Seasonal variation and abundance of Mysids in Auckland region, New Zealand

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Abstract

Over two years monthly monitoring, four mysid species were collected. *Tenagomysis chiltoni* and *T. novaezealandiae* were the most common species. *Gastrosaccus australis* and *T. macropsis* were rarely recorded. *Tenagomysis novaezealandiae* was the geographically widespread species, occurs in all sites, abundant in east coast. *Tenagomysis chiltoni* was most abundant in west coast. Seasonal patterns in abundance of *T. novaezealandiae* were less apparent and it differs among sites, it may be attributed to the site-specific factors. *Tenagomysis chiltoni* showed a considerable seasonal fluctuation: greatest numbers occurring during winter to early summer; lowest abundance during summer to autumn may reflect small scale migration within the stream due to one or more factors. It was evident from correlation analysis the physical factors: site, width of the stream, marginal vegetation cover and soil condition of the substratum influence the abundance and distribution of mysid species. The chemical factors salinity and temperature also influence the species distribution. With the combinations of all these physical, chemical and biological factors influence the species distribution and abundance. Kakamatua Stream supported higher mysid abundance, compared to other sites. This sustained by the size of the water body and dense riparian vegetation bordering the stream, which providing suitable habitats for mysids.

Key words
seasonal variation; mysids; estuarine;riparian vegetation;habitats

Introduction

Mysids are crustaceans occupy in a variety of aquatic environments all over the world and are abundant component of the zooplankton in estuarine systems (Mauchline 1980). Mysids serve as an important food source for ecologically and commercially important fish (Mauchline 1980; Fulton 1982a), play a critical part in the cycling of energy within the system (Webb, 1973; Vilas et al., 2008) and are important in the consumption of suspended matter in the detritus-based estuarine food webs (Fockedy & Mees, 1999). Despite the, worldwide distribution and their ecological significance in estuaries, no comprehensive studies undertaken in North Island New Zealand.

Among the studies on mysids on New Zealand, the major studies on temporal distribution have been undertaken in the South Island (Greenwood et al., 1985; Jones et al., 1989; Lill et al., 2011; Bierschenk et al., 2008) and only one in the North Island (Kirk, 1983). The highest number of *Tenagomysis chiltoni* was collected during spring /summer period (September & November) from the Avon-Heathcote estuary and the lowest numbers through the rest of the months of the year (Jones et al., 1989). Although similar pattern was found for *T. macropsis* in the same estuary, it did not demonstrate any consistent seasonal population cycle (Greenwood et al., 1985). It was also suggested by Greenwood et al., 1985 that population fluctuations of this species could be related to differing salinity regimes, recruitment rates, breeding aggregation and migration. In the Avon-Heathcote estuary, the highest numbers of *T. novaezealandiae* were caught in September and March but again with little evidence of seasonality (Jones et al., 1989). *T. chiltoni* populations from selected sites of the Waikato River in the North Island recorded highest abundances in late winter and spring and lowest in summer (Kirk, 1983). In contrast to that the South Island studies of Lill et al. (2011) and Bierschenk et al. (2008) showed that highest numbers of both *T. novaezealandiae* and *T. chiltoni* occurred in summer and numbers decreased towards winter. North Island and south Island geographical position is completely different, hence there is a contrast temperature variation. Therefore, seasonal differences in abundance of mysids in two geographical locations may be due to latitudinal variation in temperature (Mauchline, 1980; Wittmann, 1984; Baldo et al., 2001).

Spatial distribution study in Auckland region (Punchihewa & Krishnarajah, 2013a) showed that *T. novaezealandiae* is the dominant mysid species along the east coast while *T. chiltoni* equally dominant with *T. novaezealandiae* in west coast. Despite the well documented spatial and temporal distribution data in other areas of New Zealand, temporal distribution data from the Auckland region is absent. Therefore, the present study is to investigate the seasonal variation of mysids on both east and west coast of Auckland region, in order to extend this knowledge in a comparative manner in other geographical regions as well. The results allow comparison to be made with South Island studies.

Methodology

The selected study area is situated on the North Island, the Auckland region. Monitoring to assess temporal variation in mysid abundance was undertaken at six out of the 26 surveyed sites at where mysids were encountered: three within Manukau Harbour (Kakamatua stream, Mill Bay and Cornwallis), and three on the east coast (Big Manly Bay, Orewa-Nukumea Stream and Okoromai Bay) (Table 1, Fig. 1). These six sites were selected because of their relatively high numbers of mysids were recorded during initial reconnaissance surveys, (Punchihewa & Krishnarajah, 2013a) and on the basis of site proximity.

Table 1: Qualitative description of the main study sites, New Zealand.

Study site	Stream width (m)	Location (GPS)	Riparian Vegetation	Soil condition (substratum)
1. Kakamatua (WC)	12–14	37°00′S 174°35′E	Mainly larger trees, grasses and flaxes	Silt loam
2. Cornwallis (WC)	2–5	36°59′S 174°36′E	Mainly grasses and flaxes	Sandy loam
3. Mill Bay (WC)	2–3	36°58′S,174°38′E	Mainly grasses and flaxes	Silt loam
4. Big Manly Bay (EC)	10–14	36°37′S 174°45′E	Mainly larger trees grasses and flaxes	Silt
5.Okoromai Bay (EC)	2–3	36°36′S 174°48′E	Mainly mangroves	Sandy loam
6. Orewa-Nukumea Stream (EC)	14–18	36°34′S 174°41′E	Mainly larger trees, grasses and flaxes	Silt

WC, west coast; EC, east coast

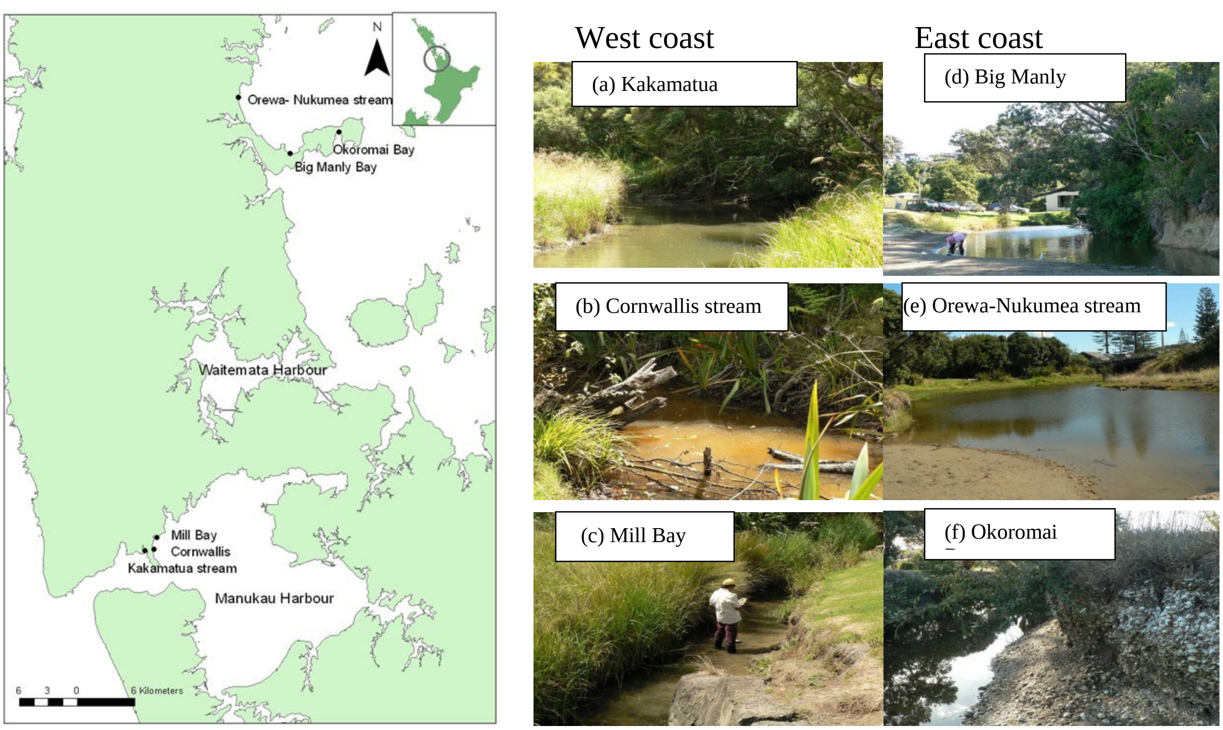

Fig 1: Main study sites, Auckland region: west and east coasts.

The general characteristics of each site are described in Table 1 and depicted on plates a–d (Fig. 1); each site was surveyed approximately monthly, ± 1 hour from low tide, over a two year period. The samples were taken using a hand held dip net with a mouth area of 25 × 20 cm^2, and with 500 µm mesh size along an eighty meter transect at the edge of the stream. Samples were taken from surface water column and tidal mixing area of the stream, but not much close to the ocean. At each site four replicate surveys were undertaken (transects of 10 m length, 10 m apart). All mysids collected, were transferred immediately into separate bottles containing 70% ethyl alcohol. Monthly sampling was carried out over two years starting in June 2006 on the west coast and September 2006 on the east coast, in selected six sites. At each site surveys took place during day time at low tide. On each sampling event, the environmental variables: salinity, pH, dissolved oxygen (DO) and temperature were measured using WTW 3400i Multi-Parameter Water Quality Field Meter, Geotech Environmental Equipment, USA. In the laboratory total body length (length of rostral tip to the telson tip) of mysids were taken using an eyepiece micrometre attached to a light (compound) microscope.

Statistical Analyses

Samples collected at each three sites (both west and east coast) at different times of the same day (day time) considered as independent samples. The mean and standard deviation of parameters and measurements were calculated. Diversity was calculated using Shanon-Wiener diversity index (H). The variation of the parameters and measurements were analysed using one-way and two-way analysis of variance (ANOVA) considering the site, month and species as factors. The mean separation was done using Tukey's honestly significant difference (HSD). The Principal component analysis (PCA) was performed on the data collected from the study. The Principle component analysis was varied out on the data obtained from the study to explore the patterns of mysid distribution or taxonomic relationships reflected from the data.

Relationship between variables may be strongly non-linear and involve high-order interactions. The CART is a modern statistical technique ideally suited for both exploratory and modelling such data, but have seldom been used in ecology. Hence, accurate analysis is now often seen as a principle objective of species-environment analysis (Steven et al., 2012). CART was used to recognize the best environmental parameters which contributed much to the variation of mysid species abundance. CART analysis has been used to establish the relationships between species and environment (De'ath & Fabricus, 2000). All the analyses including PCA and CART were performed on SPSS PC Version 20 and Minitab version 15 for ANOVA.

Results

Four species of mysids were collected over the monthly monitoring period. *Tenagomysis chiltoni*, *T. novaezealandiae*, *Gastrosaccus australis* and *T. macropsis*. *Tenagomysis chiltoni* and *T. novaezealandiae* were the most common species. Though, other species were relatively rare and recorded sporadically. The highest mysid diversity recorded from west coast site Kakamatua (H=0.56) and secondly east coast site Orewa (H=0.35), three species in each site. Lowest diversity recorded from east coast site Okoromai Bay.

To test whether there is a significant difference between the number of individuals of mysids of both *Tenagomysis* species in each site with respect to months, data were analysed using two-way ANOVA and are given in Table 2. The west coast and east coast sites showed that both factors (sites and months) and the interaction of these factors were found to be significant for the number of individuals of both species ($P \leq 0.05$) (Table 2).

West coast species

Tenagomysis chiltoni and *T. novaezealandiae* were the most common species of mysid found at west coast sites over the monitoring period; *G. australis* was recorded (12 individuals) only once at Kakamatua. The mean abundance of *T. chiltoni* at all three west coast sites differed significantly ($P \leq 0.05$) (Table 3) and it was higher at Kakamatua than Cornwallis or Mill Bay (Table 3). *Tenagomysis chiltoni* was the predominant mysid during most months surveyed at Kakamatua, with the number of individuals collected during monitoring exceeding those of *T. novaezealandiae* by a factor of 3. The peaks in abundance of *T. chiltoni* at Kakamatua site showed an obvious seasonal pattern (Fig. 2a). *Tenagomysis novaezealandiae* was not often collected at Cornwallis and only once it was collected at Mill Bay (Fig. 2c).

Table 2: Two-way ANOVA: Synopsis of significance/non significance in variation of the number of individuals of *T. novaezealandiae* and *T. chiltoni* in each site with respect to months.

Species	Site	F value	Df	Significance/ non significance
T. chiltoni	West coast-Kakamatua//Mill Bay/Cornwallis			
	Month	3.89	11	s
	Site	22.08	02	s
	Interaction	1.90	22	s

T. novaezealandiae	East coast:Manly Bay/Okoromai Bay/Orewa			
	Month	4.15	11	s
	Site	14.37	02	s
	Interaction	2.10	22	s

Df =degrees of freedom, s=significance

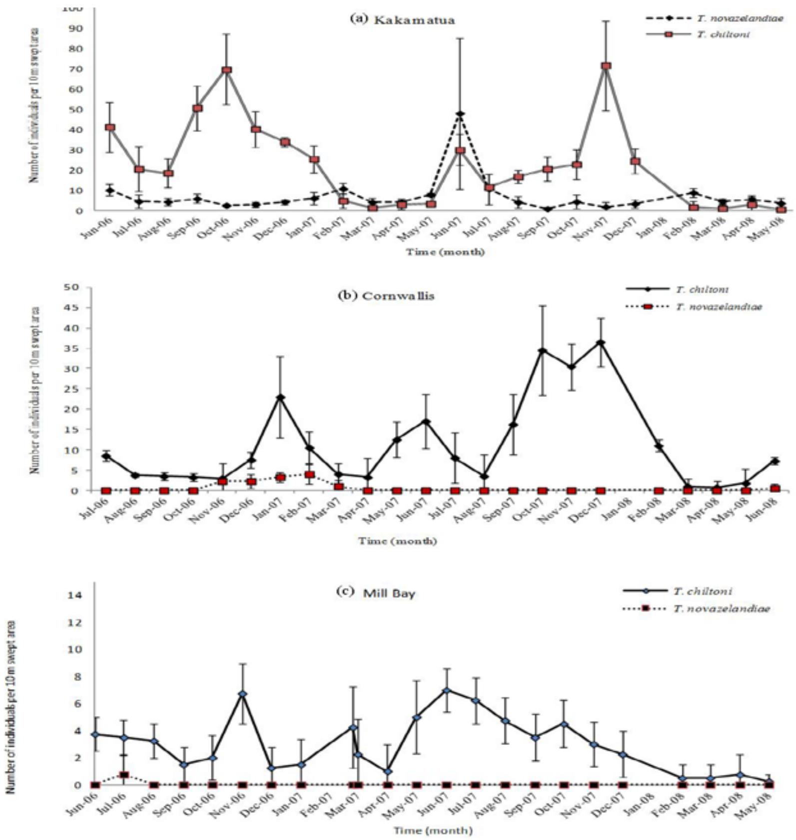

Fig. 2: Monthly variations in the mean (±SD) abundance (n=4) of *T. chiltoni* and *T. novaezealandiae*, west coast sites.

A total of 2066 *T. chiltoni* were collected over a two-year period at Kakamatua. Major peaks in the density of this species were apparent during spring (September to November) for both survey years, with secondary peaks being apparent during both winters (June to August) (Fig. 2a). The lowest abundance occurred during late summer and autumn (February to May 2007, 2008). One-way analysis of variance (ANOVA) showed that the mean abundance of mysids during June and September to December were significantly higher ($P \leq 0.05$) than the corresponding means of February to May (Table 3 & Table 4) at Kakamatua. The mean abundance values during autumn months (March to May) were significantly lower than that of the spring months (Table 3 & Table 4).

A total of 646 *T. novaezealandiae* were collected over a two-year period at Kakamatua. The greatest number of individuals were collected during early winter and late summer (June and February); the least number of individuals from mid-winter to mid-summer (July to January 2007/2008) and autumn (March to May 2007) (Fig. 2a). One-way ANOVA showed that the mean abundance values of *T. novaezealandiae* in June were significantly different ($P \leq 0.05$) from other months (Table 3 and Table 4). For the other eleven months of the year, the mean values were not significantly different. Tukey test showed that the mean abundance in June was significantly higher than the rest of the months (Table 3 and Table 4).

A total of 1003 *T. chiltoni* were collected over the monitoring period at Cornwallis. Numbers of *T. chiltoni* were initially low, and subsequently fluctuated markedly over the monitoring period; peaks in abundance occurred during winter, spring and early summer months in 2007 and 2008, with the least number of individuals caught during late-winter and spring (August to November 2006), autumn (March to April 2007 & March to May 2008) and late-winter (August 2007) (Fig. 2b), although there is no clear, recurring apparent seasonal trend. One-way ANOVA showed that the mean abundance of *T. chiltoni* at Cornwallis was significantly greater in

December and January ($P \leq 0.05$); March, April and August mean abundance values were significantly lower than those of December and January (Table 2 & Table 3). A total of 44 *T. novaezealandiae* were collected from Cornwallis in November and December (2006), January and February (2007) and June 2008 (Fig. 2b).

A total of 277 *T. chiltoni* were collected at Mill Bay during the survey period. Abundance of this species at this site was low at all times, with the exceptions of spring (November 2006) and winter (June 2007) (Fig. 2c). One-way ANOVA showed that the mean abundance values were significantly different ($P \leq 0.05$) among months (Table 2). According to Tukey test mean abundance value of April was significantly lower than those of June, July and November (Table 3). Only three *T. novaezealandiae* were collected from Mill Bay, during July 2006.

East coast species

Tenagomysis novaezealandiae was the prevalent species of mysid on the east coast; on several occasions *G. australis* occurred at Big Manly Bay (seven individuals) and Orewa-Nukumea stream (two individuals), all individuals were brooding females; *T. macropsis* occurred at Orewa-Nukumea stream on one occasion (September 2008) and all the 52 individuals were brooding females.

Temporal variation in mean abundance of *T. novaezealandiae* at the three east coast sites manifested no recurring pattern, although during December the abundance was high at all sites. *T. novaezealandiae* was present for the duration of sampling at Big Manly Bay and Orewa-Nukumea Stream. The mean abundance values of *T. novaezealandiae* at Big Manly Bay were significantly higher than Okoromai Bay and Orewa-Nukumea Stream ($P \leq 0.05$) (Table 3).

A total of 1238 *T. novaezealandiae* were collected during the monitoring period at Manly Bay. Maximum numbers occurred during mid-summer (January 2007), the least during late-autumn (March, April 2008) and late-summer (February 2008) (Fig. 3a); peaks in abundance occurred during spring, early summer and winter, although clear inter-annual trends were not apparent. One-way ANOVA showed that the mean abundance values were significantly different ($P \leq 0.05$) among months (Table 2 and 3). Tukey test showed that the mean abundance during January was significantly higher than those between February and November (Table 2 and 3).

Table 3: Synopsis of significance/non significance in variation of the number of individuals of mysids (mean±SE) among months and in different sites.

	Species	Site	F value	Df	Significance	Mean± SE
West coast	*T. chiltoni*	Kakamatua	16.03	11	S	22.58±2.53a
		Cornwallis	3.98	11	S	11.41±1.61b
		Mill Bay	3.67	11	S	2.95±0.15b
		All three sites	42.68	2	S	
	T. novaezealandiae	Kakamatua	4.31	11	S	
East coast	*T. novaezealandiae*	Big Manly Bay	10.69	11	S	14.49±1.43a
		Okoromai Bay	15.14	11	S	5.93±1.17 b
		Orewa Stream	23.71	11	S	5.26±0.30 b
		All three sites	21.91	2	S	

s = significance at $P \leq 0.05$, df =degrees of freedom.SE = standard error, Different letters show where the significant difference is evidence.

A total of 555 *T. novaezealandiae* were collected during the monitoring period at Okoromai Bay and demonstrated one annual population peak (Fig.3a). Maximum abundance occurred in spring and early summer (September to December). Mysids were not encountered at Okoromai Bay between February and May (late summer and autumn) during 2007 and 2008. The mean abundance of *T. novaezealandiae* in September to December were significantly higher than that of February to June ($P \leq 0.05$) (Table 2 & Table 3).

A total of 464 *T. novaezealandiae* were collected during the monitoring period at Orewa. Abundance of this species at this site demonstrated seasonal variation, with recurring maxima in the numbers during summer and winter (Fig. 3c), and minima during autumn and spring. One-way ANOVA showed that the mean abundance values were significantly different ($P \leq 0.05$) among months (Table 2): March to April and June to November mean values were significantly lower than December to February and May (Table 3).

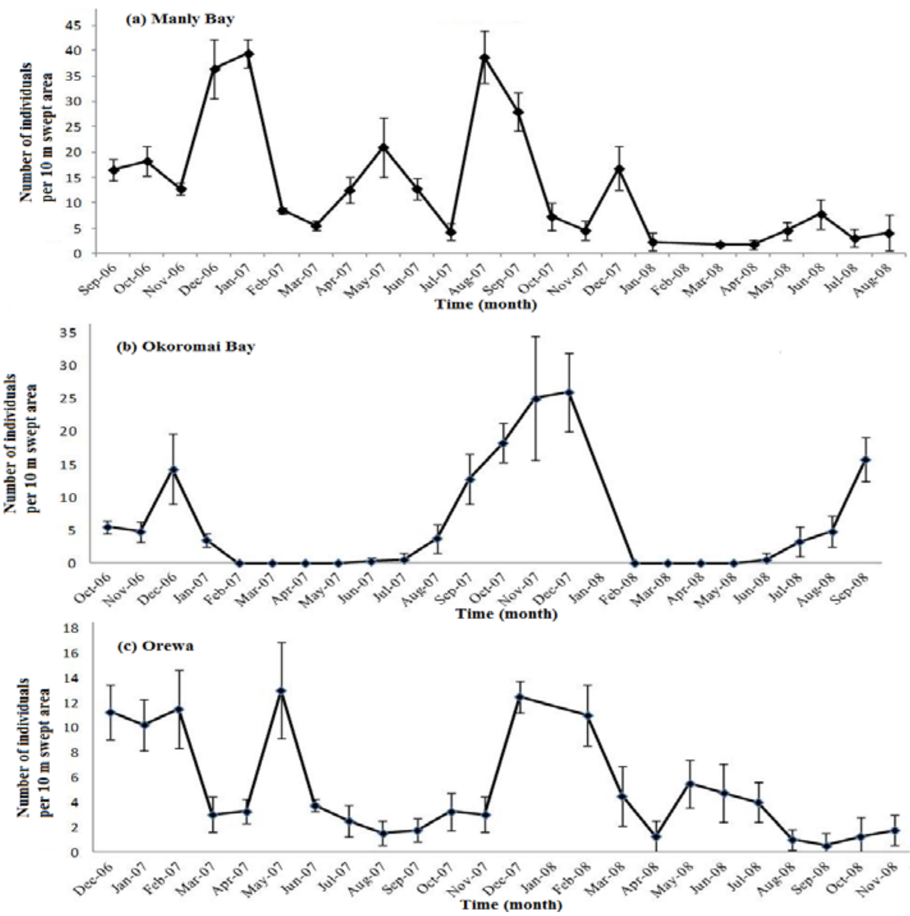

Fig. 3: Monthly variations in mean (±SD) abundance (n=4) of *T. novaezealandiae*, east coast Sites/

Table 4: Variation in the number of individuals of *T. chiltoni* and *T. novaezealandiae* (mean±SE) recorded from different sites, during monitoring period.

	T. chiltoni			*T. novaezealandiae*			
Month	Kakamatua Mean±SE	Cornwallis Mean±SE	Mill Bay Mean±SE	Kakamatua Mean±SE	Manly Bay Mean±SE	Okoromai Bay Mean±SE	Orewa Mean±SE
January	25.50±3.30	23.00±5.02a	1.50±0.96	6.00±1.58 b	39.50±1.44 a	3.50±0.5b	10.25±1.03a
February	3.13±1.22b	10.75±0.96	2.38±1.02	9.75±0.90 b	5.38±1.25b	0.00±0.0b	11.25±0.92a
March	1.13±0.52b	2.50±0.96b	1.38±0.73	4.25±0.56 b	3.63±0.75 b	0.00±0.0b	3.75±0.70b
April	3.00±1.02b	2.00±1.24b	0.88±0.58b	4.75±0.53 b	7.13±2.13 b	0.00±0.0b	2.25±0.53b
May	1.88±0.61b	7.13±2.42	2.63±1.10	5.63±1.03 b	12.75±3.43b	0.00±0.0b	9.25±1.73a
June	35.63±4.02a	12.13±2.42	5.38±0.78a	29.00±11.3a	10.25±1.26b	0.38±0.2b	4.25±0.59b
July	16.00±3.08	8.25±1.46	4.88±0.72a	7.50±2.20 b	3.63±0.63b	1.88±0.77b	3.25±0.56 b
August	17.63±1.82	3.63±1.21b	4.00±0.57	4.13±0.79 b	21.38±6.73b	4.25±0.77b	1.25±0.31b
September	35.63±6.42a	9.88±2.97	2.50±0.63	3.25±1.10 b	22.25±2.40b	14.25±1.29a	1.13±0.40b
October	46.25±9.91a	18.88±6.43	3.25±0.73	3.38±0.84 b	12.75±2.27b	11.88±2.52a	2.25±0.62b
November	56.00±8.12a	16.75±5.42	4.88±0.95a	2.38±0.63 b	8.63±1.65b	14.88±4.42a	2.38±0.50b
December	29.25±2.34a	22.00±5.67a	1.75±0.56	3.75±0.59b	26.63±4.09	20.13±2.89a	11.88±0.64a

SE = standard error, Different letters show where the significant difference is evidence

Factors effect on mysid species distribution and their abundance

1. Correlation coefficients

The correlation among the environmental parameters, site conditions on mysid species and their abundances is shown in Table 5. This indicated that mysid abundances correlated with site ($p \leq 0.01$), width of the stream and vegetation ($p \leq 0.05$) whereas species distribution correlated with site, salinity ($p \leq 0.01$), width of the stream, vegetation, soil condition and temperature ($p \leq 0.05$).

Table 5: Correlation coefficients (r) of bivariate analysis of site conditions, enviromental factors on mysid species and their abundance.

	site	Stream width	Vegetation	Salinity	Temp	Soil	pH
Abundance	0.327*	0.302**	0.273**	-0.053	0.03	0.111	-0.112
Species	0.433**	0.170*	0.164*	0.255**	0.137*	0.213*	0.118

* Significant at $P \leq 0.05$ level,** Significant at $P \leq 0.01$ level, Temp = Temperature

2. Classification and regression analysis (CART)

The results of classification and regression analysis of distribution of mysid species within monthly survey sites is shown in Fig. 4. It shows that salinity and temperature contributed much to the variation of the abundance of *T. chiltoni* and *T. novaezealandiae*. Based on the salinity, root node of the dendogram is split into two child nodes (Node 1 and 2). Node 1 includes 40.3% of *T. novaezealandiae* and 60.7% of *T. chiltoni*. The left branch of the right node of the dendogram (Node 2) further split into two child nodes (Node 3 and 4) based on temperature. The Node 3 included 34.6% of *T. novaezealandiae* and 65.4% of *T. chiltoni* and Node 4, represented 57.8 % *T. novaezealandiae* and 41.4% *T. chiltoni*. The results of the analysis revealed that the salinity and the temperature are playing the major role in the distribution of the mysid species in New Zealand.

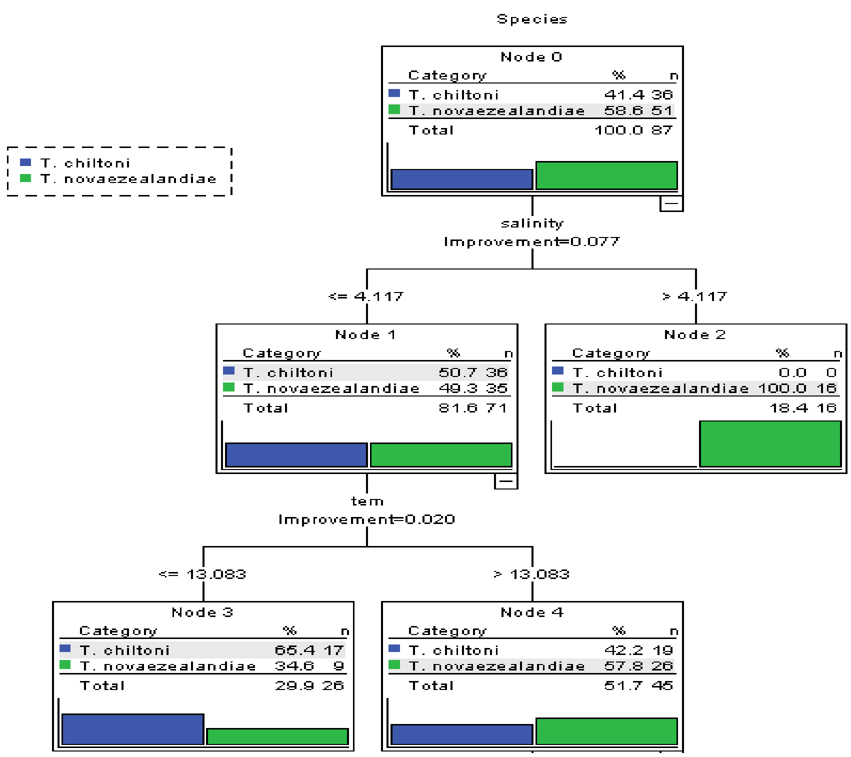

Fig. 4:Classification and Regression Tree analysis, of the distribution of mysid species within monthly survey sites, New Zealand. Legend: tem, temperature.

3. Principle component analysis

The distribution of mysid species in sites is shown in Fig. 5 & 6. The biplot produced by plotting PCA1, PCA2 and PCA3 and PCA1 with PCA 2 indicated a pattern of distribution in which species were overlapped considerably. However, both *T. chiltoni* and *T. novaezealandiae* showed a wider distribution in the plot indicating a trend which reflects site specificity (Fig. 6). The site-wise plotting of PCA1 and PCA2 (Fig. 6) showed that the New Zealand mysids were area specific in their distribution. The trends those reflected from the Fig. 6 (B) indicated that the sites distributed in the plot of PC1 with PCA 2 were not well-separated. However, Orewa and Kakamatua sites showed a weak trend of deviation and indicated a widest distribution in the plot showing its geographical position.

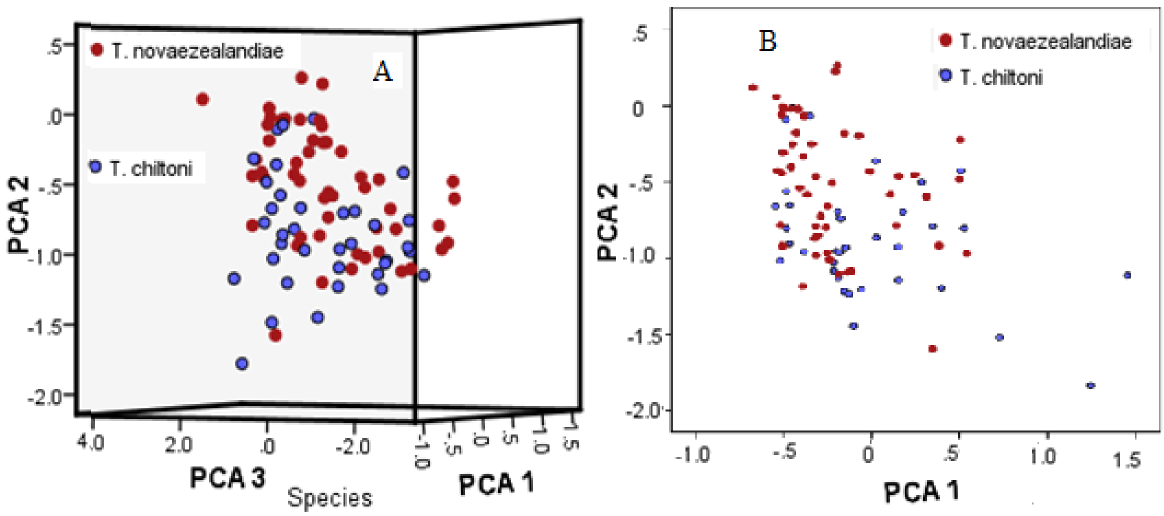

Fig. 5: Distribution of New Zealand species produced by Principle component analysis.
A) 3D plot for species using Principle components 1, 2 and 3.
B) Biplot for species using Principle components 1, 2

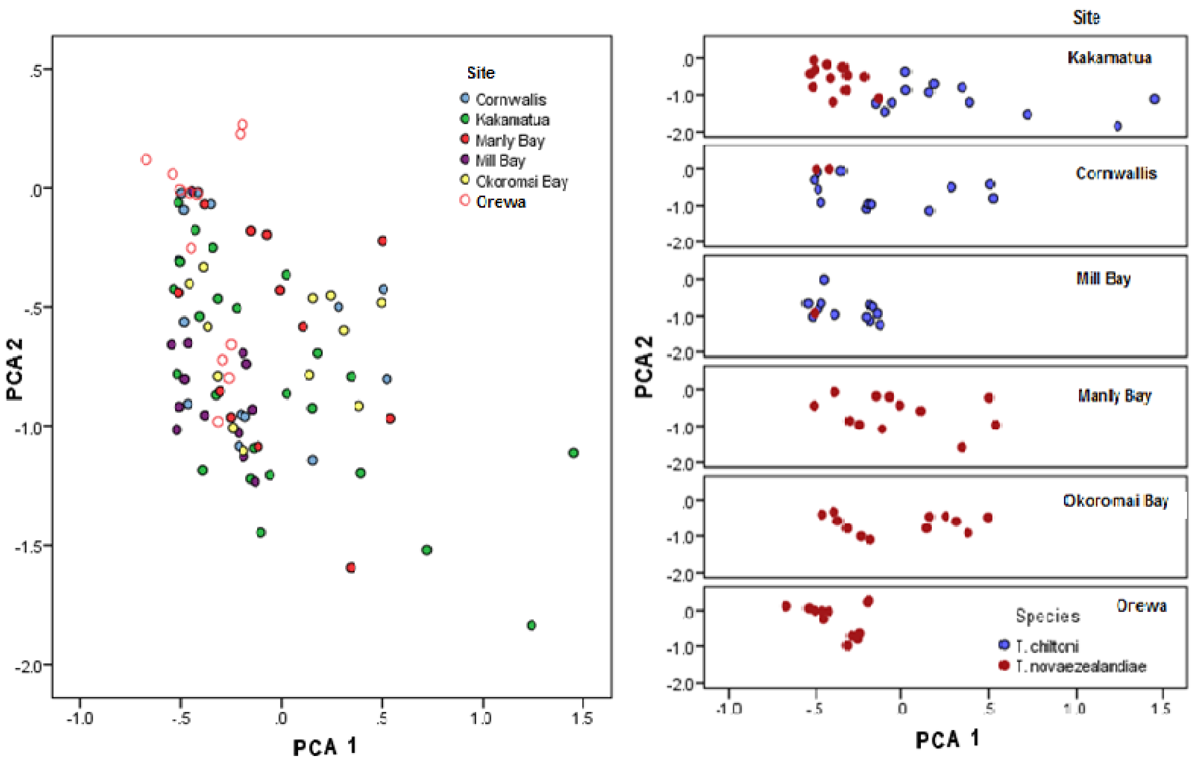

Fig. 6: Distribution pattern of New Zealand sites, in relation to mysid species, produced by Principle component analysis.
A) Biplot for species in relation to sites using PCA 1 and 2.
B) Biplot for distribution pattern of sites using PCA 1 and 2

Seasonal variations in body length

Total body length (TL) is a standard measure of size in mysids. In most of the months higher frequencies of *T. chiltoni* were recorded around the length of maturity (9–10 mm). The higher length classes 16–16.9 mm and 17–17.9 mm were recorded only from June to December for both years. During most of the months higher frequencies of *T. novaezealandiae* were recorded around the length of maturity (5–6 mm). The higher length classes 9–9.9 mm or 10–10.9 mm recorded only from September to November 2006 and August to September 2007.

To investigate the seasonal differences of body length, adult mysids of *T. chiltoni* and *T. novaezealandiae* from the pooled data were considered (monthly basis over a two-year period). The one-way ANOVA indicated that there is a seasonal difference in body length of mature males and females of both species (Table 6). Mean body length of both sexes of *T. chiltoni* and *T. novaezealandiae* differ significantly throughout the seasons ($P \leq 0.05$) (Table 6). The mean lengths of adult female *T. chiltoni* among all the seasons differ significantly except from that of spring and winter (Table 7). The mean adult body length of *T. chiltoni* female was highest in spring (13.76 mm), moderate length in winter (13.58 mm) and lowest in summer and autumn (12.44 mm & 11.78 mm respectively). During winter and spring, mean lengths of both female *T. chiltoni* and *T. novaezealandiae* differed significantly from summer and autumn lengths (Table 7). Mean length of male *T. chiltoni*, during winter differed significantly from spring and summer lengths (Table 7). Summer lengths of female *T. novaezealandiae* are significantly different from autumn lengths (Table 7). The lengths of male *T. novaezealandiae* in winter and spring differed significantly from length of autumn and summer. Accordingly, the mean adult body lengths of *T. novaezealandiae* (both sexes) and *T. chiltoni* (female) were greatest in spring and winter (Table 6). The largest *T. chiltoni* female (18.52 mm) was found in October 2006, while largest male (16.00 mm) was found in November 2006 at Kakamatua. Both largest female (10.32 mm) and male (8.56 mm) *T. novaezealandiae* was recorded in October 2006 from Big Manly Bay.

Table 6: Significance/non significance in variation of adult body length of *T. chiltoni* and *T. novaezealandiae* among seasons.

Sex	*T. chiltoni*			*T. novaezealandiae*		
	F value	df	Significance	F value	df	Significance
Female	48.60	3	s	48.00	3	s
Male	6.23	3	s	23.61	3	s

s = significance at $P \leq 0.05$, df =degrees of freedom.

Table 7: Descriptions of variation of adult body length of *T. chiltoni* and *T. novaezealandiae* (mean±SE) in different seasons.

Season	*T. chiltoni*		*T. novaezealandiae*	
	Mean±SE (Female)	Mean±SE (Male)	Mean±SE (Female)	Mean±SE (Male)
Winter	13.58±0.11a	11.82±0.09a	7.23±0.07a	6.58±0.10a
Spring	13.76±0.08a	11.43±0.07b	7.25±0.05a	6.51±0.06a
Summer	12.44±0.01b	11.37±0.12b	6.53±0.03b	6.02±0.04b
Autumn	11.78±0.25b	11.72±0.24	6.92±0.06b	5.92±0.09b

SE=standard error, df=Degree of freedom

Discussion

The variation of species abundance observed in different sites indicated that there was a higher fluctuation of abundance of *T. chiltoni.* The seasonal variation of *T. novaezealandiae* was not much evidenced but it was observed in Okoromai Bay, a smaller water body. This finding agrees with the conclusion made by Jones et al. (1989). The disappearance of *T. novaezealandiae* during January to May and reappearance in June in both years at Okoromai Bay site is a unique situation for the site. The possible explanation of this phenomenon would be the migration of *T. novaezealandiae* from refugia where it finds shades and colder temperature in the stream or nearby waters. However, *T. novaezealandiae* occur throughout the year in other east coast sites as well as Kakamatua on the west coast, with their year-round breeding. Therefore, seasonal abundance of *T. novaezealandiae* differs among sites, and it may be attributed to the site-specific factors.

Considerable seasonal variation in abundance of *T. chiltoni* is reported for Kakamatua populations. As a generalisation, two recurring seasonal peaks in abundance were apparent: during winter, and again during spring to early summer; during late summer and autumn mysid abundance generally decreased. This is similar to North Island study (Kirk, 1983), findings for *T. chiltoni* populations from the Waikato River, which showed the highest abundance in late winter and spring and lowest in summer. However, the North Island results contradicted with the research undertaken in South Island, where mysid abundance reached maxima in summer, with the decrease in abundance towards winter (Jones et al., 1989; Lill, 2011; Bierschenk et al., 2008). Seasonal differences in maximum abundance of *T. chiltoni* may well be a function of a latitudinal variation in temperature (Mauchline, 1980; Wittmann, 1984; Baldo et al., 2001) between these two geographic extremes. Due to latitudinal differences, South Island (Latitude 45.1527° S, 169.8926° E) summer temperatures almost identical to spring temperatures in Auckland (latitude 36.8485° S, 174.7633° E) and winter temperatures are very low compared to North Island. North Island maximum summer temperatures recorded during the study is 25°C. This gives the opinion of that *T. chiltoni* population avoid extreme temperatures (high or low).

The environmental parameters vary over time within each site (and between sites). This is important as estuaries are transition environments with strong environmental gradients that often determine species distribution. In addition, these environmental parameters determine the availability of food as well as appearance of other faunal species competing for the same habitat. This may lead to biological factors (other than environmental factors) to become operative in the sites and these biological factors also are likely to be contributing to the fluctuations in the mysid abundance. Seasonal variations in the abundance of *T. chiltoni* populations at Kakamatua seem to be multi-factorial. During the extensive breeding periods, from winter to early summer, there were peaks of species abundance. The decline of mysid abundance during summer to autumn could be discussed in relation to the increase in the fish and their migration. The predation of mysids by the fishes (Webb, 1973; Griffiths, 1976; Hayes & Rutledge, 1991; James & Unwin, 1996) may be an important biological factor. This supported by the finding of the trophic analysis using stable isotopic analysis, concluded that *Galaxius maculates* predation on mysids at this site (Punchihewa & Krishnarajah, 2013b). There were evidences that extensive fish migration to inland waters and as well as upstream and downstream migrations (McDowell & Elton, 1980; McDowell et al.,1994) took place during summer to autumn (personal observations). It was evident from correlation analysis that site, stream width, vegetation cover and soil condition of the substratum also influence the abundance and distribution of mysid species. Changes in abundance of mysids at Kakamatua site over seasons may reflect small scale migration within the stream due to one or more factors.

Another possible explanation that can be put forward to explain the decrease in the mysid abundance in the study sites could be the increase of the temperature during summer. The increased temperatures could cause a lowering of the survival of mysids (Rudstam et al., 1999; Yamada & Yamashita, 2000; Fockedey et al., 2006), thus leading to a decline in *T. chiltoni* abundance during late summer to autumn for which high temperatures were recorded for the site. However, seasonal variation of temperature may indirectly influence through other environmental parameters, for instance increase in temperature lead to increased evaporation which in turn cause an increase in salinity.

During two years survey, it was apparent that mysid abundance was significantly higher in Kakamatua compared to the other five sites in Auckland region. Among the other sites, the prominancy of this site was due to the larger size of the water body and associated mature and dense riparian vegetation sheltering the edge of the stream, which may provide micro habitats to meet the conditions of their habitat requirement. At summer temperatures, it was observed that mysids were abundant around the shady banks of the stream, as the observation made by Chapman and Lewis (1976). Unavailability of brooded females at Kakamatua site during late summer and autumn is an important point for concern. However, the largest individuals collected during June to December indicated that they were born during summer and autumn (Jan. to May). It is reflected that these summer and autumn cohorts probably migrate within the stream to avoid the unfavourable conditions prevailing in the study site (during Jan. to May) and they return to their original habitats when conditions become favourable (during June). This is suggested that Auckland mysids are avoiding higher temperatures. The largest individuals always recorded in spring may be due to the intermediate temperatures is more favourable for their survival and development

Cart results show that *T. novaezealandiae* occurred within a wider range of salinity than *T. chiltoni* and also agree with that *T. novaezealandiae* has wider geographical distribution due to wider salinity tolerances (Punchihewa & Krishnarajah, 2013a). Therefore, it's clear that salinity is a key distributional factor for both *Tenagomysis* species. Finally, it was evident that temperature, salinity and site-specific factors (stream width, marginal vegetation and soil condition influence the distribution of mysid species.

Conclusion

Tenagomysis chiltoni showed a considerable seasonal fluctuation while seasonal patterns of *T. novaezealandiae* were less apparent and it differs among sites. With the combinations of physical factors (site, width of the stream, marginal vegetation cover and soil condition of the substratum), chemical factors (salinity and temperature) and biological factors (fish predation) influence the species distribution and abundance. Kakamatua Stream supported higher mysid abundance, compared to other sites due to its size of the water body and dense riparian vegetation bordering the stream, which providing suitable habitats for mysids. The lack of clear pattern due to the different sizes of the water bodies and sample size might change accordingly.

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