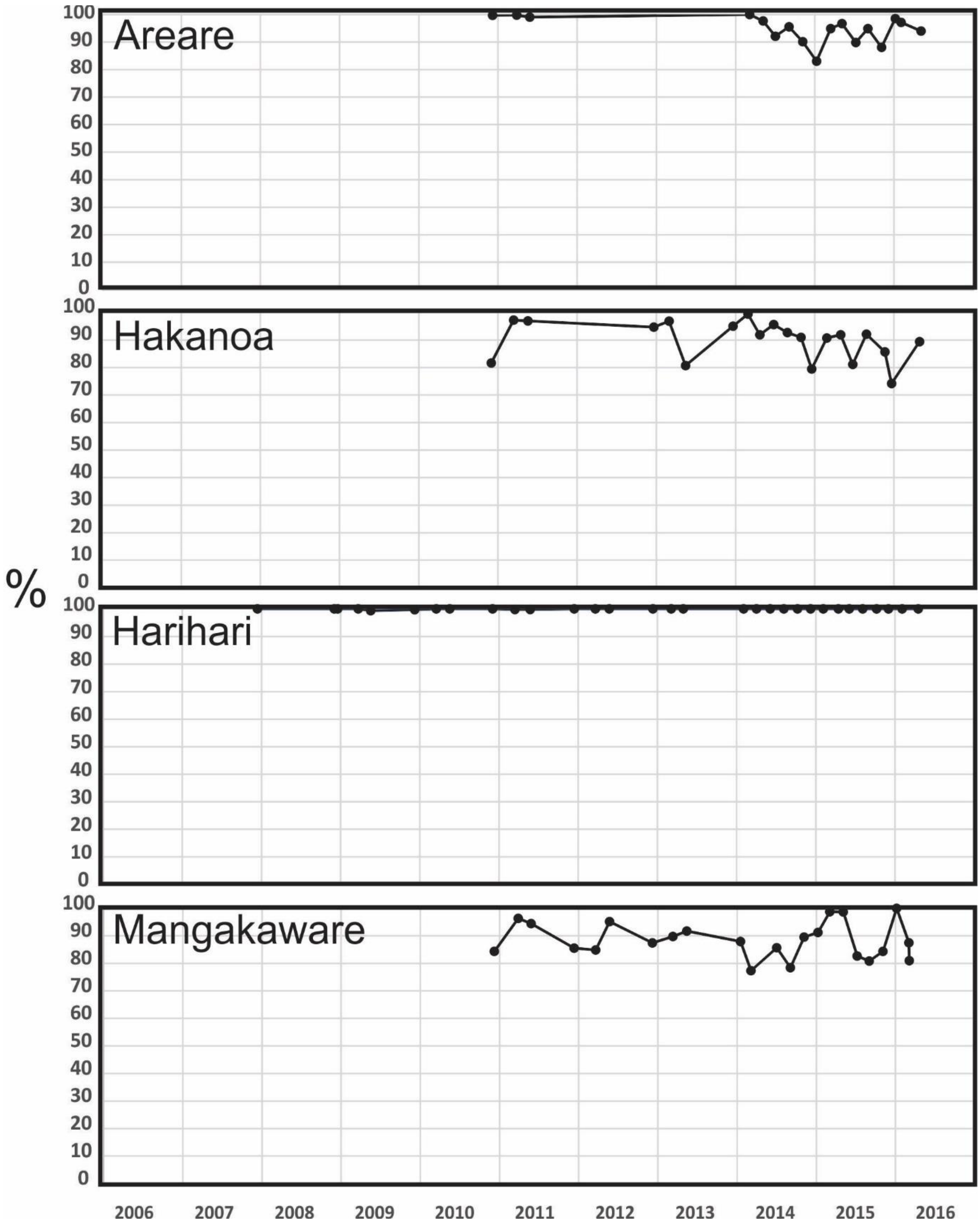

Figure 2a. **Long-term trends in the proportion of native zooplankton abundances relative to non-native species in Waikato Regional Council lakes between 2007 and 2016.**

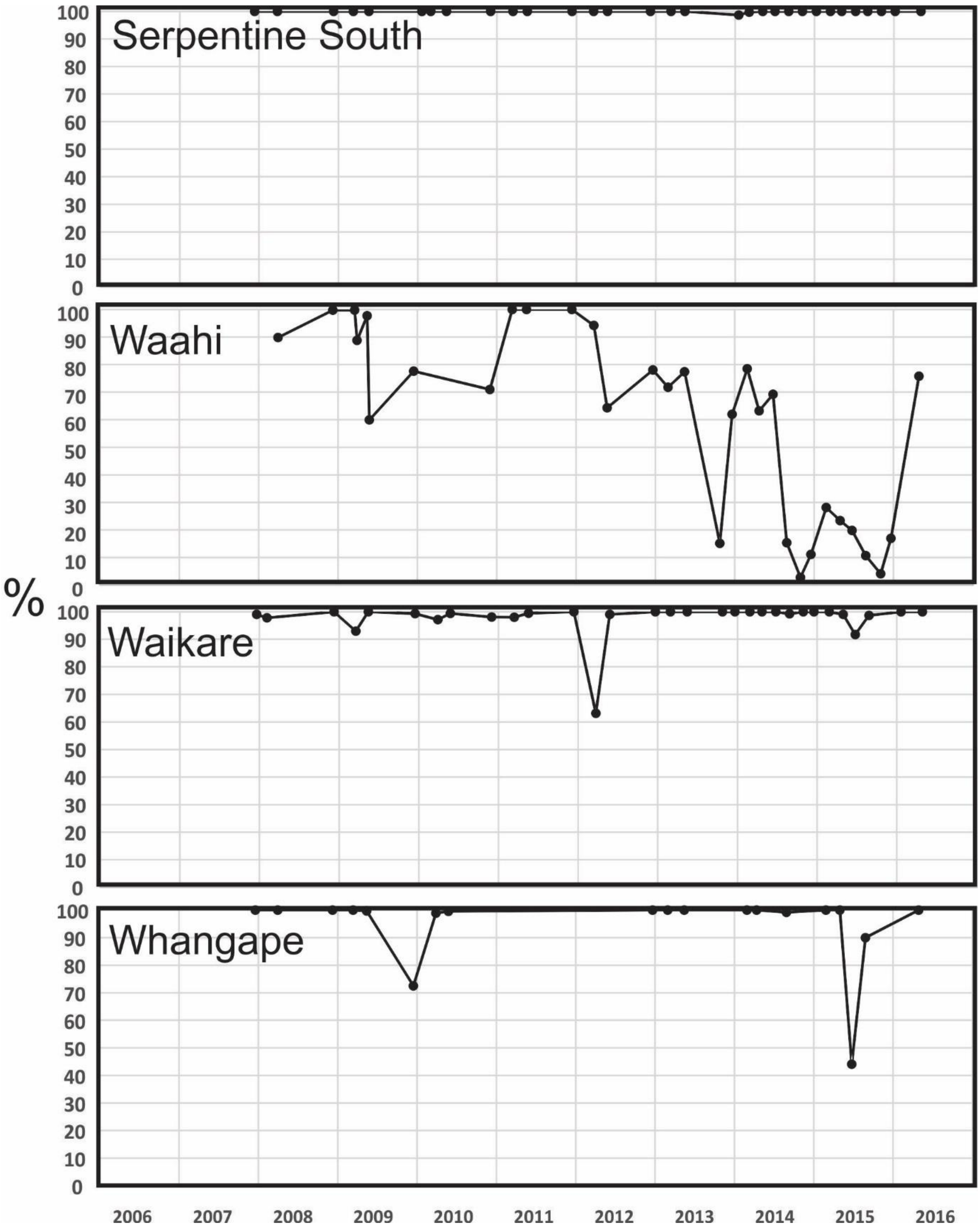

Figure 2b. **Long-term trends in the proportion of native zooplankton abundances relative to non-native species in Waikato Regional Council lakes between 2007 and 2016.**

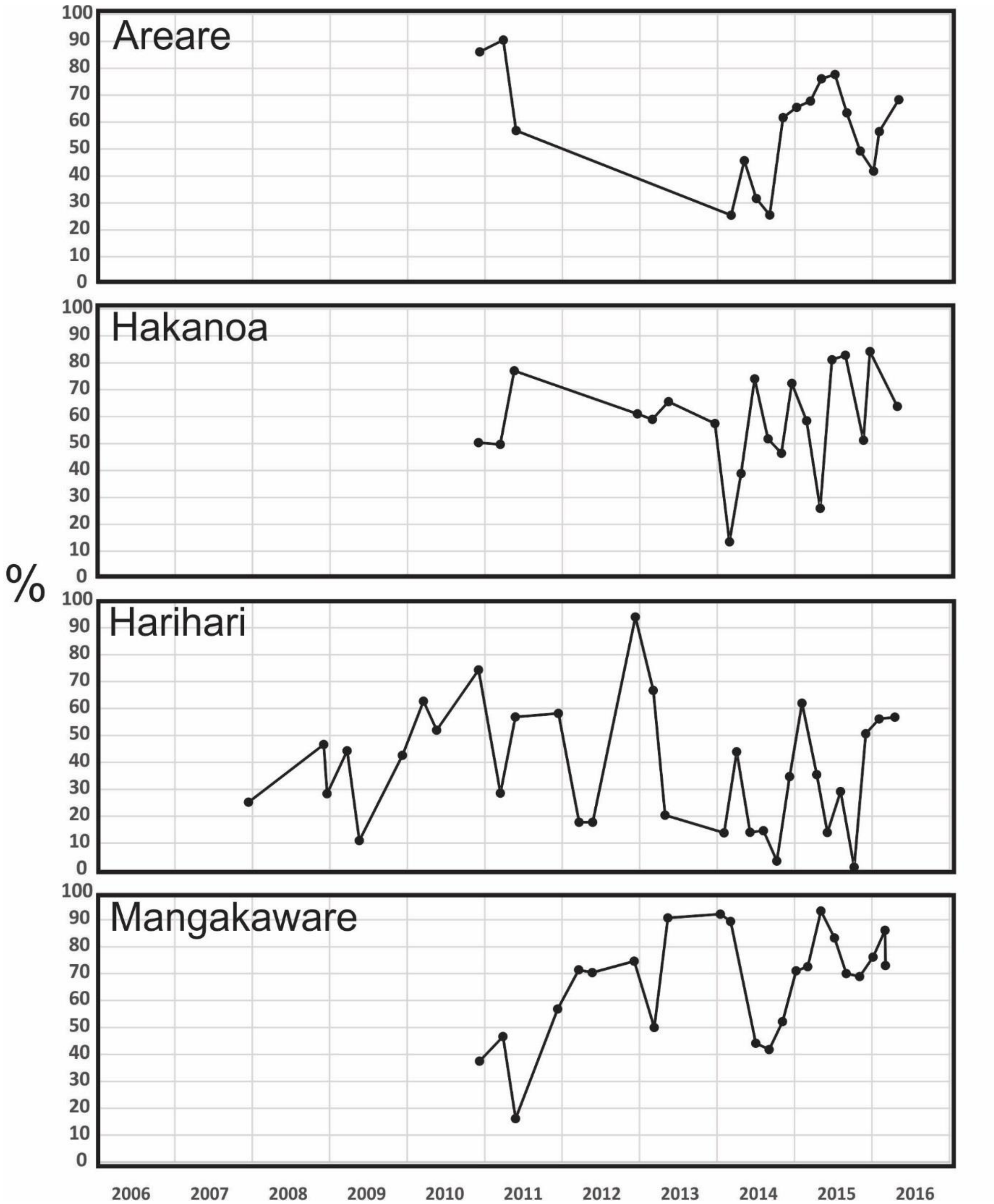

Figure 3a. **Long-term trends in the proportion of crustacean zooplankton abundances relative to rotifers in Waikato Regional Council lakes between 2007 and 2016.**

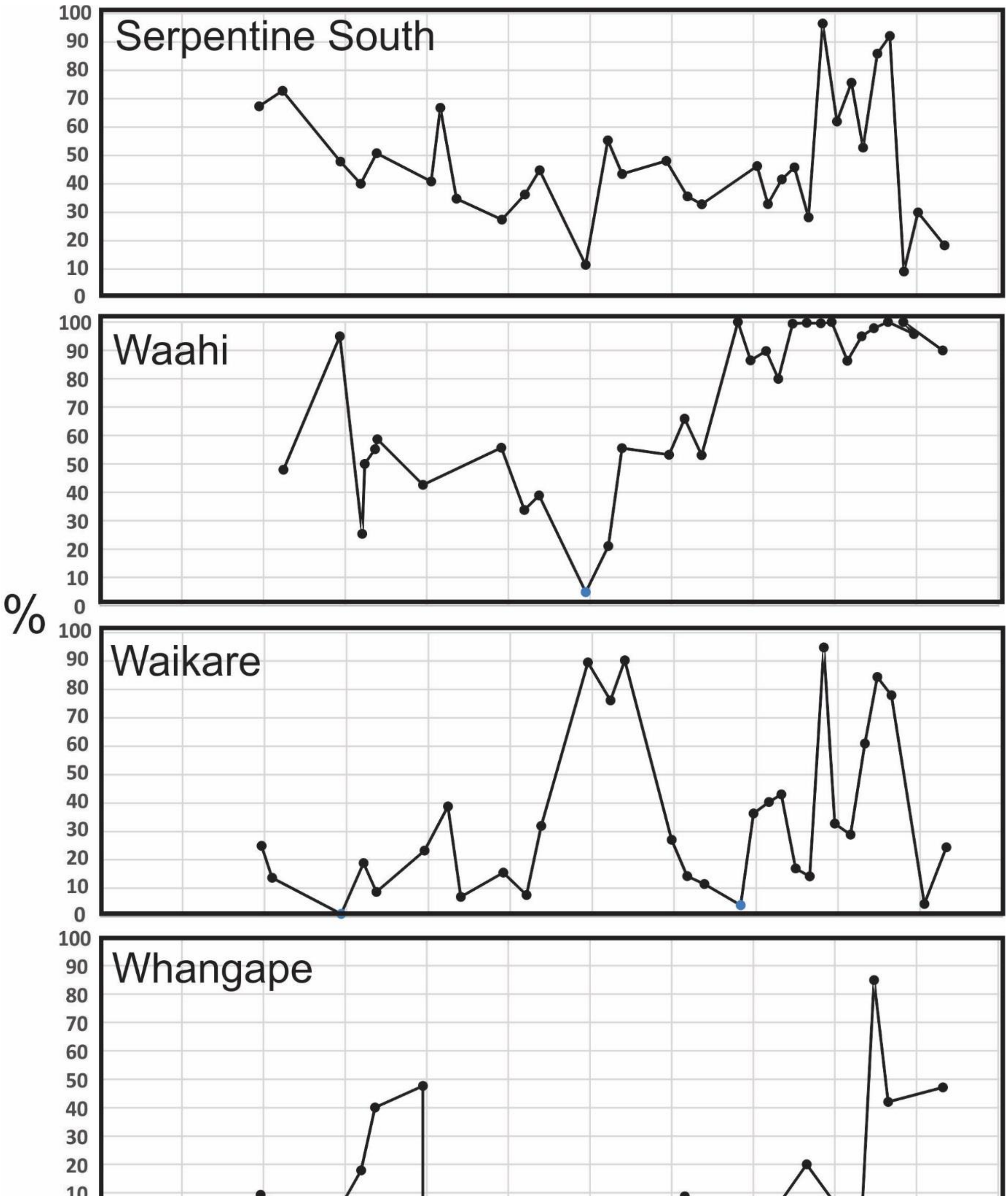

Figure 3b. **Long-term trends in the proportion of crustacean zooplankton abundances relative to rotifers in Waikato Regional Council lakes between 2007 and 2016.**

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