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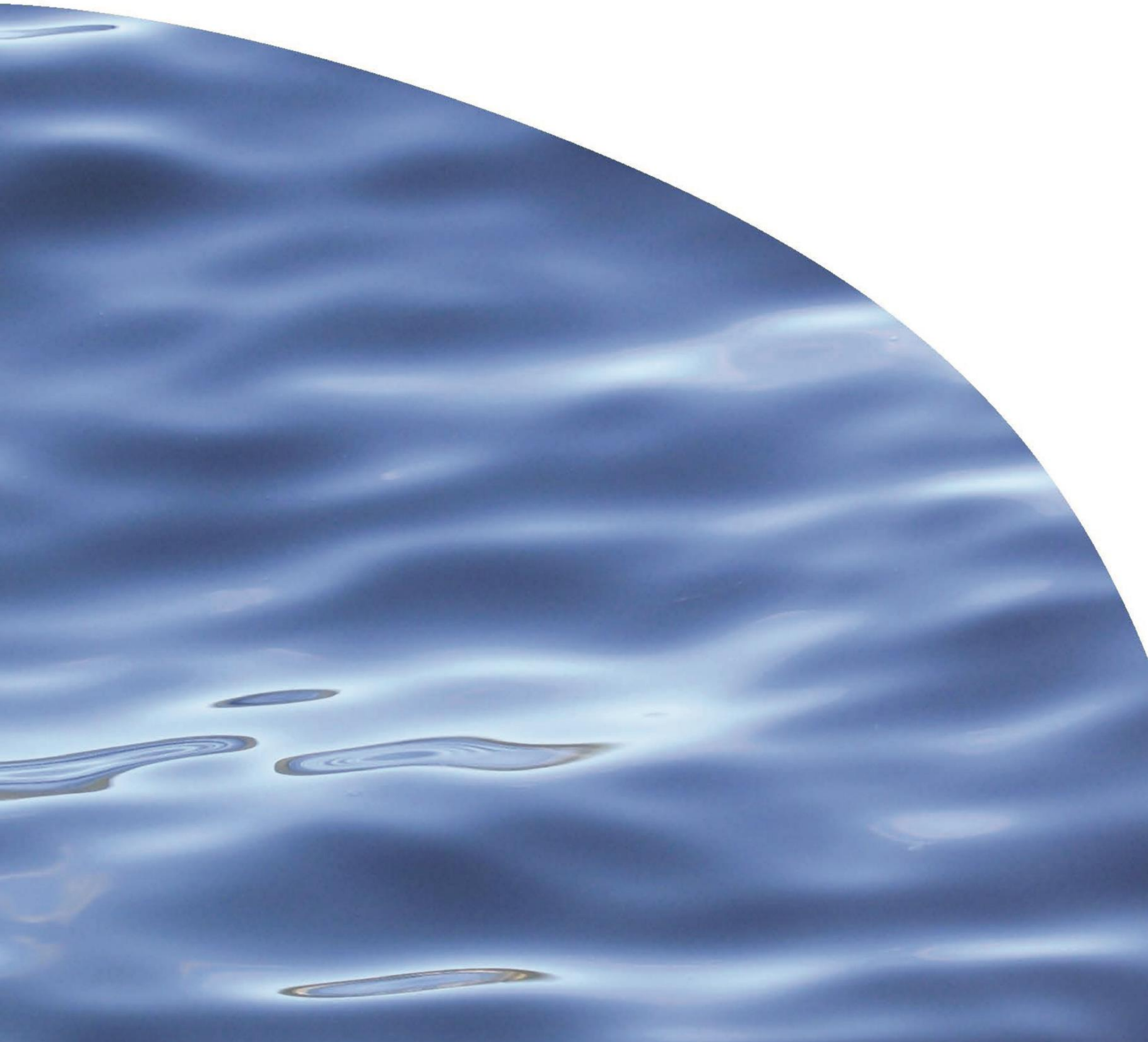
ANALYSIS OF MACROINVERTEBRATE COMMUNITY CHANGE IN NELSON STREAMS



ANALYSIS OF MACROINVERTEBRATE COMMUNITY CHANGE IN NELSON STREAMS

PAULA CASANOVAS, JOANNE CLAPCOTT, KAREN SHEARER

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CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Eric Goodwin

APPROVED FOR RELEASE BY:
Roger Young

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EXECUTIVE SUMMARY

Several State of the Environment (SOE) water quality sites in the Nelson region show declining Macroinvertebrate Community Index (MCI) median trends for the last 5 or 10 years (https://www.lawa.org.nz/explore-data/nelson-region/river-quality/), possibly indicating degrading water quality trends. There is a need to understand the community change at sites with significant declining MCI trends as the first step in identifying and understanding the drivers of the possible decline in water quality.

We calculated MCI, SQMCI (semi-quantitative MCI), %EPT (Ephemeroptera, Plecoptera and Trichoptera) and taxa richness metrics based on macroinvertebrate community data collected over 18 years (1989–2017) from 30 water quality sites and a total of 679 samples. We calculated trends in metrics for the last 5 years of data, the last 10 years of data, and all years' available data using the same non-parametric method used by LAWA 2018 (Mann-Kendall test with Sen slope) and as an alternative approach used a generalised least squares model.

At all sites, we calculated community turnover as the percentage of taxa appearing or disappearing over time and combined these with taxa richness to get the average community turnover. For sites identified as degrading from the MCI trend analysis, we also calculated the frequency of disappearance to identify dominant taxa. Ephemeroptera, Trichoptera and Diptera were the taxonomic orders most commonly lost from sites with degrading MCI trends (Table 4). Specifically, *Deleatidium*, *Nesameletus*, *Coloburiscus*, *Stenoperla, Olinga*, and *Psilochorema* were sensitive EPT taxa (high MCI scores) that were most frequently lost from decreasing MCI trend sites.

We found that overall, MCI values are highly correlated to %EPT values. However, taxa richness does not appear to have an overall effect on MCI values. These values are decreasing at more sites than increasing in the trends analysed over longer time frames (10 years and all years). The higher probability of decreasing MCI values over the 10-year period is related to community turnover. We found that at the same sites where MCI declined over time, %EPT also declined, but taxa richness did not. This suggests a shift in the community composition with the sensitive EPT taxa being substituted by other taxa, without an overall loss in biodiversity. The taxa lost from sites with degrading MCI trends are site specific, but in general, sensitive mayfly and caddis fly taxa are most often lost, reflecting the possible impacts of increased sedimentation and to a lesser degree, increased algal proliferation.

The R code used to conduct the analyses, as well as full analytical output, is provided as an html appendix for further reference.

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1. INTRODUCTION

Several State of the Environment (SOE) water quality sites in the Nelson region show declining Macroinvertebrate Community Index (MCI) median trends for the last 5 or 10 years (https://www.lawa.org.nz/explore-data/nelson-region/river-quality/), possibly indicating degrading water quality trends. The Nelson City Council (NCC) are interested to know what changes in the macroinvertebrate community are contributing to declining MCI trends. If there are taxa consistently responsible for regional trends in MCI then the potential drivers (e.g. habitat or water quality) could be identified through further analysis of macroinvertebrate traits.

The MCI was developed to assess organic enrichment in streams through the sampling and analysis of macroinvertebrates (Stark 1985). The MCI is calculated from taxon-specific tolerance values ranging from 1–10. Stark and Maxted (2007a) interpretations of MCI scores (Excellent quality > 119, Good quality = 100–119, Fair quality = 80–99 and Poor quality < 80) are a recognised metric for assessing ecosystem health, not only with respect to nutrient enrichment and organic pollution (e.g. Quinn & Hickey 1990; Niyogi et al. 2007a; Lange et al. 2014; Piggott et al. 2015), but also with respect to sedimentation (Stark & Maxted 2007b) and catchment land-use change (e.g. Collier 1995; Quinn et al. 1997; Death & Collier 2010; Clapcott et al. 2012). Like the MCI, the semi-quantitative MCI (SQMCI) is responsive to human pressures and provides additional information regarding the sensitivity of the relative abundance of taxa. Interpretation of SQMCI scores are Excellent quality ≥ 5.99, Good quality = 5.00-5.98, Fair quality = 4.00-4.99 and Poor quality ≤ 4 (Stark 1998).

The three aquatic insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies) are particularly sensitive to the decline of water quality of stream ecosystems. The proportion of these orders in macroinvertebrate samples (known as %EPT taxa) is commonly used to assess stream ecosystem health in New Zealand and worldwide. High %EPT values indicate clean water and undisturbed, structurally complex invertebrate habitat. EPT metrics have been shown to decline in response to water and habitat quality impairment in New Zealand, due to nutrient pollution, sedimentation, flow reduction, and elevated water temperature (e.g. Quinn & Hickey 1990; Matthaei et al. 2006; Niyogi et al. 2007b; Townsend et al. 2008; Piggott et al. 2015). Values decline in response to catchment land-use intensification (e.g. Matthaei et al. 2006; Death & Collier 2010; Clapcott et al. 2012; Lange et al. 2014), although EPT metrics have also been shown to initially increase with nutrient enrichment (Wagenhoff et al. 2011; Wagenhoff et al. 2012). In contrast, total taxa richness is commonly calculated but is a poor indicator of anthropogenic pressures because it combines all taxa, including those that become more prevalent under perturbed conditions, while EPT taxa are generally pollution sensitive.

Temporal turnover in ecological communities is the consequence of species immigration and extinction, population growth and density dependence. A common index of community change is temporal species turnover (i.e. the proportion of species gained or lost relative to the total number of taxa found across time periods (Hallett et al. 2016). Analysis of species turnover can give insights to understand what drives the changes in MCI scores over time because it describes how the macroinvertebrate community composition changes. A decline in MCI scores could be caused by the loss of taxa that are very sensitive to pollution (with high MCI values, for example members of the Order Ephemeroptera), or it could be caused by the addition of taxa that are very tolerant to pollution (with low MCI values, for example members of the order Diptera).

The aim of this study was to calculate macroinvertebrate metrics, conduct trend analysis and, where there are consistent degrading trends, explore the change in the macroinvertebrate community to identify taxa that might be driving the changes in MCI values over time.

2. MCI AND SQMCI TREND ANALYSIS

2.1. Source data

For all analyses in this report we used macroinvertebrate taxa data provided by the Nelson City Council (NCC) in CADDIS database form. The database included 18 years of data from 30 water quality sites in Nelson rivers and streams. The SQL query used to extract the data from CADDIS is described in Appendix 1 (along with the R-script for this report). We checked the taxonomic names for duplicates and misspellings. The MCI minimum taxonomic resolution is at the genus level, so we used only genera for the analyses even when the specific species were recorded. In the cases where there were multiple species of the same genus in the same sample, we averaged their coded abundance to represent the relative abundance of the genus.

2.2. Calculation of trends

We calculated the Macroinvertebrate Community Index (MCI) and the semi-quantitative MCI (SQMCI) metrics for all sites for all years as well as trends in the metric for the last 5 years of data, the last 10 years of data, and all years available for each site in the NCC database (Appendix 2). We used the Mann-Kendall test (Helsel et al. 2006) and calculated the Sen slope and the probability of this slope being negative (the probability of the MCI or SQMCI trend to be declining) over time for each site. This is the same non-parametric method used by LAWA. The Sen slope is an estimate of the rate of change in the central tendency of a variable through the period studied (Snelder & Fraser 2018).

As an alternative approach, we calculated the trend over time using a generalised least square model with an auto-regressive model of order 1 (Fox & Weisberg 2011). This approach models the residual at time *s* as a function of the residual at time *s-1* plus noise, and we used this model to account for the violation of independence in the time series (an MCI score at time *s* might be a function of an MCI score at time *s-1*).

2.3. Results

The number of sites with significant trends is slightly different in this analysis than that reported on the LAWA website, probably because we used the most up-to-date data.

For MCI, 6 sites out of 30 were likely/very likely decreasing over the last 5 years; 11 sites were likely/very likely decreasing over the last 10 years; and 13 sites were likely/very likely decreasing over all years available (Table 1, Figure 1, Appendix 2). There were 3 sites that showed a consistent decline in MCI values for all time periods studied: Orphanage [Stream] at Saxton Rd East, Wakapuaka [River] at Hira, and Collins [River] at SH6. Two sites that appeared to be degrading in the last 5 years showed an increase in MCI values if all years of data are considered (Teal [River] at 1.9 km, Matai [River] at Groom Rd). The MCI trends did not always agree with the SQMCI trends. MCI is less sensitive to subtle changes in community composition than SQMCI, but it responds to any perturbation that alters the list of taxa. The reason why some sites showed opposite trends between the two indices require further investigation, but it is likely due to the large variability in the abundances of the different taxa.

Table 1. The number of Nelson City Council State of the Environment water quality sites with decreasing or increasing trends in MCI and SQMCI indices using 5, 10 and all years available for the analysis. N = 30.

Trend likelihood	5 y MCI	10 y MCI	All years MCI	5 y SQMCI	10 y SQMCI	All years SQMCI
Very likely decreasing	2	6	6	0	2	6
Likely decreasing	4	5	7	6	11	6
Indeterminate	15	11	8	16	8	8
Likely increasing	6	6	3	4	8	7
Very likely increasing	2	2	6	3	1	3
NA	1	0	0	1	0	0
Proportion decreasing	0.20	0.37	0.43	0.20	0.43	0.4
Proportion increasing	0.27	0.27	0.30	0.23	0.30	0.33

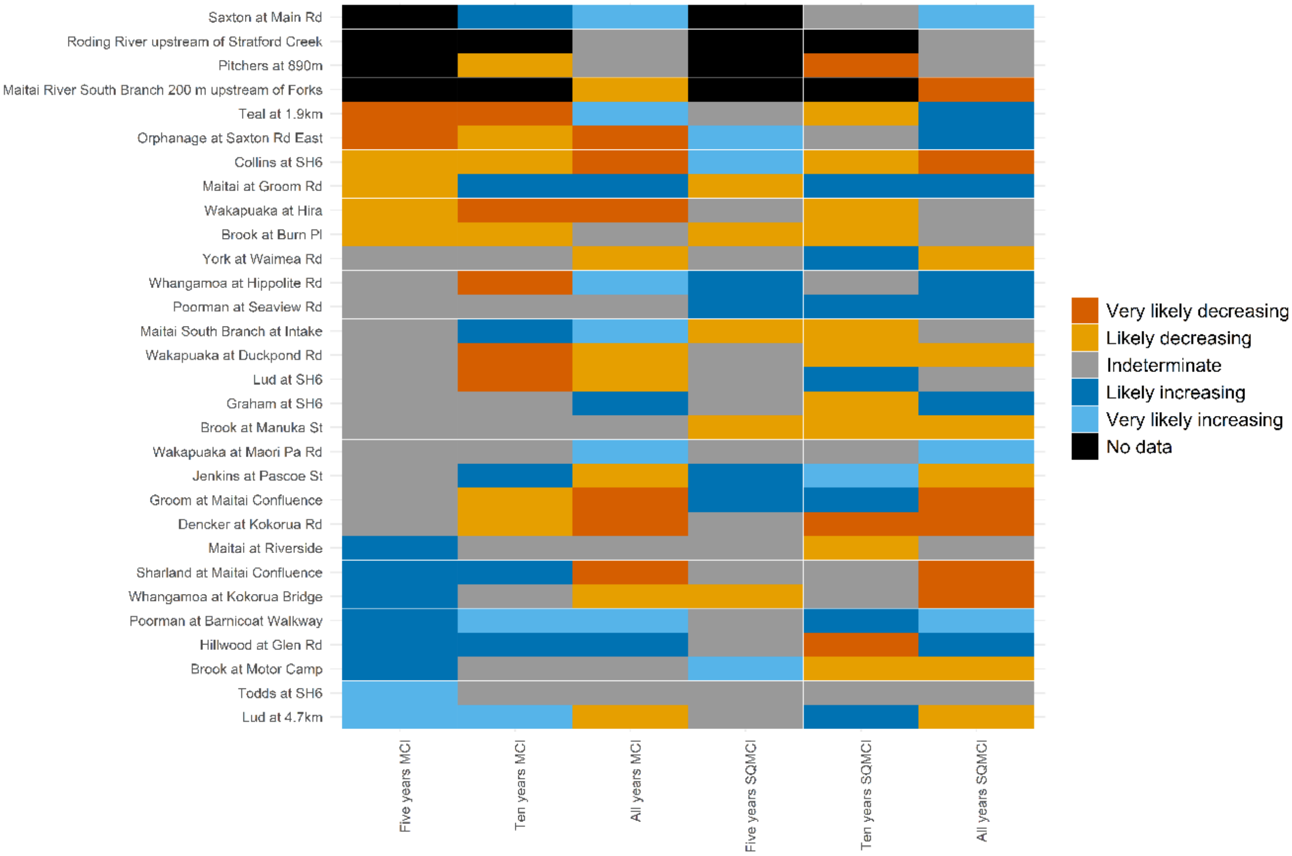

Figure 1. Comparison of the trend probabilities for MCI and SQMCI indices at Nelson City Council State of the Environment water quality sites using 5, 10 and all years available for the analysis. Note that the matrix is ordered by likelihood of decreasing trends in the last 5 years of data using MCI scores.

Exploring the data using the generalised least square model (Appendix 3), we found that even though some sites appeared to have significant trends, the slopes of these trends were close to 0, particularly for the 10-year and all-years trends, indicating that the decline or increase in MCI values over time was not clear. However, when looking at the raw differences in the MCI values between the best year in the last 10 years and 2017, 23 sites (88% of sites analysed) had in 2017 a value of 10 or more units less than the best year; and in the last 5 years, 13 sites (50% of sites analysed) had in 2017 a value of 10 or more units less than the best year in that period (Table 2). These differences are less trivial than the trend gradients. Following Stark and Maxted (2007) interpretations of MCI scores, most of the sites remained of Excellent or Good quality even after the decline (19 sites), with only 5 sites declining from Good to Fair quality, 1 site from Good to Poor (Poorman [Stream] at Seaview Rd) and 1 site from Fair to Poor quality (Jenkins [Creek] at Pascoe St).

Table 2. MCI values for the best years in the different analysis periods (10 years and 5 years), and the differences with 2017 MCI values. Red indicates that the MCI value decreased by more than 10 points from the best year. Note that 4 sites have no information for 2017 so are not included. Excellent > 119, Good 100–119, Fair 80–99, Poor < 80.

Site name	Best year MCI (last 10 years)	Best year MCI (last 5 years)	MCI 2017	Difference (last 10 years)	Difference (last 5 years)
Brook at Burn Pl	134.29 (2009)	122.31 (2015)	103.63	30.7	18.7
Brook at Manuka St	112 (2011)	102.35 (2017)	96.83	15.2	5.5
Brook at Motor Camp	138.75 (2011)	133.33 (2016)	122.52	16.2	10.8
Collins at SH6	148 (2009)	133.64 (2015)	120.2	27.8	13.4
Dencker at Kokorua Rd	140 (2009)	128.7 (2013)	114.29	25.7	14.4
Graham at SH6	152.86 (2012)	137.89 (2017)	136.01	16.8	1.9
Groom at Maitai Confluence	120 (2009)	108.57 (2016)	98.58	21.4	10.0
Hillwood at Glen Rd	125 (2015)	125 (2015)	89.77	35.2	35.2
Jenkins at Pascoe St	90 (2016)	90 (2016)	61.58	28.4	28.4
Lud at 4.7km	116.52 (2017)	116.52 (2017)	114.05	2.5	2.5
Lud at SH6	131.11 (2011)	113.14 (2016)	103.17	27.9	10.0
Maitai at Groom Rd	117.14 (2012)	110 (2015, 2016)	104.09	13.1	5.9
Maitai at Riverside	116.36 (2009)	100 (2015)	95.95	20.4	4.1
Maitai South Branch at Intake	152.86 (2015)	152.86 (2015)	142.48	10.4	10.4
Orphanage at Saxton Rd East	93.33 (2013)	93.33 (2013)	63.26	30.1	30.1
Poorman at Barnicoat Walkway	132.86 (2016)	132.86 (2016)	126.33	6.5	6.5
Poorman at Seaview Rd	106.15 (2008)	92.5 (2015)	79.17	27.0	13.3
Sharland at Maitai Confluence	121.67 (2008)	112.63 (2017)	106.32	15.3	6.3
Teal at 1.9km	149.23 (2008)	136.47 (2013)	120	29.2	16.5
Todds at SH6	103.33 (2009)	91.76 (2017)	84.97	18.4	6.8
Wakapuaka at Duckpond Rd	144.44 (2009)	130.53 (2013)	128.82	15.6	1.7
Wakapuaka at Hira	135 (2008)	120 (2015)	111	24	9
Wakapuaka at Maori Pa Rd	117.78 (2010)	111.58 (2017)	108.17	9.6	3.4
Whangamoa at Hippolite Rd	151.43 (2011)	142.86 (2017)	140.12	11.3	2.7
Whangamoa at Kokorua Bridge	135 (2009)	123.45 (2017)	117.91	17.1	5.5
York at Waimea Rd	86.15 (2008)	82.67 (2016)	64.62	21.5	18.0

3. TAXA AND %EPT RICHNESS

3.1. Calculation of metrics and trends

We calculated total taxa richness and %EPT taxa richness for all sites and each year (Appendix 2). For the calculations of %EPT we excluded the genera *Oxyethira* and *Paroxyethira* (Hydroptilidae, Trichoptera) because these two genera are strongly associated with high algal biomass and are therefore less sensitive to pollution (Clapcott et al. 2017). We calculated taxa richness using the MCI taxa resolution (i.e. we did not consider the different species of a given genus).

We also calculated the %EPT and taxa richness trends over time for 5, 10 and all years of data, (Figure 2; Appendix 2) using the same method described for MCI trends (see Section 2.2).

3.2. Results

For %EPT, 5 sites were likely/very likely decreasing over the last 5 years; 13 sites were likely/very likely decreasing over the last 10 years; and 12 sites were likely/very likely decreasing over all years considered (Table 3, Figure 2, Appendix 2). We found that the sites showing an increase in %EPT also showed an increase in MCI values, which would indicate an improvement in water quality for these sites. Taxa richness trends generally did not follow changes in MCI trends (see the next section).

Table 3. The number of Nelson City Council State of the Environment water quality sites with decreasing or increasing trends in %EPT and taxa richness indices using 5, 10 and all years available for the analysis.

Trend likelihood	5 y %EPT	10 y %EPT	All years %EPT	5 y taxa richness	10 y taxa richness	All years taxa richness
Very likely decreasing	2	7	8	0	0	7
Likely decreasing	3	6	4	1	3	8
Indeterminate	16	9	11	5	2	8
Likely increasing	6	7	5	10	16	7
Very likely increasing	2	1	2	13	8	0
NA	1	0	0	1	0	0
Proportion decreasing	0.16	0.43	0.40	0.03	0.10	0.50
Proportion increasing	0.27	0.27	0.23	0.77	0.80	0.23

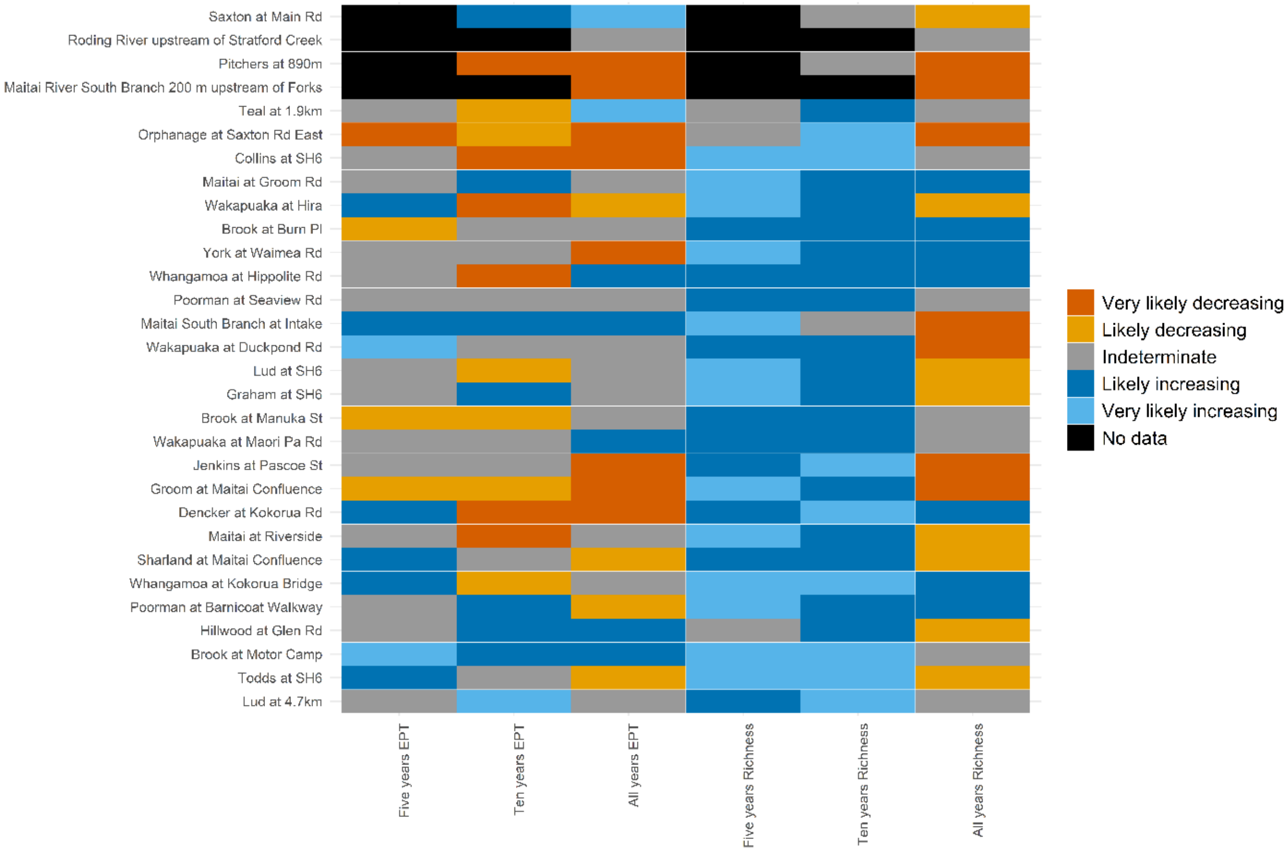

Figure 2. Comparison of the trend probabilities for %EPT and taxa richness at Nelson City Council State of the Environment water quality sites using 5, 10 and all years available for the analysis. Note that the matrix is ordered by likelihood of decreasing trends in the last 5 years of data using MCI scores (for comparison with Figure 1).

3.3. Comparison of metrics

A visual comparison of MCI trends with %EPT and taxa richness trends (i.e. Figures 1 and 2) is further supported by a linear model for all sites and dates combined that showed MCI values were highly correlated with %EPT values ($R^2 = 0.83$). Taxa richness was significantly correlated with MCI values, but the correlation was very low (with a $R^2 = 0.11$). However, even though there is not a strong relationship between taxa richness and average MCI, the minimum MCI score for a given taxa richness is correlated with taxa richness. We tested this using a quantile regression (using the 0.05 quantile). Figure 3 shows the p-value and R^2 value for the linear model for MCI and %EPT and the p-value and pseudo-R^2 for the 5th percentile regression model.

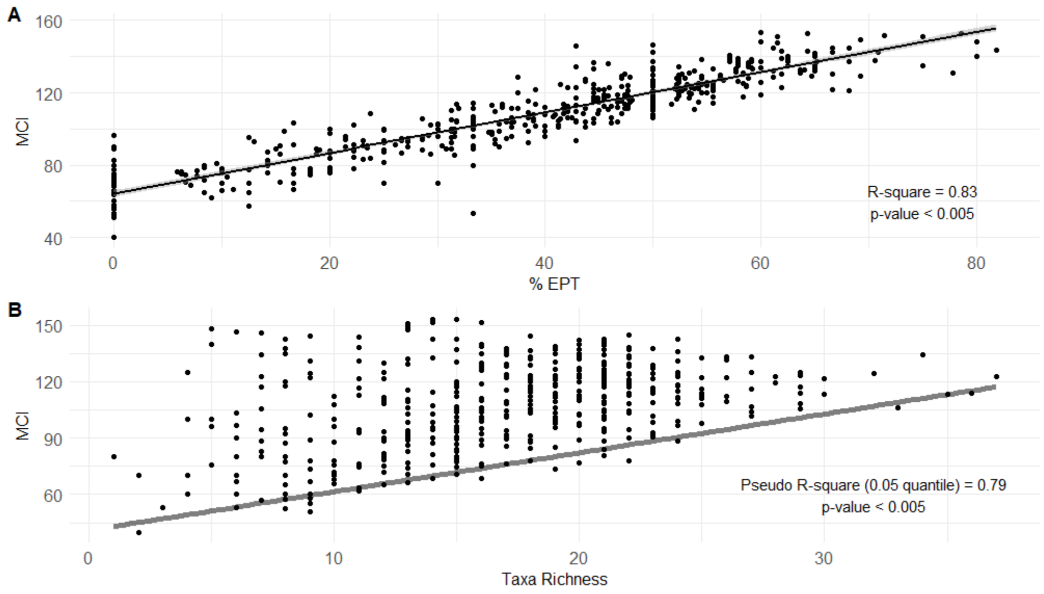

Figure 3. Significant positive relationship between MCI scores and (A) %EPT and (B) taxa richness.

For each site, we looked at the relationship between MCI scores and %EPT and taxa richness, considering that the data points are not independent from each other in time. We used a generalised least square model with an auto-regressive model of order 1 to account for the temporal dependence (continuity) of the data. We found that for most sites the %EPT is highly correlated with the MCI values when looking at all years available of data and the last 10 years of data. Taxa richness was generally not significantly related to MCI values at any sites for any time period considered (Appendix 3).

We have chosen the site Brook [Stream] at Burn Pl as an example to illustrate these analyses (Figure 4). For this site, we found that there was no significant change in MCI scores, %EPT and total taxa richness over time when analysing all years of data available (in Figure 4A, 4B and 4C the slight increases in value are not statistically significant). MCI scores were positively correlated with %EPT (Figure 4D) but we did not find a clear relationship between MCI scores and total taxa richness for this site (Figure 4E). We found a positive correlation between MCI scores and SQMCI scores (Figure 4F). This is not always the case and showing this relationship for each site can help to evaluate the difference between using one metric or the other as a measure of river health. Figures for all sites with significant MCI trends can be found in Appendix 3.

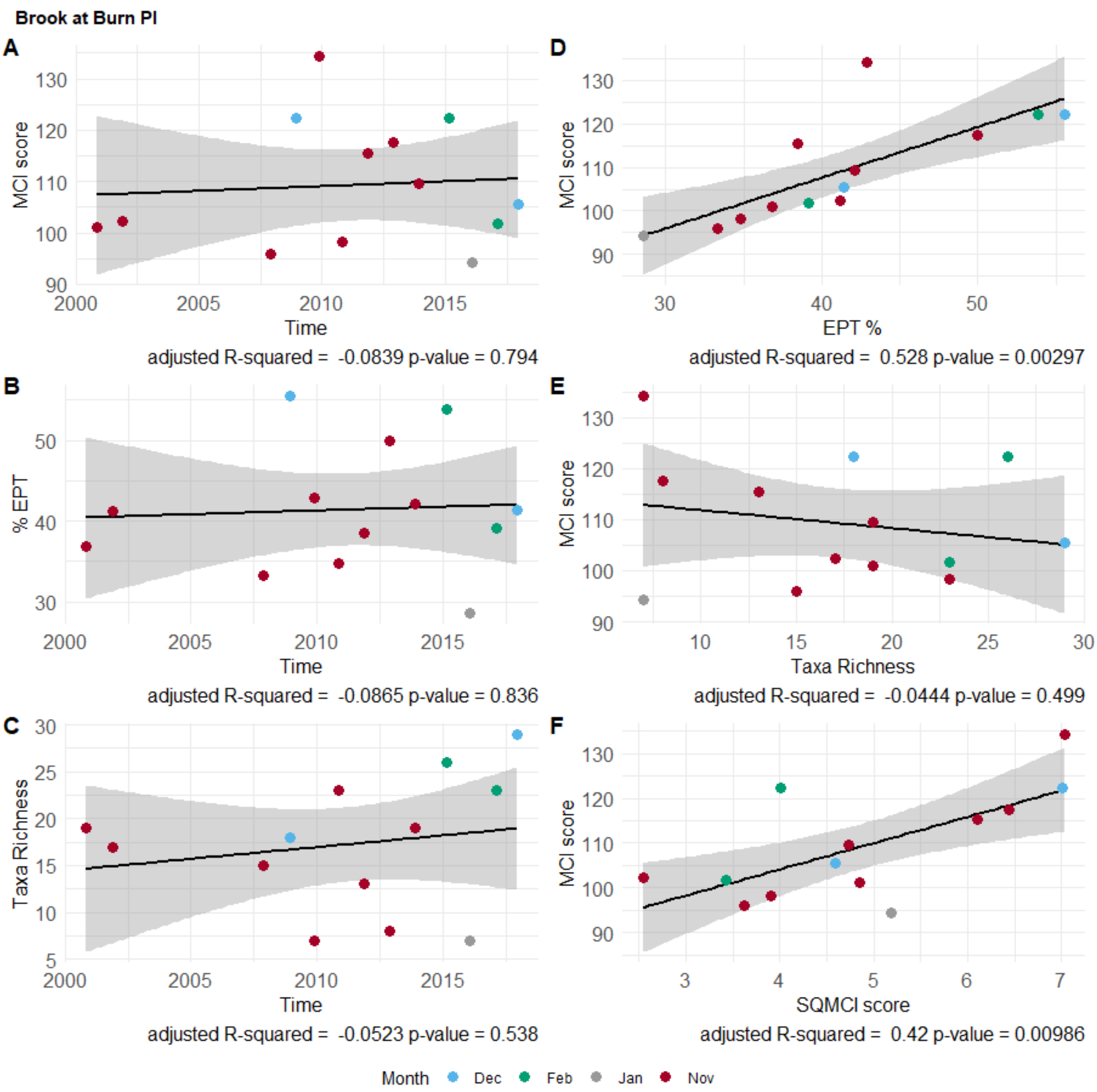

Figure 4. MCI scores for the site 'Brook at Burn Pl' was identified as likely decreasing in the last 5 years. This is an example of the results looking at MCI scores, %EPT and taxa richness over time (A, B, C), as well as the relationship between MCI scores and (D) %EPT and (E) taxa richness. Note that we also looked at the relationship between MCI scores and SQMCI scores for reference (F).

4. RELATIVE COMMUNITY CHANGE

For each site, we calculated species turnover over time using the MCI taxa resolution as well as a lower resolution of order and higher taxonomic ranks. We used the R package 'codyn' (Hallett et al. 2016), which calculates the percentage of the taxa in a community that changes from time step to time step. Total turnover is calculated as the sum of appearances and disappearances relative to total taxa richness across time periods (Equation 1). Appearance and disappearance turnover are calculated as the number of taxa that appear or 'taxa gained' (or disappear or 'taxa lost') in the second time period relative to the total taxa richness across both time periods:

(1) $$Total\ turnover = \frac{Species\ gained + Species\ lost}{Total\ species\ observed\ in\ both\ timepoints}$$

We found that total turnover from year to year was high, with an average of 37% for orders and higher taxonomic resolution (standard error of 15%), and an average of 58% for MCI taxa resolution (standard error of 13%).

We related the MCI trends with the average total turnover, the average disappearance and the average appearance turnover to understand if the changes in community composition were driving the trends in MCI values. We used the probabilities of decreasing MCI values calculated using the LAWA methodology as the response variable in a Pearson's product-moment correlation model with the average turnover for the different time periods for which the trends were calculated. We found that for the trends over the last 10 years there was a significant correlation with total turnover and disappearance turnover of MCI level taxa (Figure 5).

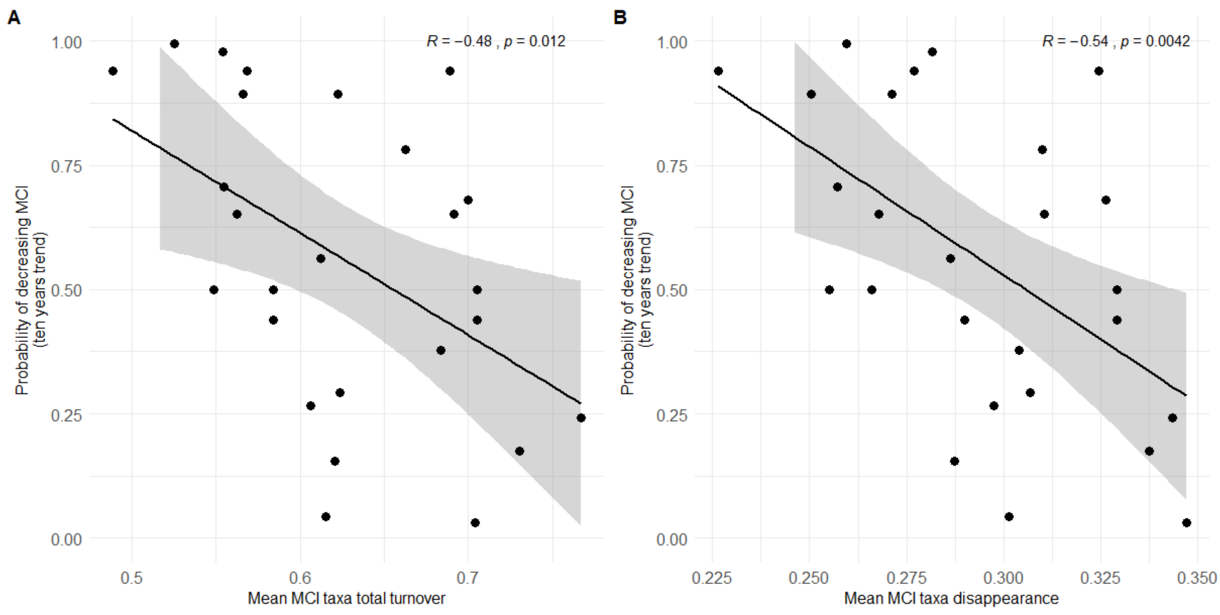

Figure 5. Significant negative relationship between MCI trend probability for the last ten years of data at all sites and (A) MCI taxa total turnover and (B) MCI taxa disappearance.

We explored the potential for community turnover to explain changes in MCI values at all sites. For each site and year, we calculated total turnover, disappearance and appearance, and we then related these to MCI values for each year. For the ‘Brook [Stream] at Burn Pl’ site (Figure 6), we found that total turnover was very high every year studied, especially when looking at all MCI taxa (some years reaching 80%). We can see also that disappearance and appearance turnover showed an opposite pattern (years with high appearance turnover had low disappearance turnover and vice versa), and this is what is expected when communities fluctuate with some external factor (e.g. a ‘good’ year would have a high proportion of new taxa appearing and a low proportion of taxa disappearing, Figure 6A and 6B). For this site, we found that only the total turnover of orders and higher taxonomic ranks was significantly correlated with the MCI values each year (Figure 6C, 6D, 6E and 6F), showing that at higher turnover the MCI values were smaller. This indicates that the overall change in orders from sensitive to tolerant may be driving the decline in MCI values (at least for the last years of data, see Figure 1 for this site). However, this result was not consistent with the results found for other sites, and it will be important to look at each site individually to understand the relationships between turnover and MCI values. The results for all sites are in Appendix 3, including a table with p-values for the generalised linear regression models and figures for all sites.

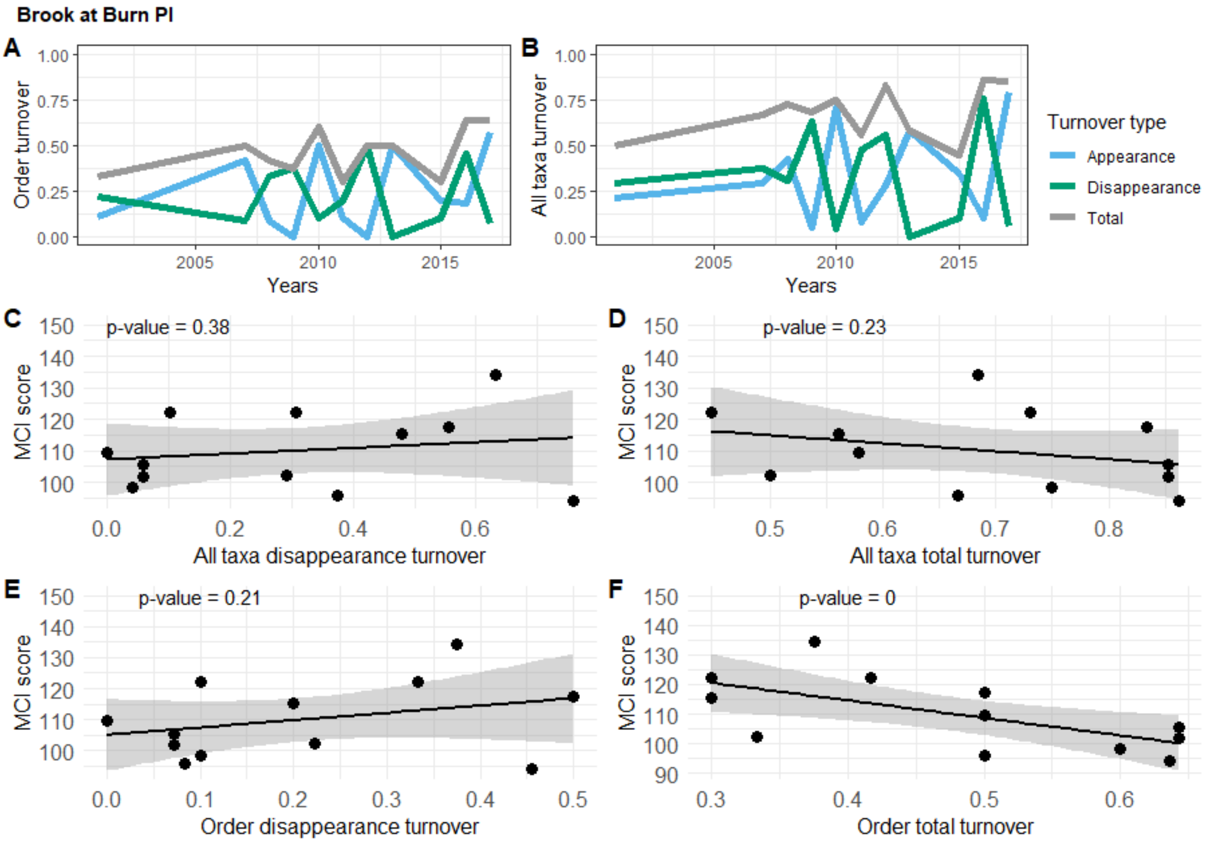

Figure 6. The MCI for the site 'Brook [Stream] at Burn Pl' was identified as being likely decreasing in the last 5 years. This provides an example of the site level results of (A) Order turnover and (B) all MCI taxa turnover, as well as the relationship between MCI scores and (C) taxa disappearance, (D) total turnover, (E) Order disappearance, and (F) total turnover.

5. DOMINANT TAXA, THEIR ECOLOGICAL FUNCTION AND HABITAT REQUIREMENTS

To understand which taxa influenced the decline in MCI values over time, we identified the taxa that disappeared from the sites that were identified as 'degrading' (i.e. likely/very likely decreasing trends) between the year with the best MCI score and 2017, over each time period analysed (5 years, 10 years and all years of data). The full lists of lost taxa for each time period are in Appendix 4. We calculated the frequency of disappearance of each MCI taxon in each time period to assess which taxa were the most important overall drivers of MCI declines. Figure 7 shows the frequency of lost taxa for all years of data (figures for the last 5 years and 10 years can be found in Appendix 4).

For all cases, looking at EPT taxa only, most lost taxa belonged to the orders Trichoptera, followed by Ephemeroptera. The order Plecoptera did not show much importance when looking at the lost taxa in comparison with the other two orders in the EPT group, for any of the time periods analysed. Members of the Plecoptera order have in general lower MCI values than the members of the other two orders (except for *Stenoperla,* with an MCI score of 10, which was 'lost' at three sites in the 5- and 10-year analyses).

Some taxa from the order Diptera also appeared as important losses for all time periods. Even though as a general rule, members of the order Diptera are associated with poor quality environments, the MCI taxa that disappeared from the sites studied (*Aphrophila* and *Tanypodinae*) had a medium MCI value of 5 and can be common in pristine streams.

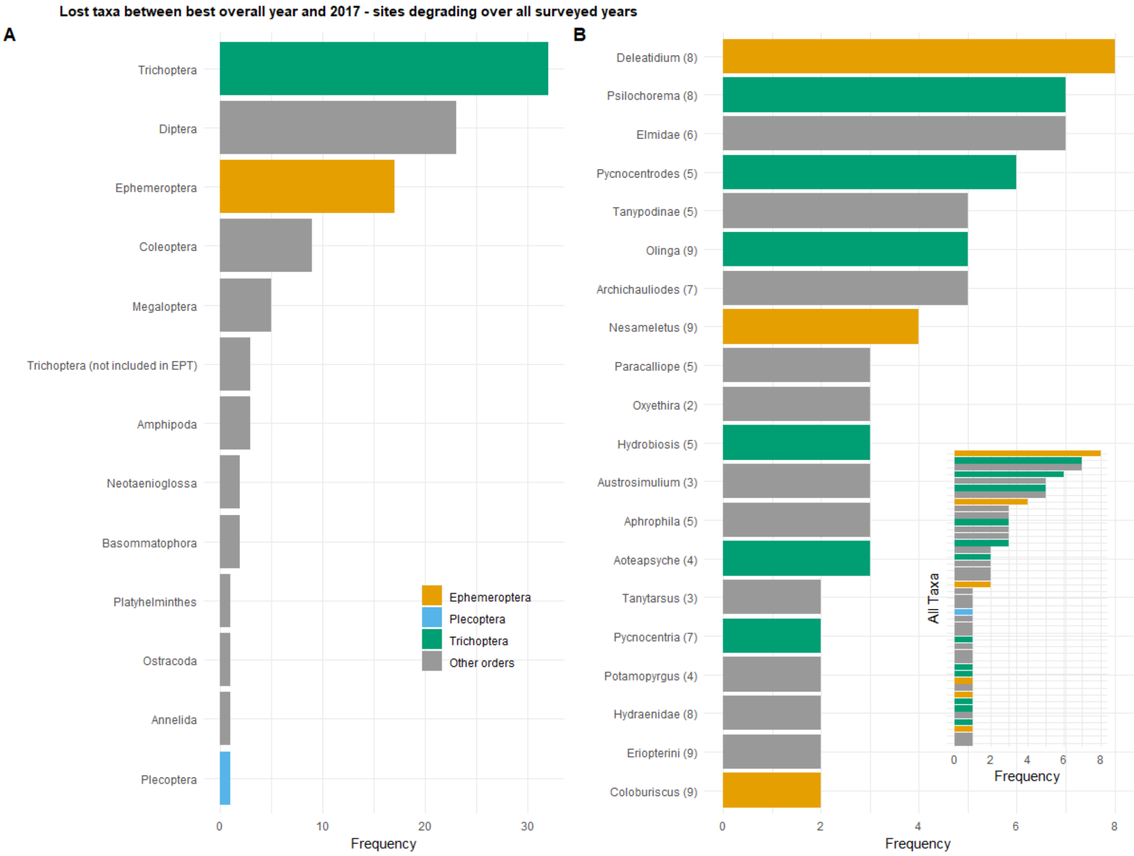

Figure 7. Frequency of lost taxa for degrading sites for all years surveyed showing the frequency of lost members of (A) the different Orders and (B) MCI taxa. Note that (B) is showing taxa that disappeared in at least two sites and all taxa in the insert figure. MCI value is shown in parentheses.

The most frequently lost taxa for all time periods analysed are shown in Table 4, along with their habitat, ecological function and indicator value. These taxa had medium to high MCI scores, most being indicators of good water/habitat quality. Looking at the characteristics of these taxa, there is no indication of a single environmental factor affecting the condition of the streams, and a case by case analysis of sites would be needed to pinpoint the causes of MCI decline.

Table 4. Summary of the habitat and ecological function of the most frequently lost taxa for all time periods analysed. Information gathered from Manaaki Whenua Freshwater Invertebrates guide: (https://www.landcareresearch.co.nz/resources/identification/animals/freshwater-invertebrates).

MCI taxa name (MCI value)	Order	Habitat	Ecological function	Indicator value
Deleatidium (8)	Ephemeroptera	larvae are the most abundant invertebrates in many fast-flowing, stony-bottom streams with cool and well aerated water	feed by scraping diatom algae and other organic matter from stone surfaces	high abundances suggest good habitat and water quality conditions
Nesameletus (9)	Ephemeroptera	larvae are most common in pools in stony or gravelly, bush covered streams	larvae feed on biofilm and plant detritus on the streambed	abundance suggest good habitat and water quality
Coloburiscus (9)	Ephemeroptera	larvae are most abundant in stony or gravelly, cold water, well aerated, bush covered streams	filter feeders, both plant fragments and small invertebrates	high abundances are indicative of good habitat and water quality
Stenoperla (10)	Plecoptera	most common in unmodified, bush covered, cold water, stony bottom streams	predators of other stream invertebrates, but small nymphs may feed on a range of streambed detritus	nymphs are an indication of good habitat and water quality conditions
Aoteapsyche (4)	Trichoptera	larvae are abundant in many stony streams and rivers, and they reach greatest abundance downstream of lake outlets	filter-feeding drifting particulate food items, including algae and other invertebrates	larvae are common in streams of moderate to good quality
Olinga (9)	Trichoptera	larvae are most common in bush covered, cold water, stony streams	collector-gatherers and shredders (feeding on fine particulate organic matter and leaf litter)	abundance of larvae indicates good habitat and water quality
Psilochorema (8)	Trichoptera	larvae can be common in bush-covered and farmland stony streams	predators of other stream invertebrates	can be an indication of good water quality
Pycnocentrodes (5)	Trichoptera	common in streams with stony or gravelly beds, both in bush covered and farmland areas	collector-gatherers feeding on fine organic matter and grazing on streambed algae	abundance of larvae indicates at least moderate to good water quality
Elmidae (6)	Coleoptera	very common in many stony and gravelly streams, and can burrow deep into streambeds	collector-gatherers, feeding on a range of fine organic matter trapped in the streambed	high abundance in gravelly streams with moderate to good water quality
Archichauliodes (7)	Megaloptera	common in hard-bottom streams in bush covered and farmland areas	predators of other stream invertebrates	common in streams with moderate to good water quality.
Aphrophila (5)	Diptera	common in many stony and gravelly, bush covered and farmland streams	feed on filamentous algae, diatoms and plant detritus	abundant in gravelly streams with moderate to good water quality
Tanypodinae (5)	Diptera	larvae are found in a wide range of streams, rivers and lagoons	may have a range of feeding strategies, but some species are known to be prey on other invertebrates	can be common in pristine streams, but also in some polluted streams

For each site with a significant declining MCI trend, we also identified the taxa contributing at least 10% to the MCI value each year. We could not find a general pattern of change for all sites, and a site by site examination would be necessary to assess these taxa. Figure 8 shows an example of these analyses, where we can see that at the site 'Brook [Stream] at Burn Pl', the order Ephemeroptera with high MCI value taxa was dominating the MCI values until 2012, but disappear from the dominant taxa in the following years where a decline in MCI score was seen. Figures for all declining sites are found in Appendix 5.

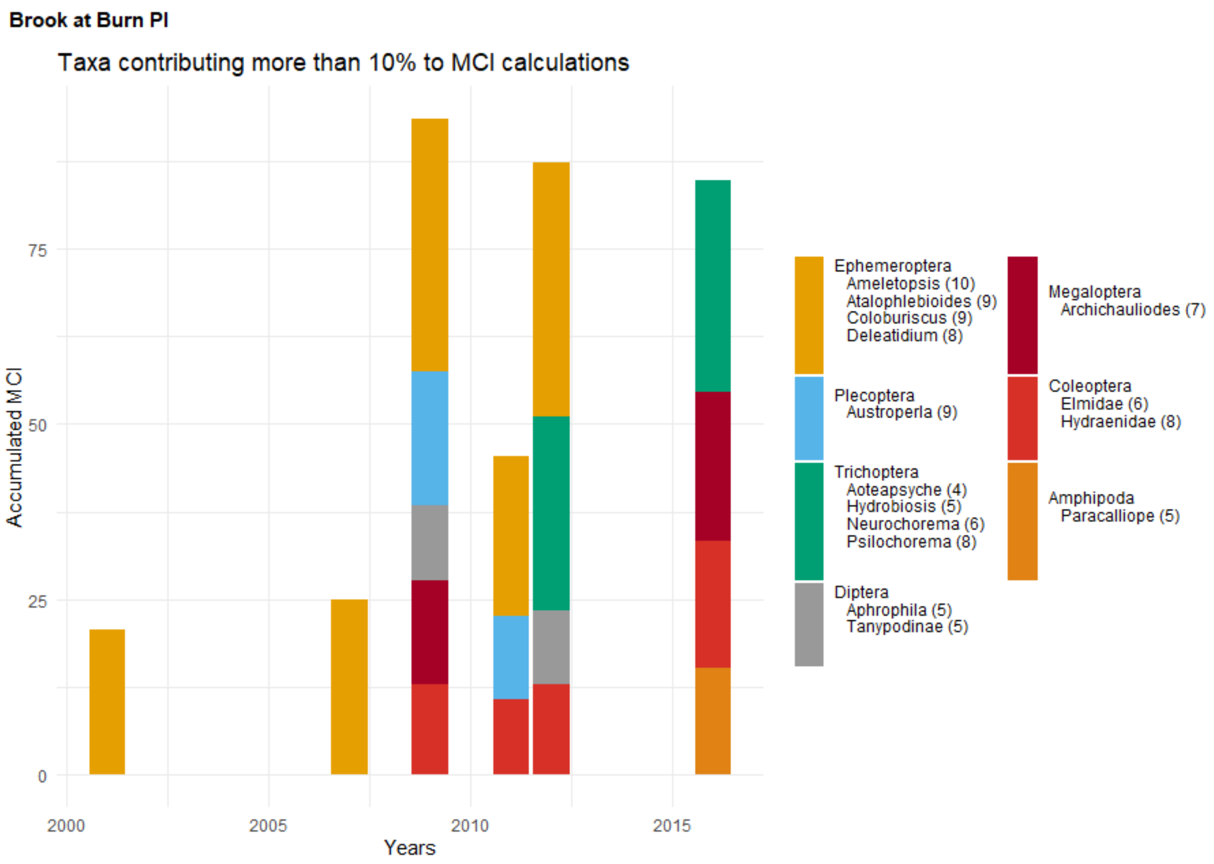

Figure 8. Example of the results of MCI taxa contributing 10% or more to the MCI score calculations for each year. Years with no bars indicate that there were no given taxa that contributed 10% or more. The site 'Brook at Burn Pl' was identified as having degraded in the last 5 years.

6. SUMMARY AND RECOMMENDATIONS

Five-year trends suggest macroinvertebrate indices (MCI, SQMCI, %EPT) are increasing at more Nelson City Council State of the Environment water quality sites than they are decreasing (Mann-Kendall with Sen slope calculations). However, ten-year and all-year trends suggest the opposite. This may indicate that a recovery is underway in recent years, reversing earlier declines, or it may indicate the effects of short-term climatic variability influencing macroinvertebrate community composition. Taxa richness also decreases at more sites than not when all-year trends are summarised (Table 1, Table 2). Three sites show consistent declines in macroinvertebrate indices across all three time periods of trend analysis: Orphanage [Creek] at Saxton Rd East, Wakapuaka [River] at Hira, and Collins [River] at SH6.

Complementary trend analysis using a generalised least squares model demonstrated that statistically significant trends were not always ecologically meaningful, with some slopes close to zero. High inter-annual variability in MCI values is evident across sites. The most recent (2017) MCI values (available for 26 sites) show that despite changes over the last 10 years, most sites (19) remained of Excellent or Good quality even after the declining trend, with 5 sites declining from Good to Fair quality, 1 site from Good to Poor (Poorman at Seaview Rd) and 1 site from Fair to Poor quality (Jenkins [Creek] at Pascoe St).

Analysis of species turnover showed high total turnover with an average of 58% at MCI taxa resolution (standard error of 13%) for all sites. Higher total turnover was related to higher probability of decreasing MCI 10-year trends, but the relationships between total turnovers, species lost, species gained, and MCI was highly site-dependent.

Ephemeroptera, Trichoptera and Diptera were the taxonomic orders most commonly lost from sites with declining MCI trends (Table 4). In particular, *Deleatidium, Nesameletus, Coloburiscus, Stenoperla, Olinga*, and *Psilochorema*, were sensitive EPT taxa (high MCI scores) that were most frequently lost from decreasing MCI trend sites along with Elmidae (Coleoptera) and Archichauliodes (Megaloptera). These taxa all have quite diverse traits that do not point to a specific environmental factor leading to their loss. However, a recent analysis by Wagenhoff et al. (2018) identified that all of the taxa in Table 4 (except Tanypodinae) decline in response to increased deposited sediment, and 5 of the 12 taxa also decline in response to algal proliferation. In general, these results suggest increased sedimentation might be one variable responsible for the decline in MCI values at Nelson City Council State of the Environment monitoring sites.

It is clear that when evaluating potential MCI declines it is necessary to look at specific sites individually. The appendices provide the R code and analytical output for each site to support specific site investigations. Tools that may help further identify factors leading to macroinvertebrate community turnover include:

1. Calculation of stressor-specific metrics (e.g. sediment and algal proliferation: (Wagenhoff et al. 2018); flow variation: (Greenwood 2018))
2. Measurement of, and regression of MCI scores with, stressors including deposited sediment (and/or sediment loads), algal proliferation, nutrients (and/or nutrient loads), flows and water temperature variability. Variance partitioning could help elucidate the influence of stressors and local and regional climatic variables driving changes in community composition.
3. Analysis of community composition at sites with increasing MCI scores over time could further help identify factors that are related to improving water quality and inform potential restoration/remediation activities.

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8. APPENDICES

Provided as Appendices.html file

Appendix 1. Commented R code for data manipulation and analyses

Appendix 2. MCI, SQMCI, %EPT and total richness for all sites for all years and trends.

Appendix 3. Relationships between MCI scores for each site.

Appendix 4. Lost taxa plots and tables.

Appendix 5. Figures of 10% taxa contribution to MCI scores.