Environment Waikato Technical Report 2006/04

Patterns and Trends in the Ecological Condition of Waikato Streams Based on the Monitoring of Aquatic Invertebrates from 1994 to 2005

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Summary

Environment Waikato has been carrying out annual assessments of invertebrate community composition in streams and rivers since 1994 as part of the Regional Ecological Monitoring of Streams (REMS) programme. Sampling has now been of sufficient duration and frequency with consistent collection protocols and invertebrate numbers to enable assessment of temporal trends in ecological condition at 49 sites. These sites comprise wadeable high-gradient streams with stony beds and low-gradient non-wadeable streams dominated by soft substrates. Condition was assessed using four invertebrate-based measures derived from 100-invertebrate counts: EPT* (mayfly, stonefly and caddisfly (excluding Hydroptilidae)) richness, %EPT* abundance, the Macroinvertebrate Community Index (MCI), and an Ecological Condition Score integrating these and a range of other metrics. Analysis across all monitoring samples indicated that values for invertebrate metrics were mostly well below/below the average for all samples in Hauraki, as well as Upper/middle Waikato and Lower Waikato. Several invertebrate-based measures of condition were mostly well above/above average in Taupo, West Coast, Waipa and Coromandel. Habitat quality scores were also below/well below the average in most assessments from Lower Waikato, Upper/middle Waikato and Hauraki, and above/well above the average in most assessments from Taupo and Coromandel. Analysis of invertebrate metric values and habitat quality scores in 2005 in relation to landcover indicated highly significant statistical differences, with lower values for sites with adjacent reaches and upstream catchments dominated by pasture compared to indigenous vegetation. Analysis of trends indicated that ecological condition appears to have been “stable” (inconclusive evidence of change) over the monitoring period at around three-quarters of sites, with the remainder of sites showing statistically and/or ecologically significant evidence of change. Of the apparently changing sites, around two-thirds showed signs of net declines and one-third showed signs of net increases in overall ecological condition. Two to three times as many sites displayed probable/clear declines in EPT* richness and MCI in Hauraki compared to their representation in the long-term monitoring network. Relationships between landscape variables and the magnitude of change in invertebrate indicators for sites where declines were deemed probable/clear suggested that the magnitude of decline over time may partly reflect upstream landcover, as well as stream size and landscape position, such that declines appear greater in smaller, lowland streams with higher proportions of upstream catchment development. Some of the previously-reported trends in water quality among sites within the region are consistent with the patterns observed in invertebrate-based measures of ecological condition at the same sites. Declines in water quality have been largely attributed to changes in landuse, particularly pastoral intensification and land drainage. The effects of these impacts on water and habitat quality are also likely to have contributed to observed patterns and trends in ecological condition based on the invertebrate measures assessed.

1 Introduction

Environment Waikato has been carrying out annual assessments of invertebrate community composition (Regional Ecological Monitoring of Streams – REMS) since 1994 as part of its Environmental Indicators Programme to document the condition of streams and rivers in the region. The history and objectives of this monitoring programme have been reviewed by Collier (2005). The composition of aquatic invertebrate communities provides a measure of the ecological condition of their habitats and upstream environments. This condition reflects a range of interacting factors thereby providing a more holistic and cumulative understanding of ecosystem health that augments non-integrative measures such as water quality. Information on invertebrate community composition is condensed into “metrics” that can be used to report on changes in stream ecological health over time. Similar approaches are widely used among other regional councils in New Zealand and territorial authorities internationally for monitoring ecological condition.

Environment Waikato’s REMS sampling has now been of sufficient duration and frequency at some sites (annually up to 10 years) to enable assessment of temporal trends in ecosystem health. A record of eight or more years over the 11 year monitoring period was considered sufficient for analysis of trends, even if this record did not cover successive years. Some sites with long-term records were not considered suitable for trend analysis because changes in sampling protocols implemented in 2002 may have compromised the interpretation of temporal patterns (see Collier 2005 for a further discussion of this). In statistical terms, eight annual monitoring occasions represent a relatively small dataset for interpreting trends, and partly because of this potential limitation different levels of confidence are used based on the perceived ecological significance <u>and</u> the statistical significance of any observed trends.

The aim of this report is to identify spatial patterns in condition and apparent trends at sites considered to have robust, long-term data based on selected invertebrate community metrics and an integrative Ecological Condition Score (ECS) that combines a wider range of metrics. It is recognised that invertebrate community metrics are one of a number of approaches to assessing ecological condition. Other approaches currently under investigation for regional monitoring and assessment are the use of fish community composition (Joy 2005) and functional indicators of ecosystem processes (e.g. decomposition rates and stream metabolism; Young 2004). Currently, invertebrate monitoring provides the only biologically-based dataset available of sufficient duration to enable the assessment of temporal trends. It is not the intention of this report to identify specific agents causing any observed increases or declines in ecological condition indicated by invertebrate community metrics, although environmental conditions related to invertebrate community metrics and their magnitude of change are explored and discussed.

2 Sites

A total of 340 sites has been sampled as part of the REMS programme over 1994 to 2005 (see Fig. 1), with the number of sites sampled in each summer varying between 47 and 147 (see Collier 2005). Over this time there have been variations in the timing of sample collection (although most sampling has been conducted sometime over early to late summer), and in field protocols and laboratory processing procedures which were altered in 2002 to conform to standardised MfE protocols for wadeable streams (Stark *et al.* 2001). In total, 1295 samples have been collected as part of the REMS programme over 11 years, with 1266 of these having $\geq$100 invertebrates in a sample.

Sixty-eight sites have been sampled for 8-10 years, but only 49 of these are considered to have consistent sampling protocols with $\geq$100 invertebrates in each year (see Section 3), and therefore be suitable for analysis of long-term trends (see Table 1 and

Fig. 1). These sites comprise 10 non-wadeable sites and 39 wadeable/hard-bottomed sites, and include three reference sites with undisturbed vegetation cover in upstream catchments (Table 1). Seven of the REMS sites correspond to regional water quality monitoring sites (1249-15, 240-5, 407-1, 428-3, 556-9, 749-10, 786-2) reported on in Vant & Smith (2004).

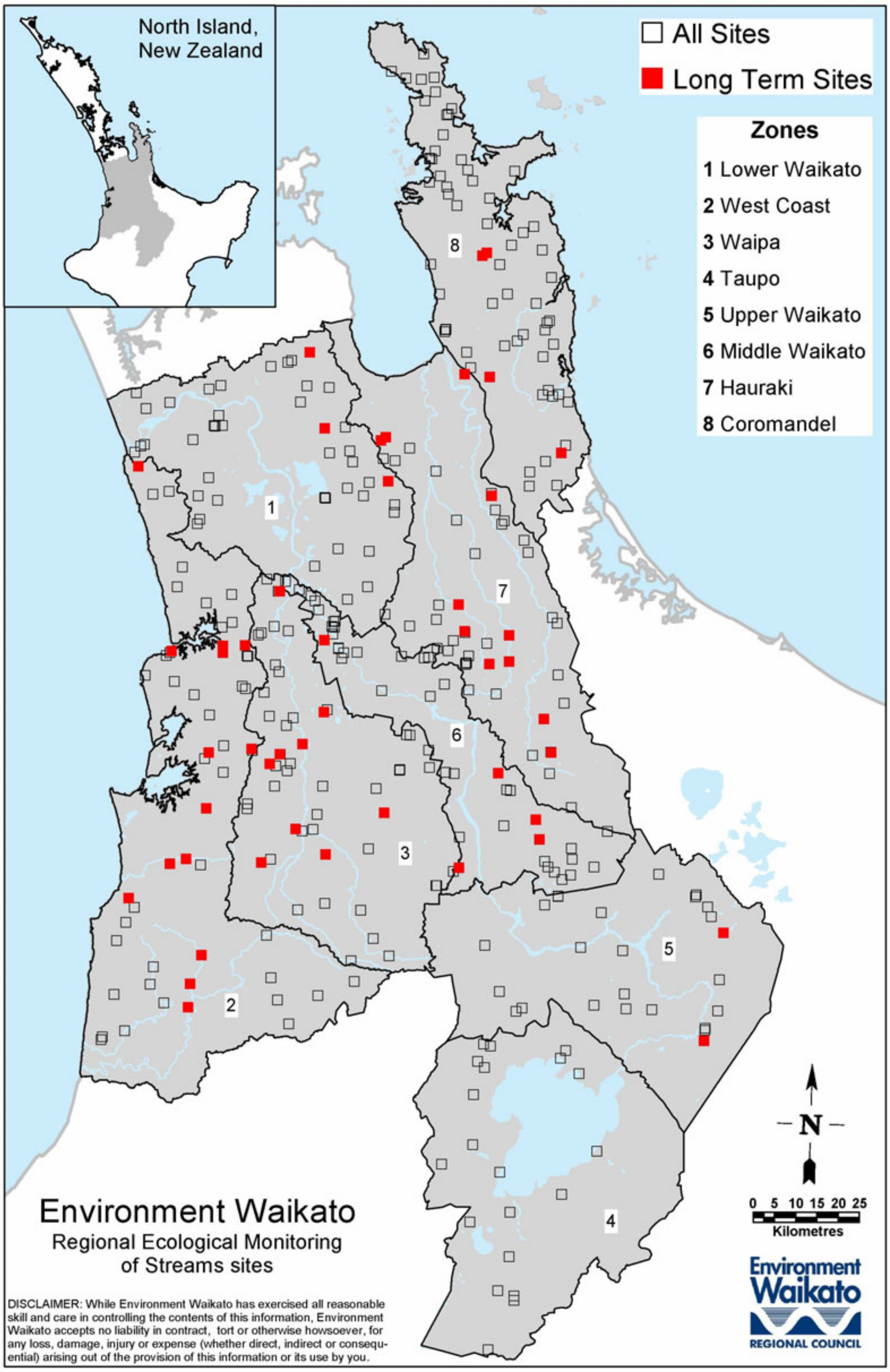

Figure 1: Location of REMS sites sampled in eight zones over the last 11 years.

For the purpose of analysis, the Upper and Middle Waikato zones were combined.

Table 1: Description and location of the 49 long-term invertebrate monitoring sites.

In the Located number column, Ref. = reference (100% native forest upstream); n.w. = non-wadeable; ‡, RERIMP monitoring sites reported on by Vant & Smith (1994). REC = River Environment Classification (see Snelder *et al.* 2004). Sites are listed by Environment Waikato management zones (see Figure 1).

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1257-4	Waiwawa	Upstream Toranoho Stm	2746600	6468500	Coromandel	WW/L/VA
23-2	Apakura	Puriri Valley Rd	2747200	6439200	Coromandel	WW/H/VA
4-2	5 Mile	Off Tapu Coroglen Rd	2745600	6467800	Coromandel	WW/L/VA
619-20	Ohinemuri	SH25 bridge	2764100	6421300	Coromandel	WW/L/VA
1055-2	Torehape	Torehape West Rd	2722721	6425025	Hauraki	WW/L/HS
1055-3	Torehape	Torehape West Rd	2721609	6424306	Hauraki	WW/L/HS
1158-7	Waimakariri	Off end of Waimakariri Rd	2761526	6350704	Hauraki	CW/H/VA
1174-10	Waiomou	Waiomou Rd	2759900	6358600	Hauraki	WW/H/VA
1249-15 (n.w.)‡	Waitoa	Landsdowne Rd bridge	2751700	6378300	Hauraki	WW/L/VA
1249-32	Waitoa	Station Rd Matamata	2751700	6372100	Hauraki	WW/L/VA
1252-3	Waitoki	Rawhiti Rd	2697600	6388800	Hauraki	WW/L/VA
433-2	Mangapapa	Henry Watson Rd	2747000	6371500	Hauraki	WW/L/VA
531-4	Matatoki Stm	Matatoki Rd	2741200	6439800	Hauraki	WW/L/VA
749-10 (n.w.)‡	Piako	Kiwitahi	2739800	6385600	Hauraki	WW/L/VA
753-7 (n.w.)	Piakonui	Downstream of Paku Rd bridge	2741229	6379291	Hauraki	WW/L/VA
1293-8 (n.w.)	Whangamarino	Jefferies Rd	2708364	6427161	Lower Waikato	WW/L/HS
453-8	Mangatangi	Stubbs Rd	2704800	6445100	Lower Waikato	WW/L/HS
481-11	Mangawara	Mangawara Rd	2723271	6414627	Lower Waikato	WW/L/HS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1236-4	Waitawhiriwhiri	U/S Maeroa Rd (above Saleyard inflow)	2708200	6377200	Up/Mid Waikato	WW/L/M
220-1	Kaiwhitwhiti	Tiverton Downs Farm	2797491	6282670	Up/Mid Waikato	CW/H/VA
240-5[‡]	Kawaunui	SH5 bridge	2802100	6308100	Up/Mid Waikato	CW/H/VA
407-1[‡]	Mangamingi	Paraonui Rd bridge	2758800	6330200	Up/Mid Waikato	CW/L/VA
495-1	Mangawhio trib.	Taupaki Rd	2739851	6323541	Up/Mid Waikato	CW/L/VA
786-2[‡]	Pokaiwhenua	Arapuni - Putaruru Rd	2749100	6345800	Up/Mid Waikato	CW/L/VA
786-22	Pokaiwhenua	Wiltsdown Rd	2757973	6334873	Up/Mid Waikato	WW/L/VA
124-4 (n.w.)	Firewood	Waingaro @ Ngaruawahia Rd	2697713	6388746	Waipa	WW/L/HS
1253-8 (n.w.)	Waitomo	Waitomo Valley Rd	2747671	6411175	Waipa	WW/L/VA
1253-9 (n.w.)	Waitomo	Tumutumu Rd	2701300	6332700	Waipa	WW/L/VA
125-4 & 125-15 (ref.)	Firewood trib.	Off Walkway (Hakarimata Scenic Reserve)	2693255	6324837	Waipa	WW/L/HS
1284-1	Whakarautawa	Mangati Rd	2695200	6348100	Waipa	CX/H/VA
429-3 (n.w.)	Mangaotama	Ryburn Rd	2708012	6360259	Waipa	WW/L/SS
476-1	Mangatutu	Lethbridge Rd	2722200	6336500	Waipa	CW/L/VA
477-14 (ref.)	Mangauika	Upstream weir [A]	2697600	6350400	Waipa	CX/L/VA
477-5	Mangauika	Mangauika Rd bridge	2703000	6352700	Waipa	WW/L/VA
493-1	Mangawhero trib.	Mangawhero Rd	2708413	6326725	Waipa	WW/L/VA
1172-6	Wainui	Wainui Stm (Raglan) at Wainui Reserve bridge	2672168	6374702	West Coast	WW/L/VA
1247-3 (n.w.)	Waitetuna	Ohautira Rd	2684200	6374300	West Coast	WW/L/HS
1414-1 (ref)	Omanawa trib.	Pirongia West Rd	2691007	6351578	West Coast	CX/H/VA
195-1	Huriwai	Waikaretu Rd	2664385	6418242	West Coast	WW/L/SS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
256-2 (n.w.)	Kiritihere	Mangatoa Rd	2661900	6316500	West Coast	WW/L/HS
36-1	Awaroa	Awaroa Rd	2680290	6337596	West Coast	WW/L/HS
365-1	Mangahoanga	Moerangi Rd	2680854	6350806	West Coast	WW/L/SS
413-2	Mangaokahu	Cogswell Rd (upper)	2689435	6376039	West Coast	WW/L/HS
428-3‡	Mangaotaki	SH3 bridge	2676400	6296300	West Coast	WW/L/VA
428-5	Mangaotaki	Mangaotaki Rd	2679097	6303031	West Coast	WW/L/VA
514-1	Marokopa	Te Anga Rd	2675500	6325700	West Coast	WW/L/VA
539-1	Maunurima	SH22	2684266	6375948	West Coast	WW/L/SS
556-9‡	Mokau	Totoro Rd recorder	2675900	6290700	West Coast	WW/L/VA
976-2	Tawarau	Speedies Rd	2671700	6324600	West Coast	WW/L/VA

3 Methods

3.1 Sample collection

Prior to 2002, field sampling protocols broadly followed the methods outlined by Edgar *et al.* (1994). This procedure involved collecting "representative**"** samples from "comparably productive habitat types" at all sites using a 250 µm mesh net. The comparable habitats focussed on were runs/riffles (2 x 1 m^2 areas) with the inclusion of pools in proportion to their abundance in the 100 m sampling reaches of "high gradient" streams (B. Moore. pers. comm.). Where stony riffles were not available, submerged boulders, soft sediments, logs and macrophytes were sampled in proportion to abundance (B. Moore, pers. comm.).

From 2002-2005, macroinvertebrate data were collected in line with MfE protocols as described by Stark *et al.* (2001). Over that period a net mesh size of 500 µm was used following MfE sampling protocols C1 or C2, and a stand-down period of at least 2-weeks was applied following large floods with estimated capacity to mobilise streambeds at index sites scattered throughout the region. The sampling methods as applied in the REMS programme from 2002 are summarised by Collier & Kelly (2005).

The high-gradient technique for stony streams was probably broadly comparable to the hard-bottomed C1 method employed since 2002, because most taxa and individuals would have been collected from riffles. However, there appear to be marked differences in protocols for wadeable, low-gradient streams dominated by fine or hard substrates (but without riffles) before and after 2002 which would compromise analysis of long-term trends. Non-wadeable, low-gradient streams dominated by fine substrates are probably comparable over the long term because sampling would have been done only on accessible substrates, which would have been mostly channel edges and submerged macrophytes.

Thus, in effect, four types of stream can be recognised to date in terms of sampling strategies in the REMS programme with two of these being suitable for analysis of long-term trends:

1. **Wadeable high gradient/hard-bottomed streams** – runs and riffles were probably the primary habitat sampled for invertebrates prior to 2002 with riffles sampled after that date using the MfE C1 approach. These sites are considered suitable for analysis of long-term trends in metrics because most invertebrates collected would have come from riffle habitat.

2. **Wadeable low gradient/hard-bottomed streams** - >50% of streambed dominated by stony substrates but no riffles were present. These sites would have been sampled over the full range of habitats including stony runs and pools prior to 2002, but only edges, wood and macrophytes would have been sampled after that using MfE protocol C2. These sites are <u>not</u> considered suitable for analysis of long-term trends in invertebrate metrics because of likely marked differences in the habitats sampled.

3. **Wadeable low gradient/soft-bottomed streams** - >50% of substrates sand/silt/clay. MfE soft-bottomed protocol C2 has been used since 2002 (mainly macrophytes, wood, edges) but prior to this soft substrates may have been included in the sample. These sites are <u>not</u> considered suitable for analysis of long-term trends in invertebrate metrics because of likely marked differences in the habitats sampled.

4. **Non-wadeable low gradient streams** - >50% of substrates sand/silt/mud and mean depth >1 m or unable to be safely waded. Sampling would most likely have

consisted of edges and macrophytes, or bedrock shelves, over the entire sampling period. These sites are considered suitable for analysis of long-term trends in invertebrate metrics because the habitats sampled are likely to have been similar.

3.2 Sample processing

Sample processing has been conducted on a fixed count basis since the start of the REMS programme (minimum fixed-count = 100 + scan for rare taxa). From 2002 the count was increased to at least 200 plus a scan for rare taxa following MfE protocol P2. All taxa counted are identified to the MCI level of taxonomy where possible, although prior to 2002 Chironomidae were not differentiated (see Collier & Kelly 2005 for accepted level of resolution and approaches to sample identification).

3.3 Data compilation

Samples that had invertebrate counts ≥100 were compiled (48 samples with <100 invertebrates were excluded). Taxa designated as a “P” in the database (indicating a rare taxon not encountered during the fixed count procedure) were excluded. All chironomids were combined into one taxon. The change in mesh size was considered to have a minor effect on metric scores (see Collier 2005).

Where sample numbers exceeded 100, the Species Diversity module in the computer program ECOSIM (Gotelli & Entsminger 2005) was used to generate species lists from 1000 iterations and a user-defined abundance level of 100. These 100-count data were used to calculate invertebrate community metrics. For MCI calculations, tolerance scores were the same as those listed in Collier & Kelly (2005), except for the combined chironomid taxon which was allocated a tolerance score of 5 based on the average value for all Chironomidae sub-families. If duplicate samples were collected in any year, the sample taken in late summer (January-March) was used, or if both were taken in late summer the average metric score was calculated (see Table 3 for list of metrics calculated).

3.4 Data analysis

Temporal trends over 8-10 years were assessed by examining Spearman rank correlations of years versus the diversity metric EPT* richness, the compositional metric %EPT*, the tolerance metric Macroinvertebrate Community Index (MCI), and an Ecological Condition Score (ECS) based on a wider range of metrics (see below for details of calculation and Table 3 for list of metrics used). Spearman coefficient values were used to define four trend classes using different levels of certainty based on professional judgement of ecological significance and a defined level of statistical significance, as outlined in Table 2. The False Discovery Rate (McBride 2005) was used to adjust for Type I error rates when making multiple comparisons to distinguish “clear” trends” (see Appendix 2).

Table 2: Trend classes used to define ecological and statistical significance of relationships for different sample sizes following Collier & McBride (in prep: manuscript for scientific journal).

r_s = Spearman rank correlation coefficient; FDR = False Discovery Rate (McBride 2005); NA = not applicable.

	Trend class			
n	**Stable**	**Possible**	**Probable**	**Clear**
5-9	$r_s \leq 0.50$	$0.50 > r_s < 0.70$	$0.70 \geq r_s \leq r_{s(FDR)}$	$r_s > r_{s(FDR)}$
10-16	$r_s \leq 0.50$	$0.50 > r_s < r_{s(\alpha=0.05)}$	$r_{s(\alpha=0.05)} \geq r_s \leq r_{s(FDR)}$	$r_s > r_{s(FDR)}$
>16	$r_s \leq r_{s(FDR)}$	NA	NA	$r_s > r_{s(FDR)}$

The ECS was derived from a multivariate analysis to develop a single score reflecting ecological condition based on 17 metrics with reference site coefficients of variation <50% (see Collier *et al.* 2005), and rank correlation coefficients among metrics of r_s <0.7. Metrics were standardised by the maximum value for each sample to generate values between 0 and 1.0. Metrics were adjusted where higher scores reflected lower condition so that increasing values for all metrics reflected better ecological condition (e.g., 1 – standardised % dominant taxon). Sample scores for Multi-dimensional scaling (MDS) axis 1 scores, which were strongly related to sample condition, were converted to positive values (by adding the minimum) and expressing values as a percentage of the maximum to derive the ECS. The ordination was conducted in Primer-E 5.2.9 and in PC-ORD 4.34 using the Slow and thorough autopilot option, and tested using Bray-Curtis and Euclidean distance measures. The latter distance measure was used because it yielded lower stress values and Axis 1 scores were highly correlated with the Bray-Curtis measure (r_s = 0.98). Axis 1 scores of the Primer and PC-ORD ordinations were very highly correlated (r_s = 0.997).

"EPT" refers to the sensitive groups Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). The asterisk after EPT reflects the exclusion from calculations of the caddisfly family Hydroptilidae, the commonest members of which are often found associated with filamentous algal growths. Scarsbrook *et al.* (2000) concluded that measures such as MCI, EPT* richness and %EPT* are appropriate biological indicators for monitoring long-term trends because they are less susceptible to fluctuations in numbers of tolerant taxa, and/or are more robust to changes in sampling intensity and less sensitive to changes in microscale habitat variables than many other metrics (see also Collier *et al.* 1998).

Differences among sites with predominantly (>95% of area) native forest or pasture in upstream catchments were assessed for 2005 samples using the Mann-Whitney U-test for selected invertebrate metrics and the ECS. Relationships between landscape variables and the magnitude of change at sites showing probable/clear declines were explored using Spearman rank correlations based on the interpretation of significance outlined in Table 2.

4 Results

4.1 Spatial patterns

The pattern of key invertebrate community metrics was assessed among zones for all monitoring data by comparing the percentage of samples above or below the regional average using the following categories:

- well above average - uppermost quartile;
- above average - upper middle quartile;
- below average - lower middle quartile; and
- well below average - lowest quartile.

Upper and lower quartile boundaries were determined by subtracting the regional mean from the maximum and minimum of each zone, respectively, and then dividing by two. The pattern within zones was compared with the average for the entire region based on the mean of all zones rather than all samples to avoid the effect of over- or under-representation of sites in certain zones (e.g., Lower Waikato). Regional and reference sample means for the invertebrate metrics used are listed in Table 3 to provide a basis for interpreting absolute values at specific sites or among zones. The median values for EPT* richness, %EPT* and MCI found for all Waikato samples are similar to values reported by Scarsbrook *et al.* (2000) for 66 national sites sampled annually from 1989 to 1996 (8, 39% and 103, respectively).

Table 3: Mean values for metrics calculated based on 100-count data from all samples collected from 1994-2005 ("regional"; *n* = 1266) and for reference (100% upstream native forest cover) samples only (*n* = 52).

Metrics indicated in bold were analysed individually for trends at 49 sites with appropriate long-term data; all the metrics listed were used in the calculation of the Ecological Condition Score. MCI = Macroinvertebrate Community Index; QMCI = Quantitative MCI.

	Reference	Regional
Total taxa richness	17.1	12.5
Ephemeroptera (E) richness	4.1	2.2
Plecoptera (P) richness	2.8	0.6
Trichoptera (T) richness	4.8	3.2
EPT* richness	**11.6**	**5.7**
%EPT* richness	68.0	40.2
%Native richness	100.0	98.0
%Ephemeroptera	47.2	17.4
%Trichoptera	20.5	15.7
%EPT*	**77.8**	**33.1**
%Dominant taxon	32.5	46.9
%Native	100.0	99.4
%Insects	95.3	61.5
%Non-worms	99.7	94.2
MCI	**146.8**	**107.9**
QMCI	7.6	5.2
Margalef diversity	3.5	2.5
Ecological Condition Score	**85**	**66**

The analysis across all monitoring samples indicated that EPT* richness, %EPT* and MCI were mostly well below/below the sample average in Hauraki, as well as Upper/middle Waikato and Lower Waikato, and %EPT* was also below the sample average in Waipa. Sample EPT* richness, MCI and ECS were mostly well above/above the sample average in Taupo, West Coast, Waipa and Coromandel, with %EPT* being mostly well above/above the average in Coromandel and Taupo (Figure 2). Overall, more than 75% of samples had EPT* richness, MCI and ECS well above/above the sample average in Taupo, whereas more than 75% of samples had EPT* richness, %EPT* and MCI values well below/below the average in Lower Waikato.

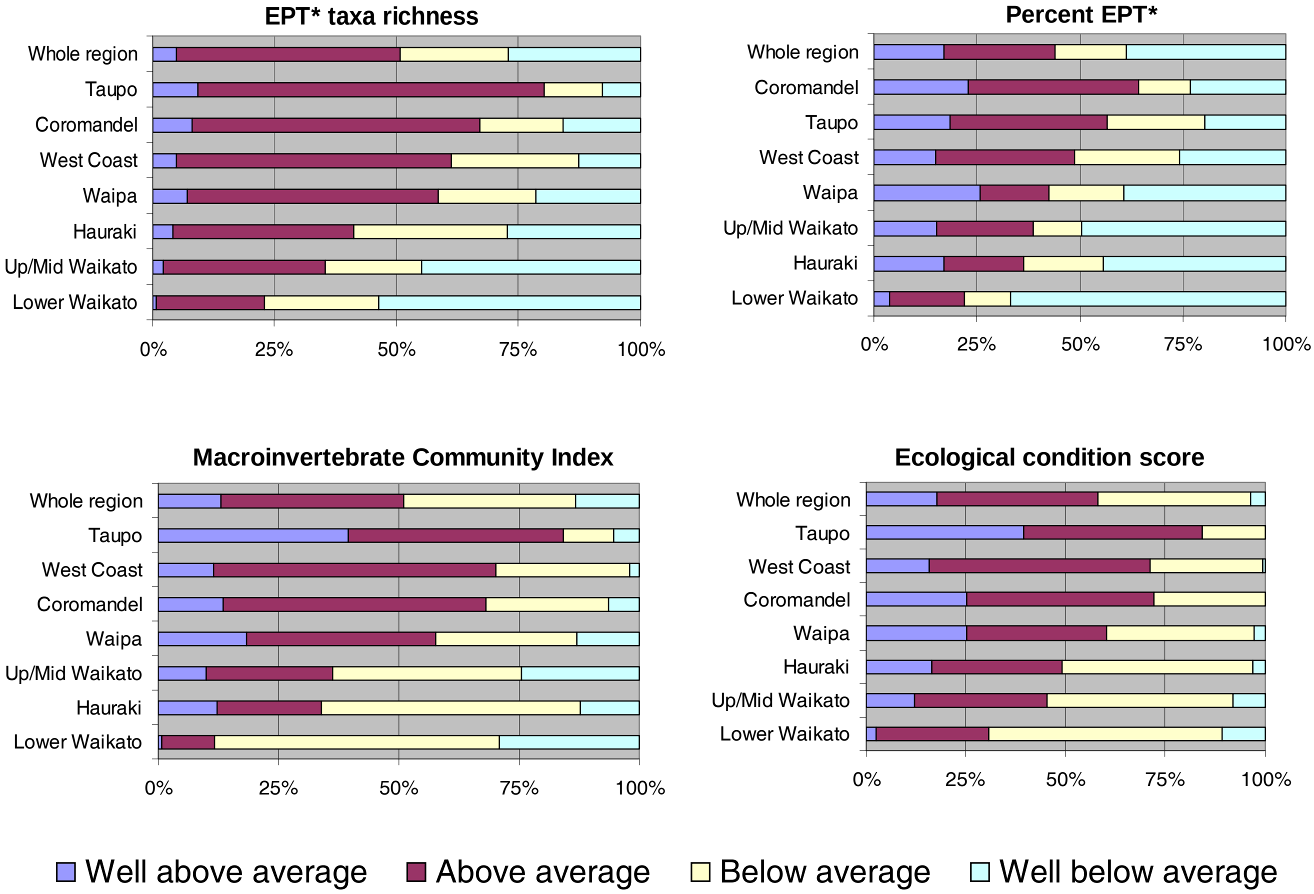

Figure 2: Percentage of all monitoring samples with invertebrate-based condition measures that were well above (uppermost quartile), above (upper middle quartile), below (lower middle quartile) or well below (lowest quartile) the average of all samples for seven zones. The "Whole region" graph is based on the average of all zones (i.e., not the average of all samples).

The same zonal analysis was performed using habitat quality scores based on the scoring of nine riparian, channel and instream habitat variables (see Appendix 1 in Collier & Kelly 2005). This habitat assessment approach differentiates high- and low-gradient (or hard- and soft-bottomed) sites, but only two variables differ between these types. Total possible scores sum to the same number. Habitat assessment has been conducted using the same method since 1999.

As with most of the invertebrate-based measures of stream condition, habitat scores were below/well below the average for all scores in most assessments from Lower Waikato, Upper/middle Waikato and Hauraki, and above/well above the score average in most assessments from Taupo and Coromandel (Figure 3). Overall, more than 75% of assessments were conducted at sites with well above/above the average habitat quality score in Taupo and Coromandel, whereas more than 75% of samples had habitat quality scores well below/below the average in Lower Waikato.

An analysis of invertebrate metric values and habitat quality scores for an approximately balanced dataset (*n* = 23-25) collected in 2005 indicated highly significant differences (Mann-Whitney U-test, P <0.0001) for sites with adjacent reaches and upstream catchments dominated (≥95% of area) by pasture or indigenous "forest" (includes scrub and tussock) (Figure 4). The same pattern of higher metric values in forested compared to pasture catchments was also evident for habitat quality scores (Figure 4).

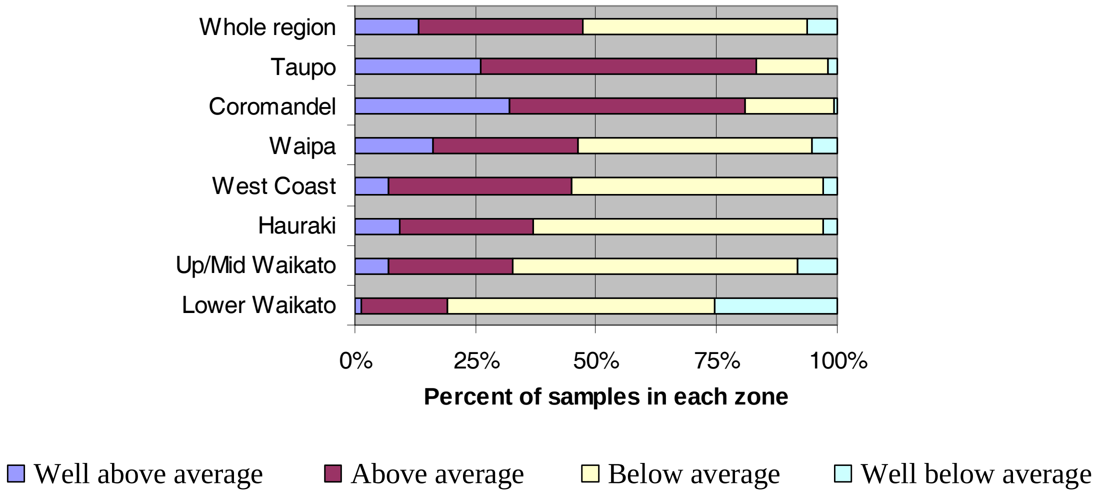

Figure 3: Percentage of all habitat quality assessments that were well above (uppermost quartile), above (upper middle quartile), below (lower middle quartile) or well below (lowest quartile) the regional sample average for seven zones. The "Whole region" graph is based on the average of all zones (i.e., not the average of all assessments).

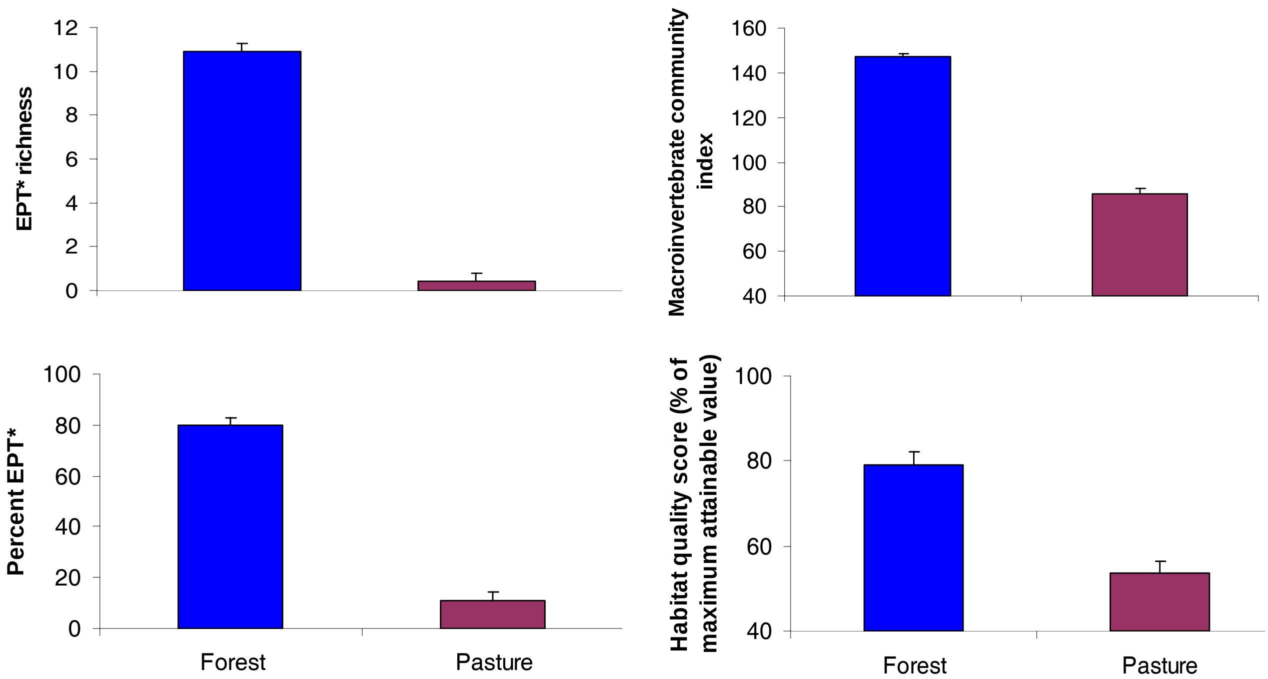

Figure 4: Mean (+1SE) values for three invertebrate community metrics and habitat quality scores for sites with upstream landcover dominated (95% of upstream catchment area) by indigenous forest (*n* = 25) or pasture (*n* = 23) sampled in 2005 (all zones combined).

4.2 Temporal trends

Graphs of selected invertebrate metrics used in the trend analysis are presented by zone in Appendix 3. Sites 125-4, 477-14 and 1414-1 are long-term reference sites which have 100% of upstream catchment area in native forest. The status of each of the 49 long-term monitoring sites in terms of the four invertebrate-based measures of condition examined and the four trend classes described above is shown in Appendices 3 and 4, and results are summarised in Table 4. The average of the three indicator metrics and the ECS is very similar. These results suggest that, in general terms, ecological condition at around three-quarters of sites has been "stable" (inconclusive evidence of change) over the monitoring period, with the remainder showing evidence of change. Of the 28% of apparently changing sites, around two-thirds showed signs of net decline and one-third showed signs of net increase in overall ecological condition. Generally, most invertebrate-based measures of condition showed a similar pattern with respect to the percentage of sites that appeared to be stable or display either overall declines or increases in condition. Some trends were considered significant based on the trend classes listed, but were small in terms of their net change because initial metric values were low (e.g., %EPT* at site 749-1 (Hauraki); see Appendix 3).

The trends observed could be separated into "stepped" responses (e.g., %EPT* at site 1284-1 (Waipa)) or "progressive" responses (e.g., EPT* richness at site 428-5 (West Coast)). Stepped responses may indicate the occurrence of a single event causing degradation or improvement that is sustained in subsequent years. Sharp dips in metrics observed at some sites in 2004 may be attributable to very high flood flows prior to sampling (e.g., 1414-1 on the West Coast; Appendix 3). These flow-related effects are typically not sustained and therefore are not considered strictly as stepped responses. Where they were identified, stepped responses did not appear to coincide for changes in sampling protocols in 2002. A possible exception was site 1172-6, although re-examination of raw data and a review of historical sampling protocols suggest that an effect of sampling protocol was unlikely.

Progressive responses suggest incremental changes in condition over time, such as might be caused by gradual landuse intensification within a catchment. Overall, substantially more metrics displaying possible-clear changes in condition were deemed to have progressive changes (50%) compared to stepped changes (10-20%). At some sites, changes may have occurred over the monitoring period but they were classified as "stable" because the changes were incremental but small relative to preceding years, or were sharp but followed by recovery and therefore not sustained.

Table 4: Percentage of sites (n = 49) classified according to different trend classes for four invertebrate-based measures of ecological condition and the average for three invertebrate metrics.

"Overall" = sum of "possible", "probable" and "stable" (see Table 2).

	EPT*[1] richness	Percent EPT*[1]	MCI[2]	Metric average[3]	ECS[4]
Stable	65	78	76	73.0	71
Possible decline	16	4	8	9.3	10
Probable decline	4	2	4	3.3	6
Clear decline	10	4	6	6.7	4
Overall decline	30	10	18	19.3	20
Possible improvement	4	2	6	4.0	6
Probable improvement	0	6	2	2.7	0
Clear improvement	0	4	0	1.3	2
Overall increase	4	12	8	8.0	8

[1], mayflies, stoneflies and caddisflies (excluding Hydroptilidae)
[2], Macroinvertebrate Community Index
[3], EPT* richness, % EPT*, MCI
[4], Ecological Condition Score based on axis 1 scores of MDS ordination using 17 standardised metrics

Table 5 Spearman correlation coefficients (r_s) between landscape variables, and the magnitude of change between initial and last monitoring dates expressed as a percentage of the initial value where there were at least 5 sites available for analysis (not possible for %EPT*).

Italics indicate coefficient values >0.5; bold indicates coefficient values ≥0.7. n = 5-7.
MCI = Macoinvertebrate Community Index; ECS = Ecological Condition Score.

	EPT* richness	MCI	ECS
Stream order	*-0.603*	**-0.791**	**-0.738**
Elevation	*0.685*	0.500	**0.700**
Channel gradient	0.030	0.103	*0.600*
% Indigenous forest	-0.054	0.500	0.100
% Exotic forest	*0.673*	0.410	0.000
% Pasture	-0.468	**-0.800**	-0.200
% Urban	-0.449	**-0.707**	0.000

4.2.1 Magnitude of change

Relationships between landcover and the magnitude of change in invertebrate indicators between initial and latest monitoring dates expressed as a percentage of the initial value (i.e., ((initial – last) / initial) x 100) were investigated for sites where declines were deemed probable/clear. Insufficient probable/clear declines were detected for %EPT* (*n* = 2) to perform this analysis. Spearman coefficients for EPT* richness and MCI from this analysis are shown in Table 5. Although none of the relationships were statistically significant based on the sample size available, r_s values of ≥ 0.7 for stream order, elevation, and % urban or pastoral landuse in the catchment upstream of the sampling site were deemed ecologically significant, and channel gradient and % exotic forest upstream were possibly significant for some metrics. These results suggest that the magnitude of decline in ecological condition may partly reflect stream size, position in the landscape and upstream landcover, such that declines are probably greater in smaller, lowland streams with higher proportions of upstream catchment development.

4.2.2 Relationships with environmental factors

Patterns in the distribution of sites displaying clear/probable changes in condition were assessed in terms of their representation by zone, and riparian and upstream landcover where there were at least five sites for each metric (Tables 6 and 7). Under- or over-representation was arbitrarily deemed to occur where differences exceeded 20% of the representation in the sampling network. Two to three times as many sites displayed probable/clear declines in EPT* richness and MCI in Hauraki compared to their representation in the long-term monitoring network (Table 6). Three of the five sites showing probable/clear in ECS were on the West Coast which had only 29% of sites in the long-term monitoring network. Waipa sites were close to the 20% difference threshold in terms of being under-represented in the sites showing clear/probable declines.

Few associations were evident for riparian and upstream catchment landuse and trends in stream condition in terms of the general representation of sites where sufficient sites were available for comparison (Table 7). However, catchments dominated by pasture were over-represented in sites showing declines in EPT* richness and to a lesser extent MCI (Table 7B).

Table 6: Percentage of sites (number of sites in parentheses) displaying probable/clear declines of invertebrate-based measures of stream condition in different zones for EPT* richness, MCI and ECS (only data for metrics and sites where *n* 5 are shown).

The percentage of total long-term sites present in each zone is indicated next to the zone name. No long-term sites were present in the Taupo zone. Bold indicates where representation was 20% more or less than that in the long-term monitoring site network.

	EPT* richness	MCI	ECS
Coromandel - 10%	0	20 (1)	0
Hauraki - 22%	**43** (3)	**60** (3)	20 (1)
Lower Waikato - 6%	0	0	0
Up/Mid Waikato - 14%	14 (1)	20 (1)	20 (1)
Waipa - 20%	0	0	0
West Coast - 29%	43 (3)	0	**60 (3)**

Table 7: Percentage of sites (number of sites in parentheses) displaying probable/clear declines in condition by different riparian (A) and upstream (B) landcover for invertebrate-based measures of ecological condition (only data for metrics and sites where *n* 5 are shown).

The percentage of total long-term sites present in each landcover is indicated next to the landcover name. Bold indicates where representation was 20% more or less than that in the long-term monitoring site network.

	EPT* richness	MCI	ECS
A. RIPARIAN LANDCOVER[1]			
Pasture (61%)	57 (4)	60 (3)	40 (2)
Pasture/trees (22%)	29 (2)	20 (1)	40 (2)
Urban (2%)	0	0	0
Restoration (2%)	0	0	0
Indigenous (14%)	14 (1)	20 (1)	20 (1)
B. UPSTREAM LANDCOVER[2]			
Pasture (65%)	**86** (6)	80 (4)	60 (3)
Urban (2%)	0	0	0
Exotic forest (2%)	0	0	0
Indigenous (33%)	14 (1)	20 (1)	40 (2)

[1], derived from site descriptions and photos; [2], derived from GIS layers

5 Discussion

Of the seven sites corresponding to long-term water quality monitoring sites, 749-10 (Piako@Kiwitahi) and 240-5 (Kawaunui@SH5) displayed clear declines in condition for three key invertebrate measures over the monitoring period, 556-9 (Mokau@Totoro) displayed a probable decline for EPT* richness with no change evident in the other measures investigated, and all metrics showed possible declines at 428-3 (Mangaotaki@SH3). Site 1249-15 indicated stable conditions for most metrics, whereas 786-2 (Pokaiwhenua@Puketurua) displayed a stable/probable increase in ecological condition over the monitoring period, and 407-1 (Mangamingi@Paraonui Br) indicated a probable increase in %EPT* and stable or possible increases in other metrics. Vant & Smith (2004) reported significant increases in conductivity at 749-10, 428-3, 240-4 and 556-9, with corresponding significant increases in total nitrogen, nitrate-N and total phosphorus and a significant decline in dissolved oxygen saturation at the latter two sites. Similar responses in conductivity and dissolved oxygen were also reported by Vant & Smith (2004) at 786-2, although no decline in ecological condition was evident at that site. Dissolved oxygen also declined significantly at 1249-15 but there was no corresponding increase in nutrients and no clear trend in invertebrate metrics. In contrast, significant declines in temperature and increases in dissolved oxygen at 407-1 were mirrored by a probable/possible increase in some metrics.

Some of the patterns of declining water quality among zones reported by Vant & Smith (2004) are similar to the patterns in invertebrate-based measures of condition. More increases than decreases in conductivity occurred in Hauraki and Upper Waikato, and more decreases than increases in turbidity and colour were found in Lower Waikato and Hauraki. They associated these patterns along with increases in total nitrogen and phosphorus largely with changes in landuse, particularly pastoral development and land drainage. Similarly, the magnitude of change in invertebrate metrics over the monitoring period at sites experiencing probable/clear declines in MCI, was strongly associated with the percentage of upstream catchment area in pasture, supporting the conclusion of Vant & Smith (2004) that land development, particularly pastoral intensification and land drainage, may be a factor contributing to the decline in the quality of streams. Position in the landscape and stream size were also implicated as factors influencing the magnitude of decline in some invertebrate metrics over the monitoring period, with smaller, lowland streams experiencing greater declines.

Invertebrate-based condition measures in Hauraki, Lower Waikato and Upper Waikato were typically below/well below the sample average, and sites with probable/clear declines in ecological condition were over-represented in Hauraki and the West Coast for some invertebrate measures compared to the distribution of sites in the long-term monitoring network. Habitat quality was also below/well below the average for all scores in Hauraki, Lower Waikato and Upper/middle Waikato, suggesting that degraded habitat may also be contributing to the observed patterns in ecological condition of streams in the region. Our analyses of 2005 data confirm that habitat quality and invertebrate metric values are significantly lower in pasture catchments compared to undeveloped catchments.

6 Conclusions

- Based on invertebrate community data available at 49 sites sampled for ≥ 8 years, ecological condition appears to have been "stable" over the monitoring period at around three-quarters of sites, with the remainder of sites showing signs of change. Of the apparently changing sites, around two-thirds showed signs of net declines and one-third showed signs of net increases in overall ecological condition.

- Analysis across all monitoring samples indicated that values for invertebrate metrics were mostly well below/below the sample average in Hauraki, as well as Upper/middle Waikato and Lower Waikato. Several invertebrate-based measures of condition were mostly well above/above the sample average in Taupo, West Coast, Waipa and Coromandel.

- Habitat quality scores were below/well below the average of all scores in most assessments from Lower Waikato, Upper/middle Waikato and Hauraki, and above/well above the score average in most assessments from Taupo and Coromandel.

- Analysis of invertebrate metric values and habitat quality scores in 2005 indicated highly significant differences in relation to catchment landuse, with lower values for sites with adjacent reaches and upstream catchments dominated by pasture compared to indigenous vegetation.

- Relationships between landcover and the magnitude of change in invertebrate indicators for sites where declines were deemed probable/clear suggest that the magnitude of decline in ecological condition may partly reflect stream size and position, and upstream landcover, such that declines appear greater in smaller, lowland streams with higher proportions of upstream catchment development.

- Some of the patterns of declining water quality among zones within the region are similar to the patterns observed in invertebrate-based measures of ecological condition and habitat quality. Declines in water quality have been largely attributed to changes in landuse, particularly pastoral intensification and land drainage. Their effects on water and habitat quality are also likely to have contributed to observed patterns and trends in ecological condition based on the invertebrate measures assessed.

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Appendix 1: Spearman rank correlation coefficients between 17 invertebrate community metrics and sampling year in summer

(n = 8-10). Shaded cells = r_s ≥0.7 for n = 8-9, or $r_{s(\alpha\ 0.05)} \geq r_s < r_{s(FDR)}$ for n = 10 (see Table 2). Bold = significant using False Discovery Rate (calculated for multiple comparisons of EPT* richness, %EPT*, MCI and ECS only).

	Taxa richness	Ephemeroptera richness	Plecoptera richness	Trichoptera richness	**EPT* richness**	%EPT* richness	%Native richness	%Ephem-eroptera	%Trich-optera	**%EPT***	%Dominant taxon	%Native	%Insects	%Non-Worms	**MCI**	QMCI	Margalef diversity	ECS
1055-2	0.59	-0.61	0.55	0.13	-0.20	-0.54		-0.68	-0.05	-0.13	-0.02		-0.37	-0.51	-0.55	-0.67	0.59	-0.13
1055-3	-0.69	-0.59	-0.16	-0.33	-0.47	0.16		-0.21	0.06	-0.17	0.30		0.17	0.18	-0.02	0.32	-0.69	-0.65
1158-7	-0.44	0.16	0.50	-0.37	-0.09	0.52		0.40	0.28	0.32	0.15		-0.07	0.37	0.20	0.38	-0.44	-0.07
1172-6	-0.77	-0.16	-0.55	-0.26	-0.43	0.40		0.05	-0.72	-0.66	0.76		-0.59	0.41	-0.02	-0.54	-0.77	-0.72
1174-10	-0.46	-0.68	-0.58	-0.62	-0.71	-0.72		-0.53	0.24	-0.25	-0.08		-0.47	0.00	-0.75	-0.50	-0.46	-0.67
1236-4	-0.37						0.06				0.43	0.13	-0.31	-0.30	-0.25	-0.30	-0.37	-0.41
124-4	-0.44	-0.58	-0.11	-0.41	-0.48	-0.10		-0.11	-0.46	-0.14	0.21		-0.45	0.66	0.00	-0.05	-0.44	-0.64
1247-3	-0.43	-0.20	0.00	-0.24	-0.24	0.38		-0.17	-0.19	-0.22	0.55		-0.13	0.64	-0.07	-0.27	-0.43	-0.40
1249-15	0.60	-0.26	-0.41	0.33	-0.25	-0.30	-0.84	-0.13	0.65	-0.08	-0.69	-0.77	0.38	0.01	-0.53	-0.68	0.60	0.17
1249-32	-0.59	-0.77		0.04	**-0.79**	-0.79	-0.56	-0.76	0.12	**-0.76**	-0.50	-0.07	0.50	-0.05	**-0.74**	-0.54	-0.59	-0.45
1252-3	0.14	0.11	0.06	-0.07	0.04	0.03	-0.52	0.16	0.24	0.12	-0.16	-0.52	0.08	-0.88	-0.35	-0.41	0.14	0.12
1253-8	-0.31	-0.15		-0.63	-0.53	-0.62		-0.42	-0.24	-0.60	0.77		-0.21	0.72	-0.02	-0.18	-0.31	-0.55
1253-9	-0.01	0.40	-0.73	-0.01	0.07	0.28		-0.17	-0.01	-0.43	0.44		-0.59	-0.24	0.16	-0.52	-0.01	-0.26
125-4	-0.19	-0.26	-0.08	0.15	-0.28	-0.02		0.31	0.28	0.55	-0.29		0.22	0.25	0.57	0.62	-0.19	-0.23
1257-4	0.04	0.20	-0.26	0.25	-0.17	-0.05		0.50	-0.01	**0.86**	-0.41		0.17	-0.54	-0.52	-0.21	0.04	0.29
1284-1	0.28	0.06	0.71	0.69	0.51	0.45		0.65	0.60	0.70	-0.38		0.22	0.75	0.60	0.70	0.28	0.48
1293-8	0.07	-0.37		-0.15	-0.37	-0.49	-0.39	-0.37	-0.07	-0.37	0.22	-0.41	0.02	0.15	-0.45	-0.53	0.07	-0.26
1414-1	0.02	-0.26	-0.09	0.47	0.10	0.02		-0.22	0.03	-0.21	-0.03		-0.15	-0.41	-0.15	-0.33	0.02	0.03
195-1	0.11	0.12		0.51	0.40	0.37		0.21	0.17	0.29	-0.12		0.41	-0.13	0.17	-0.07	0.11	0.43
220-1	-0.08	-0.40	-0.44	-0.27	-0.52	-0.55		0.43	0.30	0.03	-0.08		-0.70	0.55	0.02	0.25	-0.08	-0.44
23-2	0.29	-0.21	0.33	0.46	0.35	0.35		-0.15	0.56	0.17	-0.59		-0.08	-0.22	-0.08	0.00	0.29	0.22
240-5	-0.30	-0.85	-0.06	0.52	**-0.79**	-0.66	-0.50	-0.12	0.49	-0.19	0.40	-0.48	-0.30	0.02	**-0.88**	-0.62	-0.30	**-0.76**
256-2	-0.62	-0.69	0.00	-0.75	**-0.75**	-0.49		-0.17	-0.79	-0.38	0.63		-0.63	0.25	-0.44	-0.62	-0.62	**-0.80**
36-1	0.10	-0.28	0.39	-0.15	-0.11	-0.12		-0.13	-0.25	-0.26	0.41		-0.18	-0.76	-0.43	-0.19	0.10	-0.38
365-1	-0.18	-0.63	0.30	0.24	0.02	0.20		0.27	-0.60	0.20	0.71		0.10	-0.27	-0.50	0.07	-0.18	-0.03
4-2	-0.53	-0.25	-0.21	-0.14	-0.34	0.10		-0.27	0.67	0.50	0.75		0.50	-0.37	-0.77	-0.57	-0.53	-0.02
407-1	-0.18	-0.58		0.73	0.28	0.57	0.66	-0.58	0.76	0.76	-0.05	0.66	0.67	0.27	-0.23	-0.07	-0.18	0.69
413-2	-0.78	-0.76	-0.04	-0.24	-0.58	-0.09	-0.06	-0.04	-0.36	-0.24	-0.02	-0.06	0.78	0.68	0.06	0.20	-0.78	-0.64
428-3	-0.54	-0.57		-0.50	-0.54	-0.37		-0.30	-0.70	-0.63	-0.18		-0.23	-0.66	-0.57	-0.55	-0.54	-0.63

	Taxa richness	Ephemeroptera richness	Plecoptera richness	Trichoptera richness	**EPT* richness**	%EPT* richness	%Native richness	%Ephem-eroptera	%Trich-optera	**%EPT***	%Dominant taxon	%Native	%Insects	%Non-Worms	**MCI**	QMCI	Margalef diversity	ECS
428-5	-0.52	-0.75	0.76	-0.80	**-0.91**	-0.66		0.14	0.18	0.07	0.08		0.38	-0.73	0.12	0.14	-0.52	-0.01
429-3	0.26			0.08	-0.27	-0.27	-0.04		0.20	-0.27	0.00	0.25	-0.05	-0.20	-0.37	0.10	0.26	0.05
433-2	-0.60	-0.45		-0.20	-0.62	0.27		-0.09	0.02	0.03	0.49		0.62	0.32	0.13	0.73	-0.60	0.17
453-8	0.01	0.34		-0.09	0.19	0.13	0.07	0.67	-0.28	0.23	0.15	0.17	-0.22	0.00	0.26	0.63	0.01	0.27
476-1	-0.24	-0.09	0.27	-0.79	-0.54	0.13		0.47	-0.36	0.30	-0.10		0.22	0.50	0.40	0.33	-0.24	0.10
477-14	-0.73	-0.55	-0.45	-0.37	-0.58	0.33		0.25	-0.10	0.44	0.48		0.74	0.55	0.52	0.55	-0.73	-0.54
477-5	0.72	0.27	0.10	0.78	0.48	0.03		0.06	0.37	0.37	-0.58		0.25	-0.31	0.22	-0.45	0.72	0.38
481-11	0.18	-0.06	-0.28	-0.25	-0.33	-0.49	0.25	-0.30	-0.56	-0.44	0.26	0.25	-0.26	-0.65	-0.42	-0.45	0.18	-0.44
493-1	-0.26	-0.69		0.13	-0.29	-0.36	0.25	-0.76	-0.05	-0.49	0.16	0.62	-0.02	0.04	-0.28	0.30	-0.26	-0.48
495-1	-0.90	-0.58	0.00	-0.26	-0.51	0.00		0.07	-0.43	-0.14	0.07		0.10	-0.03	0.17	0.00	-0.90	-0.24
514-1	-0.52	-0.79	0.42	-0.01	-0.29	0.24		-0.20	0.67	-0.10	-0.04		-0.17	-0.27	-0.17	-0.13	-0.52	-0.35
531-4	-0.56	0.29	0.55	-0.19	0.01	0.58	0.19	0.28	0.16	0.34	0.09	0.18	0.45	0.35	0.47	0.08	-0.56	0.13
539-1	-0.11	-0.26		0.17	-0.25	-0.01	0.55	0.93	-0.24	**0.80**	-0.18	0.55	0.83	0.31	0.34	0.83	-0.11	**0.75**
556-9	-0.93	-0.26	-0.55	-0.90	-0.74	-0.17		0.24	0.24	0.09	0.33		-0.30	-0.57	-0.37	-0.53	-0.93	-0.49
619-20	-0.46	-0.19	0.41	-0.43	-0.04	0.22	0.00	-0.19	0.02	0.14	-0.02	0.00	-0.23	0.32	0.07	-0.39	-0.46	-0.22
749-10	-0.12	-0.73		0.55	**-0.73**	-0.71	-0.55	-0.73	0.55	**-0.73**	0.13	-0.55	-0.06	0.29	**-0.73**	-0.13	-0.12	-0.33
753-7	-0.66	-0.04	-0.55	0.27	-0.13	0.42	0.41	-0.12	0.52	0.27	0.70	0.41	0.49	0.49	0.33	0.33	-0.66	0.23
786-2	-0.05	0.63	0.28	0.13	0.47	0.33	0.41	0.64	0.57	0.69	-0.15	0.41	0.67	0.28	0.48	0.31	-0.05	0.56
786-22	0.16	0.19		0.40	0.51	0.56	0.58	0.16	0.21	0.21	-0.76	0.58	0.19	0.15	0.71	0.33	0.16	0.67
976-2	0.12	-0.08	0.73	0.23	0.21	0.07		-0.07	0.21	0.01	-0.18		0.05	-0.58	-0.37	-0.17	0.12	0.31

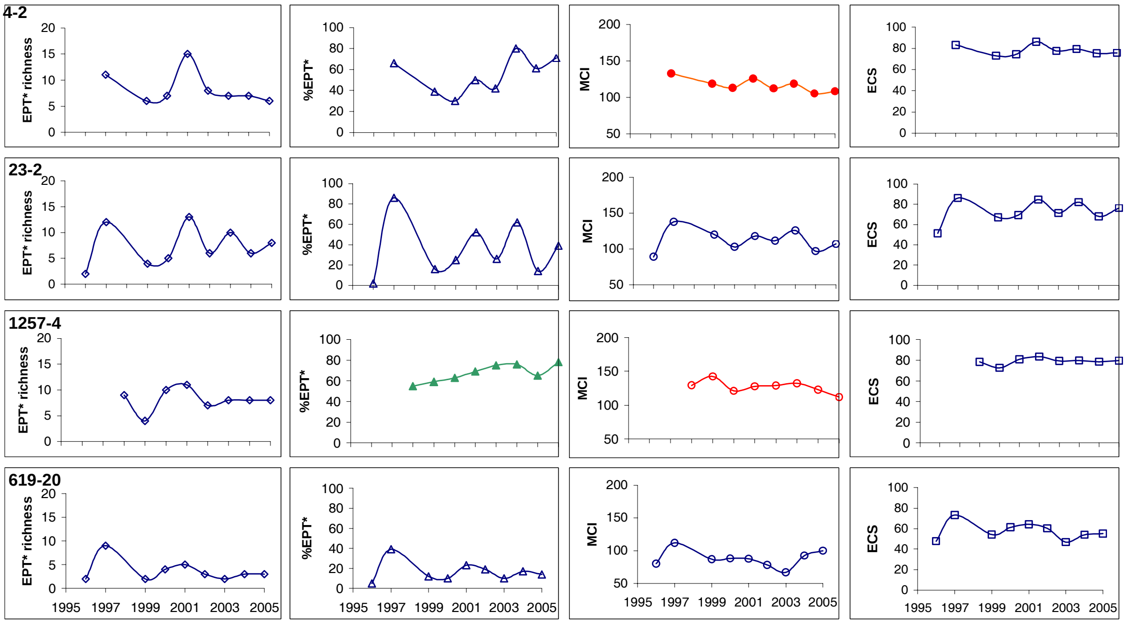
Appendix 2: Spearman rank probability values for EPT* richness, %EPT*, MCI and ECS, with probabilities deemed significant using the False Discovery Rate highlighted with ***.

	Number	EPT* richness	%EPT*	MCI	ECS
1055-2	9	0.602	0.737	0.115	0.737
1055-3	10	0.163	0.636	0.956	0.036
1158-7	9	0.816	0.395	0.602	0.857
1172-6	10	0.208	0.032	0.956	0.015
1174-10	9	0.026	0.512	0.015	0.041
1236-4	8				
124-4	8	0.182	0.717	1.000	0.055
1247-3	9	0.182	0.717	1.000	0.055
1249-15	9	0.512	0.837	0.133	0.659
1249-32	8	0.013***	0.021***	0.027***	0.252
1252-3	10	0.912	0.740	0.315	0.740
1253-8	9	0.133	0.079	0.959	0.115
1253-9	8	0.868	0.277	0.702	0.528
125-4	8	0.495	0.145	0.128	0.579
1257-4	8	0.684	0.003***	0.174	0.479
1284-1	9	0.151	0.029	0.079	0.182
1293-8	9	0.319	0.319	0.215	0.494
1414-1	9	0.796	0.584	0.697	0.938
195-1	8	0.316	0.479	0.684	0.277
220-1	9	0.142	0.938	0.959	0.227
23-2	9	0.349	0.659	0.837	0.565
240-5	8	0.013***	0.648	0.002***	0.021***
256-2	9	0.015***	0.305	0.227	0.006***
36-1	8	0.793	0.528	0.277	0.344
365-1	9	0.959	0.602	0.161	0.938
4-2	8	0.402	0.195	0.018	0.962
407-1	8	0.495	0.021	0.579	0.048
413-2	10	0.072	0.500	0.868	0.040
428-3	9	0.124	0.060	0.100	0.060
428-5	8	<0.001***	0.868	0.775	0.981
429-3	9	0.477	0.477	0.319	0.898
433-2	9	0.066	0.938	0.737	0.659
453-8	9	0.621	0.547	0.494	0.477
476-1	9	0.124	0.427	0.278	0.796
477-14	9	0.092	0.227	0.142	0.124
477-5	9	0.182	0.319	0.565	0.305
481-11	8	0.417	0.264	0.290	0.264
493-1	9	0.443	0.171	0.460	0.182
495-1	8	0.184	0.738	0.684	0.562
514-1	9	0.443	0.796	0.659	0.349
531-4	9	0.979	0.364	0.192	0.737
539-1	9	0.512	0.006***	0.364	0.015***
556-9	9	0.017	0.816	0.319	0.171
619-20	9	0.918	0.717	0.857	0.565
749-10	9	0.020***	0.020***	0.020***	0.379
753-7	9	0.737	0.477	0.379	0.547
786-2	10	0.163	0.022	0.153	0.085
786-22	8	0.184	0.613	0.039	0.058
976-2	8	0.613	0.981	0.358	0.448

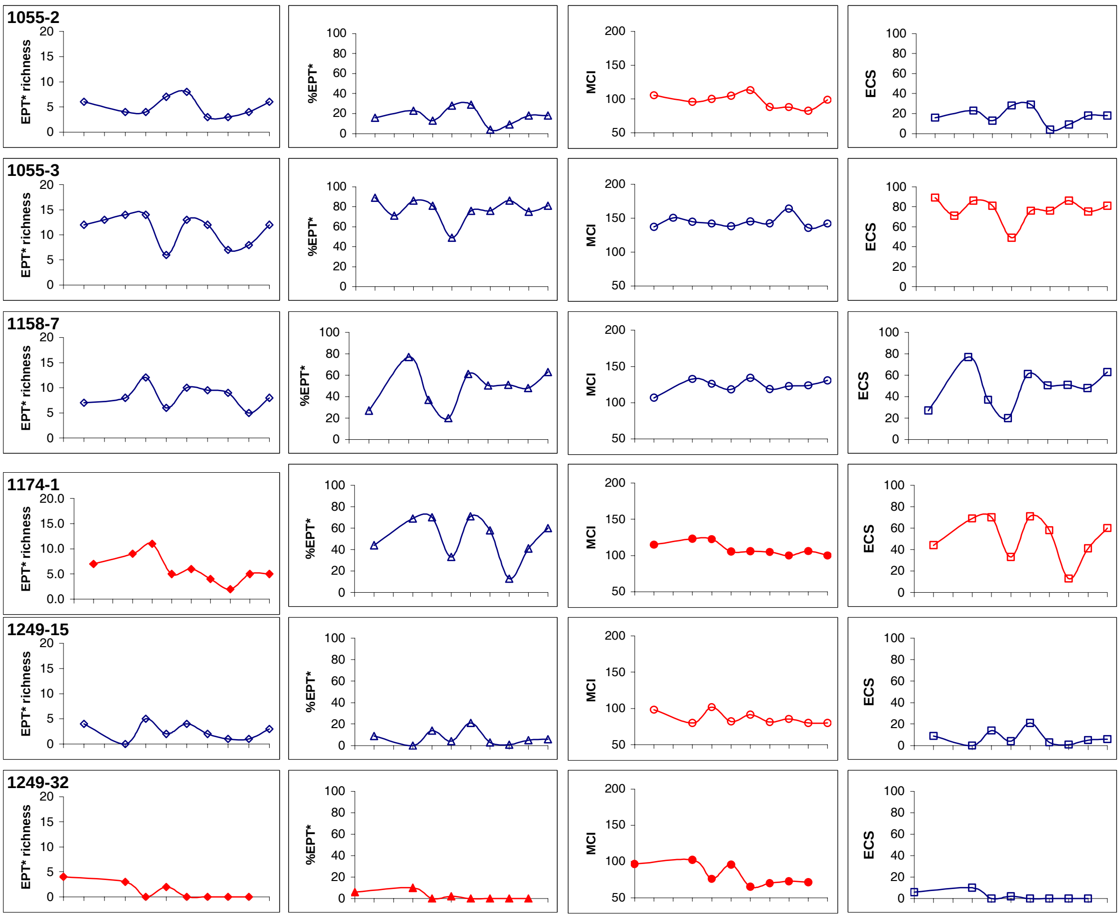
Appendix 3: Plots of selected invertebrate community metrics over time (summer).

Sites interpreted as showing temporal trends are indicated in green for positive trends and red for declining trends. Solid red or green symbols indicate probable-clear trends whereas open symbols indicate possible trends. Blue lines are interpreted as indicating stable conditions.

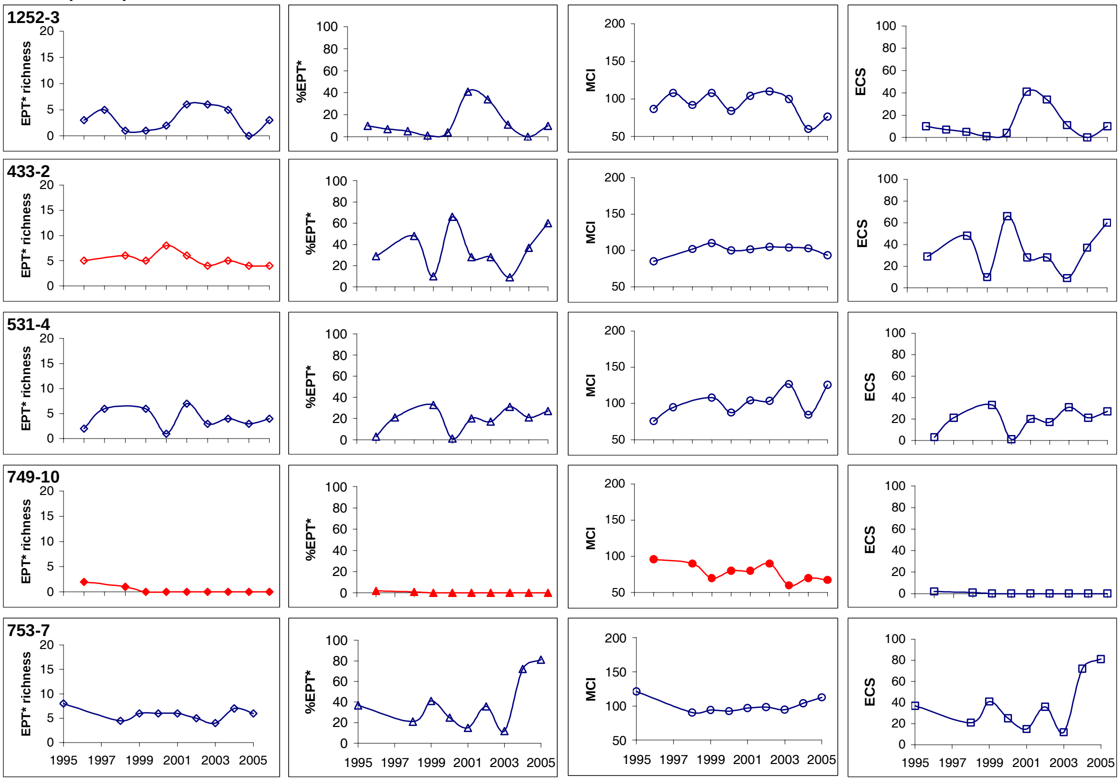
Coromandel



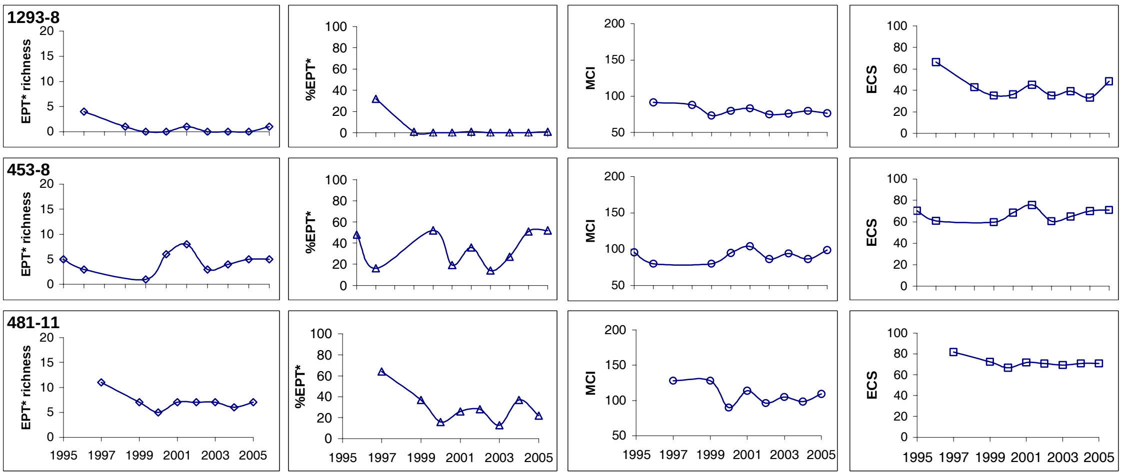
Hauraki



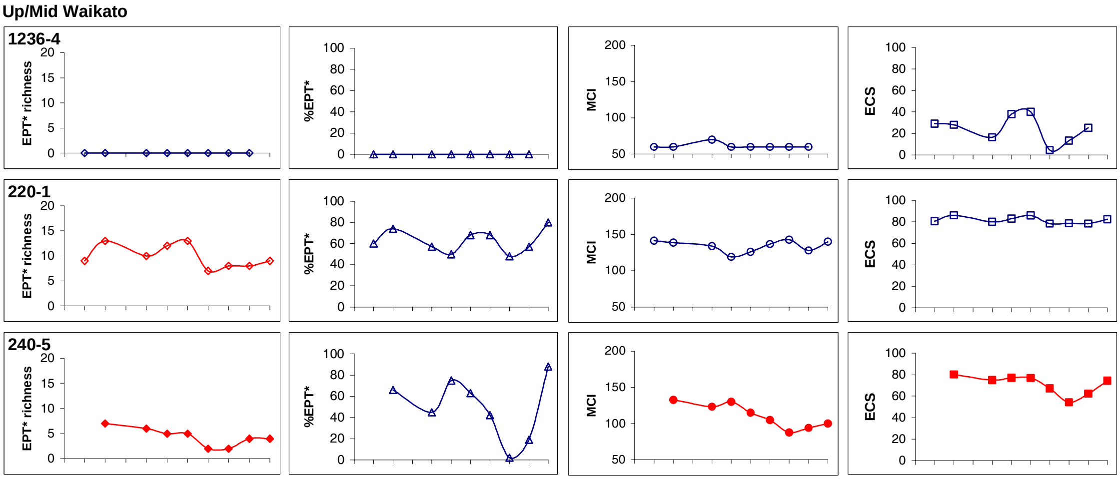
Hauraki (condt.)



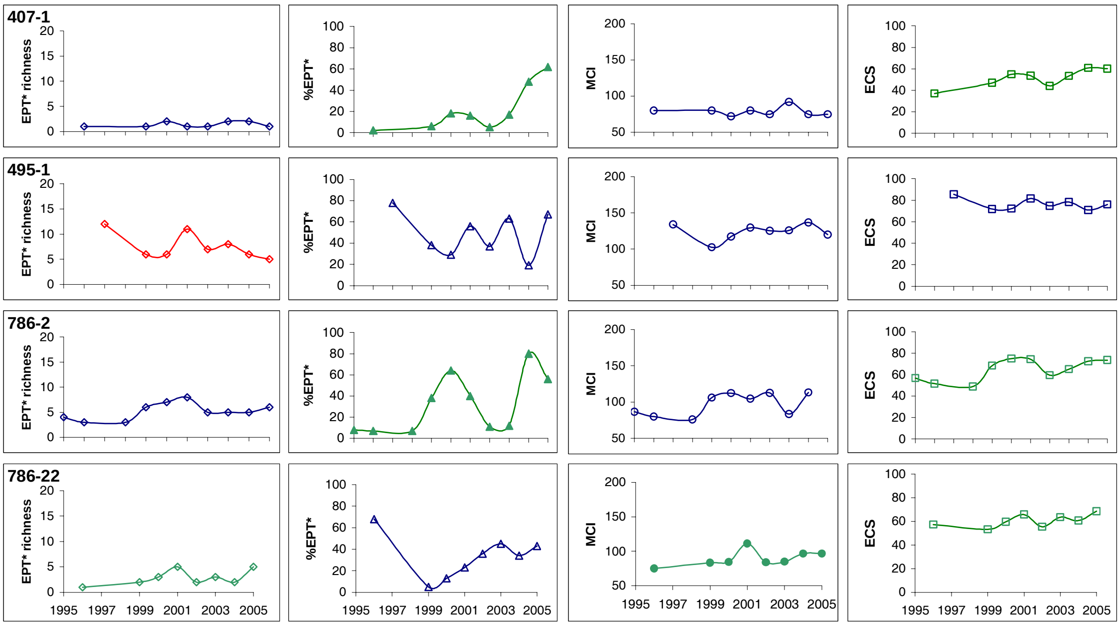
Lower Waikato



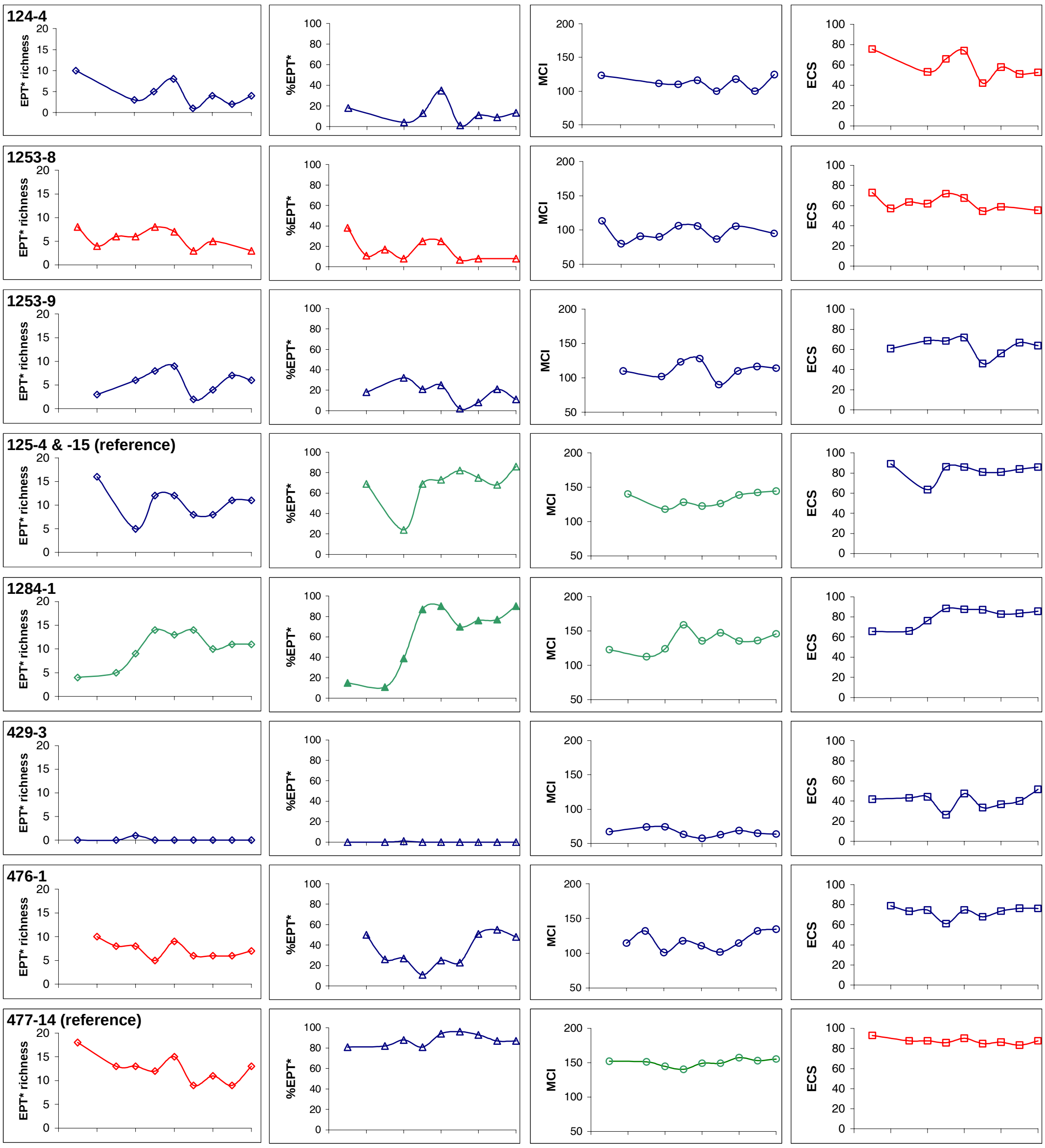
Up/Mid Waikato



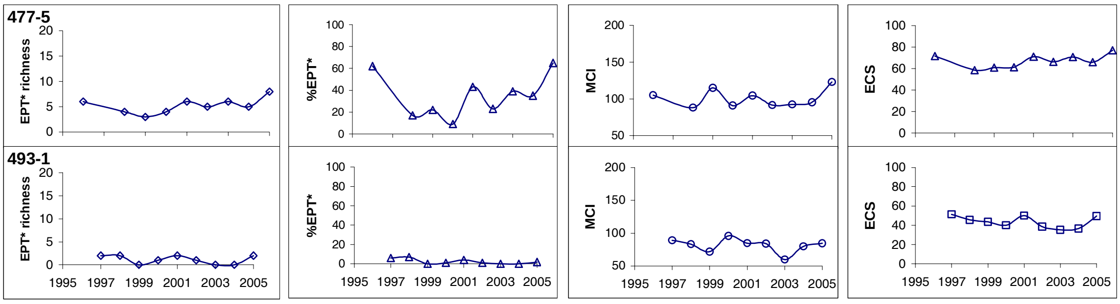
Up/Mid Waikato (contd.)



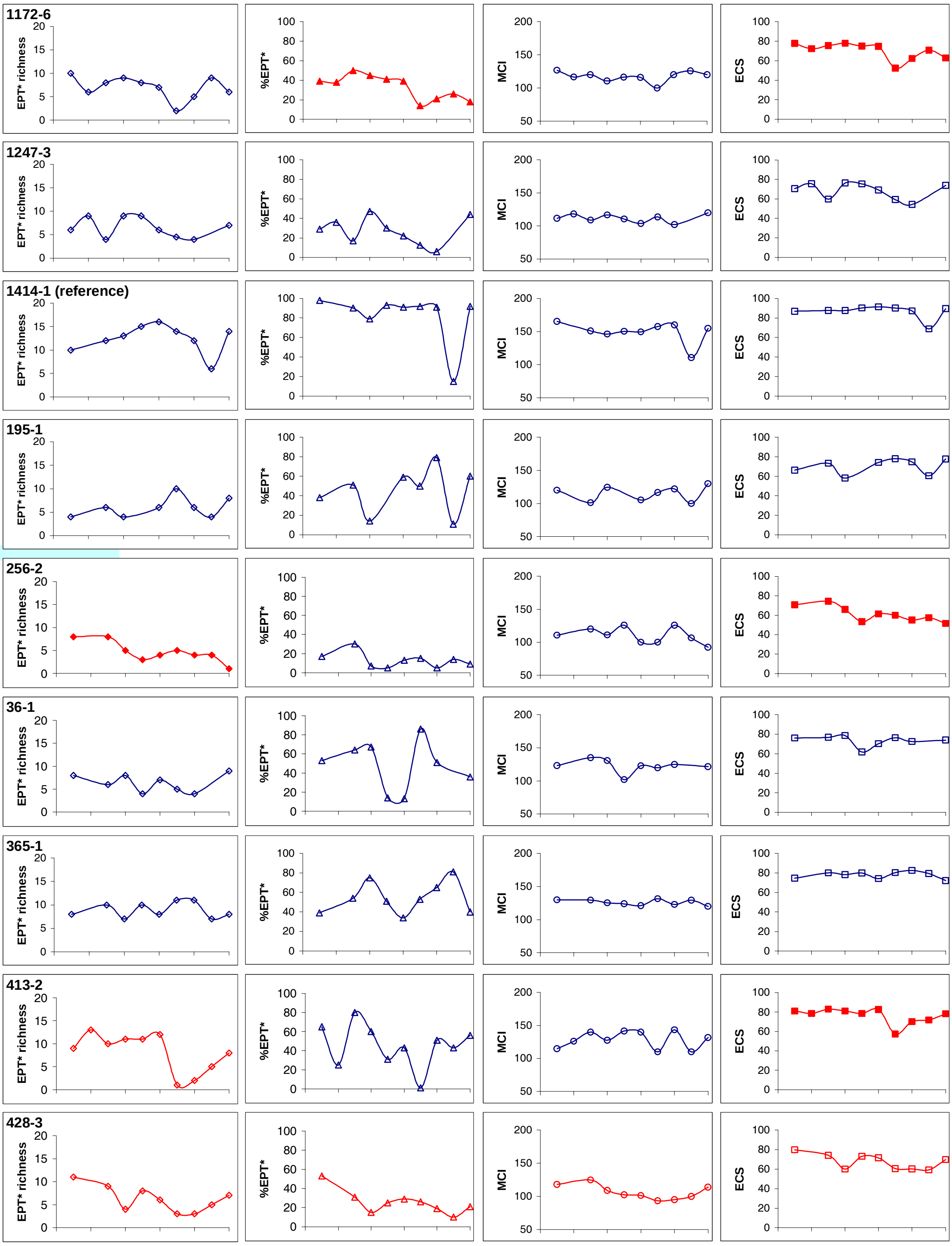
Waipa



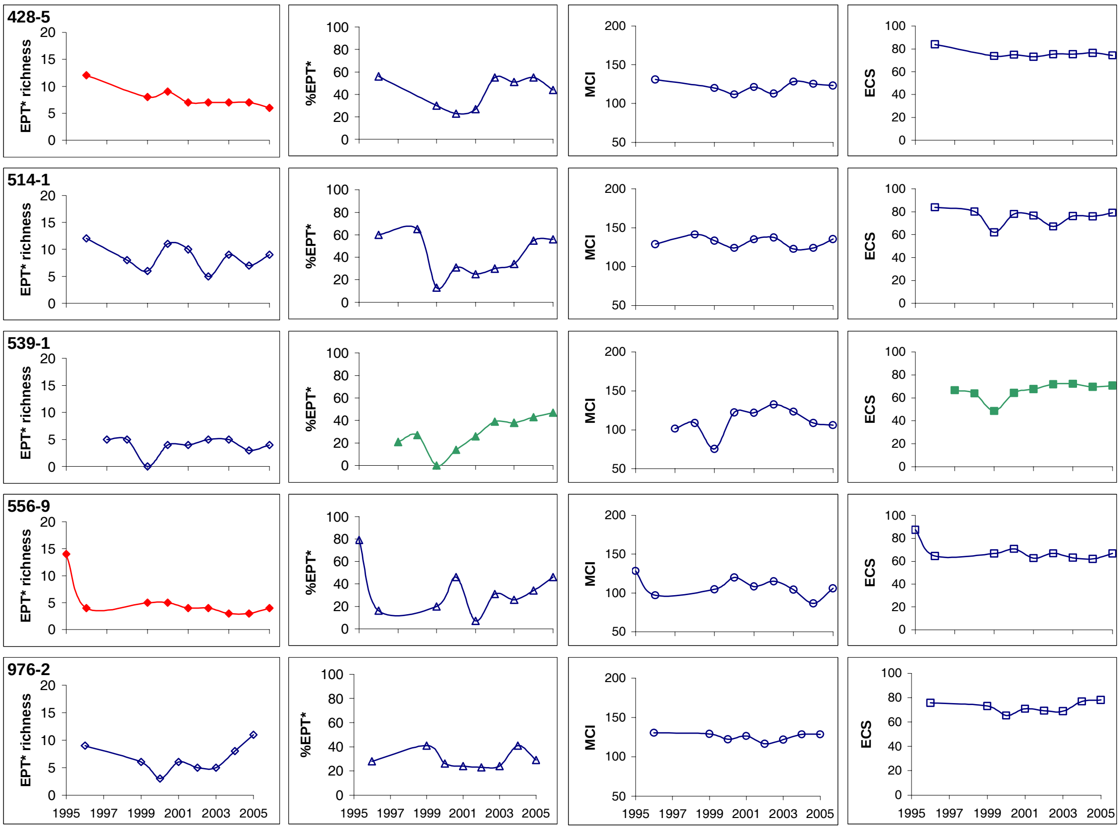
Waipa (condt.)



West Coast



West Coast (condt.)



Appendix 4: Summary of trend classes for four invertebrate metrics at long-term monitoring sites. Probable-clear trends are indicated in bold.

Located number	EPT* richness	%EPT*	MCI	ECS
1055-2	Stable	Stable	Possible decline	Stable
1055-3	Stable	Stable	Stable	Possible decline
1158-7	Stable	Stable	Stable	Stable
1172-6	Stable	Possible decline	Stable	**Probable decline**
1174-10	**Probable decline**	Stable	**Probable decline**	Possible decline
1236-4	Stable	Stable	Stable	Stable
124-4	Stable	Stable	Stable	Possible decline
1247-3	Stable	Stable	Stable	Stable
1249-15	Stable	Stable	Possible decline	Stable
1249-32	**Clear decline**	**Clear decline**	**Clear decline**	Stable
1252-3	Stable	Stable	Stable	Stable
1253-8	Possible decline	Possible decline	Stable	Possible decline
1253-9	Stable	Stable	Stable	Stable
125-4	Stable	Possible increase	Possible increase	Stable
1257-4	Stable	**Clear increase**	Possible decline	Stable
1284-1	Possible increase	**Probable increase**	Possible increase	Stable
1293-8	Stable	Stable	Stable	Stable
1414-1	Stable	Stable	Stable	Stable
195-1	Stable	Stable	Stable	Stable
220-1	Possible decline	Stable	Stable	Stable
23-2	Stable	Stable	Stable	Stable
240-5	**Clear decline**	Stable	**Clear decline**	**Clear decline**
256-2	**Clear decline**	Stable	Stable	**Clear decline**
36-1	Stable	Stable	Stable	Stable
365-1	Stable	Stable	Stable	Stable
4-2	Stable	Stable	**Probable decline**	Stable
407-1	Stable	**Probable increase**	Stable	Possible increase

Located number	EPT* richness	%EPT*	MCI	ECS
413-2	Possible decline	Stable	Stable	Possible decline
428-3	Possible decline	Possible decline	Possible decline	Possible decline
428-5	**Clear decline**	Stable	Stable	Stable
429-3	Stable	Stable	Stable	Stable
433-2	Possible decline	Stable	Stable	Stable
453-8	Stable	Stable	Stable	Stable
476-1	Possible decline	Stable	Stable	Stable
477-14	Possible decline	Stable	Possible increase	Possible decline
477-5	Stable	Stable	Stable	Stable
481-11	Stable	Stable	Stable	Stable
493-1	Stable	Stable	Stable	Stable
495-1	Possible decline	Stable	Stable	Stable
514-1	Stable	Stable	Stable	Stable
531-4	Stable	Stable	Stable	Stable
539-1	Stable	**Clear increase**	Stable	**Clear increase**
556-9	**Probable decline**	Stable	Stable	Stable
619-20	Stable	Stable	Stable	Stable
749-10	**Clear decline**	**Clear decline**	**Clear decline**	Stable
753-7	Stable	Stable	Stable	Stable
786-2	Stable	Possible increase	Stable	Possible increase
786-22	Possible increase	Stable	**Probable increase**	Possible increase
976-2	Stable	Stable	Stable	Stable