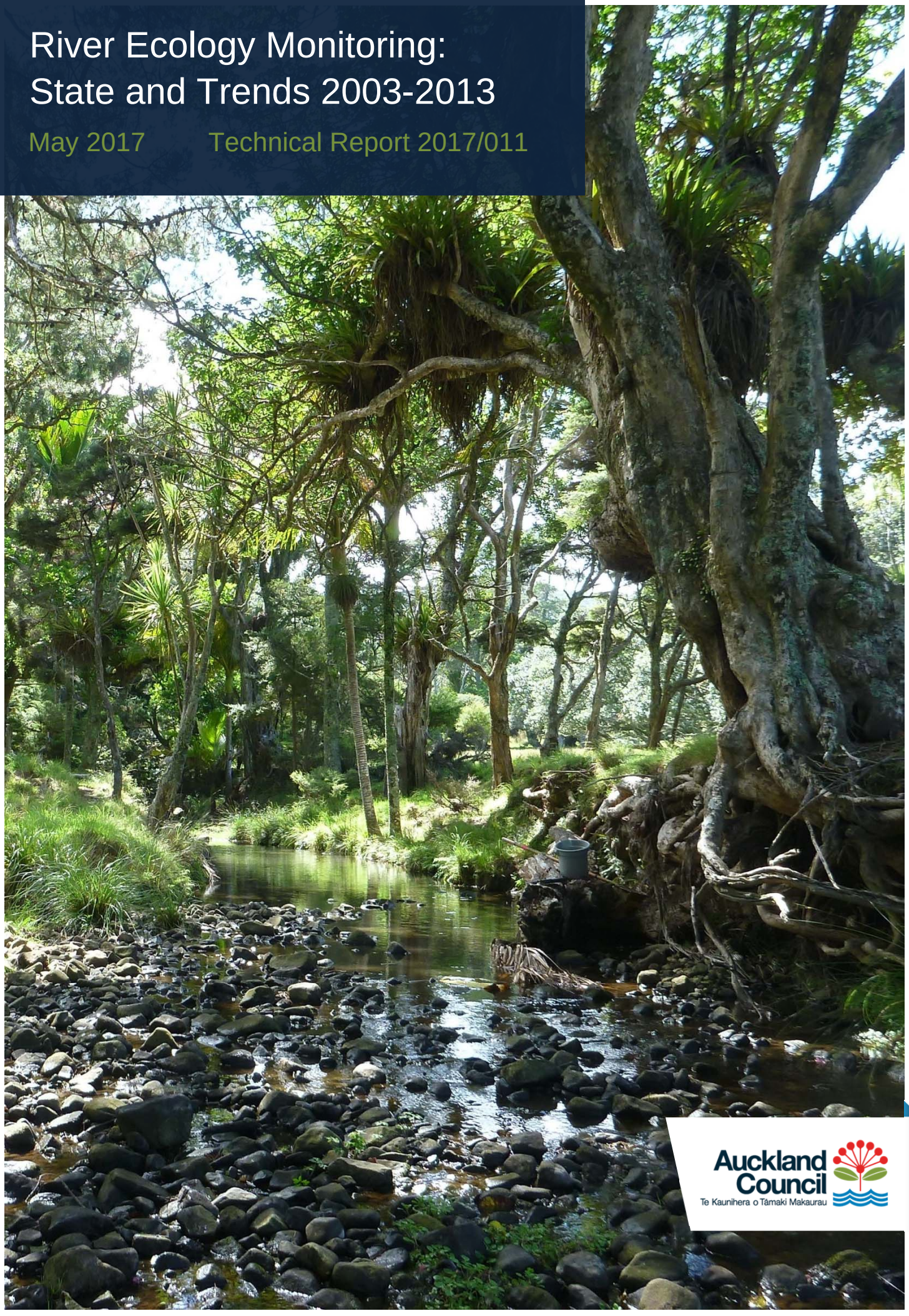
River Ecology Monitoring: State and Trends 2003-2013

May 2017 Technical Report 2017/011



Auckland Council
Te Kaunihera o Tāmaki Makaurau

River Ecology Monitoring: State and Trends 2003-2013

May 2017 Technical Report 2017/011

Auckland Council
Technical Report 2017/011
ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-1-98-852922-6 (Print)
ISBN 978-1-98-852923-3 (PDF)

This report has been peer reviewed by the Peer Review Panel.
Review submitted on 5 December 2016 Review completed on 5 May 2017 Reviewed by two reviewers
Approved for Auckland Council publication by: Name: Dr Lucy Baragwanath Position: Manager, Research and Evaluation (RIMU)
Name: Simon Tredgett Position: Manager, Environmental Monitoring, Research and Evaluation (RIMU)
Date: 5 May 2017

Recommended citation

Neale, M.W., Moffett, E.R., Hancock, P., Phillips, N and Holland, K (2017). River ecology monitoring: state and trends 2003-2013. Auckland Council technical report, TR2017/011

River Ecology Monitoring: State and Trends 2003-2013

Martin Neale
Emma Moffett
Peter Hancock
Research and Evaluation Unit (RIMU), Auckland Council

Ngaire Phillips
Streamlined Environmental

Kristi Holland
Research and Evaluation Unit (RIMU), Auckland Council

Executive summary

Auckland Council's River Ecology Monitoring Programme (REMP) collects macroinvertebrate data annually to assess stream ecological health. The programme is also a state of the environment (SOE) monitoring network that helps with better understanding of Auckland's freshwater stream ecosystems and contributes to council's environmental reporting for the Resource Management Act 1991 (RMA), the Auckland Unitary Plan, and the National Policy Statement for Freshwater Management (NPSFM). This report presents an assessment of the current ecological state of Auckland's streams from 2011 to 2013 and an analysis of trends from 2003 to 2013.

Across Auckland 48 per cent of sites had excellent or good and 30 per cent had poor stream ecological health from 2011 to 2013. Auckland's urban streams had the worst ecological health of any land-cover category; and were often rated as fair or poor according to their Macroinvertebrate Community Index (MCI) scores. Urban sites, Puhinui LTB and Otara LTB, had the lowest ecological health scores (<80 MCI), while reference sites, Konini and Milne, had the highest ecological health scores (>120 MCI).

Regionally, taxon richness increased while MCI decreased from 2003 to 2013. Stream health at the 'extreme end' of the scale, the 5th percentile, increased over time. As these were mostly urban streams, this indicated an improvement in urban stream health. However, there was also evidence of MCI values worsening at reference sites, in particular the streams West Hoe and Wekatahi demonstrated significant decreasing trends.

Exotic forestry sites had good or excellent ecological health; however, their health is tightly linked to re-forestation and clear felling cycles. Long-term trends indicate that initial disturbance effects last approximately two years, with full recovery taking up to 12 years.

Restoration projects across the region have shown mixed results, with positive ecological trends (MCI) at the Vaughan Lower site, but decreasing trends at Lucas Creek. Increasing land-cover intensity or low recruitment rates may be limiting restoration success at Lucas Creek. Continuing to monitor such sites in an effort to understand what drives successful resoration will be a priority for Auckland Council.

Table of contents

List of figures

List of tables

1.0 Introduction

1.1 River Ecology Monitoring Programme (REMP)

The Auckland Council collects macroinvertebrate data annually as part of the River Ecology Monitoring Programme (REMP). This programme began in 1999 and was initially designed to support the development of national sampling protocols (Stark et al., 2001; Maxted et al., 2003) and soft bottom stream reporting indices (Stark and Maxted, 2004; Stark & Maxted, 2007). This programme also contributes to reporting on the state of the Auckland environment, assisting with council's environmental reporting obligations for the Resource Management Act 1991, the Auckland Unitary Plan, and the National Policy Statement for Freshwater Management.

Following the development of standard sampling protocols, the programme entered a phase of annual data collection from a range of sites to identify the state of, and trends in, the ecological health of Auckland's streams. This is consistent with the approach to monitoring stream ecological health undertaken by numerous councils throughout New Zealand, for example, Waikato Regional Council (Collier and Hamer, 2012), Northland Regional Council (Pohe, 2011), Horizons Regional Council (Stark, 2012) and Greater Wellington Regional Council (Perrie et al., 2012).

To date, the reporting for Auckland Council's monitoring programme has been limited to 'state' analysis due to the short duration of data collection. This reporting includes a summary from the 41 sites used in the development of soft bottom reporting indices (Maxted, 2005) and an in-depth state analysis of macroinvertebrate communities (Moore & Neale, 2008).

Given the data collection and processing methods for this programme have been stable since 2003; there is now a sufficiently long data record to undertake an analysis of how the invertebrate communities have changed over time at the sites in the programme. Hence, this report provides the first 'trend' analysis of Auckland Council's river ecology monitoring dataset, together with an updated assessment of the state.

The state analysis used the invertebrate data to answer the question 'what is the current health of monitoring sites in the region'? The state analysis focussed on the most recent three years of data (2011-2013) to provide an assessment of the current state.

While an assessment of the state of river health is a useful exercise, it is often more informative to know whether the state is changing over time. Therefore, trend analyses were used to investigate whether the health of monitoring sites were improving, deteriorating, or stable over the then year period from 2003 to 2013. These analyses were undertaken at a range of scales, including the region as a whole, across catchment land-cover categories and individual sites.

1.2 The use of freshwater invertebrates in biological assessment

Many species of aquatic insects, crustaceans, molluscs, worms and other invertebrates (also known as “macroinvertebrates”) live in rivers and streams. These freshwater invertebrates have been used extensively for the biological assessment of aquatic ecosystems since the early 1900s (Metcalfe, 1989; Cairns & Pratt, 1993). While other biological groups (such as fish, algae and plants) are used in some biological monitoring programmes, a clear preference for the use of invertebrates has emerged (Hellawell, 1977; Rosenberg & Resh, 1993). The ecology of invertebrates is well suited to this role as a biological assessment tool for the following reasons:

- Invertebrates are ubiquitous and abundant in most freshwater habitats
- Sampling procedures are well developed, relatively easy to apply and inexpensive
- Comprehensive keys are available allowing relatively easy identification
- Invertebrate communities are relatively heterogeneous (species rich) offering a spectrum of potential responses to environmental stresses
- Many invertebrates are relatively sedentary and are therefore representative of local condition
- Many invertebrates have relatively long life cycles (commonly months to years) and consequently provide an integrated record of temporal changes in environmental quality.

As a result of a combination of these characteristics, invertebrates act as continuous indicators of the environment they inhabit. In contrast, other biological groups possess some, but not all, of these important attributes (Metcalfe, 1989). The complex taxonomic information that is generated from invertebrate samples is commonly summarised into indices. The use of indices aids communication of complex information to non-experts and allows for relatively quick comparisons among numerous sites by coping with differences in species composition.

The most commonly used freshwater biological index in New Zealand is the Macroinvertebrate Community Index (MCI) (Stark, 1985). The MCI method assigns a score to each invertebrate found at a site based on its sensitivity to environmental stress, for example organic enrichment; the overall MCI score for a site is based on the mean score for all the invertebrates found. Other indices applied in this report are the number of MCI taxa (taxon richness) and %EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness, which represents three orders of pollution sensitive invertebrates.

2.0 Methods

2.1 Site network

The composition and number of sites in the monitoring programme has varied from year to year as the programme has been adapted to meet a range of objectives. In total, 100 different sites were sampled between 2003 and 2013, with the number of sites sampled in any particular year ranging from 9 in 2003 to 88 in 2012 and 2013 (Figure 1).

The sites in the programme have been selected based on professional judgement and to meet specific criteria as follows:

- Providing for the effectiveness monitoring of freshwater management practices
- Increasing the coverage of under-represented land-cover categories present in the region
- Providing geographically representative monitoring for the region, particularly in relation to the Local Board areas created by the Auckland local government reforms of 2010
- Co-ordinating monitoring activity to collect multiple data types at the same location (i.e. water quantity, water quality, and ecology).

In this report, sites with data collected in 2011, 2012 and 2013 were used for state analysis (n=71) (Figure 2). A subset of these sites with at least 10 years of data (n=51) were used for trend analysis.

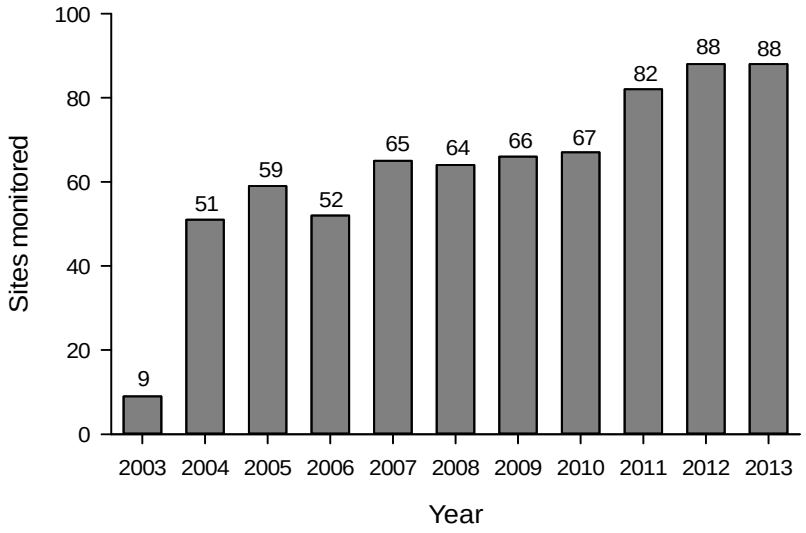


Figure 1: Number of sites sampled for the river ecology programme annually since 2003.

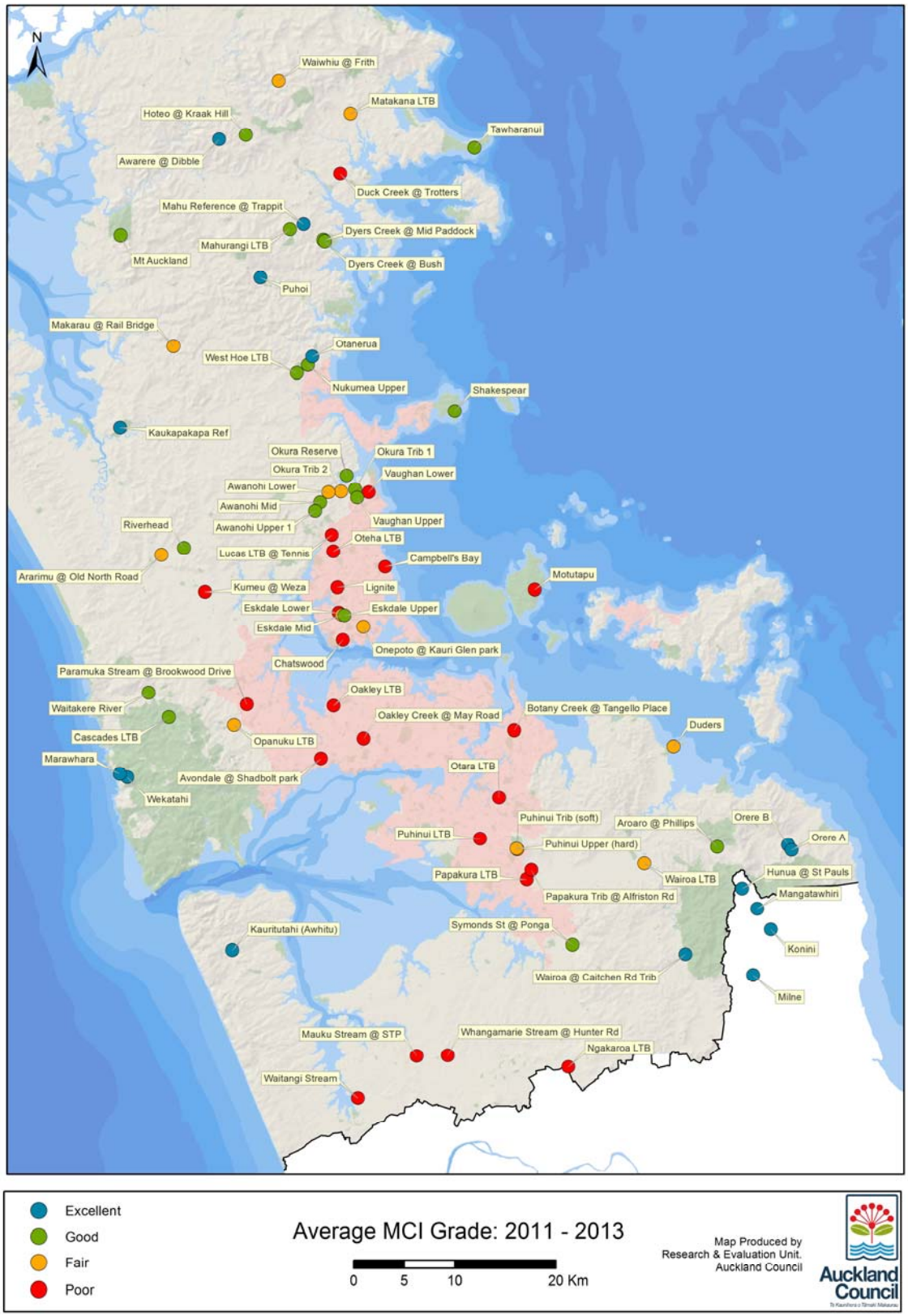


Figure 2: Distribution of River Ecology Monitoring sites (n=71). Sites are coloured according to their average MCI scores over the 2011-2013 period.

2.2 Sampling method

All macroinvertebrate samples were collected by Auckland Council staff using standard New Zealand protocols (Stark *et al.,* 2001). Hard-bottom streams were sampled using protocol C1, where a fixed area of stream bed is disturbed upstream of a hand held net. Soft-bottom streams were sampled using protocol C2, where a fixed area of stable substrate (woody debris, macrophyte or bank margins) is sampled by dislodging organisms into a hand held net. Sampling protocols are such that the same m^2 areas is sampled by the C1 and C2 methods. Samples were collected annually in summer (January - March).

Samples were preserved in 70% ethanol in the field and subsequently processed and identified in accordance with protocol P1. Quality control was undertaken in 10% of samples each year using protocol QC1 (Stark *et al.,* 2001). Samples collected up to and including 2007 were processed by the Cawthron Institute, and samples collected from 2008 to 2013 were processed by Landcare Research. Quality control was undertaken by NIWA in all years.

2.3 Land-cover categories

Using catchment scale land-cover data from Land Cover Database 3 (LCDB3) sites were categorised into five major land-cover categories; reference, exotic forestry, rural low intensity, rural high intensity and urban.

The five land-cover categories were based on analysis of the LCDB3 data and defined as: 1) reference – having native land-cover greater than 95 per cent of the catchment , 2) exotic forestry – having exotic forestry land-cover greater than 80 per cent in the catchment, 3) rural low intensity – having greater than 60 per cent forest and less than 2 per cent urban in the catchment, 4) rural high intensity – having less than 60 per cent forest and or more than 2 per cent urban in the catchment, 5) urban – having greater than 7 per cent urban land-cover in the catchment (Table 1).These categories were assigned through professional judgement, based on similar approaches used throughout New Zealand.

Table 1: Percentage of sites in each land-cover category in 2013, sites are limited to those used in this report. *There is only a single 'Rural' category for the proportion of rivers within each land-cover category.

Primary land-cover category	Percentage (%)	Number of sites	Number of soft substrate sites	Number of hard substrate sites	River percentage (%)
Reference	19.7	14	7	7	21
Exotic forestry	9.9	7	4	3	8
Rural low	15.5	11	7	4	63*
Rural high	29.6	21	19	2	
Urban	25.4	18	15	3	8

2.4 Data analysis

2.4.1 Data processing

Raw macroinvertebrate data are stored in the Auckland Council's ecological database, *Ecobase*. Due to taxonomic changes and differences in identification level among sample processors, the data were standardised prior to analysis to ensure all indices and analyses were based on a taxonomically consistent dataset. This processing involved reducing the level of identification to the 'MCI level' and removing non-MCI taxa from the analysis. A sample from Awanohi Upper 1 in 2005 had taxa richness of only four, but a MCI score of 168.5. Based on this very unusual result, this sample was removed for all analyses, as this data point was considered to be an outlier.

The following indices were calculated and used in this report:

- Taxon richness (number of MCI taxa)
- Macroinvertebrate Community Index (MCI)
- %EPT richness (percentage of total taxa number that are Ephemeroptera, Plecoptera, and Trichoptera).

2.4.2 State analysis

The state analysis used a network of 71 sites across the Auckland region sampled from 2011 to 2013 (Figure 2). Mean, minimum, and maximum values were calculated for all three macroinvertebrate indices (taxon richness, MCI, %EPT richness) for the region as a whole, for each land-cover category and per site. The percentage of sites falling within each MCI ecological quality class were also summarised regionally and by land-cover category.

Macroinvertebrate index data were plotted against land-cover category and substrate type, where the sites had a hard:soft substrate split of 27%:73% (Table 1). Differences between land-cover categories were determined using a two-way Analysis of Variance (ANOVA). If an interaction between land-cover categories was found to be significant ($p < 0.05$), a Tukey's range test was undertaken. These interactions related to similarities in substrate type between land-cover categories, where similar substrates in different land-cover categories created interactions between those land-cover categories. Data were analysed using Datadesk 6.0 and plotted using SigmaPlot 12.0.

Inter-site differences in macroinvertebrate indices were displayed with boxplots using data from 2011 to 2013.

2.4.3 Trend analysis

Regional and land-cover trends from 2003-2013 were analysed using Spearman rank correlation coefficients (Statistica v12, STATSoft). This method uses ranks to calculate the correlation between variables and is robust against assumptions of linearity and normality. The strength of the relationship between year and macroinvertebrate index are described with a correlation coefficient (r_s). Coefficients range between +1 and -1, where an r_s of +1 indicates a strong positive relationship (e.g. an increasing MCI), and an r_s of -1 indicates a strong negative relationship. Relationships were considered significant where $p < 0.05$.

Regional trends for all macroinvertebrate indices were assessed by median values and 95th and 5th percentile values. MCI trends within each land-use category were also plotted.

At each site trends in taxon richness, MCI, and %EPT richness were assessed using the Mann Kendall Trend test (Time Trends V3.2, NIWA, New Zealand), one of the most commonly used non-parametric statistical methods of detecting trends. The Mann-Kendall test involves computing a statistic S, which is the difference between the number of pairwise slopes that are positive, minus the number that are negative.

If S is a large positive value, then there is evidence of an increasing trend in the data. If S is a large negative value, then there is evidence of a decreasing trend in the data. Trends are described using Sen Slope values, which are the median slope of all possible pairs of values (Smith et al. 1996) and indicates the magnitude and direction of the relationship. The Sen Slope is similar to a regression line, and represents the average change through the course of the data record. The Sen Slope values are in the same units as the data analysed. Statistical significance is indicated by P-values for the analysis of the long-term datasets, determined at $P < 0.05$.

3.0 Results

3.1 Ecological state

3.1.1 Key findings

- Between 2011 and 2013, all reference sites had good or excellent ecological health based on MCI scores, compared to 19 per cent of rural high intensity sites and 6 per cent of urban sites
- Sites in urban catchments had the lowest mean taxon richness, MCI, and %EPT richness
- Ecological health was good in catchments dominated by exotic forestry. Two reference sites, namely Milne and Konini, had the highest ecological health in the Auckland region based on MCI scores, possibly due the isolated nature of these two sites, which are located in the Hunuas
- Two urban streams, namely Puhinui and Otara had the lowest ecological health in the Auckland region based on MCI scores, possible due to urban stream syndrome.

3.1.2 Regional assessment

Regionally, 48 per cent of sites were classed as excellent or good and 30 per cent as poor based on mean MCI scores (Table 3). All reference sites were classed as excellent or good compared to only 19 per cent of rural-high intensity sites and 6 per cent of urban sites. While, 29 per cent of rural high intensity and 83 per cent of urban sites had poor ecological health.

The mean taxon richness for all sites was 25, ranging from a high of 45 at the reference site Weketahi, to a low of 7 at the high intensity rural site Okura Trib 2. Ecological health was good in catchments dominated by exotic forestry, with a mean taxon richness of 28 and MCI of 118.5. This was also true of sites with low intensity rural land cover, with a mean taxon richness of 26 and MCI of 108.2. Sites classed as having high intensity rural land-cover had fair ecologic health, with a mean taxon richness of 24.3 and MCI of 85.8. Unsurprisingly, ecologic health was excellent for sites in the reference category, with a mean taxon richness of 28 and MCI of 124.9, and poor for urban sites, with a mean taxon richness of 21 and MCI of 73.

All three of the invertebrate metrics had the highest mean values in reference sites compared with human-dominated land-cover sites (rural/urban) (Table 2).

Table 2: Summary of Auckland's stream ecological health from 2011-2013.

Site category	Metric	Taxon richness	MCI	%EPT richness
All sites	Mean	25	96.9	28.9%
	Min	7	45.7	0.0%
	Max	45	146.9	71.0%
Reference	Mean	28	124.9	48.2%
	Min	16	97.4	29.4%
	Max	45	146.9	71.0%
Exotic forestry	Mean	28	118.5	41.5 %
	Min	12	89.4	17.4%
	Max	39	138.1	61.8%
Rural low intensity	Mean	26	108.2	37.6%
	Min	15	72.2	22.2%
	Max	40	133.8	64.3%
Rural high intensity	Mean	24	85.8	22.9%
	Min	7	50.0	0.0%
	Max	41	119.3	54.2%
Urban	Mean	21	73.0	10.6%
	Min	12	45.7	0.0%
	Max	32	118.6	30.4%

Table 3: Percentage of river ecology sites which fall into MCI quality classes, thresholds are excellent > 120, good >100, fair >80, and poor <80 (Stark and Maxted, 2007).

Site category	Excellent	Good	Fair	Poor
All sites	23%	25%	22%	30%
Reference	71%	29%	0%	0%
Exotic forestry	57%	43%	0%	0%
Rural low intensity	18%	46%	27%	9%
Rural high intensity	0%	19%	52%	29%
Urban	0%	6%	11%	83%

3.1.3 Land-cover assessment

Increasing land-cover intensity, from native and exotic forests to rural and urban land cover, was associated with declines in taxon richness, MCI, and %EPT richness in Auckland streams (two-way ANOVA, $p < 0.05$) (Figure 3). Reference and exotic forestry categories ranked as excellent or good and did not differ significantly across all three indices. Urban streams consistently had the lowest values for all indices and were ranked as fair or poor according to their MCI values.

Substrate type affected patterns in macroinvertebrate health, but its effect was not consistent across land-cover categories or macroinvertebrate indices (Figure 3a). For example, the pattern of declining taxon richness with increasing land-cover was evident for hard bottomed streams (n=19) but not soft bottomed streams (n=52).

3.1.4 Site specific assessment

Taxon richness, MCI, and %EPT richness were lower at sites with intensive land-cover categories (i.e. urban, rural low/high) (Figures 4-6).

The reference sites Milne and Konini had the highest MCI and %EPT values, reflecting excellent ecological health (Figure 5 and 6). Stream health at these sites was closely followed by the exotic forestry sites Orere A and B which were also rated excellent according to their MCI scores. Cascades was the lowest ranking reference site with a MCI score varying from fair (92) to excellent (145) over the 2011-2013 period. Based on MCI score the lowest ranking of the rural sites, regardless of intensity, was Vaughan Lower. The lowest scoring site for all metrics was the urban site, Puhinui.

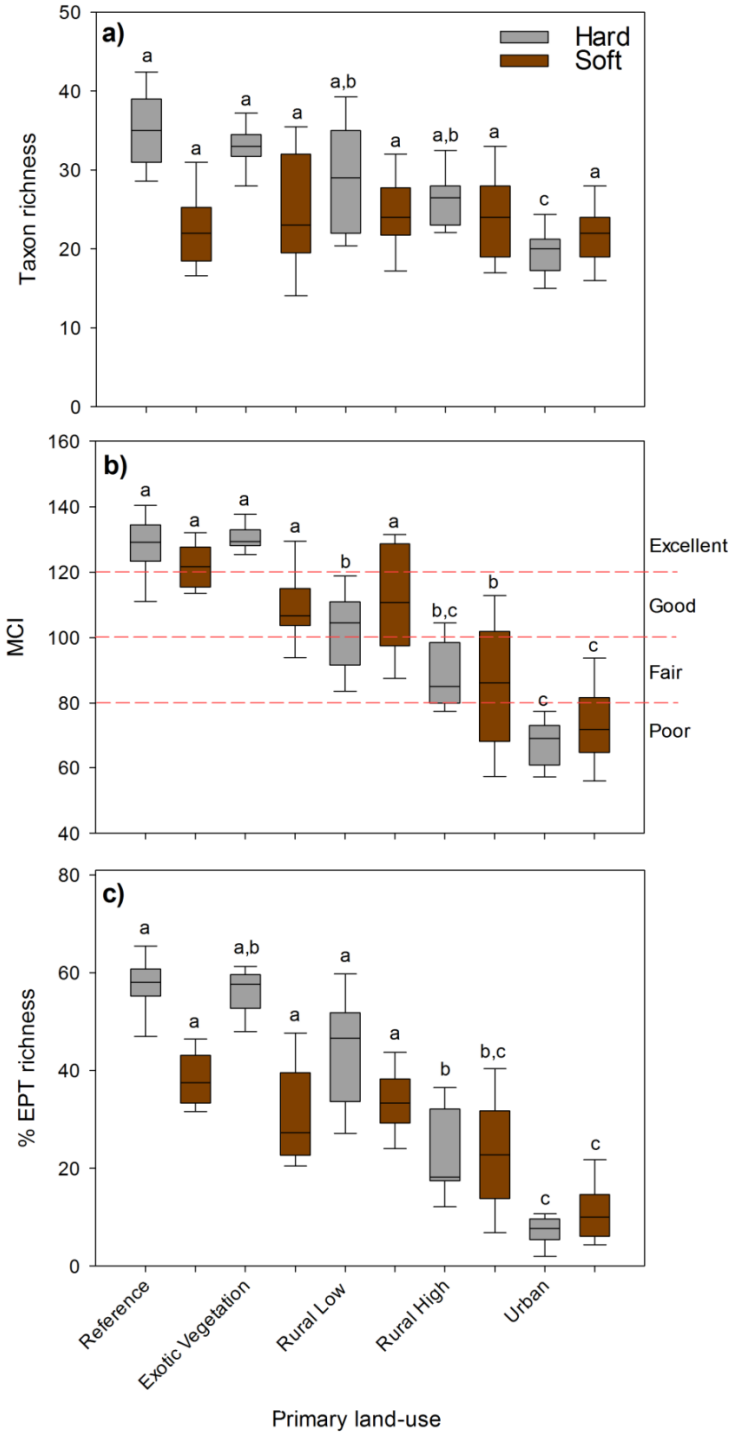


Figure 3: Boxplots showing a) taxon richness, b) MCI, and c) %EPT richness across land-cover categories, data are presented by substrate type (hard bottomed n=19, soft bottomed n=52). MCI quality thresholds are noted on graph b (Stark and Maxted, 2007). Outliers have been omitted from plots. Matching letters indicate significant differences between land-cover categories.

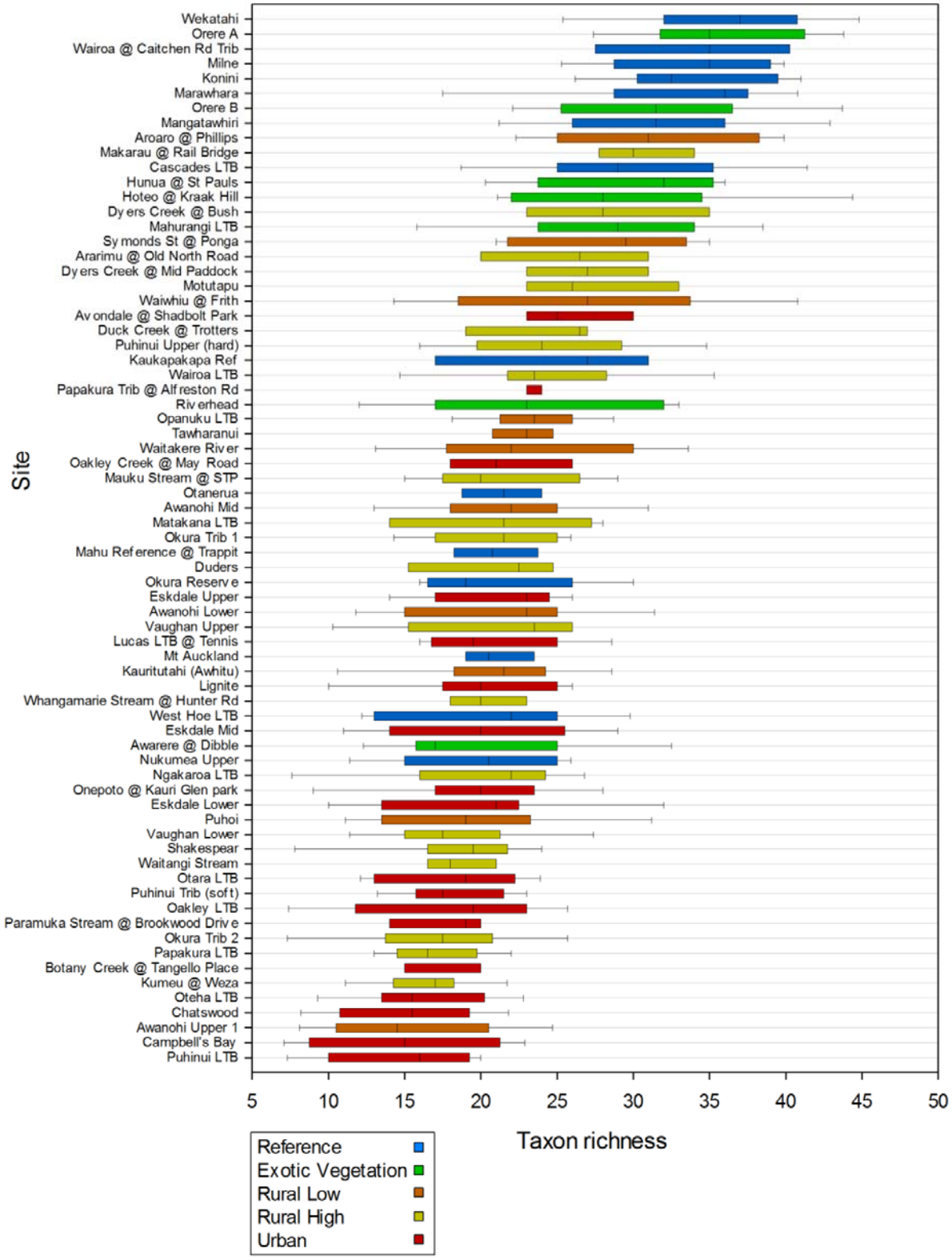


Figure 4: Boxplots of taxon richness across Auckland's 71 REMP sites. Data are from 2003-2013, sites are ordered by mean values. Land-cover is indicated by colour.

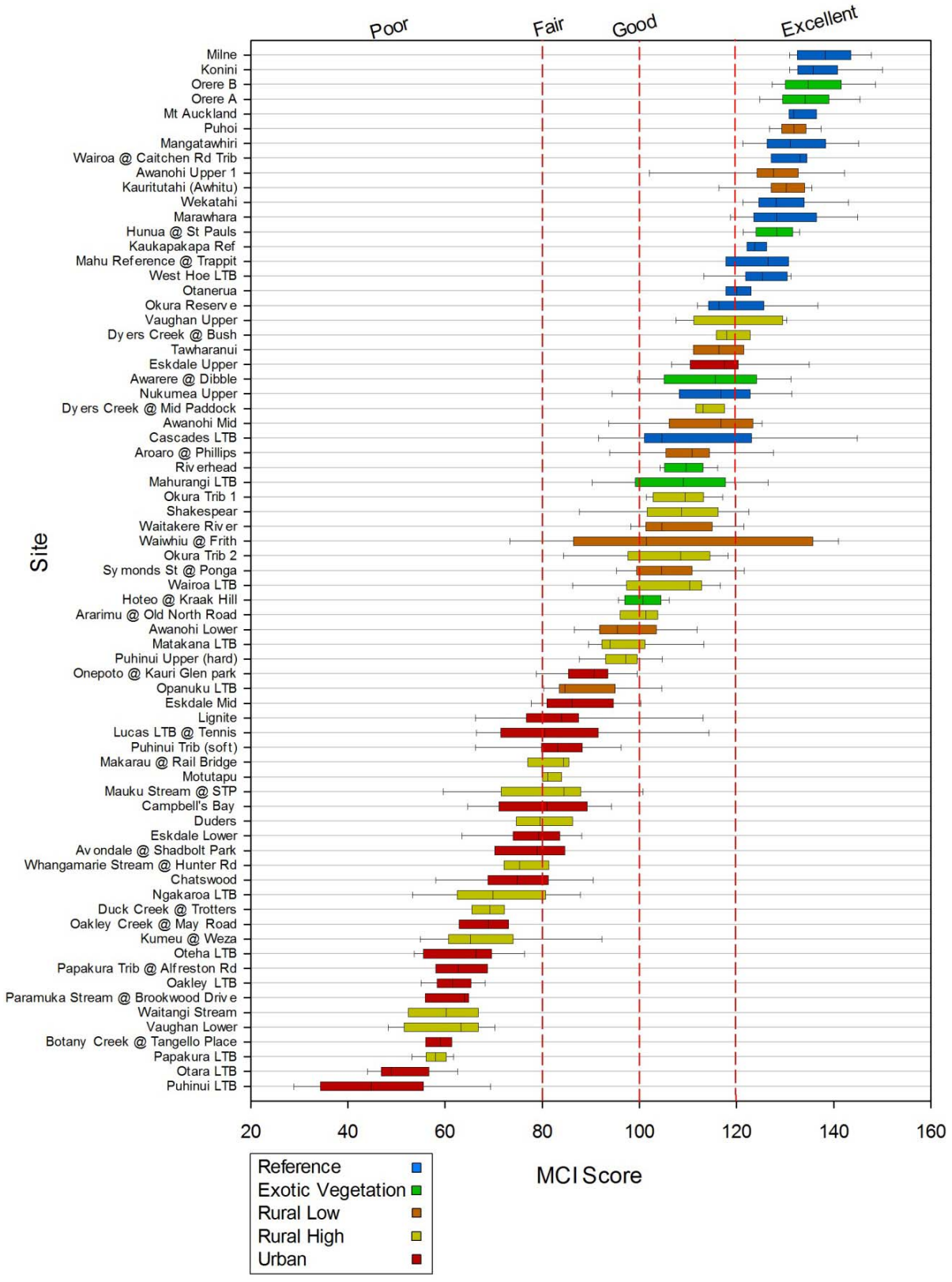


Figure 5: Boxplots of MCI scores across Auckland's 71 REMP sites. Data are from 2003-2013, sites are ordered by mean values. Land-cover is indicated by colour. MCI quality thresholds from Stark and Maxted (2007) are marked on the graph.

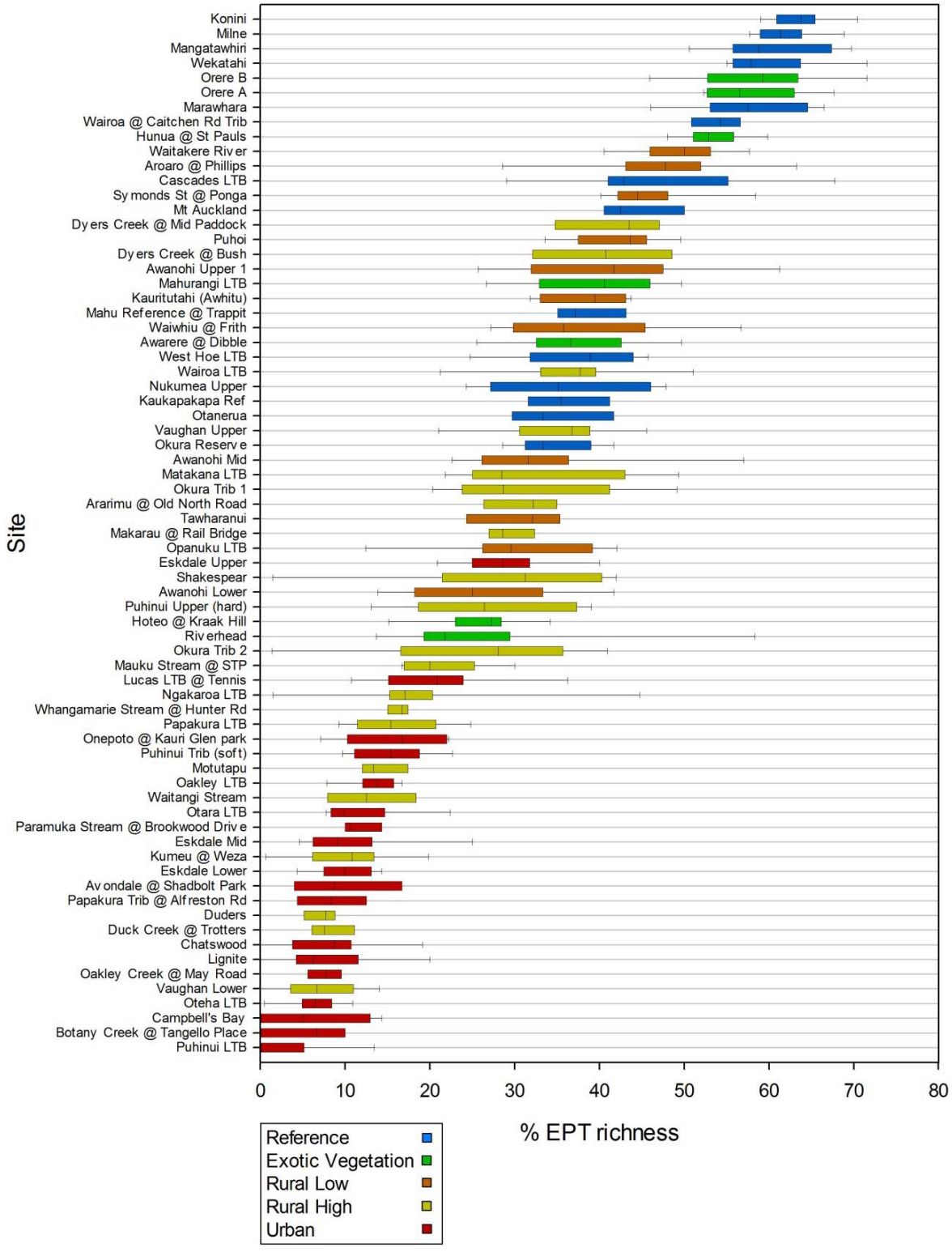


Figure 6: Boxplots of %EPT richness across Auckland's 71 REMP sites. Data are from 2003-2013, sites are ordered by mean values. Land-cover is indicated by colour.

3.2 Ecological trends

3.2.1 Key findings

- At a regional scale, taxon richness increased, whereas MCI scores generally decreased for Auckland streams from 2003 to 2013
- Median MCI values in reference and rural low intensity land-cover categories decreased over the 2003-2013 period, however median taxon richness in these land-cover types showed statistically significant increases
- MCI scores at urban sites, Puhinui and Oakley improved while scores at reference sites Wekatahi and West Hoe declined. This may be due to the fact that chance addition or removal of taxa from any site is more likely to cause an increase in MCI in a site with already very low MCI scores, and conversely cause a decrease in MCI at a high scoring site.

3.2.2 Regional trends

Regionally, taxon richness median values increased significantly from 2003 to 2013 (Table 4). Increasing richness values may be related to change in sample processor in 2008, where a stepwise increase is evident (Figure 7).

The MCI score decreased significantly for monitored sites across the region (Table 4; Figure 8). There were no significant regional trends for %EPT richness ($p > 0.05$) (Table 4; Figure 9).

The large changes in MCI and %EPT between 2003 and 2004 are likely due to changes in the site network. The network increased from 9 sites in 2003 to 51 sites in 2004, when a greater range of additional high and low scoring sites were added to the programme.

Table 4: Spearman rank correlation coefficients (r_s) for macroinvertebrate indices measured between 2003 and 2013 across the Auckland region. Significant values (p < 0.05) are in bold.

	5th percentile		50th percentile (median)		95th percentile	
Index	**r_s**	**p**	**r_s**	**p**	**r_s**	**p**
Taxon richness	0.35	0.28	**0.88**	**<0.0001**	**0.72**	**0.013**
MCI	-0.25	0.45	**-0.85**	**0.001**	-0.35	0.29
%EPT richness	-0.11	0.75	-0.52	0.102	-0.21	0.54

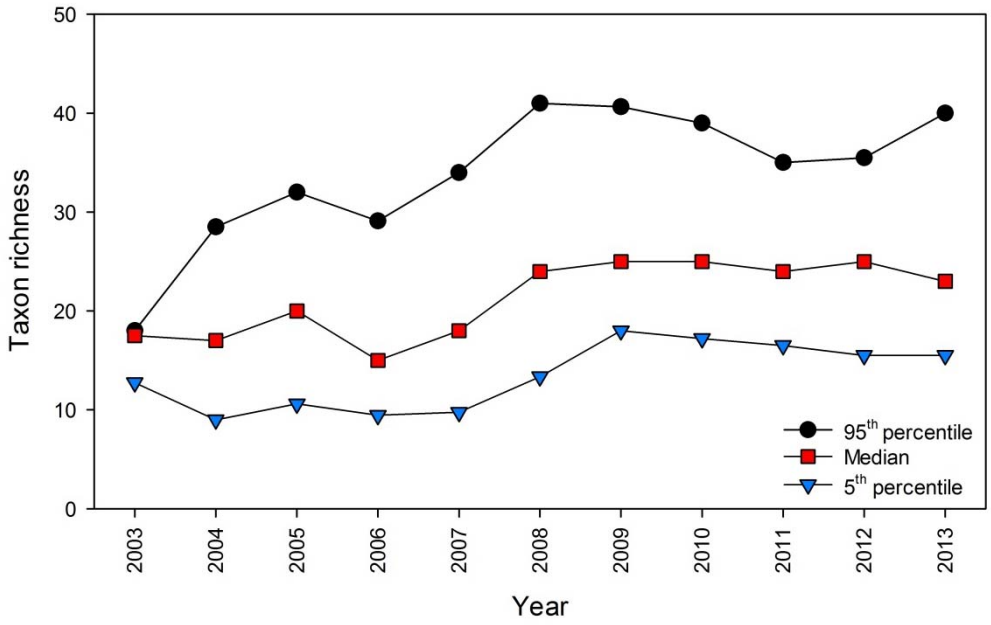


Figure 7: Taxon richness trends across Auckland from 2003 to 2013, median, best (95th percentile), and worst (5th percentile) data are shown. Median and 95th percentile values showed significant increasing trends ($p < 0.05$) (Table 4).

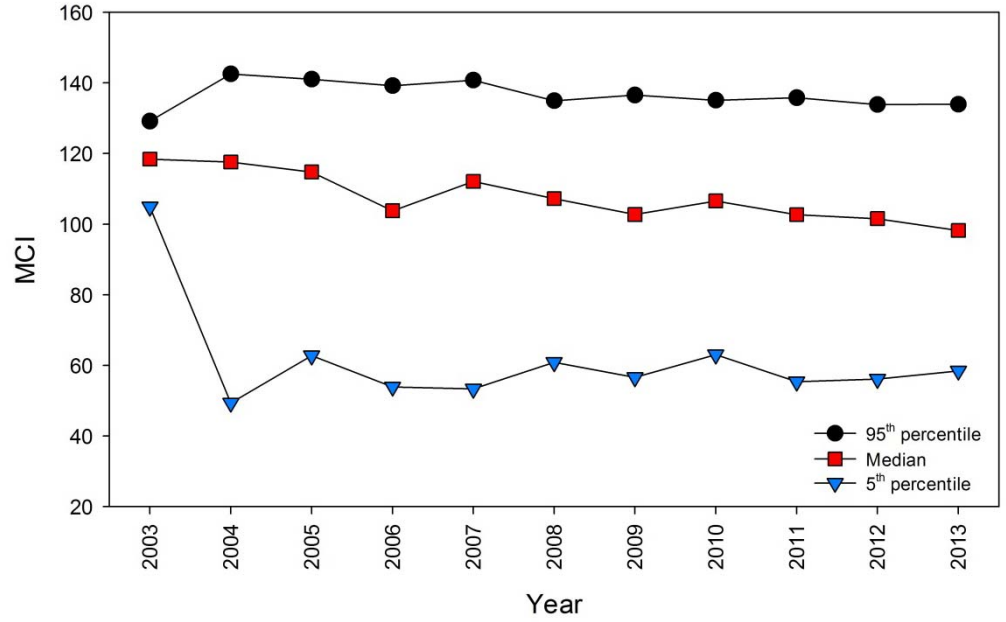


Figure 8: MCI trends across Auckland from 2003 to 2013, median, best (95th percentile), and worst (5th percentile) are shown. Median MCI scores showed a significant decreasing trend ($r_s = -0.85$, $p < 0.001$) (Table 4).

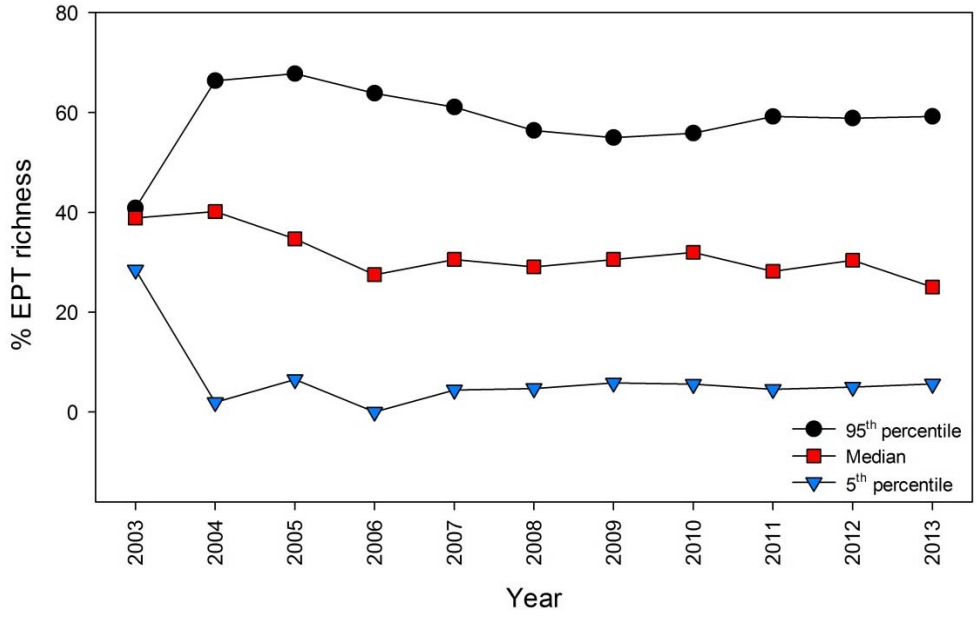


Figure 9: %EPT richness trends across Auckland from 2003 to 2013, median, best (95th percentile), and worst (5th percentile) are shown. Trends are not significant (p > 0.05).

3.2.3 Land-cover trends

Taxon richness increased for four of the five land-cover categories, with the exotic forestry the exception; trends were significant for median and 5th percentile values for four categories (Table 5). The 95th percentile trend was significant for rural low intensity and urban land-cover categories only.

Median MCI scores decreased in reference (Figure 10) and rural low intensity (Figure 12) land-cover categories (Table 5). There was also a significant decrease in the 95th percentile at exotic forestry sites (Figure 11). In contrast, MCI scores at low scoring urban sites improved over time, shown by a significant increase in 5th percentile values (Table 5; Figure 14).

There were no significant trends detected for %EPT richness (Table 5).

Table 5: Spearman rank correlation coefficients (r_s) for macroinvertebrate indices measured between 2003 and 2013 for each land-cover category. Significant values (p = <0.05) are in bold. N is the number of sites.

Land-cover	Taxon richness		MCI		%EPT richness		N
	r_s	*p*	r_s	*p*	r_s	*p*	
5th percentile							
Reference	**0.77**	**0.006**	-0.43	0.190	0.27	0.416	11
Exotic forestry	0.55	0.100	-0.08	0.829	-0.56	0.093	10
Rural low	**0.78**	**0.005**	-0.58	0.060	0.05	0.893	11
Rural high	**0.69**	**0.019**	0.05	0.894	-0.23	0.500	11
Urban	**0.84**	**0.002**	**0.78**	**0.007**	0.62	0.056	10
50th percentile (median)							
Reference	**0.96**	**<0.0001**	**-0.79**	**0.004**	0.23	0.492	11
Exotic forestry	0.58	0.080	0.26	0.467	-0.35	0.327	10
Rural low	**0.89**	**<0.0001**	**-0.91**	**<0.0001**	-0.57	0.066	11
Rural high	**0.65**	**0.029**	-0.26	0.433	-0.54	0.088	11
Urban	**0.90**	**<0.0001**	-0.15	0.676	-0.01	0.973	10
95th percentile							
Reference	0.41	0.214	-0.03	0.937	-0.15	0.650	11
Exotic forestry	-0.29	0.419	**-0.73**	**0.016**	-0.55	0.096	10
Rural low	**0.75**	**0.008**	-0.25	0.467	0.17	0.612	11
Rural high	0.07	0.840	-0.58	0.060	-0.54	0.087	11
Urban	**0.78**	**0.008**	-0.35	0.328	-0.39	0.260	10

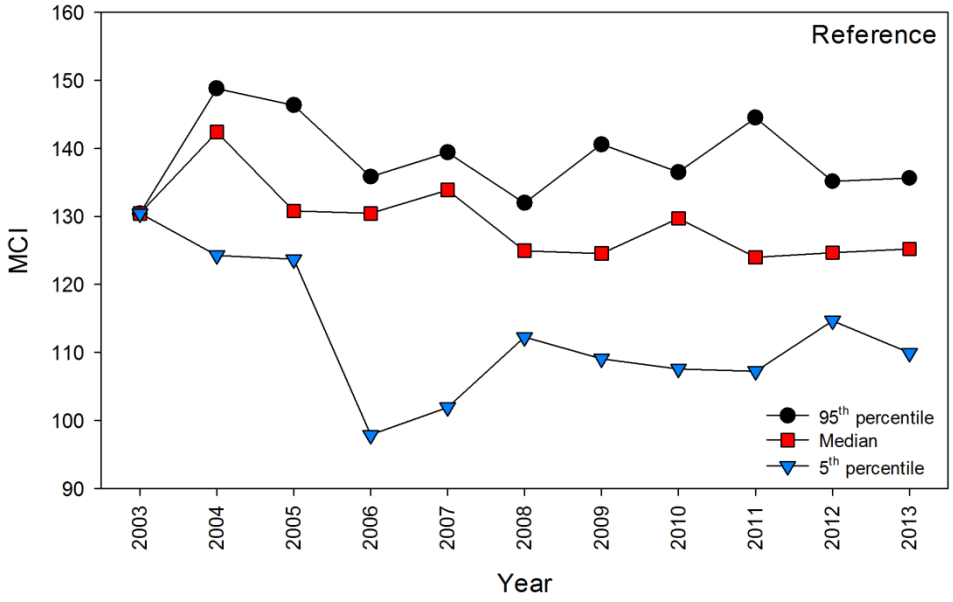


Figure 10: Reference MCI trends in Auckland from 2003 to 2013. Median, best (95th percentile), and worst (5th percentile) data are shown. Median MCI values demonstrated a significant negative trend (r_s = -0.79, p = 0.004).

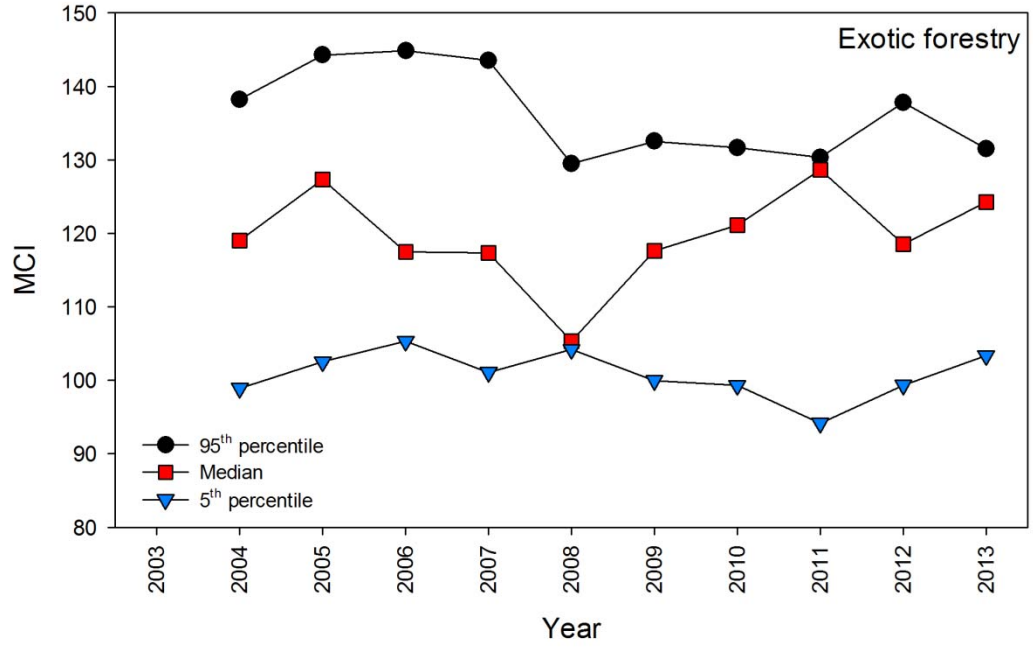


Figure 11: Exotic forestry MCI trends in Auckland from 2003 to 2013. Median, best (95th percentile), and worst (5th percentile) data are shown. 95th percentile MCI values demonstrated a significant negative trend (r_s = -0.73, p = 0.016).

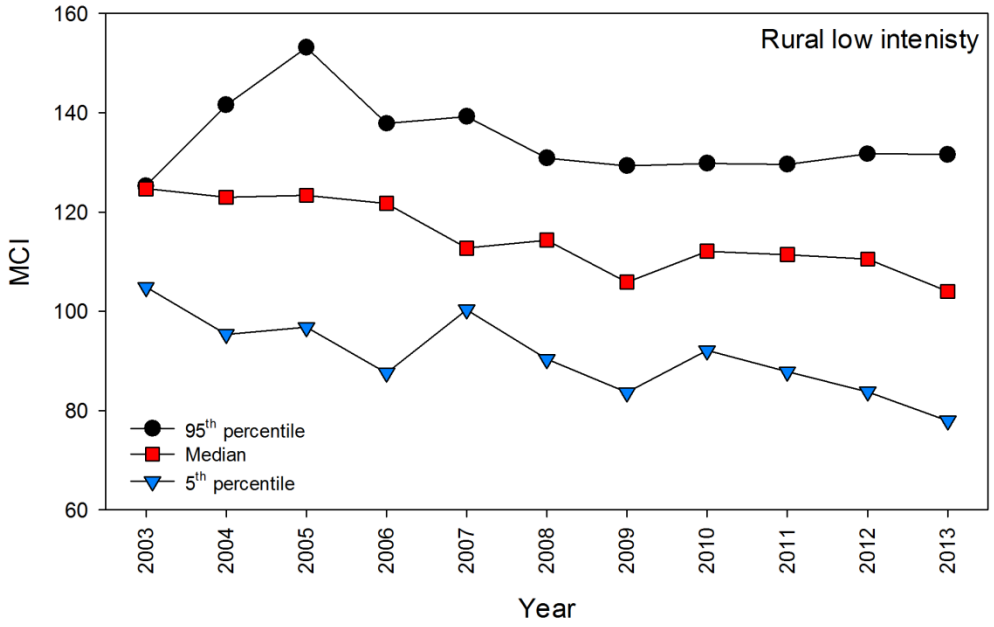


Figure 12: Rural low intensity MCI trends in Auckland from 2003 to 2013. Median, best (95th percentile), and worst (5th percentile) data are shown. Median MCI values demonstrated a significant negative trend (r_s = -0.91, p < 0.0001).

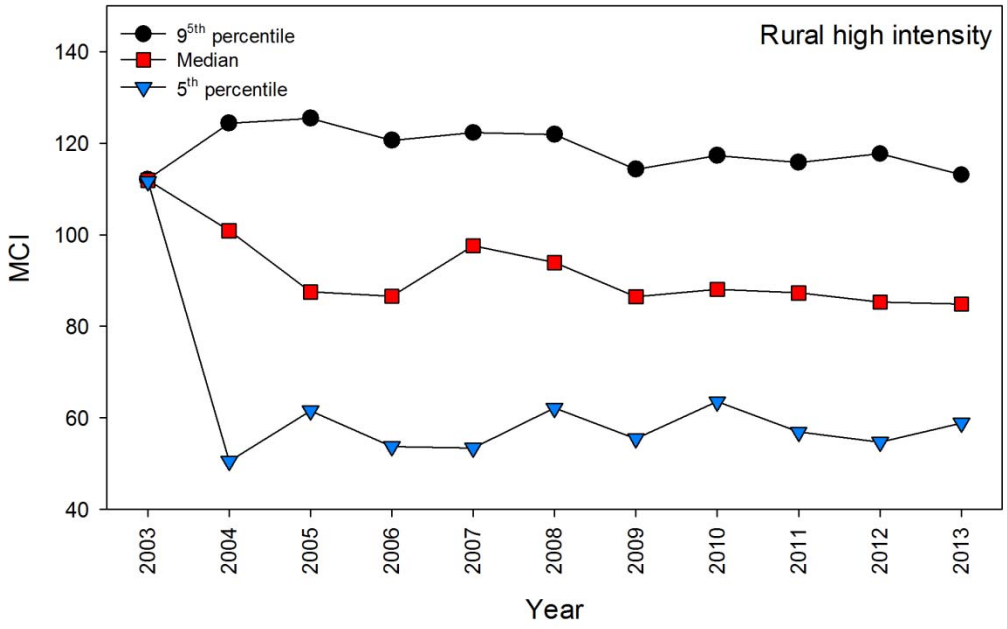


Figure 13: Rural high intensity MCI trends in Auckland from 2003 to 2013. Median, best (95th percentile), and worst (5th percentile) data are shown. Trends are not significant (p > 0.05).

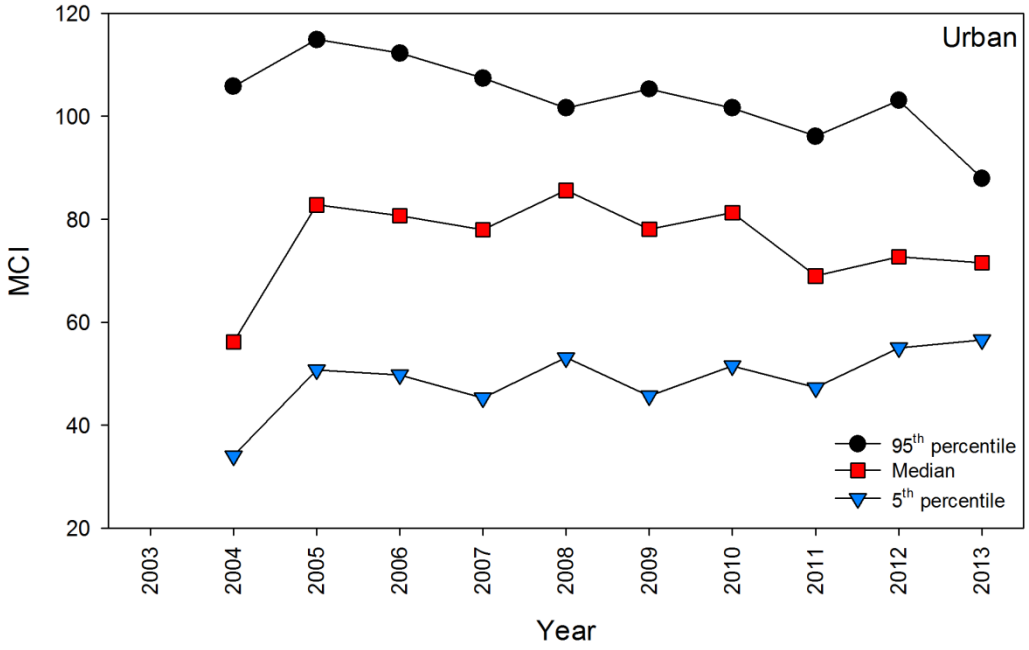


Figure 14: Urban MCI trends in Auckland from 2003 to 2013. Median, best (95th percentile), and worst (5th percentile) data are shown. 5th percentile MCI values demonstrated a significant positive trend (r_s = 0.78, p = 0.007).

3.2.4 Site-specific trends

The significant trends identified through the Mann-Kendall trend tests for taxon richness, MCI, and %EPT richness are presented in the following sections. Full results, including all non-significant results are in Appendices C-E.

3.2.4.1 Taxon richness

Taxon richness improved over time at 21 or the 51 sites listed in Table 6, consistent with the observed regional trend (Figure 7). There was no significant trend in taxon richness at the remaining 30 sites. There were no significant decreasing trends found at any of the 51 sites.

Table 6: Significant taxon richness results from Mann-Kendall trends tests.

Land-cover	Site	*p*	SEN Slope
Reference	West Hoe LTB	0.004	1.61
	Wekatahi	0.011	1.82
	Konini	0.02	1.01
Exotic forestry	Hunua @ St Pauls	0.02	1.19
	Mahurangi LTB	0.02	1.27
Rural low	Awanohi Lower	<0.001	1.66
	Aroaro @ Phillips	0.01	1.78
	Awanohi Upper 1	0.02	1.29
	Symonds St @ Ponga	0.029	1.17
Rural high	Matakana LTB	<0.001	1.87
	Wairoa LTB	0.006	1.10
	Vaughan Upper	0.014	1.69
	Okura Trib 1	0.02	1.02
Urban	Eskdale Lower	<0.001	2.25
	Chatswood	<0.001	1.66
	Onepoto @ Kauri Glen park	<0.001	1.51
	Puhinui LTB	0.002	1.42
	Campbell's Bay	0.01	1.74
	Eskdale Mid	0.02	1.77
	Oakley LTB	0.02	1.75
	Lucas LTB @ Tennis	0.02	1.28

3.2.4.2 MCI

Significant trends in MCI were observed at 17 sites, including an increasing MCI trend at 4 sites and decreases at 13 sites (Table 7). The majority of sites, (34 of 51), showed no significant trend in MCI score.

Monitoring sites at urban streams had the lowest individual MCI scores, with sites Puhinui Stream, Otara Creek, and Botany Creek recording the lowest ecological health in the Auckland region (MCI < 80). In particular Puhinui Stream was often ranked the lowest despite showing a positive increase in stream health over the past 10 years (Table 7). In contrast, the reference sites Milne and Konini in the Hunua ranges had the best ecological health in the Auckland region and were followed closely by exotic forestry sites Orere A and B (MCI >120).

The MCI score at West Hoe and Wekatahi (two reference sites) decreased significantly over time; however trend slope values are low indicating these changes may not be ecologically meaningful. Within the exotic forestry category one site showed an increase (Awarere @ Dibble) while another decreased (Orere B).These differences likely relate to the disturbance cycles seen within forestry categories, and is elaborated on in the case study section 4.3.1.

Of the seven rural sites with a significant trend, six showed a decline in MCI score, the exception being Vaughan Lower. The low sen slope value for this site may indicate that the trend is not ecologically significant. This data is discussed in the case study section 4.3.2. .

MCI trends at urban sites were mixed; with improving trends at Oakley and Puhinui, while trends at Lignite and Lucas worsened.

Table 7: Significant MCI results from Mann-Kendall trends tests.

Land-cover	Site	*p*	Slope
Reference	Wekatahi	<0.01	-1.75
	West Hoe	0.04	-0.99
Exotic forestry	Awarere @ Dibble	0.01	2.96
	Orere B	0.04	-1.67
Rural low	Awanohi Mid	0.01	-2.02
	Puhoi	0.01	-0.67
	Waiwhiu @ Frith	0.01	-7.53
Rural high	Kumeu @ Weza	<0.01	-3.00
	Matakana	0.01	-1.27
	Okura Trib 1	0.01	-1.28
	Okura Trib 2	0.01	-2.24
	Vaughan Lower	0.01	1.71
	Vaughan Upper	<0.01	-2.59
Urban	Lignite	0.00	-3.37
	Lucas	0.02	-3.16
	Oakley	0.01	0.95
	Puhinui	0.01	3.18

3.2.4.3 %EPT richness

Of the small number of significant trends in %EPT richness (8 of 51 sites), most were negative, indicating decreasing ecological health. The exception was Awarere @ Dibble (Table 8) which likely relates to this sites stage in the disturbance cycle of exotic forest streams. All %EPT richness trends have low slope values, indicative of small trend magnitude.

There was some concordance between %EPT and MCI trends, with six of the sites in Table 8 also showing corresponding changes in MCI scores over time (Table 7).

Table 8: Significant %EPT results from Mann-Kendall trends tests.

Land-cover	Site	*p*	Slope
Exotic forestry	Awarere @ Dibble	0.03	0.02
	Riverhead	0.03	-0.02
	Mahurangi LTB	0.04	-0.02
	Orere B	0.04	-0.02
Rural low	Waiwhiu @ Frith	0.01	-0.03
	Awanohi Mid	0.02	-0.02
Rural high	Okura Trib 1	0.01	-0.03
	Okura Trib 2	0.01	-0.04

4.0 Discussion

4.1 Current state

The state analysis, based on 2011 to 2013 data, showed that 48 per cent of monitored streams across Auckland had excellent or good ecological quality. This value is lower than reported from 2003 to 2007 where 59 per cent of streams in Auckland were reported as excellent or good (Moore and Neale, 2008). Stream health was strongly determined by catchment land-cover, for example, 98 per cent of reference sites were good or excellent, compared with only 19 per cent of rural high intensity and 6 per cent of urban streams.

Across land-cover categories urban and rural land-covers had the lowest MCI and %EPT richness scores consistent with other studies (Moore and Neale 2008; Maxted 2005; Scarsbrook *et al.,* 2000).

Streams in predominately urban catchments had the lowest stream health scores according to MCI and %EPT richness indices. This is consistent with water quality monitoring, where urban streams also had the lowest ranked water quality in the Auckland region (Lockie and Neale, 2012; 2013). Inputs of pollutants (sediments, nutrients, heavy metals) and changes to stream hydrology and morphology associated with increasing land-cover intensity are likely to be driving this decline in urban stream health (Larned *et al.,* 2004; Walsh *et al.,* 2005).

4.2 Regional trends

Regional trend analysis, based on 2003 to 2013 data, showed a decrease in median MCI scores indicating a decline in stream health over this period. Similar declining stream ecological health trends were noted nationally in New Zealand (Scarsbrook *et al.,* 2000) and regionally in developed streams in the Waikato region (Collier and Hamer, 2012). Taxon richness increased regionally, though it is worth noting that a change of sample processor in 2008 may have resulted in a stepwise increase in taxa richness, which has the potential to confound results. As a result, the trends identified in richness measures should be treated with caution.

Ecological health improved at low scoring urban streams over time. This trend was primarily driven by improvements at Puhinui LTB and Oakley Creek. In contrast, stream ecological health declined in reference and rural low intensity streams. In particular, MCI scores at reference sites Wekatahi and West Hoe streams worsened

from 2003 to 2013. However, the trend slope values at these sites are minor, suggesting that changes may not be ecologically meaningful.

There were relatively few significant trends identified across all spatial scales analysed. For example, there were no significant changes in MCI at 35 of 51 sites. This may indicate that macroinvertebrate communities across many of Auckland's streams are relatively stable. It should also be recognised that the river ecology dataset remains relatively short and hence lacks statistical power. It is likely that trend analysis of such ecologically short data records will only identify strong or consistent trends (Garman *et al.,* 2012).

4.3 Case studies

4.3.1 Forestry

The health of forestry sites in Auckland appears to be associated with the forestry cycle. The effects of harvesting on streams includes a sudden increase in light and sediment, leading to physico-chemical changes such as increased temperature and increased nutrient concentrations. As such decreases in stream health are often observed following harvesting (Death *et al.,* 2003). Currently, forestry sites monitored by Auckland Council are at different stages of the forestry cycle. In general, the good to excellent ecological health is likely to be related to an increase in channel shading with tree growth and inputs of woody debris from felling and thinning (Gustafsson *et al.,* 2014).

Currently, the monitoring does not span a full forestry cycle, however there are multiple sites in the council's monitoring network which are at different stages of re-vegetation. By combining data from these sites, it is evident that the disturbance caused by harvesting has an abrupt impact on stream health (MCI dropped by 45 points) followed by a slow recovery in stream health (Figure 15). Our data suggest that initial disturbance effects last for approximately 2 years with a near-full recovery of stream health after 10 years. This is consistent with Death et al. (2003), where the initial disturbance effects of harvesting lasted from 1.5 to 2.5 years, with recovery predicted in 10-15 years.

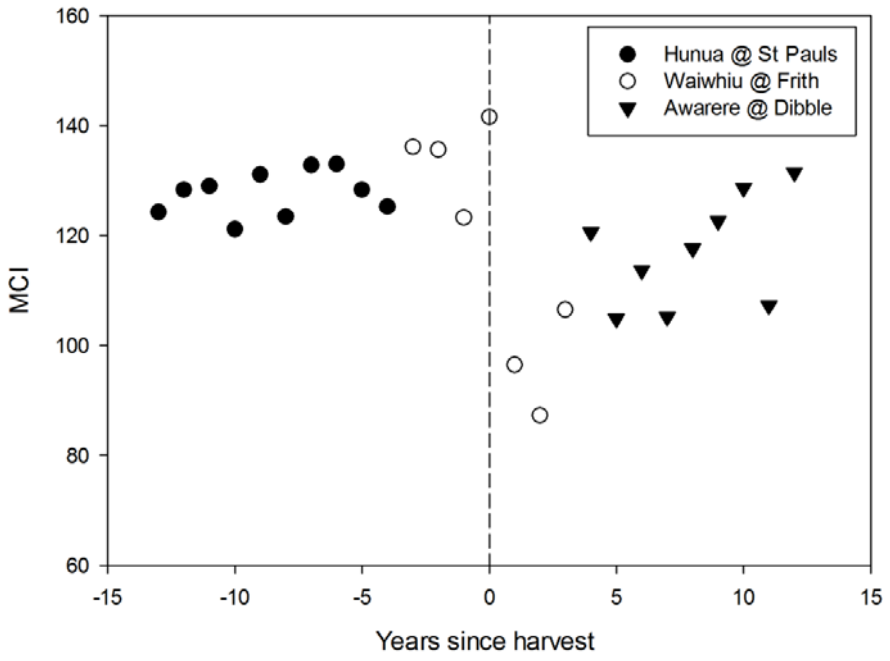


Figure 15: Years since harvest at exotic forestry sites Hunua @ St Pauls, Waiwhiu @ Frith, and Awarere @ Dibble. MCI trends were significant at Waiwhiu @ Frith and Awarere @ Dibble ($p < 0.05$); MCI scores were stable at Hunua @ St Pauls (Table 7). Data were statistically tested as presented in table 7.

4.3.2 Restoration

Restoration activities are frequently carried out in an effort to improve stream health, although such activities are rarely monitored to assess the effectiveness of the restoration (Bernhardt et al., 2007). There are two sites that have been subject to restoration activities in this river ecology programme and the trend analysis allows the effectiveness of the restoration to be assessed.

Restoration at Lucas Creek began in 2008, and was completed in February 2011 and included widening the floodplain, bank shaping, bank armouring, riparian planting, and the addition of large rocks/woody debris. Pre-restoration, MCI scores at the site were 115.6 in 2004 and 89.6 in 2008, the year the restoration began. In the three years following restoration MCI decreased from 89.7 (fair) in 2010 (mid restoration) to 65.9 (poor) in 2013 (Figure 16a). This negative trend may have been caused by a decrease in channel shading following bank widening, a lack of macroinvertebrate recruitment, or a continued increase in land-cover intensity. For example, catchment urban land-cover increased from 36 per cent in 2004 to 61 per cent in 2013 accompanied by a noticeable downward trend in MCI.

In contrast, restoration at Vaughan Lower, a low intensity rural site, was followed by improvements in stream ecological health (Figure 16b). This stream was fenced

between 2006 and 2008, excluding stock and allowing grasses to grow which in-turn stabilised the stream banks. MCI values increased from 48 in 2006 (pre fencing) to 66 in 2013, taxon richness also increased from 15 to 28 over the same period. Upstream from this site, Vaughan Upper had excellent ecological health in 2013, potentially acting as a source population, assisting in the recovery of macroinvertebrate populations. Continuing to monitor such sites in an effort to understand what drives successful restoration should be a priority for Auckland Council into the future.

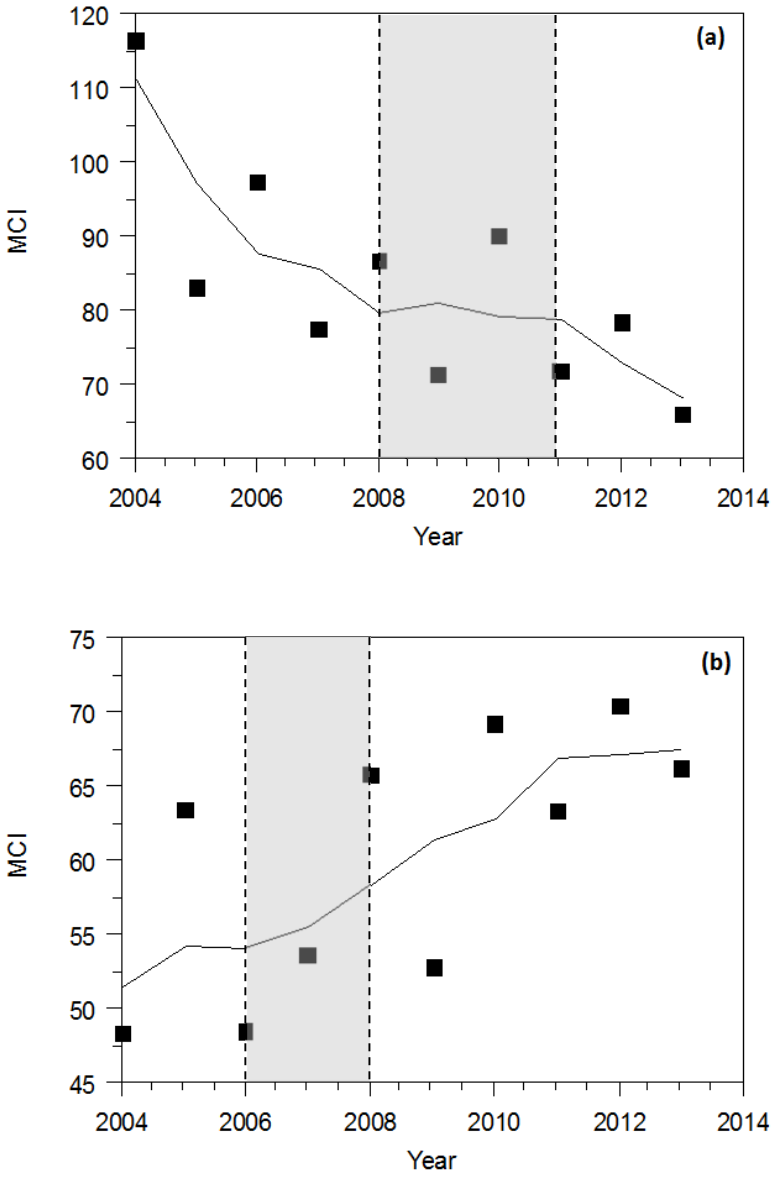


Figure 16: MCI trends at (a) Lucas Creek and (b) Vaughan Lower, both sites have been subject to restoration efforts, the time periods for which are marked in grey; data are fitted with lowess models where 62.8 per cent of variation at Lucas Creek and 49.8 per cent of variation at Vaughan Lower is explained by the model. Both sites had significant results from Mann-Kendall trend tests ($P < 0.05$) (Table 7).

4.4 Key findings

- High intensity land-cover, particularly urban land-cover, is associated with a decrease in stream ecological health
- Between 2003 and 2013 MCI sores decreased at 13 sites, increased at 4 sites and remained stable at 35 sites
- MCI scores improved within the urban land-cover category for low scoring sites (5th percentile), while median MCI values worsened in reference and rural low intensity categories
- Simple management options such as stream fencing, which was carried out at Vaughan Lower, appear to have ecological benefits in rural streams, but restoration of urban streams is more complex, requiring more data and time to see patterns.

5.0 Acknowledgements

The Auckland Council River Ecology Programme has benefited from the efforts of numerous people since its inception in 1999.

John Maxted initiated the programme in 1999 and the current programme owes much to John's efforts. Mike McMurtry, Joanne Wilks and Marcus Cameron administered the field programme in the earlier years, with Kylie Park administering the field programme until late 2009. Peter Hancock has since been administering data management and field operations.

During the past few years, Peter Williams, Graham Surrey, Simon Tredgett, Hazel Meadows and Stacey Lockie have helped manage field teams. Julie Williams, Aaron Hodges, Jessica Reaburn, Sarah Roth, Jordan Markham, Emma Moffett, Sophie Barclay, Rhian Moyle, Benjamin Hanns, Joshua Bilkey, Kelly Grover, Reender Buikema, and Victoria Jollands have all contributed to the programme by assisting with fieldwork and data management as part of the council's Student Partnership Programme with Auckland University. Laura Buckthought and Edda Kalbus assisted with the final report editing.

Laboratory analysis was carried out by Stephen Moore of Landcare Research. Independent quality control was undertaken by Brian Smith of NIWA.

We would also like to thank the numerous volunteers and staff that helped with field work.

6.0 References

Cairns, J., and Pratt, J. 1993. A history of biological monitoring using macroinvertebrates, in: *Freshwater biomonitoring and benthic macroinvertebrates,* edited by Rosenberg, D.M. and Resh, V.H. Chapman and Hall, London. U.K.

Collier, K., Hammer, M. 2012 *The ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) programme*. Waikato Regional Council Technical Report TR2012/27.

Death, R.G., Baillie, B. and Fransen, P. 2003 Effect of *Pinus radiata* logging on stream invertebrate communities in Hawke's Bay, New Zealand, *New Zealand Journal of Marine and Freshwater Research*, 37(3): 507-520.

Garman, S.L., Schweiger, E.W., Manier, D.J., 2012 Simulating future uncertainty to guide the selection of survey designers for long-term monitoring. In: Gitzen,R.A., Millspaugh, J.J., Cooper, A.B., Licht, D.S. (Eds.), *Design and Analysis of Long-term Ecological Monitoring Studies*. Cambridge University Press, New York, NY, USA, pp. 228–252.

Gustafsson, P., Greenberg, L.A. and Bergman, E. 2014 Woody debris and terrestrial invertebrates – effects on prey resources for brown trout (*Salmo trutta*) in a boreal stream, *Environmental Biology of Fishes,* 97: 529-542.

Hellawell, J. 1977 Change in natural and managed ecosystems: Detection, measurement and assessment. *Proceedings of the Royal Society (B)*, 197: 31-57.

Larned, S.T., Scarsbrook, M.R., Snelder, T.H., Norton, N.J. and Biggs, B.J.F. 2004 Water quality in low-elevation streams and rivers of New Zealand: Recent state and trends in contrasting land-cover classes, *New Zealand Journal of Marine and Freshwater Research*, 38:2, 347-366.

Lockie, S. and Neale, M.W. 2011 *State of the Environment Monitoring: River Water Quality Annual Report 2010*. Auckland Council Technical Report 2012/006.

Lockie, S. and Neale, M. W. 2012 *State of the Environment Monitoring: River Water Quality Annual Report 2011*. Auckland Council Technical Report 2012/013.

Maxted, J. 2005 *Summary of the ecological health of Auckland streams based on State of the Environment monitoring 2000-2004*. Auckland Regional Council Technical Publication 304.

Metcalfe, J. 1989 Biological water quality assessment of running waters based on macroinvertebrate communities: history and present status in Europe. *Environmental Pollution*, 60: 101-139.

Moore, S. and Neale, M. W. 2008 *Freshwater Invertebrate Monitoring: 2003–2007 analysis and evaluation*. Prepared by Landcare Research and Auckland Regional Council for Auckland Regional Council. Auckland Regional Council Technical Report 2008/010.

Perrie, A., Morar, S. Milne, J. R. and Greenfield, S. 2012. *River and stream water quality an ecology in the Wellington region: State and trends.* Greater Wellington Regional Council, Publication No GW/EMI-T-12/143, Wellington.

Pohe, S.R. 2013 *Northland Macroinvertebrate Monitoring Programme: 2013 monitoring report*. Unpublished report prepared by Pohe Environmental for Northland Regional Council. 13p.

Rosenberg. D.M. and Resh, V.H. 1993 I*ntroduction to freshwater biomonitoring and benthic macroinvertebrates*. In: Rosenberg, D.M. and Resh, V.H. (Eds.). Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, London. U.K.

Scarsbrook, M.R., Boothroyd, I.K.G. and Quinn, J.M. 2000 New Zealand's National River Quality Network: long-term trends in macroinvertebrate communities, *New Zealand Journal of Marine and Freshwater Research*, 34: 289-302.

Scarsbrook, M. 2007 *River Water Quality State and Trends in Auckland Region*. Prepared by NIWA for the Auckland Regional Council. Auckland Regional Council Technical Publication TP336.

Stark, J. 1985 *A Macroinvertebrate Community Index of water quality for stony streams*. Water and Soil Miscellaneous Publication No 87. National Water and Soil Conservation Authority, Wellington.

Stark, J. D., Boothroyd, I. K. G., Harding, J. S., Maxted, J. R. and Scarsbrook, M. R. 2001 *Protocols for sampling macroinvertebrates in wadeable streams*. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for Ministry for the Environment Sustainable Management Fund Project No. 5103. 60p.

Stark, J. D. 2012 *Aquatic invertebrate communities of the Manawatu – Wanganui Region – 2012 State of the Environment Report*. Prepared for Horizons Regional Council. HRC Report No. 2012/EXT/1277, Stark Environmental Report No. 2012-10. 133p.

Stark, J. D. and Maxted, J. R. 2007 *A user guide for the Macroinvertebrate Community Index*. Prepared for the Ministry for the Environment. Cawthron Report No. 1166. 58p.

Stark, J. D. and Maxted, J. R. 2004 *Macroinvertebrate community index for Auckland's soft-bottomed streams and application to SOE reporting*. Prepared for the Auckland Regional Council by the Cawthron Institute, Nelson, Cawthron report 970.

Stark, J. D. and Fowles, C. R. 2006 *An approach to the evaluation of temporal trends in Taranaki state of the environment macroinvertebrate data*. Prepared for the Taranaki Regional Council by the Cawthron Institute, Nelson. Cawthron report No. 1135.

StatSoft, Inc. 2011 *STATISTICA version 10*. www.statsoft.com.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. and Morgam II, R.P. 2005 The urban stream syndrome: current knowledge and the search for a cure*, Journal of the North American Benthological Society*, 24(3): 706-723.

Warwick, R.M. and Clarke, K.R. 1993 Increased variability as a symptom of stress in marine communities. *Journal of Experimental Marine Biology and Ecology,* 172 (1–2): 215-226.

Appendix A Survey site details

Sites used for ecological state analysis (n=71).

Site ID	Site FWM number	Site name	Substrate	Primary land-cover	NZTM	NZTM
45368	FWM080	Ararimu @ Old North Road	Soft	Rural high	1734910	5932518
8557	FWM068	Aroaro @ Phillips	Hard	Rural Low	1789897	5903472
8019	FWM099	Avondale @ Shadbolt Park	Soft	Urban	1750685	5912301
7308	FWM061	Awanohi Lower	Soft	Rural low	1751424	5938711
7309	FWM060	Awanohi Mid	Soft	Rural low	1750635	5937678
7311	FWM057	Awanohi Upper 1	Soft	Rural low	1750102	5936833
45742	FWM004	Awarere @ Dibble	Hard	Exotic forestry	1740623	5973867
8268	FWM102	Botany Creek @ Tangelo Place	Hard	Urban	1769802	5915087
7524	FWM064	Campbell's Bay	Soft	Urban	1757043	5931334
44618	FWM048	Cascades LTB	Hard	Reference	1735633	5916371
7721	FWM016	Chatswood	Hard	Urban	1752860	5924026
6606	FWM076	Duck Creek @ Trotters	Soft	Rural high	1752605	5970451
8407	FWM069	Duders	Soft	Rural high	1785588	5913500
6847	FWM087	Dyers Creek @ Bush	Soft	Rural high	1751076	5963704
6852	FWM088	Dyers Creek @ Mid Paddock	Soft	Rural high	1750910	5963846
7722	FWM071	Eskdale Lower	Soft	Urban	1752441	5926765
7723	FWM072	Eskdale Mid	Soft	Urban	1752739	5926517
7724	FWM073	Eskdale Upper	Soft	Urban	1752993	5926470
45743	FWM022	Hoteo @ Kraak Hill	Soft	Exotic forestry	1743264	5974291
8552	FWM018	Hunua @ St Pauls	Hard	Exotic forestry	1792352	5899343
45416	FWM086	Kaukapakapa Ref	Soft	Reference	1730776	5945155
43512	FWM065	Kauritutahi (Awhitu)	Soft	Rural low	1741899	5893226
1543482	FWM044	Konini	Hard	Reference	1795198	5895283
45369	FWM021	Kumeu @ Weza	Soft	Rural high	1739216	5928819
7725	FWM070	Lignite	Soft	Urban	1752340	5929258

Site ID	Site FWM number	Site name	Substrate	Primary land-cover	NZTM	NZTM
7899	FWM040	Lucas LTB @ Tennis	Soft	Urban	1751795	5934561
6862	FWM089	Mahu Reference @ Trappit	Soft	Reference	1748960	5965400
6850	FWM028	Mahurangi LTB	Soft	Exotic forestry	1747626	5964882
45505	FWM091	Makarau @ Rail Bridge	Soft	Rural high	1736090	5953237
1543483	FWM045	Mangatawhiri	Hard	Reference	1793923	5897394
44460	FWM049	Marawhara	Hard	Reference	1730774	5910762
6604	FWM031	Matakana LTB	Soft	Rural high	1753615	5976422
43720	FWM074	Mauku Stream @ STP	Soft	Rural high	1760162	5882718
1043404	FWM043	Milne	Hard	Reference	1793462	5890730
7407	FWM084	Motutapu	Hard	Rural high	1771846	5929049
45605	FWM056	Mt Auckland	Soft	Reference	1730852	5964294
1043824	FWM037	Ngakaroa LTB	Soft	Rural high	1775165	5881618
7171	FWM047	Nukumea Upper	Soft	Reference	1749411	5951400
10812	FWM101	Oakley Creek @ May Road	Hard	Urban	1754919	5914268
8177	FWM035	Oakley LTB	Soft	Urban	1751914	5917503
7313	FWM075	Okura Reserve	Soft	Reference	1753241	5940408
7314	FWM062	Okura Trib 1	Soft	Rural high	1754059	5939002
7315	FWM063	Okura Trib 2	Soft	Rural high	1752669	5938790
7726	FWM009	Onepoto @ Kauri Glen park	Soft	Urban	1754873	5925353
7925	FWM034	Opanuku LTB	Hard	Rural low	1742087	5915597
8608	FWM020	Orere A	Hard	Exotic forestry	1797276	5903177
8609	FWM019	Orere B	Hard	Exotic forestry	1796917	5903677
7172	FWM052	Otanerua	Soft	Reference	1749829	5952217
8241	FWM038	Otara LTB	Soft	Urban	1768326	5908371
107801	FWM013	Oteha LTB	Soft	Urban	1751903	5932876
1043825	FWM033	Papakura LTB	Soft	Rural high	1771066	5900274
1043835	FWM104	Papakura Trib @ Alfreston Rd	Soft	Urban	1771523	5901203
7939	FWM096	Paramuka Stream @ Brookwood Drive	Soft	Urban	1743365	5917644
1043826	FWM039	Puhinui LTB	Soft	Urban	1766445	5904298

Site ID	Site FWM number	Site name	Substrate	Primary land-cover	NZTM	NZTM
1043827	FWM011	Puhinui Trib (soft)	Soft	Urban	1770124	5903226
1043828	FWM015	Puhinui Upper (hard)	Hard	Rural high	1770055	5903290
7012	FWM012	Puhoi	Soft	Rural low	1744684	5960107
45371	FWM008	Riverhead	Soft	Exotic forestry	1737125	5933216
7212	FWM051	Shakespear	Soft	Rural high	1763934	5946824
43918	FWM024	Symonds St @ Ponga	Hard	Rural low	1775578	5893744
6517	FWM090	Tawharanui	Soft	Rural low	1765885	5973009
7527	FWM041	Vaughan Lower	Soft	Rural high	1755414	5938729
7526	FWM014	Vaughan Upper	Soft	Rural high	1754271	5938178
8569	FWM092	Wairoa @ Caitchen Rd Trib	Hard	Reference	1786762	5892804
8553	FWM032	Wairoa LTB	Soft	Rural high	1782680	5901828
44619	FWM066	Waitakere River	Hard	Rural low	1733630	5918805
43601	FWM093	Waitangi Stream	Soft	Rural high	1754347	5878524
45745	FWM010	Waiwhiu @ Frith	Soft	Rural low	1746500	5979619
44470	FWM050	Wekatahi	Hard	Reference	1731543	5910437
7213	FWM046	West Hoe LTB	Soft	Reference	1748300	5950608
104300	FWM095	Whangamarie Stream @ Hunter Rd	Soft	Rural high	1763241	5882752

Appendix B MCI tolerance values (Stark and Maxted 2007)

Taxon	HB	SB
COELENTERATA		
Hydra	3	1.6*
PLATYHELMINTHES	3	0.9
RHABDOCOELA	-	0.9*
BRYOZOA	-	4.0*
NEMATODA	3	3.1
NEMATOMORPHA	3	4.3
NEMERTEA	3	1.8
OLIGOCHAETA	1	3.8
POLYCHAETA	-	6.7*
HIRUDINEA	3	1.2
TARDIGRADA	-	4.5*
CRUSTACEA		
Amphipoda	5	5.5
Cladocera	5	0.7*
Copepoda	5	2.4*
Halicarcinus	-	5.1*
Helice	-	6.6*
Isopoda	5	4.5
Mysidae	-	6.4*
Ostracoda	3	1.9
Paracalliope	5	-
Paraleptamphopus	5	-
Paranephrops	5	8.4
Paranthura	-	4.9*
Paratya	5	3.6
Tanaidacea	4	6.8*
INSECTA		
Ephemeroptera		
Acanthophlebia	7	9.6
Ameletopsis	10	10.0
Arachnocolus	8	8.1
Atalophlebioides	9	4.4*
Austroclima	9	6.5
Austronella	7	4.7
Coloburiscus	9	8.1
Deleatidium	8	5.6
Ichthybotus	8	9.2
Isothraulus	8	7.1
Mauulus	5	4.1
Neozephlebia	7	7.6
Nesameletus	9	8.6
Oniscigaster	10	5.1*
Rallidens	9	3.9
Siphlaenigma	9	-
Tepakia	8	7.6
Zephlebia	7	8.8
Plecoptera		
Acroperla	5	5.1
Austroperla	9	8.4
Cristaperla	8	-
Halticoperla	8	-
Megaleptoperla	9	7.3
Nesoperla	5	5.7
Spaniocerca	8	8.8
Spaniocercoides	8	-
Stenoperla	10	9.1
Taraperla	7	8.3*
Zelandobius	5	7.4
Zelandoperla	10	8.9
Megaloptera		
Archichauliodes	7	7.3
Odonata		
Aeshna	5	1.4*
Anisoptera	5	6.0
Antipodochlora	6	6.3
Austrolestes	6	0.7
Hemianax	-	1.1*
Hemicordulia	5	0.4
Ischnura	-	3.1*
Odonata (continued)		
Procordulia	6	3.8*
Uropetala	5	0.4
Xanthocnemis	5	1.2
Hemiptera		
Anisops	5	2.2
Diaprepocoris	5	4.7*
Microvelia	5	4.6
Sigara	5	2.4
Coleoptera		
Antiporus	5	3.5
Berosus	5	-
Copelatus	5	3.7
Dytiscidae	5	0.4*
Elmidae	6	7.2
Enochrus	5	2.6
Hydraenidae	8	6.7
Hydrophilidae	5	8.0
Liodessus	5	4.9*
Onychohydrus	5	-
Podaena	8	-
Ptilodactylidae	8	7.1
Rhantus	5	1.0
Scirtidae	8	6.4
Staphylinidae	5	6.2
Neuroptera		
Kempynus	5	-
Diptera		
Anthomyiidae	3	6.0
Aphrophila	5	5.6
Austrosimulium	3	3.9
Calopsectra	4	-
Ceratopogonidae	3	6.2
Chironomidae	2	3.8
Chironomus	1	3.4
Corynoneura	2	1.7*
Cryptochironomus	3	-
Culex	3	-
Culicidae	3	1.2
Diptera indet.	3	2.9
Dixidae	4	7.1
Dolichopodidae	3	8.6
Empididae	3	5.4
Ephydridae	4	1.4*
Eriopterini	9	7.5
Harrisius	6	4.7
Hexatomini	5	6.7
Limnophora	3	4.5
Limonia	6	6.3
Lobodiamesa	5	7.7
Maoridiamesa	3	4.9
Mischoderus	4	5.9
Molophilus	5	6.3
Muscidae	3	1.6
Nannochorista	7	-
Neocurupira	7	-
Neolimnia	3	5.1
Nothodixa	4	9.3
Orthocladiinae	2	3.2
Parochlus	8	-
Paradixa	4	8.5
Paralimnophila	6	7.4
Paucispinigera	6	7.7
Pelecorhyncidae	9	-
Peritheates	7	-
Podonominae	8	6.4*
Polypedilum	3	8.0
Psychodidae	1	6.1
Scatella	7	-
Diptera (continued)		
Sciomyzidae	3	3.0
Stratiomyidae	5	4.2
Syrphidae	1	1.6*
Tabanidae	3	6.8
Tanypodinae	5	6.5
Tanytarsini	3	4.5
Tanytarsus	3	-
Thaumaleidae	9	8.8
Tipulidae	5	3.4
Zelandotipula	6	3.6
Trichoptera		
Alloecentrella	9	-
Aoteapsyche	4	6.0
Beraeoptera	8	7.0*
Confluens	5	7.2*
Conuxia	8	-
Costachorema	7	7.2*
Cryptobiosella	9	-
Diplectrona	9	-
Ecnomina	8	9.6
Edpercivalia	9	6.3*
Ecnominidae	8	-
Helicopsyche	10	8.6
Hudsonema	6	6.5
Hydrobiosella	9	7.6*
Hydrobiosis	5	6.7
Hydrochorema	9	-
Kokiria	9	-
Neurochorema	6	6.0
Oecetis	6	6.8
Oeconesidae	9	6.4
Olinga	9	7.9
Orthopsyche	9	7.5
Oxyethira	2	1.2
Paroxyethira	2	3.7
Philorheithrus	8	5.3*
Plectrocnemia	8	6.6*
Polyplectropus	8	8.1
Psilochorema	8	7.8
Pycnocentrella	9	-
Pycnocentria	7	6.8
Pycnocentrodes	5	3.8
Rakiura	10	-
Synchorema	9	-
Tiphobiosis	6	9.3
Triplectides	5	5.7
Triplectidina	5	-
Zelandoptila	8	7.0
Zelolessica	10	6.5*
Lepidoptera		
Hygraula	4	1.3
Collembola	6	5.3
ACARINA	5	5.2
ARACHNIDA		
Dolomedes	5	6.2
MOLLUSCA		
Gundlachia = Ferrissia	3	2.4
Glyptophysa = Physastra	5	0.3*
Gyraulus	3	1.7
Hyridella	3	6.7
Latia	3	6.1
Lymnaeidae	3	1.2
Melanopsis	3	1.9
Physa = Physella	3	0.1
Potamopyrgus	4	2.1
Sphaeriidae	3	2.9

Notes: '-' indicates tolerance value not yet assigned. All tolerance values were derived from Auckland data only, except for those marked '*', where data from other regions were used.

Appendix C Taxon richness Mann-Kendall trend results

Taxon richness results from the Mann-Kendall trend test. Significant results at the 95% significance level are highlighted in bold.

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Period analysed	Number of records	Number of ties
Aroaro @ Phillips	Unadjusted	31.00	27	123.00	2.34	**0.01**	**1.78**	0.60	2.88	2004-13	10	2
Awanohi Lower	Unadjusted	23.00	44	162.00	3.38	**0.00**	**1.66**	1.01	2.53	2003-13	11	3
Awanohi Mid	Unadjusted	22.00	25	163.00	1.88	0.06	1.24	0.13	2.14	2003-13	11	2
Awanohi Upper 1	Unadjusted	14.00	31	165.00	2.34	**0.02**	**1.29**	0.74	2.51	2003-13	11	0
Awarere @ Dibble	Unadjusted	17.00	-13	123.00	-1.08	0.15	-0.57	-2.17	0.51	2004-13	10	2
Campbell's Bay	Unadjusted	15.00	29	125.00	2.50	**0.01**	**1.74**	1.00	2.56	2004-13	10	0
Cascades LTB	Unadjusted	29.00	17	120.33	1.46	0.08	1.21	0.00	2.61	2004-13	10	3
Chatswood	Unadjusted	15.50	38	124.00	3.32	**0.00**	**1.66**	1.29	1.86	2004-13	10	1
Eskdale Lower	Unadjusted	21.00	31	91.00	3.15	**0.00**	**2.25**	1.37	3.22	2005-13	9	1
Eskdale Mid	Unadjusted	20.00	21	91.00	2.10	**0.02**	**1.77**	0.70	3.39	2005-13	9	1
Eskdale Upper	Unadjusted	23.00	3	91.00	0.21	0.42	0.74	-0.69	1.48	2005-13	9	1
Hoteo @ Kraak Hill	Unadjusted	28.00	-6	124.00	-0.45	0.33	-0.69	-2.82	1.62	2004-13	10	1
Hunua @ St Pauls	Unadjusted	32.00	23	123.00	1.98	**0.02**	**1.19**	0.35	2.52	2004-13	10	2
Kauritutahi (Awhitu)	Unadjusted	21.50	19	125.00	1.61	0.05	0.75	-0.19	1.97	2004-13	10	0
Konini	Unadjusted	32.50	23	123.00	1.98	**0.02**	**1.01**	0.17	2.04	2004-13	10	2

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Period analysed	Number of records	Number of ties
Kumeu @ Weza	Unadjusted	17.00	18	121.33	1.54	0.07	0.51	0.00	1.12	2004-13	10	2
Lignite	Unadjusted	20.00	6	90.00	0.53	0.31	0.75	-1.07	1.77	2005-13	9	2
Lucas LTB @ Tennis	Unadjusted	19.50	23	123.00	1.98	**0.02**	**1.28**	0.12	1.81	2004-13	10	2
Mahurangi LTB	Unadjusted	29.00	23	120.33	2.01	**0.02**	**1.27**	0.16	2.65	2004-13	10	3
Mangatawhiri	Unadjusted	31.50	15	125.00	1.25	0.11	1.03	-0.58	2.80	2004-13	10	0
Marawhara	Unadjusted	36.00	17	123.00	1.44	0.08	1.26	-0.09	2.70	2004-13	10	2
Matakana LTB	Unadjusted	21.50	33	120.33	2.92	**0.00**	**1.87**	1.06	2.61	2004-13	10	3
Mauku Stream @ STP	Unadjusted	20.00	2	92.00	0.10	0.46	0.35	-1.96	2.46	2005-13	9	0
Milne	Unadjusted	35.00	18	124.00	1.53	0.07	0.89	-0.13	2.64	2004-13	10	1
Ngakaroa LTB	Unadjusted	22.00	16	124.00	1.35	0.09	0.99	-0.29	2.45	2004-13	10	1
Nukumea Upper	Unadjusted	20.50	9	123.00	0.72	0.24	0.34	-0.95	1.59	2004-13	10	2
Oakley LTB	Unadjusted	19.50	24	121.33	2.09	**0.02**	**1.75**	0.61	2.52	2004-13	10	2
Okura Reserve	Unadjusted	19.00	8	90.00	0.74	0.24	0.42	-0.92	2.41	2005-13	9	2
Okura Trib 1	Unadjusted	21.50	23	120.33	2.01	**0.02**	**1.02**	0.08	1.52	2003-13	10	3
Okura Trib 2	Unadjusted	17.50	-6	124.00	-0.45	0.33	-0.34	-2.07	0.76	2003-13	10	1
Onepoto @ Kauri Glen park	Unadjusted	20.00	28	92.00	2.82	**0.00**	**1.51**	1.00	2.60	2005-13	9	0
Opanuku LTB	Unadjusted	23.50	8	119.33	0.64	0.27	0.34	-0.75	1.02	2004-13	10	4
Orere A	Unadjusted	35.00	14	124.00	1.17	0.13	0.88	-0.62	2.85	2004-13	10	1

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Period analysed	Number of records	Number of ties
Orere B	Unadjusted	31.50	7	125.00	0.54	0.30	0.73	-1.41	2.62	2004-13	10	0
Otara LTB	Unadjusted	19.00	16	122.00	1.36	0.09	0.83	-0.28	2.05	2004-13	10	3
Oteha LTB	Unadjusted	15.50	12	124.00	0.99	0.17	0.78	-0.56	1.56	2004-13	10	1
Papakura LTB	Unadjusted	16.50	13	121.00	1.09	0.15	0.34	-0.33	1.34	2004-13	10	4
Puhinui LTB	Unadjusted	16	32	122	2.807	**0.002**	**1.42**	0.904	1.838	2004-13	10	3
Puhinui Trib (soft)	Unadjusted	17.5	6	122	0.453	0.332	0.33	-0.588	1.28	2004-13	10	3
Puhinui Upper (hard)	Unadjusted	24	8	124	0.629	0.271	0.68	-1.777	2.037	2004-13	10	1
Puhoi	Unadjusted	19	14	124	1.167	0.127	1.17	-0.676	2.678	2004-13	10	1
Riverhead	Unadjusted	23	11	89	1.06	0.154	0.94	-0.932	3.329	2005-13	9	3
Shakespear	Unadjusted	19.5	16	122	1.358	0.093	0.51	-0.199	1.661	2004-13	10	3
Symonds St @ Ponga	Unadjusted	29.5	22	122	1.901	**0.029**	**1.17**	0.083	2.062	2004-13	10	3
Vaughan Lower	Unadjusted	17.5	18	122	1.539	0.066	0.99	0	1.867	2004-13	10	3
Vaughan Upper	Unadjusted	23.5	25	120.3	2.188	**0.014**	**1.69**	0.67	2.265	2004-13	10	3
Wairoa LTB	Unadjusted	23.5	28	124	2.425	**0.006**	**1.1**	0.61	2.159	2004-13	10	1
Waitakere River	Unadjusted	22	16	122	1.358	0.093	1.59	-0.145	2.537	2004-13	10	3
Waiwhiu @ Frith	Unadjusted	27	13	125	1.073	0.146	1.59	1.503	3.161	2004-13	10	0
Wekatahi	Unadjusted	37	26	124	2.245	**0.011**	**1.82**	0.658	2.223	2004-13	10	1
West Hoe LTB	Unadjusted	22	37	160.3	2.843	**0.004**	**1.61**	1.022	2.403	2003-13	11	3

Appendix D MCI Mann-Kendall trend test results

MCI results from the Mann-Kendall trend test. Significant results at the 95% significance level are highlighted in bold.

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Period analysed	Number of records	Number of ties
Aroaro @ Phillips	Unadjusted	110.85	-1	125	0.00	0.50	-0.1	-1.18	2.84	2004-13	10	0
Awanohi Lower	Unadjusted	95.48	-9	165	-0.62	0.53	-0.61	-2.31	1.31	2003-13	11	0
Awanohi Mid	Unadjusted	116.81	-37	165	-2.80	**0.01**	**-2.02**	-2.83	-1.64	2003-13	11	0
Awanohi Upper 1	Unadjusted	128.30	-17	165	-1.25	0.21	-2.28	-5.47	0.46	2003-13	11	0
Awarere @ Dibble	Unadjusted	115.66	25	125	2.15	**0.01**	**2.96**	0.45	4.48	2004-13	10	0
Campbell's Bay	Unadjusted	80.97	-5	125	-0.36	0.36	-0.56	-3.35	2.53	2004-13	10	0
Cascades LTB	Unadjusted	104.69	-19	125	-1.61	0.05	-3.24	-7.84	0.04	2004-13	10	0
Chatswood	Unadjusted	74.83	11	125	0.89	0.19	1.16	-1.17	4.19	2004-13	10	0
Eskdale Lower	Unadjusted	79.33	4	92	0.31	0.38	0.54	-1.53	2.94	2005-13	9	0
Eskdale Mid	Unadjusted	86.20	-12	92	-1.15	0.13	-1.64	-3.93	0.20	2005-13	9	0
Eskdale Upper	Unadjusted	117.54	-14	92	-1.36	0.09	-1.61	-4.24	0.59	2005-13	9	0
Hoteo @ Kraak Hill	Unadjusted	100.76	3	125	0.18	0.43	0.08	-1.18	1.20	2004-13	10	0
Hunua @ St Pauls	Unadjusted	128.33	-10	124	-0.81	0.22	-0.66	-1.12	0.66	2004-13	10	1
Kauritutahi (Awhitu)	Unadjusted	131.22	-7	125	-0.54	0.30	-0.23	-1.36	1.00	2004-13	10	0
Konini	Unadjusted	135.83	-19	125	-1.61	0.05	-0.95	-2.17	-0.08	2004-13	10	0

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Period analysed	Number of records	Number of ties
Kumeu @ Weza	Unadjusted	65.23	-31	125	-2.68	**0.00**	**-3**	-4.65	-1.64	2004-13	10	0
Lignite	Unadjusted	84.00	-32	92	-3.23	**0.00**	**-3.37**	-5.76	-2.04	2005-13	9	0
Lucas LTB @ Tennis	Unadjusted	80.53	-23	125	-1.97	**0.02**	**-3.16**	-5.74	-1.33	2004-13	10	0
Mahurangi LTB	Unadjusted	109.09	-17	125	-1.43	0.08	-2.79	-5.98	0.22	2004-13	10	0
Mangatawhiri	Unadjusted	131.14	1	125	0.00	0.50	0.04	-3.17	1.60	2004-13	10	0
Marawhara	Unadjusted	128.23	-13	125	-1.07	0.15	-1.27	-3.06	1.14	2004-13	10	0
Matakana LTB	Unadjusted	93.96	-25	125	-2.15	**0.01**	**-1.27**	-2.64	-0.64	2004-13	10	0
Mauku Stream @ STP	Unadjusted	84.48	-12	92	-1.15	0.13	-2.61	-7.65	0.77	2005-13	9	0
Milne	Unadjusted	138.30	1	125	0.00	0.50	0.32	-1.56	1.35	2004-13	10	0
Ngakaroa LTB	Unadjusted	69.80	7	125	0.54	0.30	0.95	-2.05	4.00	2004-13	10	0
Nukumea Upper	Unadjusted	116.84	-7	125	-0.54	0.30	-0.87	-2.47	3.30	2004-13	10	0
Oakley LTB	Unadjusted	61.59	25	125	2.15	**0.01**	**0.95**	0.44	1.96	2004-13	10	0
Okura Reserve	Unadjusted	116.42	-8	92	-0.73	0.24	-0.88	-2.60	0.96	2005-13	9	0
Okura Trib 1	Unadjusted	109.47	-25	125	-2.15	**0.01**	**-1.28**	-2.26	-0.45	2003-13	10	0
Okura Trib 2	Unadjusted	108.50	-29	125	-2.50	**0.01**	**-2.24**	-4.01	-1.08	2003-13	10	0
Onepoto @ Kauri Glen park	Unadjusted	90.75	-8	92	-0.73	0.24	-1.22	-2.05	0.44	2005-13	9	0
Opanuku LTB	Unadjusted	84.69	-14	124	-1.17	0.13	-1.14	-3.82	0.25	2004-13	10	1
Orere A	Unadjusted	134.09	-15	125	-1.25	0.11	-1.02	-2.60	0.62	2004-13	10	0

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Period analysed	Number of records	Number of ties
Orere B	Unadjusted	134.82	-21	125	-1.79	**0.04**	**-1.67**	-3.10	-0.21	2004-13	10	0
Otara LTB	Unadjusted	48.85	-3	125	-0.18	0.43	-0.2	-1.89	0.87	2004-13	10	0
Oteha LTB	Unadjusted	66.34	13	125	1.07	0.15	1.39	-0.62	2.48	2004-13	10	0
Papakura LTB	Unadjusted	57.96	11	125	0.89	0.19	0.36	-0.43	0.84	2004-13	10	0
Puhinui LTB	Unadjusted	44.84	29	125	2.50	**0.01**	**3.18**	1.99	5.33	2004-13	10	0
Puhinui Trib (soft)	Unadjusted	83.22	-13	125	-1.07	0.15	-0.46	-3.19	1.23	2004-13	10	0
Puhinui Upper (hard)	Unadjusted	97.24	7	125	0.54	0.30	0.55	-0.85	1.80	2004-13	10	0
Puhoi	Unadjusted	131.92	-26	124	-2.25	**0.01**	**-0.67**	-1.36	-0.41	2004-13	10	1
Riverhead	Unadjusted	109.64	-4	92	-0.31	0.38	-0.36	-1.66	0.86	2005-13	9	0
Shakespear	Unadjusted	108.73	-17	125	-1.43	0.08	-2.04	-3.23	0.99	2004-13	10	0
Symonds St @ Ponga	Unadjusted	104.57	1	125	0.00	0.50	0.07	-2.06	1.95	2004-13	10	0
Vaughan Lower	Unadjusted	63.25	25	125	2.15	**0.01**	**1.71**	0.43	3.44	2004-13	10	0
Vaughan Upper	Unadjusted	119.71	-31	125	-2.68	**0.00**	**-2.59**	-3.44	-1.63	2004-13	10	0
Wairoa LTB	Unadjusted	110.39	-19	125	-1.61	0.05	-1.67	-3.75	0.31	2004-13	10	0
Waitakere River	Unadjusted	104.59	-13	125	-1.07	0.15	-1.26	-2.00	0.62	2004-13	10	0
Waiwhiu @ Frith	Unadjusted	101.48	-27	125	-2.33	**0.01**	**-7.53**	-11.04	-3.33	2004-13	10	0
Wekatahi	Unadjusted	128.17	-31	125	-2.68	**0.00**	**-1.75**	-2.63	-1.02	2004-13	10	0
West Hoe LTB	Unadjusted	125.38	-27	165	-2.02	**0.04**	**-0.99**	-2.25	-0.34	2003-13	11	0

[1] Greater than 10 and normal approximation used to determine P value [2] Less than 11 and small probabilities were used.

Appendix E %EPT results from the Mann-Kendall trend test.

Significant results at the 95% significance level are highlighted in bold.

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Values excluded because of multiple values in a season	Period analysed	Number of records	Number of ties
Aroaro @ Phillips	Unadjusted	0.48	12	124.00	0.99	0.17	0.01	-0.01	0.04	0	2004-13	10	1
Awanohi Lower	Unadjusted	0.25	0	164.00	0.00	1.00	0.00	-0.03	0.02	0	2003-13	11	1
Awanohi Mid	Unadjusted	0.32	-31	165.00	-2.34	**0.02**	**-0.02**	-0.03	-0.01	0	2003-13	11	1
Awanohi Upper 1	Unadjusted	0.39	-2	164.00	-0.08	0.94	0.00	-0.02	0.02	0	2003-13	11	1
Awarere @ Dibble	Unadjusted	0.37	22	124.00	1.89	**0.03**	**0.02**	0.00	0.04	0	2004-13	10	1
Campbell's Bay	Unadjusted	0.05	-4	115.33	-0.28	0.40	0.00	-0.02	0.01	0	2004-13	10	1
Cascades LTB	Unadjusted	0.43	4	124.00	0.27	0.40	0.01	-0.03	0.02	0	2004-13	10	1
Chatswood	Unadjusted	0.09	3	123.00	0.18	0.43	0.00	-0.01	0.01	0	2004-13	10	1
Eskdale Lower	Unadjusted	0.10	10	92.00	0.94	0.18	0.01	-0.01	0.01	0	2005-13	9	2
Eskdale Mid	Unadjusted	0.09	-8	92.00	-0.73	0.24	-0.01	-0.02	0.01	0	2005-13	9	2
Eskdale Upper	Unadjusted	0.29	-4	92.00	-0.31	0.38	0.00	-0.02	0.01	0	2005-13	9	2
Hoteo @ Kraak Hill	Unadjusted	0.27	-14	124.00	-1.17	0.13	-0.01	-0.02	0.00	0	2004-13	10	1
Hunua @ St Pauls	Unadjusted	0.53	10	124.00	0.81	0.22	0.01	-0.01	0.01	0	2004-13	10	1
Kauritutahi (Awhitu)	Unadjusted	0.39	2	124.00	0.09	0.47	0.00	-0.01	0.01	3	2004-13	10	1
Konini	Unadjusted	0.64	-11	125.00	-0.89	0.19	0.00	-0.01	0.01	0	2004-13	10	1

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Values excluded because of multiple values in a season	Period analysed	Number of records	Number of ties
Kumeu @ Weza	Unadjusted	0.11	-8	124.00	-0.63	0.27	-0.01	-0.02	0.01	0	2004-13	10	1
Lignite	Unadjusted	0.06	-2	92.00	-0.10	0.46	-0.01	-0.02	0.01	0	2005-13	9	2
Lucas LTB @ Tennis	Unadjusted	0.21	-3	125.00	-0.18	0.43	-0.01	-0.02	0.01	0	2004-13	10	1
Mahurangi LTB	Unadjusted	0.41	-21	125.00	-1.79	**0.04**	**-0.02**	-0.03	0.00	0	2004-13	10	1
Mangatawhiri	Unadjusted	0.59	-7	125.00	-0.54	0.30	-0.01	-0.02	0.01	0	2004-13	10	1
Marawhara	Unadjusted	0.58	0	124.00	0.00	0.50	0.00	-0.02	0.02	0	2004-13	10	1
Matakana LTB	Unadjusted	0.29	-18	124.00	-1.53	0.07	-0.02	-0.04	0.00	0	2004-13	10	1
Mauku Stream @ STP	Unadjusted	0.20	-11	91.00	-1.05	0.15	-0.01	-0.02	0.01	0	2005-13	9	2
Milne	Unadjusted	0.61	1	123.00	0.00	0.50	0.00	-0.01	0.01	0	2004-13	10	1
Ngakaroa LTB	Unadjusted	0.17	6	124.00	0.45	0.33	0.00	-0.01	0.02	0	2004-13	10	1
Nukumea Upper	Unadjusted	0.35	7	125.00	0.54	0.30	0.00	-0.02	0.03	0	2004-13	10	1
Oakley LTB	Unadjusted	0.14	-8	119.33	-0.64	0.27	0.00	-0.01	0.01	0	2004-13	10	1
Okura Reserve	Unadjusted	0.33	6	90.00	0.53	0.31	0.00	-0.01	0.02	0	2005-13	9	2
Okura Trib 1	Unadjusted	0.29	-29	123.00	-2.53	**0.01**	**-0.03**	-0.03	-0.01	0	2003-13	10	1
Okura Trib 2	Unadjusted	0.28	-29	125.00	-2.50	**0.01**	**-0.04**	-0.05	-0.01	0	2003-13	10	1
Onepoto @ Kauri Glen park	Unadjusted	0.17	-11	91.00	-1.05	0.15	-0.01	-0.03	0.02	0	2005-13	9	2
Opanuku LTB	Unadjusted	0.30	-10	124.00	-0.81	0.22	-0.01	-0.03	0.01	0	2004-13	10	1
Orere A	Unadjusted	0.57	-9	125.00	-0.72	0.24	0.00	-0.02	0.01	0	2004-13	10	1

Site	Adjusted?	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit	Values excluded because of multiple values in a season	Period analysed	Number of records	Number of ties
Orere B	Unadjusted	0.59	-21	125.00	-1.79	**0.04**	**-0.02**	-0.03	0.00	0	2004-13	10	1
Otara LTB	Unadjusted	0.10	9	123.00	0.72	0.24	0.00	-0.01	0.01	0	2004-13	10	1
Oteha LTB	Unadjusted	0.07	9	125.00	0.72	0.24	0.00	0.00	0.01	0	2004-13	10	1
Papakura LTB	Unadjusted	0.15	-6	122.00	-0.45	0.33	-0.01	-0.02	0.01	0	2004-13	10	1
Puhinui LTB	Unadjusted	0.00	7	95.67	0.61	0.30	0.00	0.00	0.01	0	2004-13	10	1
Puhinui Trib (soft)	Unadjusted	0.15	-13	123.00	-1.08	0.15	-0.01	-0.02	0.00	0	2004-13	10	1
Puhinui Upper (hard)	Unadjusted	0.26	5	125.00	0.36	0.36	0.01	-0.02	0.04	0	2004-13	10	1
Puhoi	Unadjusted	0.44	-5	125.00	-0.36	0.36	0.00	-0.02	0.01	0	2004-13	10	1
Riverhead	Unadjusted	0.22	-19	91.00	-1.89	**0.03**	**-0.02**	-0.05	0.00	0	2005-13	9	2
Shakespear	Unadjusted	0.31	-7	125.00	-0.54	0.30	-0.02	-0.04	0.04	0	2004-13	10	1
Symonds St @ Ponga	Unadjusted	0.45	-5	125.00	-0.36	0.36	0.00	-0.02	0.01	0	2004-13	10	1
Vaughan Lower	Unadjusted	0.07	7	123.00	0.54	0.30	0.01	-0.01	0.01	0	2004-13	10	1
Vaughan Upper	Unadjusted	0.37	-16	124.00	-1.35	0.09	-0.01	-0.03	0.00	0	2004-13	10	1
Wairoa LTB	Unadjusted	0.38	-7	125.00	-0.54	0.30	-0.01	-0.02	0.01	0	2004-13	10	1
Waitakere River	Unadjusted	0.50	0	121.33	0.00	0.50	0.00	-0.01	0.01	0	2004-13	10	1
Waiwhiu @ Frith	Unadjusted	0.36	-27	125.00	-2.33	**0.01**	**-0.03**	-0.04	-0.01	0	2004-13	10	1
Wekatahi	Unadjusted	0.58	-11	125.00	-0.89	0.19	-0.01	-0.02	0.00	0	2004-13	10	1
West Hoe LTB	Unadjusted	0.39	8	164.00	0.55	0.59	0.00	-0.01	0.02	0	2003-13	11	1

Appendix F Abbreviations

- %EPT – Per cent Ephemoptera, Plecoptera, Trichoptera
- GIS - Geographic Information System
- HB – Hard Bottom
- LCDB3 - Land Cover Database 3
- LTB – Long- Term Baseline
- MCI – Macroinvertebrate Community Index
- SB – Soft Bottom
- SOE – State of the Environment
- WQI – Water Quality Index.

Find out more: phone 09 301 0101, email rimu@aucklandcouncil.govt.nz or visit aucklandcouncil.govt.nz **and knowledgeauckland.org.nz**

Auckland Council
Te Kaunihera o Tāmaki Makaurau