Abundance of mysid shrimp (*Tenagomysis chiltoni*) in shallow lakes in the Waikato region and implications for fish diet.

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Executive summary

Tenagomysis chiltoni, a species of mysid shrimp, is widely distributed amongst the riverine lakes of the lower Waikato basin. They appear to thrive in turbid waters, with the greatest abundances found in lakes such as Waahi and Waikare, which have low Secchi transparencies and sparse aquatic macrophyte communities representing remnants of formerly dense beds (Kirk, 1983; Chapman et al., 1991). Maximum mysid abundances of 2,868 and 857 individuals m^{-2} in Lake Waahi and Waikare respectively were recorded by Chapman et al. (1991) in March-April 1987. Anecdotal evidence suggests that mysid abundance in Lake Waikare is markedly reduced since the late 1980s (Gary Watson, Te Kauwhata, pers. comm.) with the arrival and proliferation of koi carp (*Cyprinus carpio*) presumed to be the cause. Koi carp arrived in Lake Waikare after 1987 and by 2007 it was estimated that over 80% of the fish biomass present in Lake Waikare was comprised of koi carp (Hicks, 2007). Stable isotope studies on carp (Matsuzaki et al., 2007) have shown that mysid shrimp can form a significant component of their diet. This suggests that mysid shrimp may be predated on by koi carp in the Waikato which has implications on mysid shrimp abundance as well as the abundance of native fish species which rely on mysid shrimp as a food source (Chapman et al., 1991). The objective of this study was to measure mysid abundance in three shallow, turbid lakes in the lower Waikato basin (Lake Waikare, Whangape and Waahi) to compare with previous abundance estimates made in the late 1980s. A second objective was to determine whether mysid shrimp form a significant component of the diet of koi carp in the study sites by examining their stable isotope signatures.

Ten sampling sites distributed around the perimeter of each lake were selected for each of the study lakes. Mysid shrimp were collected from the study lakes with a bottom-closing net (BCN) between Dec-07 and Jan-09. Individual mysid shrimp were counted for each BCN sample to calculate density and biomass. Dual stable isotope analysis was also carried out on samples of mysid shrimp as well as a range of fish species captured from Lake Waikare and Waahi. Results of the BCN sampling show that mysid shrimp are still present in moderate to high densities in all three lakes. Maximum densities of mysids captured by a BCN during 2008 in Lake Waikare (1,353 mysids m^{-2}), Whangape (1,347 mysids m^{-2}) and Waahi (7,020 mysids m^{-2}) were all higher than maximum densities recorded in 1987, which were 857, 898 and 2,868 mysids m^{-2}, respectively (Chapman et al., 1991). The maximum mysid density of 7,020 mysids m^{-2} in Lake Waahi during November 2008 is the highest ever recorded mysid density from a single BCN sample in the lower Waikato Basin (Dave Lasenby, pers. comm.). Although koi carp now dominate the biomass of fish species in the lakes, they appear to have had no measurable, detrimental effect on mysid abundance in the three study lakes. Isotope analysis on fish species and mysids in lakes Waahi and Waikare show that mysids do not form a primary component of the diet of small, medium or large carp. Instead it appears that mysid shrimp may form a significant component of the diet of goldfish in Lake Waikare as goldfish almost exactly matched the presumed trophic enrichment (+0.4‰ for $\delta^{13}C$, and +2.3‰ for $\delta^{15}N$; McCutchan et al., 2003) between a food and its consumer.

1. Introduction

Of the nine mysid shrimp species present in New Zealand, only two (*Tenagomysis chiltoni* and *Tenagomysis novaezealandiae*) have been recorded in freshwater (Chapman and Lewis, 1976). *T. chiltoni* are widely distributed amongst the riverine lakes of the lower Waikato basin, but are less abundant or absent from peat lakes in the area. They appear to thrive in turbid waters, with the greatest abundances found in lakes such as Waahi and Waikare, which have low Secchi transparencies and sparse aquatic macrophyte communities representing remnants of formerly dense beds (Kirk, 1983; Chapman et al., 1991). Chapman et al. (1991) recorded maximum mysid abundances of 2,868 and 857 individuals m^{-2} in lakes Waahi and Waikare respectively in March-April 1987, indicating that reasonably large populations persisted in the high suspended sediment and reduced littoral wetland conditions present in these lakes following catchment development (primarily agricultural) and flood control works.

Freshwater mysids are important components of food webs in freshwater ecosystems as they are links in the transfer of energy from lower trophic levels such as algae, zooplankton and detritus to higher trophic levels such as fish (Lasenby and Langford, 1972; Morgan et al., 1982; Wilhelm et al., 2002). Mysids were a key component of the diets of many New Zealand native fish species such as shortfin eels (*Anguilla australis*), common bullies (*Gobiomorphus cotidianus*), and common smelt (*Retropinna retropinna*) in the turbid lakes of the lower Waikato basin (Chapman et al., 1991). Data from several studies on fish diets in Lake Waahi from 1973 to 1987 showed that the collapse of the macrophyte beds in the late 1970s appeared to have caused a dietary switch in fish from invertebrates associated with macrophytes to mysid shrimp (Stephens, 1978; Northcote and Ward, 1985; Wakelin, 1986; Chapman et al., 1991). Chapman et al. (1991) speculated that reductions in mysid abundance could result in drastic decline in the growth rates of native fish species. It is well documented that mysids function as predators capable of influencing zooplankton communities (Grossnickle, 1982; Langeland et al., 1991; Chapman and Thomas, 1998). Laboratory based experiments carried out by Thomas (1991) showed that mysids preferentially fed on *Bosmina meridionalis* over *Calamoecia* sp. and *Daphnia carinata*. Extrapolation of these laboratory derived results suggests that mysids have little effect on the Lake Waikare *Calamoecia* sp. population, but is likely controlling the presence and density of *Bosmina* in the lake. Studies have also shown that mysids may actively prey on invertebrates such as amphipods in aquatic systems where they co-occur (Wilhelm et al., 2002).

Koi carp (*Cyprinus carpio*) were introduced widely into the Waikato basin in the late 1960s and early 1970s, from accidental releases and deliberate introduction for coarse fishing purposes (Pullan and Little, 1979). They were recognised as a threat to aquatic ecosystems in New Zealand by the late 1970s but they did not become a concern until 1983 when self-sustaining populations were discovered in the Waikato River system (Pullan, 1986). Fish community surveys using a range of methods (gee minnow traps, fyke nets, trap nets, gill nets, beach seines and purse seines) were carried out in Lakes Waahi and Whangape during 1986-1988 (Hayes, 1989; Hayes et al., 1992). Koi carp were not observed or captured during 1986 or 1987 suggesting that they had not yet

invaded these lakes (Hayes, 1989). However, in 1988, it was found that the invasion of koi carp had begun in Lake Whangape as a few individuals were captured (Hayes et al., 1992). Koi carp were present in Lake Waikare by 1984 but in low numbers (Pullan, 1986). In 2007, preliminary estimates of fish abundance in Lake Waikare suggested that there was a fish biomass of at least 82 kg ha^{-1}, of which over 80% was koi carp (Hicks, 2007). Anecdotal evidence suggests that mysid abundance in Lake Waikare is markedly reduced since the late 1980s (Gary Watson, Te Kauwhata, pers. comm.), though recent non-quantitative sampling shows that they are still present, at least in low abundance (Ian Hogg, unpublished data). Stable isotope studies of common carp in Lake Kasumigaura, Japan (Matsuzaki et al., 2007) have shown that mysid shrimp comprised approximately 30% of their diet. This suggests that mysid shrimp could form a significant component of the diet of koi carp in the Waikato leading to a possible decline of mysid shrimp populations in the lower Waikato basin. Eel fishers now consider shortfin eels in Lake Waikare to be in poor condition (Mike Brook, Huntly, pers. comm.), which could be a response to lowered mysid abundance.

The objective of this study was to measure mysid abundance in three shallow, turbid lakes in the lower Waikato basin to compare with previous abundance estimates made in the late 1980s. A second objective was to determine whether mysid shrimp form a significant component of the diet of koi carp in the study sites by examining their stable isotope signatures. This would provide some evidence as to whether koi carp use mysid shrimp as a primary food source and consequently cause a decrease in the abundance of mysid shrimp in the lower Waikato basin.

2. Study Sites

Lakes Waikare, Whangape and Waahi are all located in the lower Waikato basin (Figure 1), Drainage and flood control schemes, agricultural development (e.g. high intensity dairy farming) and introduction of exotic fish species have all been implicated in causing major biotic changes in these riverine lakes. The lakes are all relatively shallow, readily mixed by wind action and support large populations of exotic fish species which result in low Secchi transparencies and high turbidities.

Lake Waikare (Figure 2), a hypertrophic lake, is the largest lake in the Waikato region with an area of 3,442 ha and a maximum depth of 1.5 m. The lake regularly suffers from algal blooms and has been consistently turbid over the last 30 years with Secchi depths prior to koi carp invasion ranging from 0.07 to 0.30 m in 1981 (WVA, 1982) and Secchi depths post koi carp invasion ranging from 0.03 to 0.19 m in 2008 (Environment Waikato, unpublished data). Lake Waikare currently does not sustain native macrophyte populations due to the high suspended sediment loads and high wind exposure.

Lake Whangape (Figure 3), also considered hypertrophic, is the second largest lake in the Waikato region with an area of 1,450 ha and a maximum depth of 3.5 m. In the late 1860s to early 1870s, Lake Whangape supported a diverse community of native plant species and had secchi depths of up to 2 m (Kirk, 1871). By 1982, the majority of the lake (>95%) was covered by the invasive *Egeria densa* and *Ceratophyllum demersum*

(Barnes, 2002). By 1987, the complete collapse of macrophytes in Lake Whangape occurred.

Lake Waahi (Figure 4), a supertrophic lake, is the third largest lake in the Waikato region with an area of 522 ha and a maximum depth of 5 m. High levels of suspended sediment originating from pastoral and mine drainage continuously enter the lake, resulting in a steady decline in water quality. Low lake levels, high nutrient concentrations and continued suspended sediment input caused the crash of macrophyte populations in the lake in the late 1970s and the lake has remained predominantly devegetated ever since (Dell et al., 1988; Edwards et al., 2006).

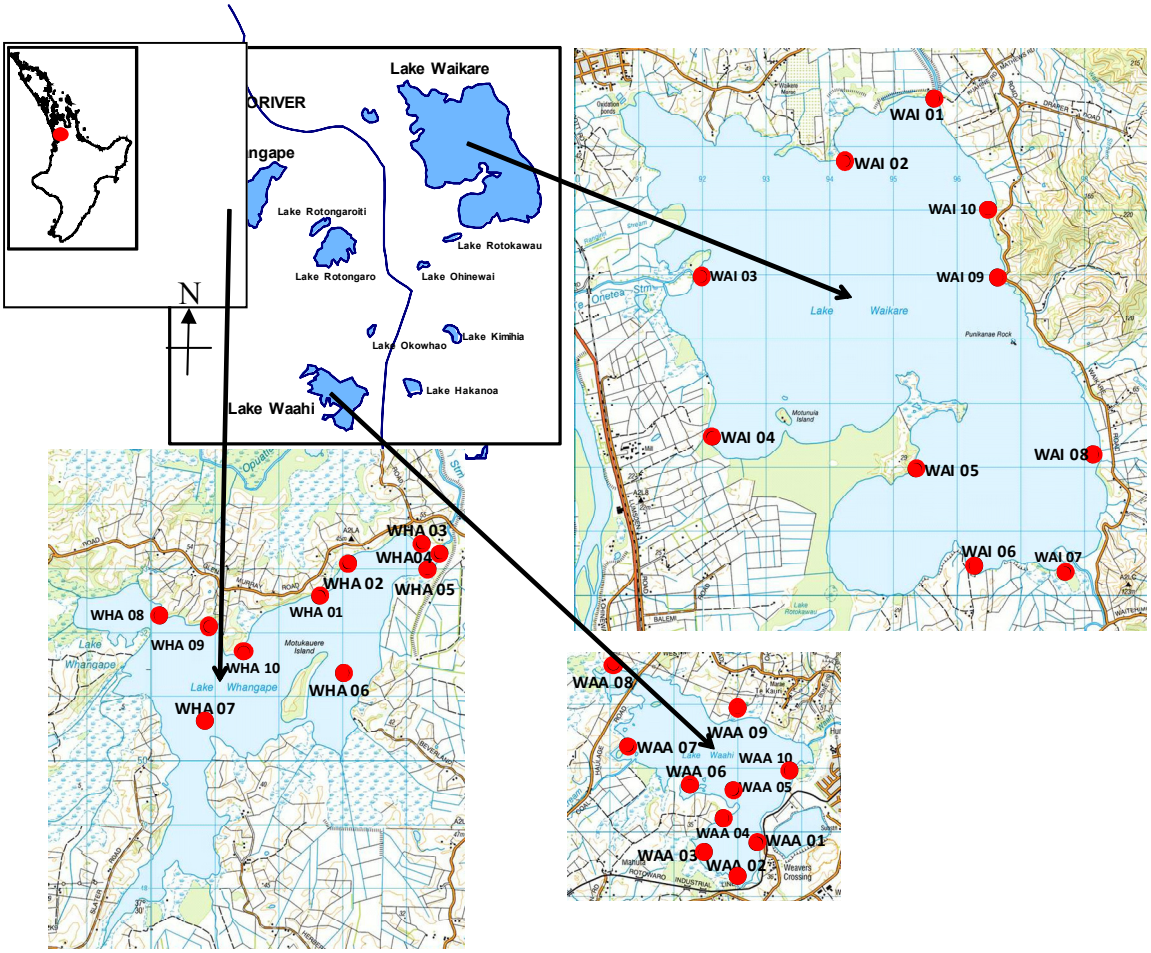

Figure 1. Map of the lower Waikato basin showing study lakes (Lake Waikare, Whangape and Waahi) and sampling sites within each lake.

Figure 2. Aerial photo of Lake Waikare looking north in August, 2007. Photo: B. Hicks.

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Figure 3. Aerial photo of Lake Whangape looking southwest in September, 2007. Photo: D. Özkundakci.

Figure 4. Aerial photo of Weavers Lake (left) and Lake Waahi (right) looking southwest in September, 2007. Photo: D. Özkundakci.

3. Methods

Mysid collection

Ten sampling sites were selected for each of the study lakes and the coordinates were stored in a Garmin eTrex Legend handheld GPS unit (Figure 1). The sampling sites were distributed around the perimeter of each lake so that both windward and leeward shores were sampled. Due to the low water levels during sampling periods, the southwestern arm of Lake Whangape was unable to be sampled as it was inaccessible by boat. We attempted to take samples from areas of maximal mysid abundance as shown by the transect sampling of Chapman et al. (1991). With the exception of WHA06 (too shallow to get closer to shore by boat), all sampling sites were between 10-12 m from the shore. At each site Secchi depth, surface water temperatures, depth of water column, conductivity measurements and substrate type (sand, mud, clay etc.) were recorded. Mysids were collected from the study lakes between December 2007 and January 2009 (Table 1) with a bottom-closing net (BCN) similar to that described by Lasenby and Sherman (1991). The BCN is a vertically operated, 500 μm mesh size net which is supported within a square metal frame (Figure 5). The sampling area of the BCN is 0.15 m^2 and it is closed off by two slightly overlapping flaps of netting that snap shut when the net reaches the bottom thus entrapping the mysid shrimp. Mysids were stored in lake water on ice and frozen upon arrival at the laboratory. One BCN sample was taken at each of the ten sites in each of the study lakes giving a total of ten BCN samples per lake for every sampling period.

Mysid density, biomass and isotope analysis

Mysid shrimp samples were defrosted and individual mysid shrimp were counted in each sample. Once counted they were dried to constant weight at 50°C. Samples were then ground with a mortar and pestle and stored in glass vials until dual stable isotope analysis (δ13C and δ15N). Isotope analysis was carried out on a pooled sample of mysids containing a range of body sizes with their gut contents intact. Incidental fish samples were collected by boat electrofishing from Lakes Waikare (January 2008) and Waahi (March 2007). Shortfin eels, koi carp and goldfish (*Carassius auratus*) were captured from both lakes. Common bullies and mosquitofish (*Gambusia affinis*) were only caught in Lake Waikare while European perch (*Perca fluviatilis*), catfish (*Ameiurus nebulosus*) and rudd (*Scardinius erythrophthalmus*) were caught in Lake Waahi. Sample sizes varied from 2 to 10 fish per species per lake. Samples were kept on ice during transit from the field to the laboratory and either processed immediately or stored at -20°C. A flesh sample was removed from the epaxial muscle on the anterior dorsal side of the fish. The flesh sample was then dried as per the mysid shrimp preparation for isotope analysis.

Table 1. Sampling dates of mysid collection from the three study lakes in the lower Waikato basin. – represents no sampling.

Sampling Dates		
Lake Waikare	**Lake Whangape**	**Lake Waahi**
3-Dec-07	5-Dec-07	-
18-Jan-08	-	-
9-Oct-08	-	29-Oct-08
24-Nov-08	20-Nov-08	20-Nov-08
19-Dec-08	18-Dec-08	18-Dec-08
13-Jan-09	14-Jan-09	14-Jan-09

Figure 5. Bottom closing net (BCN) used for mysid sampling displayed by Dr Ann Chapman.

4. Results

4.1. Mysid abundance

All three study lakes had consistently low mean Secchi depths of less than 0.30 m throughout the sampling periods reflecting their highly turbid state (Table 2). Surface water temperatures were relatively similar between Lake Waikare and Waahi with means ranging from 16°C to above 25°C. Lake Whangape was slightly colder (2-3°C) than the other two lakes during the same time periods. The highest surface water temperatures were all observed in January 2009. Mean specific conductivities (standardised to 25°C) in Lake Waikare (<180 μS cm^{-1}) and Whangape (<230 μS cm^{-1}) were lower than those of Lake Waahi (277 to 428 μS cm^{-1}) (Table 2). The depth sampled for mysids at each site ranged between 0.4 – 1.1 m in all three study lakes with an average depth of 0.64, 0.58 and 0.68 m for Lakes Waikare, Whangape and Waahi respectively (Table 3). Substrate type varied not only between the lakes but also between sites within each lake. Generally, Lake Waikare consisted of a hard clay/sand type substrate, whereas Lake Whangape substrate was mainly composed of mud and Lake Waahi had a lot of sites with high levels of detritus and clay.

Table 2. Mean Secchi depths, surface water temperatures and conductivities in Lake Waikare, Whangape and Waahi between Dec 07 and Jan 09. *N* = 10 except in Lake Whangape, Dec 07 where *N* = 1. – represents measurements not taken.

Study Site	Mean secchi depth (m)	Mean surface water temperature (°C)	Mean ambient conductivity (μS cm^{-1})	Mean specific conductivity (μS cm^{-1})
Lake Waikare				
Dec-07	-	-	-	-
Jan-08	0.20	-	-	-
Oct-08	0.15	16.0	123	149
Nov-08	0.16	20.2	132	147
Dec-08	0.14	21.1	148	159
Jan-09	0.20	25.3	172	172
Lake Whangape				
Dec-07	0.30	22.2	213	224
Nov-08	0.14	16.6	161	192
Dec-08	0.13	18.8	195	221
Jan-09	0.15	22.6	203	213
Lake Waahi				
Oct-08	0.26	16.6	235	277
Nov-08	0.17	19.5	286	325
Dec-08	0.17	22.3	362	382
Jan-09	0.21	26.1	438	428

Table 3. Depth sampled for mysids and substrate type at each site in the study lakes.

Site	Mean depth sampled (m)	Substrate
Waikare		
WAI01	0.54	Hard clay/Sand
WAI02	0.59	Hard clay/ Sand
WAI03	0.55	Hard clay/ Sand
WAI04	0.61	Hard clay/Sand
WAI05	1.03	Hard clay/ Mud
WAI06	0.78	Hard clay/ Mud
WAI07	0.73	Mud
WAI08	0.58	Hard clay/Mud
WAI09	0.60	Sand
WAI10	0.45	Sand
Whangape		
WHA01	0.48	Hard Clay
WHA02	0.60	Soft Clay
WHA03	0.44	Hard Clay
WHA04	0.56	Sand
WHA05	0.52	Mud/Detritus
WHA06	0.46	Mud
WHA07	0.82	Mud
WHA08	0.66	Mud/Detritus
WHA09	0.65	Mud
WHA10	0.63	Clay
Waahi		
WAA01	0.57	Gravel/Clay
WAA02	1.08	Detritus
WAA03	0.76	Mud/Detritus
WAA04	0.61	Clay
WAA05	1.02	Clay
WAA06	0.44	Gravel
WAA07	0.46	Clay
WAA08	0.64	Detritus
WAA09	0.60	Clay
WAA10	0.59	Clay

Mean densities of mysids ranged between 5 and 1923 mysids m^{-2} but varied between lakes and season (Table 3). Lake Waahi had the highest densities and biomasses, with means of 1923 mysids m^{-2} and 2.02 g DW m^{-2} respectively in November 2008. A maximum abundance of 7020 mysids m^{-2} was recorded during this sampling period. After November 2008, mean mysid densities in Lake Waahi decreased significantly from 1923 mysids m^{-2} to 5 mysids m^{-2} in January 2009. Mean mysid densities and biomasses in Lake Whangape remained relatively consistent throughout the sampling periods with means ranging from 242 to 411 mysids m^{-2} and 0.10 to 0.65 g DW m^{-2} respectively. Mean mysid densities in Lake Waikare displayed a similar pattern to Lake Waahi with moderately high densities in November 2008 (555 mysids m^{-2}) and much lower densities

in January 2009 (65 mysids m^{-2}). Both Lake Waikare and Whangape had similar maximum abundances of approximately 1350 mysids m^{-2}. Mean mysid shrimp densities peaked in November 2008 in all three lakes with densities decreasing during the months of December 2008 and January 2009.

Table 4. Densities and biomasses (dry weight) of *Tenagomysis chiltoni* sampled with the bottom-closing net in Lake Waikare, Whangape and Waahi. $N = 10$ for all sampling periods in all three lakes.

	Density (mysids m^{-2})			Biomass (g DW m^{-2})		
Sampling period	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Lake Waikare						
Dec-07	153	13	393	0.13	0.01	0.29
Jan-08	260	0	1353	0.35	0.00	2.29
Oct-08	97	0	313	0.12	0.00	0.38
Nov-08	555	40	1260	0.55	0.02	1.77
Dec-08	159	13	373	0.09	0.01	0.26
Jan-09	65	0	287	0.03	0.00	0.14
Lake Whangape						
Dec-07	256	87	600	0.24	0.06	1.05
Nov-08	411	207	813	0.62	0.22	1.39
Dec-08	351	27	1347	0.65	0.05	2.70
Jan-09	242	47	833	0.10	0.01	0.28
Lake Waahi						
Oct-08	526	33	1240	0.78	0.04	2.29
Nov-08	1923	0	7020	2.02	0.00	8.06
Dec-08	107	7	440	0.15	0.00	0.62
Jan-09	5	0	40	0.00	0.00	0.01

The highest densities in Lake Waikare were generally found in the southern and northern section of the lake at sites WAI05-WAI08 where it was noted that there was less wave action and the substrate was a mixture of hard clay and mud (Figure 6). The western and eastern shores (WAI03, 04, 09 and 10) of the lake had relatively low densities compared to the southern section. Wave action was generally more intense at these sites and the substrate consisted primarily of sand. Mysids were absent from the eastern half of the lake in January 08 and found at all of the western sites. In October 2008, mysids were distributed in low densities around the lake. Mysid densities peaked in November 2008 at sites in the southern section of the lake (>500 mysids m^{-2}) but were relatively low at all the other sites with the exception of WAI01. After November 2008, mysid densities decreased at all sites around the lake.

With the exception of sites WHA01 and WHA08 (mean densities of 647 and 560 mysids m^{-2}), mysid densities in Lake Whangape were fairly similar throughout the lake with mean densities at individual sites ranging from 165 to 323 mysids m^{-2}. Densities

remained fairly similar at each site throughout the different sampling periods in Lake Whangape (Figure 7). The pronounced November peak and subsequent population decrease in December and January found in Lake Waikare and Waahi was not as obvious in Lake Whangape. A range of substrates (sand, mud and clay) were found in Lake Whangape but they did not seem to influence mysid abundance as similar densities were found at sites with different substrates.

A peak in density during November 2008 followed by a substantial decrease in density during December (all sites had less than 500 mysids m^{-2}) and January (most sites had no mysids) was observed at most sites in Lake Waahi (Figure 8). A density of 7020 mysids m^{-2} from a single BCN sample was recorded at site WAA05 in November 2008. Sites in Lake Waahi with a substrate type mainly consisting of detritus (Sites WAA02, 03 and 08) generally had low mysid densities.. Mysid densities were relatively low at site WAA08 throughout all the sampling periods and it was observed that the water was usually anoxic with a high level of suspended organic material. Site WAA10 also had relatively low mysid densities but also greater wave action occurred at this site compared to the other sites.

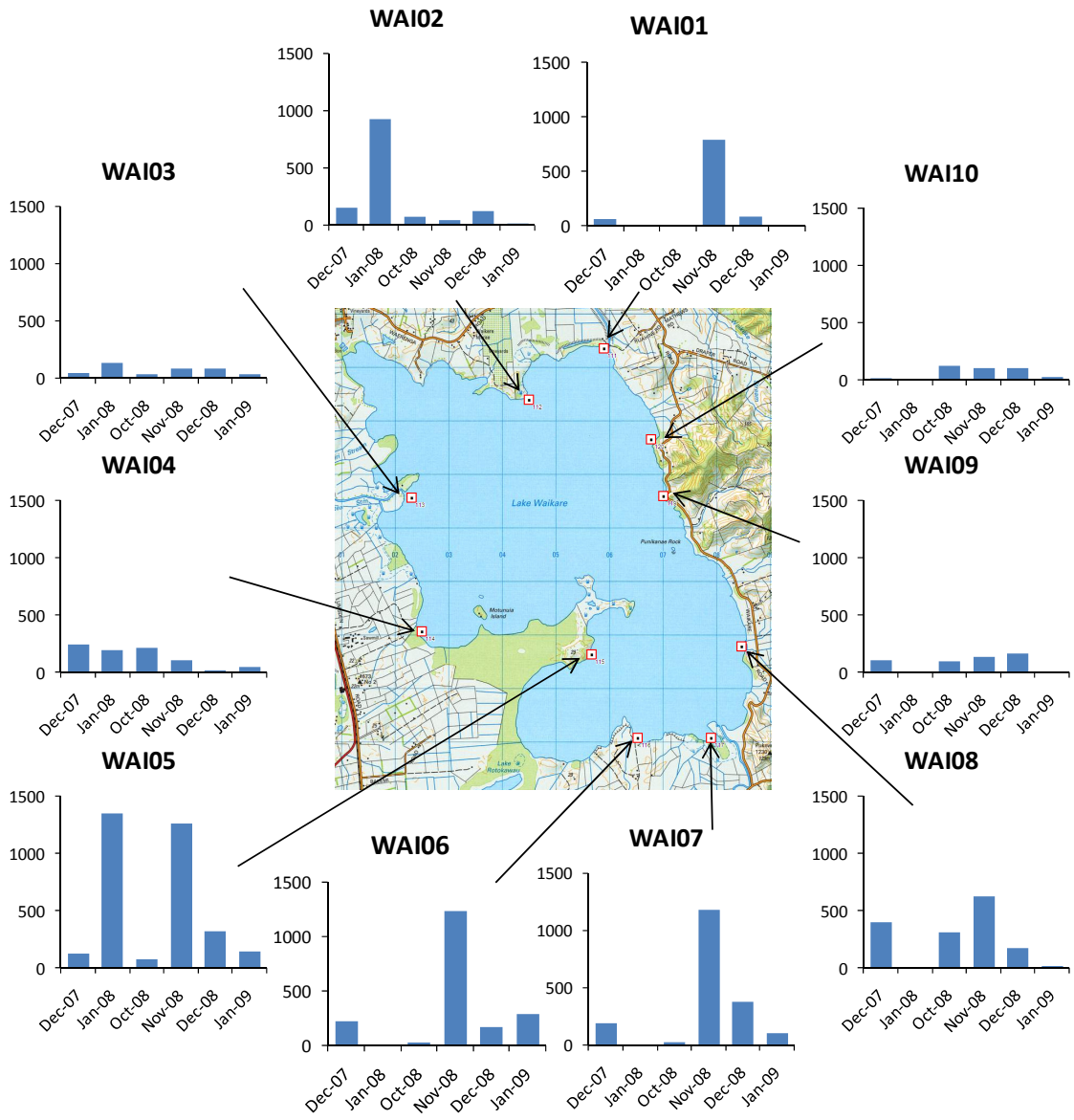

Figure 6. Spatial and temporal distribution of mysid shrimp in Lake Waikare between Dec-07 and Jan-09. Y-axis represents single-sample density (mysids m^{-2}).

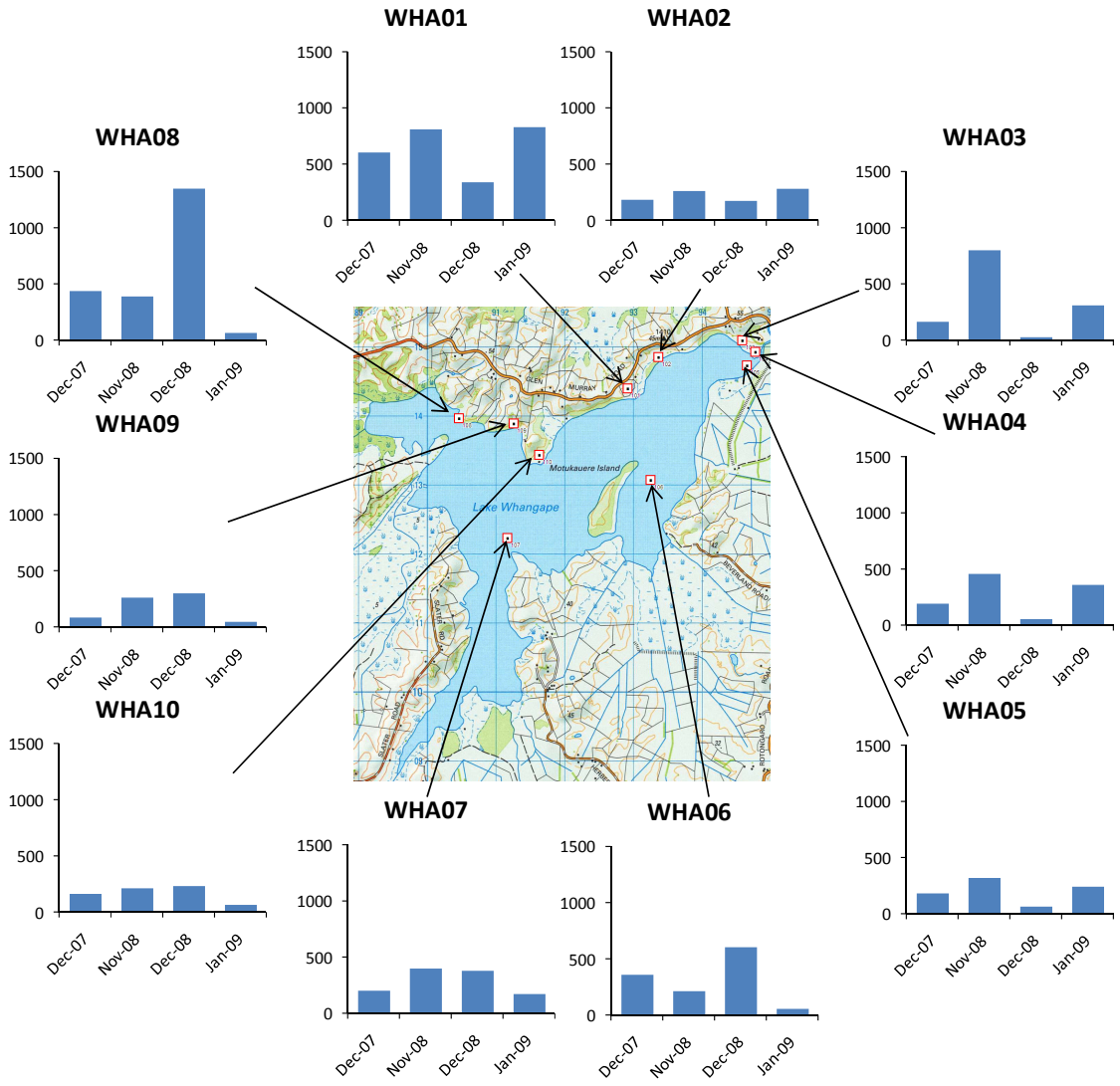

Figure 7. Spatial and temporal distribution of mysid shrimp in Lake Whangape between Dec-07 and Jan-09. Y-axis represents single-sample density (mysids m^{-2}).

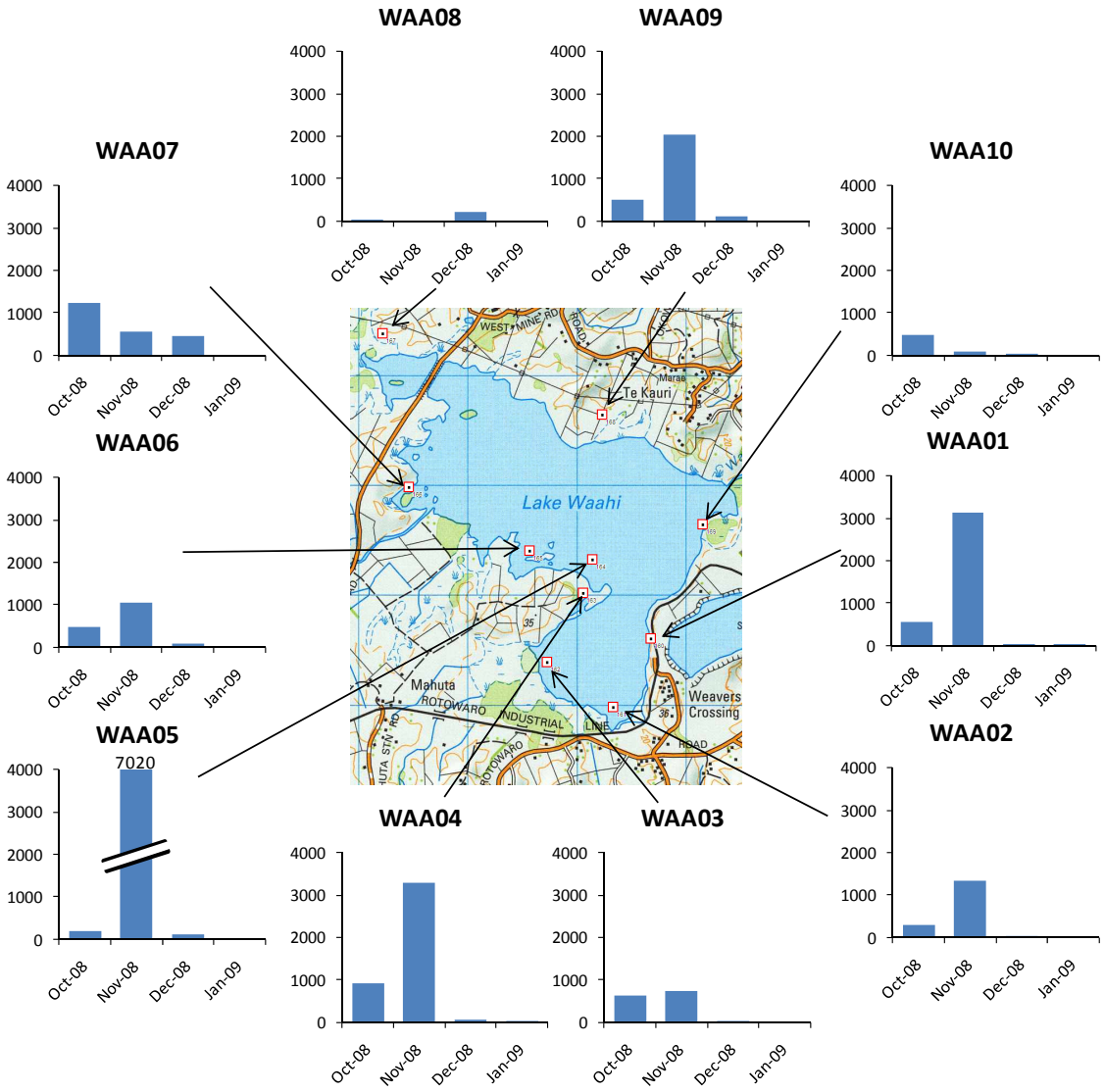

Figure 8. Spatial and temporal distribution of mysid shrimp in Lake Waahi between Oct-08 and Jan-09. Y-axis represents single sample density (mysids m^{-2}).

4.2. Dual stable isotope analysis

Of the fish sampled in Lake Waikare, goldfish and common bully showed the closest relationship with mysids as a food source (Figure 9) assuming a trophic enrichment of +0.4‰ for $\delta^{13}C$, and +2.3‰ for $\delta^{15}N$ occurs between a food and its consumer (McCutchan et al., 2003). Mysids were not the primary food source for any of the fish species sampled in Lake Waahi as all sampled fish species had isotope signatures more enriched than the presumed trophic enrichment between a food source and its consumer (Figure 10). Although out of all the sampled fish species goldfish were again the closest to matching the trophic enrichment. According to the isotope signatures, mysids did not seem to be a primary food source for koi carp in either Lake Waikare or Waahi. Extreme differences in $\delta^{13}C$ values were observed between Lake Waikare and Waahi. $\delta^{13}C$ values

for sampled species in Lake Waikare ranged from -19.4 to -17.1‰ whereas in Waahi $\delta^{13}C$ values ranged from -29.2 to -25.7‰.

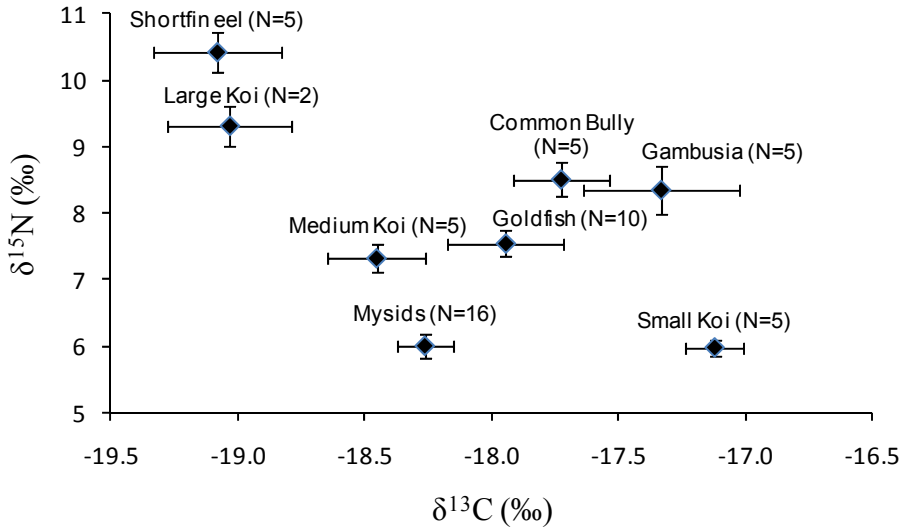

Figure 9. Mean isotope signatures (± s.e) of mysid shrimp (Dec-07, Nov-08) and fish species (Jan-08) present in Lake Waikare.

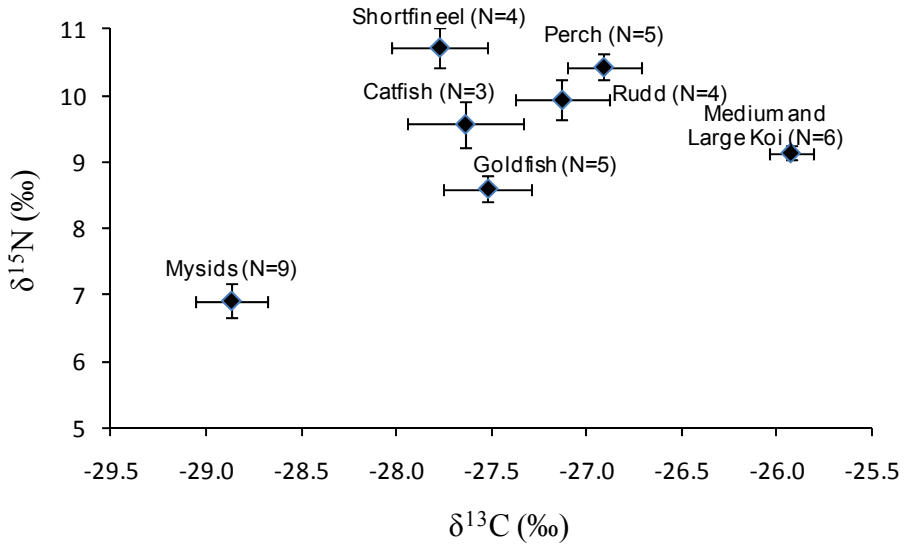

Figure 10. Mean isotope signatures (± s.e) of mysid shrimp (Nov-08) and fish species (Mar-08) present in Lake Waahi.

5. Discussion

In 1987, before koi carp were abundant, the recorded maximum mysid abundances were said to be exceptional for freshwater mysids (Chapman et al., 1991), approaching the maxima reported in the literature (Mauchline, 1980). Since 1987, koi carp have become abundant throughout the lower Waikato basin with preliminary abundance estimates of around 466,000 adult koi (~851 tonnes of biomass) present in Lake Waikare (Hicks, 2007). The results of the BCN sampling during 2008 in Lake Waikare, Whangape and Waahi showed that mysids are still present in moderate to high densities in all three lakes. Maximum densities of mysids captured by a BCN during 2008 in Lake Waikare (1,353 mysids m^{-2}), Whangape (1,347 mysids m^{-2}) and Waahi (7,020 mysids m^{-2}) were all higher than maximum densities recorded in 1987 which were 857, 898 and 2,868 mysids m^{-2}, respectively (Chapman et al., 1991). The maximum mysid density of 7,020 mysids m^{-2} in Lake Waahi during November 2008 is the highest ever recorded mysid density from a BCN sample in the lower Waikato Basin (Dave Lasenby, pers. comm.). Mean mysid densities in Lake Waikare (65-555 mysids m^{-2}) and Whangape (242-411 mysids m^{-2}) were generally higher than the modal abundance of ~100 mysids m^{-2} recorded for those lakes in 1987 (Chapman et al., 1991). Mysid densities in Lake Waahi were variable with mean spring densities ranging from 526-1,923 mysids m^{-2} (comparable to modal abundance of 500-1,000 mysids m^{-2} in 1987) and mean summer densities of 5-107 mysids m^{-2}. Although koi carp now dominate the biomass of fish species in the lakes (Hicks, 2007), they appear to have had no measurable, detrimental effect on mysid abundance in the three study lakes, at least by the mysid sampling method used in this and previous studies.

Up to four generations of mysid shrimp per year may occur, with peaks in egg-bearing females evident in every season. Increased water temperatures and brood releases of young by over-wintering females during September-November resulted in the highest annual abundance of mysids in riverine lakes in spring (Kirk, 1983). Thomas (1991) also discovered that mysid abundance was highest during November in Lake Waikare with abundances decreasing directly after. During our study, the highest mean densities in Lake Waikare (555 mysids m^{-2}), Whangape (411 mysids m^{-2}) and Waahi (1923 mysids m^{-2}) were all collected during November. Thus the increase in mysid densities in all three lakes between our study and Chapman et al. (1991) could be due to our sampling occurring in spring and summer whereas Chapman et al. (1991) carried out their BCN surveys during autumn. However, a comparison of mean mysid densities in Lake Waikare during November 1990 (~150 mysids m^{-2}; Thomas, 1991) and November 2008 (555 mysids m^{-2}) using the same sampling method (BCN) does show that mysid density has increased in Lake Waikare.

Isotope analysis on fish species and mysids in Lake Waahi and Waikare show that mysids do not form a primary component of the diet of small, medium or large carp. In Lake Waikare, goldfish almost exactly matched the presumed trophic enrichment (+0.4‰ for $\delta^{13}C$, and +2.3‰ for $\delta^{15}N$; McCutchan et al., 2003) between a food and its consumer. According to the isotope signatures of fish species sampled in Lake Waahi, mysids did not appear to be a primary food source for any of them although goldfish were again

closest to the presumed trophic enrichment between a food and its consumer. More data needs to be collected from both lakes (more species, bigger samples size, investigate seasonal differences) to better understand the role of mysid shrimps in the food web of these lakes. The examination of stomach contents of all the fish species would also have been a useful addition to this preliminary analysis as a combination of both stable isotopes and stomach contents provide a good independent description of the feeding habits of the fish species. However, the preliminary data do appear to show that mysids do not form a significant part of the diet of koi carp.

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