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The ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) Programme

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Disclaimer

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Summary

The Waikato Regional Council has been carrying out summer assessments of invertebrate community composition and habitat in streams and rivers annually since 1994 for the Regional Ecological Monitoring of Streams (REMS) programme. The aim of this work is to document the state and trend of ecological health in the Region's streams as part of State of the Environment monitoring. The current sampling network comprises (i) '**long-term sites**' that have been sampled for 10 years or more using consistent protocols for assessment of trends over time (40 sites including 3 reference sites and 6 'restoration' sites where riparian management has been implemented or is planned) (ii) '**random sites**' selected using a probability-based survey design to provide an unbiased estimate of the regional condition of perennial non-tidal wadeable streams on developed land (60 sites sampled once each year for 3 years–180 sites in total; this cycle is repeated every 3 years); and (iii) '**reference sites**' in undeveloped (native forest) catchments to provide a baseline against which to measure change (24 sites sampled annually since 2005). The sites include wadeable hard-bottom streams with stony beds, and wadeable soft-bottom streams with beds dominated by sand and silt. Some long-term sites on rivers that are not wadeable have been retained while appropriate non-wadeable monitoring protocols are developed.

Stream ecological condition is assessed using four macroinvertebrate-based measures (referred to as 'metrics') derived from 200+ counts of individuals: number of different types of mayflies, stoneflies and caddisflies (excluding algal-piercing Hydroptilidae)—EPT* richness; the percent abundance of these sensitive insects—%EPT*; a measure of tolerance to organic pollution—the Macroinvertebrate Community Index or MCI for assessment of trends and its quantitative derivative the QMCI for assessment of state; and an integrative score of these three metrics (EPT* richness, %EPT* and MCI) benchmarked against reference site condition—Average Score Per Metric or ASPM. Metrics are also calculated to assess (i) habitat quality based on qualitative assessments of 9 riparian, bank and channel conditions, and (ii) instream plant cover.

Of the 37 long-term sites on developed land, almost half showed trends over time based on the MCI and ASPM metrics, with 10 sites showing 'clear' trends ($P<0.05$) and 10 sites indicating possible 'borderline' trends ($0.05<P<0.1$) for one or both of these metrics. Of the sites showing clear trends, 2 showed improvements in condition and 8 showed deteriorations in condition. Both metrics increased at the group of 'restoration' sites monitored where riparian management had been implemented and did not change significantly across the long-term reference sites, suggesting that riparian management was having a quantifiable benefit to stream ecological condition at these sites.

Unbiased estimates of wadeable stream condition on developed land based on the random site data indicated that, over 3 years of sampling, 60% of wadeable stream length was unshaded, 69% had 'clear' water at the time of sampling, and most (50-56% of stream length) had unconsolidated beds with high cover by fine sediment. Mean habitat score was 86 compared to 151 at reference sites, macrophyte cover averaged 29% (with 3% of this cover comprising native species), and mean cover by long algal filaments and thick algal mats was 8% at the time of sampling. Overall, median MCI and QMCI values for target wadeable streams on developed land in the Region were 98 and 4.2, respectively, EPT* richness was 7.5, %EPT* was 15.5 and ASPM was 0.39. QMCI (soft- or hard-bottom versions as appropriate) and interim ASPM condition classes indicated that, over the 3 years of sampling, around one-third (c.35%) of wadeable stream length on developed land was rated as 'good-excellent' and two-thirds (c.65%) were rated as 'fair-poor'.

1 Introduction

The Waikato Regional Council has been carrying out annual surveys of aquatic invertebrates and habitat (Regional Ecological Monitoring of Streams—REMS) since 1994 as part of its Environmental Indicators Programme to document the state and trend of the ecological condition of streams and rivers in the region. The history and objectives of this monitoring programme have been reviewed by Collier (2005), and results up to 2008 were reported in Collier & Hamer (2010). The composition of invertebrate communities provides an integrated measure of a stream's health influenced by local and upstream activities that affect water quality and the physical stream environment or habitat. Information on invertebrate community composition is condensed into 'metrics' that can be used as indicators to report on changes over time (trends) or patterns across the region (state). Similar monitoring approaches are widely used among other regional councils in New Zealand and management agencies internationally for documenting stream ecological condition. As invertebrate community composition reflects a range of interacting factors, it provides a holistic and cumulative understanding of ecosystem condition, and augments other measures such as water quality (e.g., chemistry, microbes). Aspects of habitat and instream plant cover are assessed concurrently with macroinvertebrate collections (see Collier & Kelly 2005; Collier et al. 2006).

In 2005, the REMS network was modified to incorporate (i) a network of reference sites on streams in unmodified (native forest) catchments (see Collier et al. 2005, 2007), and (ii) a range of sites around the region reflecting different levels of upstream catchment development (see Collier 2005). In the 2005/06 sampling season, the site network also included a range of urban and periurban sites within and around Hamilton City (see Collier et al. 2009), some of which have been retained in the current sampling programme to document the effects of periurban development or urban stream restoration. In 2009, the landcover assessment (reported in Collier & Hamer 2010) was replaced by a revised survey design involving the sampling of 60 randomly-selected sites in each of three years (i.e., 180 in total over 2009-11) using a probability-based site selection process to provide an unbiased estimate of wadeable stream condition on developed land across the Region. Survey designs that involve random selection of sites with known probabilities of inclusion are now widely used in the USA following acknowledgement that previous designs did not adequately describe the condition of waterways (Shapiro et al. 2008), and the recent demonstration of the value of these designs for cost-effectively quantifying the features, extent and condition of aquatic resources (Olsen & Peck 2008; Paulsen et al. 2008).

This report presents the results of the first set of random sampling for the three-year 'rotating panel', and updates trends for long-term sites. Results are interpreted relative to the reference network of 24 sites in undeveloped catchments sampled annually, including 3–4 reference 'index sites' that were sampled at the beginning and end of the sampling period to determine any changes that may have occurred temporally due to regional climate variations. In addition, 40 'long-term sites' (including 3 'reference' sites and 6 'restoration' sites) were sampled 1-3 times over 2009-11.

The principal aims of this report are to:

(i) identify **temporal trends in key invertebrate metrics** at sites considered to have robust, long-term data; and

(ii) provide an unbiased estimate of the **ecological condition of perennial, non-tidal, wadeable streams on developed land** in the Waikato Region, incorporating macroinvertebrate, habitat, macrophyte and periphyton metrics.

2 Network design

Since the inception of the REMS programme in 1994 there have been variations in the timing of sample collection (although most sampling has been conducted sometime over summer), and in field protocols and laboratory processing procedures which were altered in 2002 to conform to standardised MfE protocols for wadeable stream monitoring (Stark et al. 2001). In total, 1307 samples have been collected as part of the REMS programme since 2002 using these standard protocols, comprising 60% hard-bottomed samples and 40% soft-bottomed samples. Most current REMS sites are part of the long-term, reference or random site monitoring networks (see below). In addition, 4 sites are monitored to assess the effects of periurban development (1132_68, 1132_69, 1132_70, 398_13), and over time it is envisaged that these sites will become part of the long-term monitoring network.

2.1 Reference site monitoring network

In 2005, a regional network was established of wadeable stream ‘reference sites’ whose catchments were entirely in unmodified native vegetation. Site selection was based on achieving a spread of sites across geographic zones within the Region and across 4 dominant stream types identified by Level 3 of the River Environment Classification (REC; Snelder & Biggs 2002). These reference sites are used to provide an undisturbed baseline against which to measure the magnitude of change at other sites and to factor out any regional influences of climatic variation between years (see Collier et al. 2005, 2007).

From 2009 to 2011, 24 reference sites were sampled annually. They included 3 long-term reference sites sampled since 1995 or 1996, and 3 sites where samples were collected from ‘hard’ (stones) and ‘soft’ (mainly wood) substrates to determine the influence of substrate type on macroinvertebrate metric scores (see Appendix 1). Since 2009, 3-4 reference sites have been sampled at both the beginning and end of the sampling period to evaluate any effects of short-term climatic events; these are referred to as ‘index sites’. Collectively, the reference sites generally provided a good representation of environment types across the region identified at the 100- and 250-group level of the Freshwater Environments of New Zealand (FENZ) classification (Figure 1).

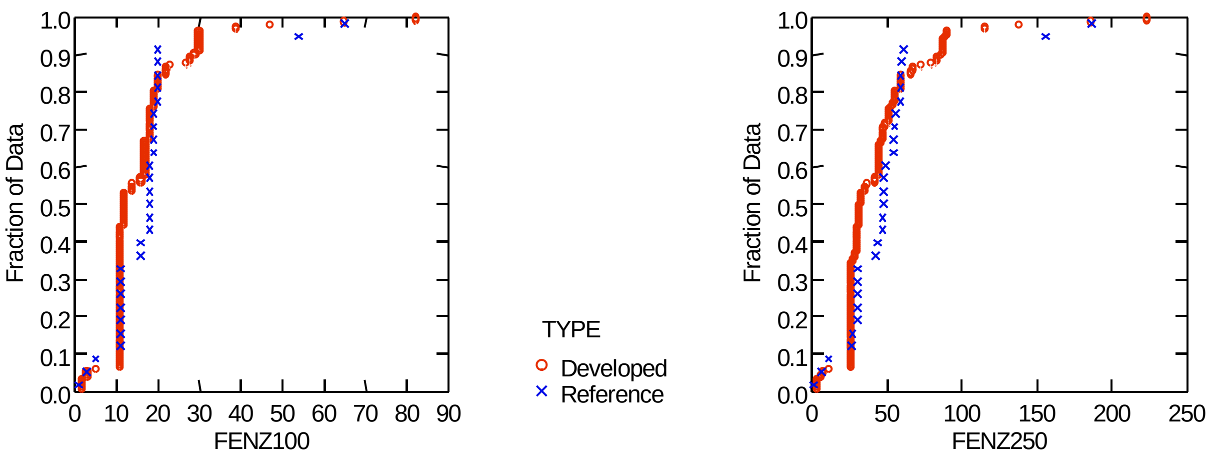


Figure 1: Representativeness of reference sites relative to developed random sites for FENZ100- and 250-groups in the REMS monitoring network over 2009–11.

2.2 Long-term site monitoring network

Fifty-one sites had been sampled in a consistent fashion for at least 10 years by 2011, with 40 of these sites sampled at least once over 2009-11 (Table 1). Six of these were on sites where riparian management is being carried out or is planned (‘restoration sites'; see Table 1). Six sites were incorporated into the long-term network for this report because, by 2011, they had been sampled for a sufficient period to provide at least 10 years of data for trend analysis: these sites were 1252_3/1252_1 (Waitoki@Rawhiti Rd), 1043_1 (Toenepi Stm @ Tahuroa Rd), 1300_2 (Whangamata Stm @ Kinloch; rural restoration), 1323_1 (Whirinaki Stm @ Corbett Rd), 398_1 (Mangakotukutuku Stm (Rukuhia) @ Peacockes Rd), and 47_2 (Bankwood Stm @ Emerald Tce).

The 40 recently-sampled 'long-term sites' discussed in this report include 3 reference sites, and 3 non-wadeable sites of which 2 have been maintained because they have both flow and water quality monitoring data (Table 1). Fourteen sites correspond to regional water quality monitoring sites reported on in Tulagi (2011), 15 sites correspond to near-by locations with comparable long-term flow records, and 9 sites have both flow and water quality records (Table 1). Two current long-term sites are located in each of the Coromandel and Lower Waikato zones, 7 occur in Hauraki, 9 in the Upper/Middle Waikato, 7 in Waipa and 12 on the West Coast (Table 1; see also Figure 2).

Table 1: Description and location of 51 long-term invertebrate monitoring sites sampled for at least 10 years up to 2011.

In the located number column, ref. = reference site (100% native forest upstream); n.w. = non-wadeable; [†], flow monitoring site; [‡], RERIMP monitoring sites reported on by Tulagi (2011); *, restoration/management site. Sites sampled over 2009-11 are shown in bold (see Collier & Hamer 2010 for results for other sites). Site 407_1 has since been discontinued for safety reasons.

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC group	FENZ group (100/250)	% native vege.	Years sampled
1257_4‡,[†]	**Waiwawa**	**Upstream Toranoho Stm**	**2746600**	**6468500**	**Coromandel**	**WW/L/VA**	**3/6**	**98**	**14**
23_2	Apakura	Puriri Valley Rd	2747200	6439200	Coromandel	WW/L/VA	20/59	66	12
4_2	Five Mile	Off Tapu Coroglen Rd	2745600	6467800	Coromandel	WW/L/VA	3/6	99	11
619_20‡,[†]	**Ohinemuri**	**SH25 bridge**	**2764100**	**6421300**	**Coromandel**	**WW/L/VA**	**11/26**	**39**	**14**
1043_1*	**Toenepi**	**Tahuroa Rd**	**2735100**	**6385500**	**Hauraki**	**WD/L/VA**	**12/33**	**0**	**10**
1055_2	Torehape	Torehape West Rd	2722721	6425025	Hauraki	WW/L/HS	11/30	35	12
1055_3	**Torehape**	**Torehape West Rd**	**2721609**	**6424306**	**Hauraki**	**WW/L/HS**	**18/47**	**52**	**15**
1158_7	**Waimakariri**	**Off end of Waimakariri Rd**	**2761526**	**6350704**	**Hauraki**	**WW/H/VA**	**11/26**	**56**	**13**
1174_10[†]	**Waiomou**	**Waiomou Rd**	**2759900**	**6358600**	**Hauraki**	**WW/H/VA**	**28/83**	**45**	**15**
1249_15 (n.w.)‡,[†]	**Waitoa**	**Landsdowne Rd bridge**	**2751700**	**6378300**	**Hauraki**	**WW/L/VA**	**28/83**	**0.1**	**15**
1252_3/1252_1*	**Waitoki**	**Rawhiti Rd**	**2697600**	**6388800**	**Hauraki**	**WW/L/VA**	**20/59**	**21**	**14**
433_2	**Mangapapa**	**Henry Watson Rd**	**2747000**	**6371500**	**Hauraki**	**WW/L/VA**	**11/26**	**27**	**15**
531_4	Matatoki	Matatoki Rd	2741200	6439800	Hauraki	WW/L/VA	23/71	60	12
749_10 (n.w.)‡,[†]	**Piako**	**Kiwitahi**	**2739800**	**6385600**	**Hauraki**	**WW/L/VA**	**28/83**	**14**	**15**
753_7 (n.w.)	Piakonui	Downstream of Paku Rd bridge	2741229	6379291	Hauraki	WW/L/VA	11/28	35	12
1293_8 (n.w.)‡	Whangamarino	Jefferies Rd	2708364	6427161	Lower Waikato	WW/L/HS	11/30	8	12
481_11[†]	**Mangawara**	**Mangawara Rd**	**2723271**	**6414627**	**Lower Waikato**	**WW/L/HS**	**18/47**	**47**	**13**
453_8[†]	**Mangatangi**	**Stubbs Rd**	**2704800**	**6445100**	**Lower Waikato**	**WW/L/HS**	**11/30**	**69**	**15**
1300_2*	**Whangamata**	**Kinloch Rd**	**2763632**	**6278614**	**Up/Mid Waikato**	**CW/H/VA**	**17/45**	**8**	**10**
1323_1‡	**Whirinaki**	**Corbett Rd**	**2795700**	**6317100**	**Up/Mid Waikato**	**CW/H/VA**	**17/45**	**23**	**10**
398_1*,‡,[†]	**Mangakotukutuku**	**Peacockes Rd**	**2712700**	**6374300**	**Up/Mid Waikato**	**WW/L/M**	**12/31**	**2**	**10**
47_2	**Bankwood**	**Emerald Tce**	**2710500**	**6380300**	**Up/Mid Waikato**	**WD/L/M**	**12/31**	**10**	**10**
220_1	**Kaiwhitwhiti**	**Tiverton Downs Farm**	**2797491**	**6282670**	**Up/Mid Waikato**	**CW/H/VA**	**17/45**	**1**	**13**
240_5‡	**Kawaunui**	**SH5 bridge**	**2802100**	**6308100**	**Up/Mid Waikato**	**CW/H/VA**	**17/45**	**18**	**14**

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC group	FENZ group (100/250)	% native vege.	Years sampled
407_1‡	**Mangamingi**	**Paraonui Rd bridge**	**2758800**	**6330200**	**Up/Mid Waikato**	**CW/L/VA**	**11/26**	**0**	**14**
495_1	**Mangawhio trib.**	**Taupaki Rd**	**2739851**	**6323541**	**Up/Mid Waikato**	**CW/H/VA**	**19/54**	**49**	**12**
786_2‡	**Pokaiwhenua**	**Arapuni - Putaruru Rd**	**2749100**	**6345800**	**Up/Mid Waikato**	**CW/L/VA**	**28/83**	**4**	**16**
786_22	Pokaiwhenua	Wiltsdown Rd	2757973	6334873	Up/Mid Waikato	CW/H/VA	29/87	4	11
124_4 (n.w.)	Firewood	Waingaro @ Ngaruawahia Rd	2697713	6388746	Waipa	WW/L/HS	11/30	33	11
125_4/125_15 (ref.)	**Firewood trib.**	**Off walkway (Hakarimata Scenic Res.)**	**2693255**	**6324837**	**Waipa**	**WW/L/HS**	**18/47**	**100**	**14**
1253_9*,‡,†	**Waitomo Stm**	**Tumutumu Rd**	**2693255**	**6324837**	**Waipa**	**WW/L/VA**	**30/90**	**30**	**13**
1284_1	**Whakarautawa**	**Mangati Rd**	**2695200**	**6348100**	**Waipa**	**CX/H/VA**	**5/11**	**82**	**15**
429_3 (n.w.)	Mangaotama	Ryburn Rd	2708012	6360259	Waipa	WW/L/SS	12/31	0.2	12
476_1†	**Mangatutu**	**Lethbridge Rd**	**2722200**	**6336500**	**Waipa**	**CW/L/VA**	**30/90**	**57**	**13**
477_14 (ref.) ‡	**Mangauika**	**Upstream weir**	**2697600**	**6350400**	**Waipa**	**CX/H/VA**	**5/11**	**100**	**15**
477_5	**Mangauika**	**Mangauika Rd bridge**	**2703000**	**6352700**	**Waipa**	**WW/L/VA**	**19/56**	**60**	**14**
493_1	**Mangawhero trib.**	**Mangawhero Rd**	**2708413**	**6326725**	**Waipa**	**WW/L/VA**	**11/26**	**1**	**13**
1172_6*	**Wainui (Raglan)**	**Wainui Reserve bridge**	**2672168**	**6374702**	**West Coast**	**WW/L/VA**	**3/6**	**69**	**16**
1247_3 (n.w.)‡,†	Waitetuna	Ohautira Rd	2684200	6374300	West Coast	WW/L/HS	23/74	45	12
1414_1 (ref)	**Omanawa trib.**	**Pirongia West Rd**	**2691007**	**6351578**	**West Coast**	**CX/H/VA**	**54/156**	**100**	**15**
195_1	**Huriwai**	**Waikaretu Rd**	**2664385**	**6418242**	**West Coast**	**WW/L/SS**	**18/49**	**25**	**13**
256_2 (n.w.)	**Kiritihere**	**Mangatoa Rd**	**2661900**	**6316500**	**West Coast**	**WW/L/HS**	**23/74**	**88**	**14**
36_1†	**Awaroa**	**Awaroa Rd**	**2680290**	**6337596**	**West Coast**	**WW/L/HS**	**30/88**	**53**	**13**
365_1	**Mangahoanga**	**Moerangi Rd**	**2680854**	**6350806**	**West Coast**	**WW/L/SS**	**18/49**	**49**	**13**
413_2	**Mangaokahu**	**Cogswell Rd (upper)**	**2689435**	**6376039**	**West Coast**	**WW/L/HS**	**18/49**	**92**	**14**
428_3‡	**Mangaotaki**	**SH3 bridge**	**2676400**	**6296300**	**West Coast**	**WW/L/VA**	**28/83**	**13**	**15**
428_5	Mangaotaki	Mangaotaki Rd	2679097	6303031	West Coast	WW/L/VA	28/83	14	10
514_1	**Marokopa**	**Te Anga Rd**	**2675500**	**6325700**	**West Coast**	**WW/L/VA**	**30/88**	**61**	**13**
736_2	**Parawai**	**Ohautira Rd**	**2684268**	**6376186**	**West Coast**	**WW/L/SS**	**20/60**	**42**	**11**
556_9‡,†	**Mokau**	**Totoro Rd recorder**	**2675900**	**6290700**	**West Coast**	**WW/L/VA**	**30/92**	**17**	**13**
976_2‡,†	**Tawarau**	**Speedies Rd**	**2671700**	**6324600**	**West Coast**	**WW/L/VA**	**30/88**	**49**	**14**

Footnote: Where site numbers don't correspond exactly the following water quality (wq) or flow recording (fr) sites are considered applicable to the long-term REMS sites: 1257_4 = 1257_3 (wq); 1249_15 = 1249_38 (fr); 1253_9 = 1253_7 (wq); 1253_9 = 1253_3 (fr); 477_14 = 477_10 (wq); 1247_3 = 1247_2 (wq & fr); 976_2 = 976_1 (wq&fr).

2.3 Random site monitoring network

The 2009-11 probability survey design was implemented by randomly selecting wadeable sites on developed land with known probability of inclusion using the survey design software package spsurvey (www.epa.gov/nheerl/arm). The target population for site selection was non-reference (i.e., on developed land), non-tidal, perennial, wadeable streams. Equal numbers of 1st, 2nd, 3rd and ≥4th order streams were selected (i.e., balanced unequal probability design) using the REC river network layer as the sample frame. This survey design ensures an even spread of sites across stream sizes so that sampling sites are not skewed towards small streams which comprise most of the stream network length regionally. However, it should be noted that the REC network layer does not identify all small perennial headwater streams, and therefore the target network length will be underestimated. A key benefit of this monitoring network design is that inferences can be made from a limited number of sites with a quantified level of precision, making it highly cost-effective in terms of providing unbiased estimates of regional stream resources and quality quantified as km of stream length.

Potential sites were visited and defined as non-target if they were non-wadeable, non-perennial, drained catchments entirely in native forest, or represented non-target habitats (e.g. lakes, wetlands) or sample frame inaccuracies (see Table 2 for estimated network lengths). Candidate sites were screened initially using aerial photos to determine whether they could form part of the target population. A total of 486 sites was screened to arrive at 228 target sites, of which 48 were not sampled mainly because of access difficulties (Table 2. Sixty target sites were sampled each year on a rotating basis for 3 years (i,e., each year a new set of random sites was sampled providing 180 samples from 180 sites over 2009-11; Figure 2). Estimated network lengths varied each year depending on the outcome of the random selection process and which sites were designated as target, but estimates of network length for non-target reference streams and non-wadeable river length were relatively consistent across years (Table 2).

Table 2: Mean river network length (km; SE in parentheses) represented by target and non-target (excluded) sites from the random monitoring network for each year and combined years. Length is calculated using the software package spsurvey by adjusting site values by their probability of selection based on the REC sample frame.

	2009 (n=60)	2010 (n=60)	2011 (n=60)	Combined (n=180)
Target				
Sampled	17466 (1378)	12988 (1059)	10596 (953)	13196 (644)
Inaccessible	2288 (549)	2660 (594)	3073 (567)	2695 (350)
Other	124 (107)	0 (0)	125 (104)	75 (66)
Total	19879 (1678)	15648 (1398)	13794 (1337)	15965 (818)
Non-target				
Reference	6766 (1171)	6861 (1070)	7124 (1180)	6901 (609)
Non-wadeable	3297 (702)	3200 (390)	2682 (565)	3105 (306)
Tidal	248 (150)	94 (79)	181 (147)	186 (85)
Drain	1111 (548)	683 (312)	1723 (558)	1185 (284)
Dry	2469 (827)	4340 (820)	8975 (1190)	5458 (607)
Lentic	460 (297)	2222 (627)	1269 (570)	1406 (312)
Wetland	1885 (800)	3920 (1040)	1326 (623)	2595 (499)
Network inaccuracy[1]	1548 (806)	695 (443)	590 (393)	860 (298)
Total	17785 (1678)	22016 (1398)	23870 (1337)	21699 (818)

[1], typically refers to locations where a channel was shown on the REC drainage layer but could not be located on a site visit. This does not include small perennial streams that were not delineated by the REC drainage layer (i.e., these streams did not form part of the sampling frame).

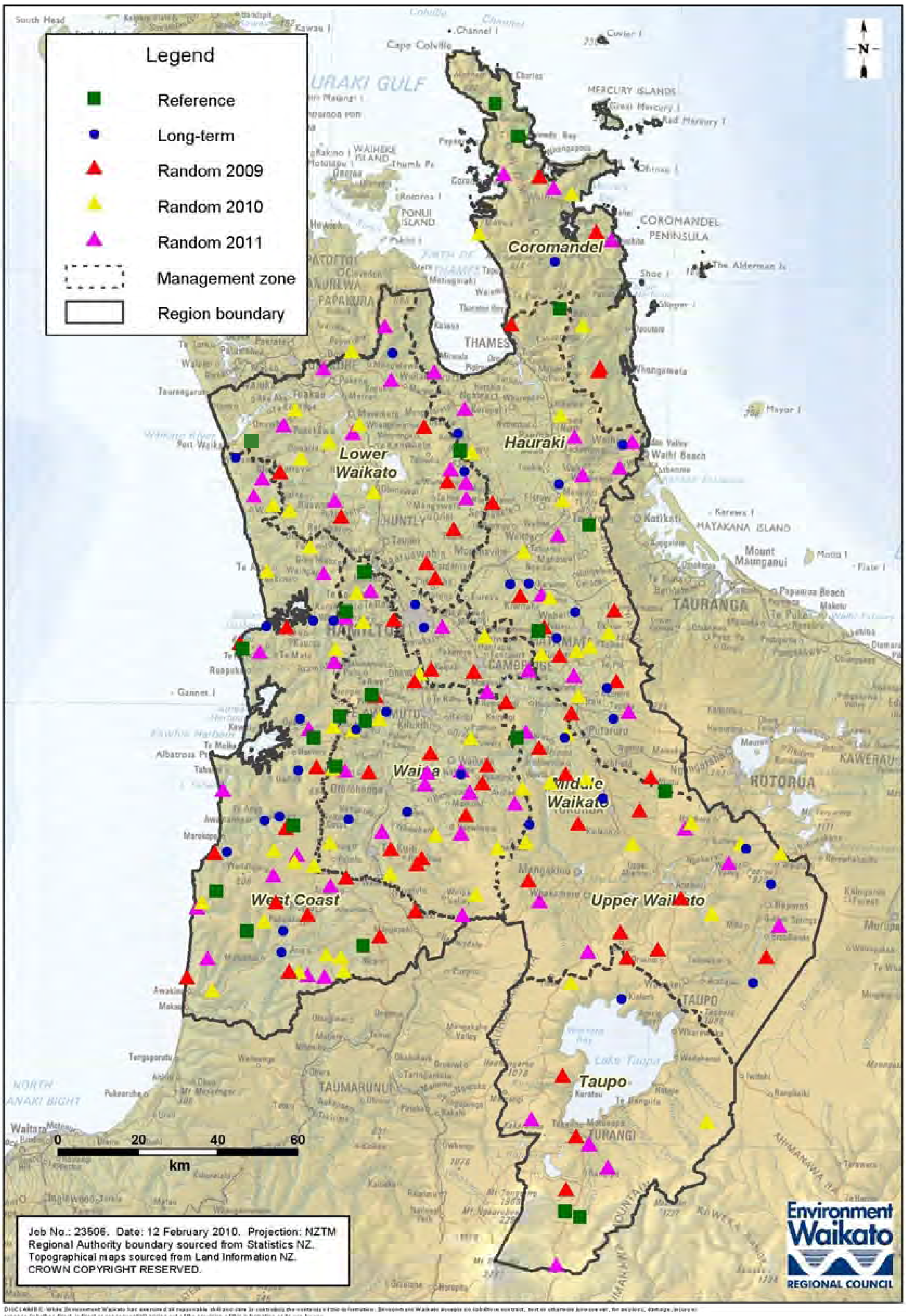


Figure 2: Location of REMS stream monitoring sites sampled over 2009–11 that were part of the random network, the reference site network, and the long-term network.

3 Methods

3.1 Sample collection and data compilation

The history of REMS sample collection methods is outlined in Collier (2005) and Collier & Kelly (2006). Prior to 2002, field sampling protocols differed from those used currently, notably in terms of habitats sampled, net mesh size and number of invertebrates counted. From 2002–05, macroinvertebrate data were collected in line with MfE protocols as described by Stark et al. (2001) and refined for the Waikato region by Collier & Kelly (2005). This change involved focussing on ‘hard’- or ‘soft’-bottom habitats at particular sites, use of a coarser mesh size for the sampling net, increasing the fixed count from 100 to 200+ individuals (and recording of rare taxa), and increasing the level of taxonomic resolution (notably for Chironomidae). Collier (2005) discusses the implications of these changes for assessing long-term trends.

Five metrics are calculated from these data: EPT* richness, %EPT* abundance, the Macroinvertebrate Community Index (MCI), the quantitative MCI (QMCI), and the ASPM which is an aggregation of the two EPT metrics and MCI benchmarked to reference condition in a particular year (see Collier (2008)). ‘EPT’ refers to the sensitive groups Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). EPT metrics exclude Hydroptilidae (denoted by “*”) because the commonest members of this family can proliferate in degraded conditions characterised by growths of filamentous algae (Maxted et al. 2003). Scarsbrook et al. (2000) concluded that measures such as MCI, EPT richness and %EPT are appropriate for monitoring long-term trends because they are less susceptible to fluctuations in numbers of tolerant taxa, 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). The QMCI is considered better suited to determining ecological state (cf trends) than MCI because it accounts for abundance (Hudson et al. 2012). For the purposes of this analysis, MCI and ASPM (which includes MCI and 2 EPT metrics) were used to evaluate trends, and QMCI and ASPM were used to evaluate state. Tolerance scores for MCI calculations were the same as those listed in Collier & Kelly (2005), except prior to 2005 when Chironomidae were not differentiated and the combined chironomid taxon was allocated a tolerance score of 5 based on the average value for all Chironomidae sub-families.

Prior to 2002, metrics were calculated from 100-count data, whereas from 2002 metrics were calculated from 200+ counts following publication of standardised wadeable stream monitoring protocols (Stark et al. 2001). Comparison of the two sample sizes showed little influence on the calculation of %EPT, MCI or ASPM (r^2 = 0.91 to 0.99), although it did influence the number of EPT taxa due to abundance-richness relationships (Collier 2008). When calculating ASPM prior to 2002 using 100-count data, EPT reference site richness was adjusted by 0.68 to account for the abundance-richness effect (see Collier 2008).The highest metric scores at reference sites for each year were used to standardise metrics for calculation of ASPM, except prior to 2005 when the 2005-11 annual mean was used because few reference sites had been sampled.

For assignment to condition classes, soft-bottom or hard-bottom MCI and QMCI values were calculated and assigned to the degradation classes listed in Stark & Maxted (2006). **Interim** quality classes for ASPM followed the same narrative descriptions of Stark & Maxted (2006). These classes were derived from the average annual mean reference score for all data available minus 1 standard deviation to define “Excellent” (>0.74) and even splits between this and the lowest recorded ASPM value to define “Good” (0.52-0.74), “Fair” (0.31-0.51), and “Poor” (<0.31). The ASPM classes are considered interim because almost all available reference sites are in hard-bottom streams, and we do not know what to expect in unmodified low-gradient soft-bottom streams which now all occur in highly developed landscapes. Waikato Regional Council ecologists are currently working on ways to resolve this issue.

Qualitative assessments of habitat quality have been conducted on most occasions since 1998 (corresponding to 94% of macroinvertebrate samples), but due to changes in assessment methods long-term trends in habitat quality cannot yet be investigated for most sites (see Collier 2005). Habitat quality scores are derived by adding qualitative assessments of 9 measures of riparian, bank and channel condition on a scale of 1 (lowest condition) to 20 (highest condition), with reference sites averaging 152 over 2009-11. Assessments of periphyton and macrophyte metrics have also been made at most sites sampled since 2005, following the methods described in Collier et al. (2006). The metrics reported here are Periphyton Proliferation Index (PPI; the sum of long filaments and thick mats), Periphyton Slimyness Index (PSI; algal cover classes weighted by length/thickness), Macrophyte Total Cover (MTC; % planar surface covered), Macrophyte Channel Clogginess (MCC; areal cover weighted by plant height class), and Macrophyte Native Cover (MNC; % planar cover by native species).

3.2 Statistical analyses

3.2.1 Trend analysis (long-term sites)

Trend analysis was applied only to sites where macroinvertebrates had been sampled consistently over a sufficient length of time. Collier & Kelly (2006) used a stratified Spearman correlation approach to infer likely trends in metric data of limited temporal duration, and Collier & Hamer (2010) combined this approach with the Mann-Kendall trend test which is more appropriate for longer-term datasets. Only the Mann-Kendall test was applied in this report, using TimeTrends software (version 3.20; 2011), for sites with ≥10 years of data that included at least one sample over 2009-11. Statistically significant trends were identified at P <0.05 and 'borderline' trends were inferred where P values fell between 0.05 and 0.1. Overall trends were inferred for all long-term sites sampled over 2009-11 that were on developed land (i.e., excluding reference sites and sites where restoration/management was underway) using the Regional Mann Kendall test (Helsel et al. 2006). Overall trends were also assessed across 5 long-term restoration sites where riparian management had been implemented, and the 3 reference sites consistently monitored since 2002 using the Regional Mann Kendall test.

Collier (2006) and Stark & Fowles (2006) raised the issue of 'ecological relevance' versus statistical significance, whereby statistically significant trends may be detected but the magnitude of change in metric values over time may be small and within the range of variation encountered naturally. We calculated the percentage change in the rounded mean difference of 10th and 90th metric percentiles relative to the median at the 3 long-term reference sites as a basis for inferring ecological relevance of statistically significant changes at non-reference sites. These equated to changes of 15% for MCI and 12% for ASPM; the lower value (12%) was used conservatively for both metrics. Ecological significance was inferred where the percentage change exceeded 12% and the trend slope exceeded 1% per annum. However, it should be noted that smaller increases may be important ecologically at previously degraded sites, and thus assessments of ecological relevance should be interpreted with caution and regarded as interim.

3.2.2 State analysis (random sites)

The R software package spsurvey was used to calculate the percentage and total length of wadeable stream on developed land for (i) different metrics expressed as continuous variables and plotted as cumulative distribution functions; (ii) categorical variables (e.g., level of shade – open, partial, closed; metric condition classes – excellent, good, fair, poor); and (iii) percentile values for continuous and categorical variables. Because the network design involved unequal probability of selection to achieve balanced numbers of 1st, 2nd, 3rd and ≥4th order sites from the sample frame, rather than being a simple random sample, it was necessary to adjust the data for the known probability of site selection. This adjustment enabled calculation of an unbiased estimate of stream length represented by particular metric values based on the target population of streams, and was achieved using the spsurvey package. Standard error (SE) estimates were based on the local neighbourhood method described by Stevens & Olsen (2003). Appendices 3 and 4 show the percentile outputs for physical habitat and macroinvertebrate metrics, respectively, and Appendix 5 presents cumulative distribution plots of metrics against regional stream length.

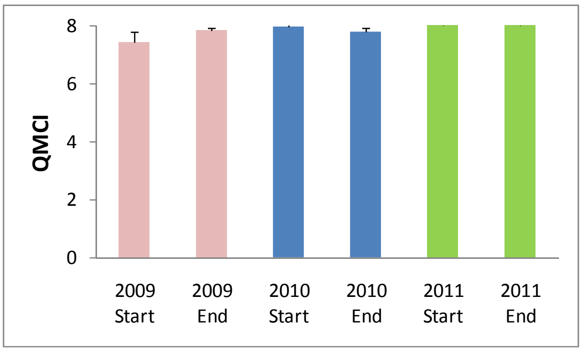
4 Results & Discussion

4.1 Ecological state (random sites)

4.1.1 Reference sites

Reference sites draining native forested catchments are sampled to provide a benchmark against which to compare changes in other sites. Over the three years 2009-11, the median values for these reference sites were; QMCI 7.8, MCI 132, EPT* richness was 16, %EPT* was 86 and ASPM 0.83 (Appendix 6).

Reference index sites were sampled towards the start and end of the monitoring period to assess whether any regional phenomena (e.g., climatic events such as major storms or prolonged dry spells) could affect inferences about the state of wadeable streams in particular years. The graphs shown in Figure 3 indicate little difference in the QMCI and ASPM state metrics within or between years at the sites sampled, suggesting that inferences regarding wadeable stream condition over January-March were not affected by natural environmental variation during that period. Statistical analyses on these data were not deemed necessary as any differences apparent within years were considered minor ecologically. The effects on macroinvertebrate metrics of a flood event that triggered a 2-week stand down in January 2011 are described in Appendix 2 for reference and developed sites.



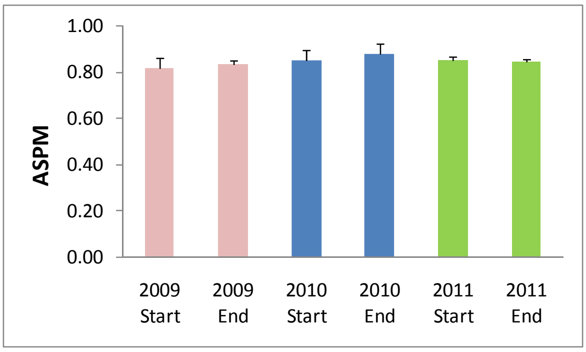


Figure 3: Change in QMCI and ASPM (mean±SE) for index reference sites (33_16, 234_28, 1888_4, 125_15, 1968_1; n=3-4 per year) sampled at the start and end of each monitoring period (January-March) over 2009-11.

4.1.2 Physical characteristics

Wetted width of wadeable stream channels on developed land averaged around 4 m with water occupying about half the unvegetated active channel at the time of sampling (i.e., channel:wetted width ratio about 2; Table 3). Overall, 60% of wadeable stream length assessed had no overhead shade with 10% having riparian vegetation that provided full shade. Stream water was mostly clear, although estimates varied considerably between 2009-11, possibly reflecting antecedent flow conditions (56-82% of stream length 'clear'; Table 3). Streambed substrates were dominated on average (>50%) by fine particles, although this varied between years and was related to the level of compaction and embeddedness encountered. Consequently a similar proportion of stream length was sampled using soft- and hard-bottom macroinvertebrate protocols. Previous monitoring designs not involving random selection have tended to sample a higher proportion of hard bottomed streams, thereby not providing an accurate assessment of stream habitat and condition.

Average habitat quality scores were consistent across years, as was the extent of macrophyte cover and channel clogginess; native macrophyte species were poorly represented in terms of cover (<3% overall; Table 3). Mean periphyton proliferation and slimyness indices were <11 indicating limited algal growth typically in wadeable streams on developed land during summer, although 10% of sites had >25% cover (see Appendix 3 and Appendix 5). Shade and habitat quality score are considerably higher at reference sites than on developed land, while percent sand/silt/clay, macrophyte and periphyton cover are much lower at reference sites (Table 3). This overall difference in physical characteristics on developed land when compared to reference condition shows the overall physical changes that land development has had on the region's streams, although to some degree this will reflect the fact that all reference sites are native forested hill-country streams.

Table 3: Mean (SE) regional estimates of wadeable stream characteristics on developed land based on the probability survey design analysis for (A) categorical classifications of shade, water turbidity, substrate compaction and embeddedness, and macroinvertebrate sampling method expressed as % of wadeable stream length; and (B) absolute values of the continuous variables for substrate size and channel indices, habitat score, and macrophyte and periphyton metrics. Reference site data are shown as % of samples for categorical variables and absolute values for continuous variables.

Variable	Category	2009 (n=60)	2010 (n=60)	2011 (n=60)	Combined (n=180)	Reference samples
A. Categorical habitat variables						**(%)**
Shade	None	62.9 (6.0)	58.6 (5.9)	59.0 (6.1)	**60.3 (3.6)**	4.2
	Partial	26.8 (5.8)	26.8 (5.2)	36.4 (5.8)	**29.3 (3.2)**	13.7
	Full	10.3 (3.4)	14.7 (5.2)	4.6 (2.4)	**10.4 (2.3)**	82.1
Turbidity	Clear	82.1 (3.9)	55.6 (6.8)	68.1 (5.5)	**68.8 (3.4)**	92.6
	Slight	14.1 (3.7)	29.7 (6.5)	18.1 (4.9)	**20.6 (3.0)**	6.4
	High	3.0 (1.2)	8.9 (3.7)	4.2 (1.9)	**5.4 (1.5)**	0
	Stained	0.7 (0.6)	5.8 (3.2)	9.5 (4.2)	**5.2 (1.6)**	1.1
Compaction	Tight	6.0 (2.7)	7.7 (3.4)	9.5 (4.3)	**7.5 (1.9)**	23.2
(packing of	Moderate	11.3 (3.2)	16.3 (5.0)	22.1 (5.0)	**17.1 (2.6)**	45.3
substrate)	Loose	11.4 (4.1)	33.5 (6.3)	32.0 (6.3)	**25.4 (3.2)**	23.2
	None	71.3 (5.6)	42.5 (6.0)	36.4 (7.0)	**50.1 (3.5)**	8.4
Embeddedness	<5%	7.5 (3.2)	6.9 (2.7)	11.8 (4.3)	**8.4 (1.9)**	42.1
(cover by fine	5-25%	15.4 (4.3)	23.2 (5.5)	20.3 (4.5)	**20.4 (2.8)**	32.6
sediment)	26-50%	10.6 (4.3)	16.2 (5.0)	20.9 (5.2)	**15.9 (2.8)**	116.8
	51-75%	16.7 (4.7)	11.2 (4.4)	17.4 (5.8)	**14.9 (2.7)**	5.3
	>75%	49.7 (6.2)	42.5 (6.3)	29.6 (6.5)	**40.4 (3.4)**	3.2
Sampling method	Hard (H)	27.2 (5.6)	47.5 (6.0)	54.8 (6.4)	**43.3 (3.4)**	89.3
	Soft (S)	70.1 (5.9)	50.3 (6.0)	39.6 (6.8)	**53.5 (3.5)**	0
	H+S	2.6 (1.7)	2.2 (1.2)	5.6 (3.8)	**3.2 (1.1)**	9.5
B. Continuous habitat variables						
Percent sand/silt/clay		68.2 (4.4)	52.8 (4.5)	47.0 (4.6)	**56.0 (2.5)**	10
Channel width:wetted width		1.9 (0.1)	2.6 (0.2)	2.3 (0.3)	**2.3 (0.1)**	1.8
Habitat quality score		84.9 (4.1)	85.0 (3.9)	88.6 (4.8)	**86.4 (2.4)**	154
Macrophyte total cover (%)		34.2 (4.5)	32.0 (4.6)	21.9 (4.8)	**29.1 (2.6)**	<0.1
Macrophyte channel clogginess %		32.3 (4.4)	30.2 (4.5)	24.6 (4.9)	**28.8 (2.6)**	0
Macrophyte native cover (%)		3.2 (1.2)	2.1 (0.6)	2.9 (0.8)	**2.7 (0.6)**	0
Periphyton proliferation index		7.1 (1.5)	8.2 (1.9)	10.0 (2.3)	**8.2 (1.0)**	0.5 (0.2)
Periphyton slimyness index		9.6 (1.4)	10.0 (1.5)	13.2 (2.0)	**10.7 (0.9)**	2.9 (0.6)

4.1.3 Macroinvertebrate condition metrics

Cumulative distribution functions for the two invertebrate state metrics are shown in Figure 4 (see Appendix 4 for percentile values). Overall, median MCI and QMCI values for target wadeable streams on developed land in the Region were 98 and 4.2, respectively, EPT* richness was 7.5, %EPT* was 15.5 and ASPM was 0.39. The proportion of stream length in each condition class for QMCI and ASPM (interim classes only) varied among years and partly reflected differences in percentages of soft-bottom streams sampled, although QMCI class designations took this into account. Using QMCI over 2009-11, 19-30% of wadeable stream length (non-tidal, perennial) on developed land was rated as 'excellent', 8-15% was rated as 'good', 10-21% was rated as 'fair', and 45-63% was rated as 'poor' (Figure 5). Using the interim ASPM condition classes, these figures were: 6-12% 'excellent', 19-37% 'good', 18-31% 'fair', and 31-55% 'poor'.

Across all 3 years combined for both state metrics (QMCI and ASPM), 41-51% of the wadeable stream length on developed land in the Waikato Region was classified as in 'poor' ecological condition, compared to 14-23% as 'fair', 10-27% as 'good' and 9-25% as 'excellent' (Figure 5). Overall, around one-third of target wadeable stream length defined by the REC network layer was rated as good-excellent and two-thirds were rated as fair-poor. On average, fair-poor sites had significantly more fine sediment on the streambed, lower habitat quality, and higher levels of calcium and phosphorus-bearing rocks and proportions of pasture in upstream catchments, while excellent-good sites had higher levels of hard rocks and more indigenous forest in upstream catchments. Further analysis is required to determine the relative importance and interaction of these factors.

Table 4: Mean (SE) values for local habitat characteristics (fine sediment on the streambed, habitat quality), and upstream geology (calcium and phosphorus bearing rocks, indurated rocks) and landcover (indigenous forest, pasture) for probability survey sampling sites classed as "Excellent-Good" or "Fair-Poor" according to QMCI and interim ASPM classes. All differences between Excellent-Good and Fair-Poor were statistically significant (Mann-Whitney U test, P<0.05).

	QMCI class				ASMP class			
	Excellent-Good		Fair-Poor		Excellent-Good		Fair-Poor	
% sand/silt/ clay	28.84	(2.84)	66.92	(3.27)	27.21	(2.64)	70.06	3.20
Habitat score	111.03	(3.30)	78.24	(2.34)	111.41	(2.85)	76.19	2.40
Upstream calcium	1.43	(0.05)	1.74	(0.04)	1.45	(0.05)	1.75	0.04
Upstream hardness	2.89	(0.09)	2.60	(0.07)	2.88	(0.08)	2.59	0.08
Upstream phosphorus	1.68	(0.08)	1.98	(0.07)	1.70	(0.08)	1.99	0.07
Upstream indig-enous forest	0.31	(0.04)	0.14	(0.02)	0.32	(0.04)	0.12	0.02
Upstream pasture	0.47	(0.04)	0.77	(0.03)	0.46	(0.04)	0.80	0.03

Footnote: Values are for sites and are not adjusted for probability of selection

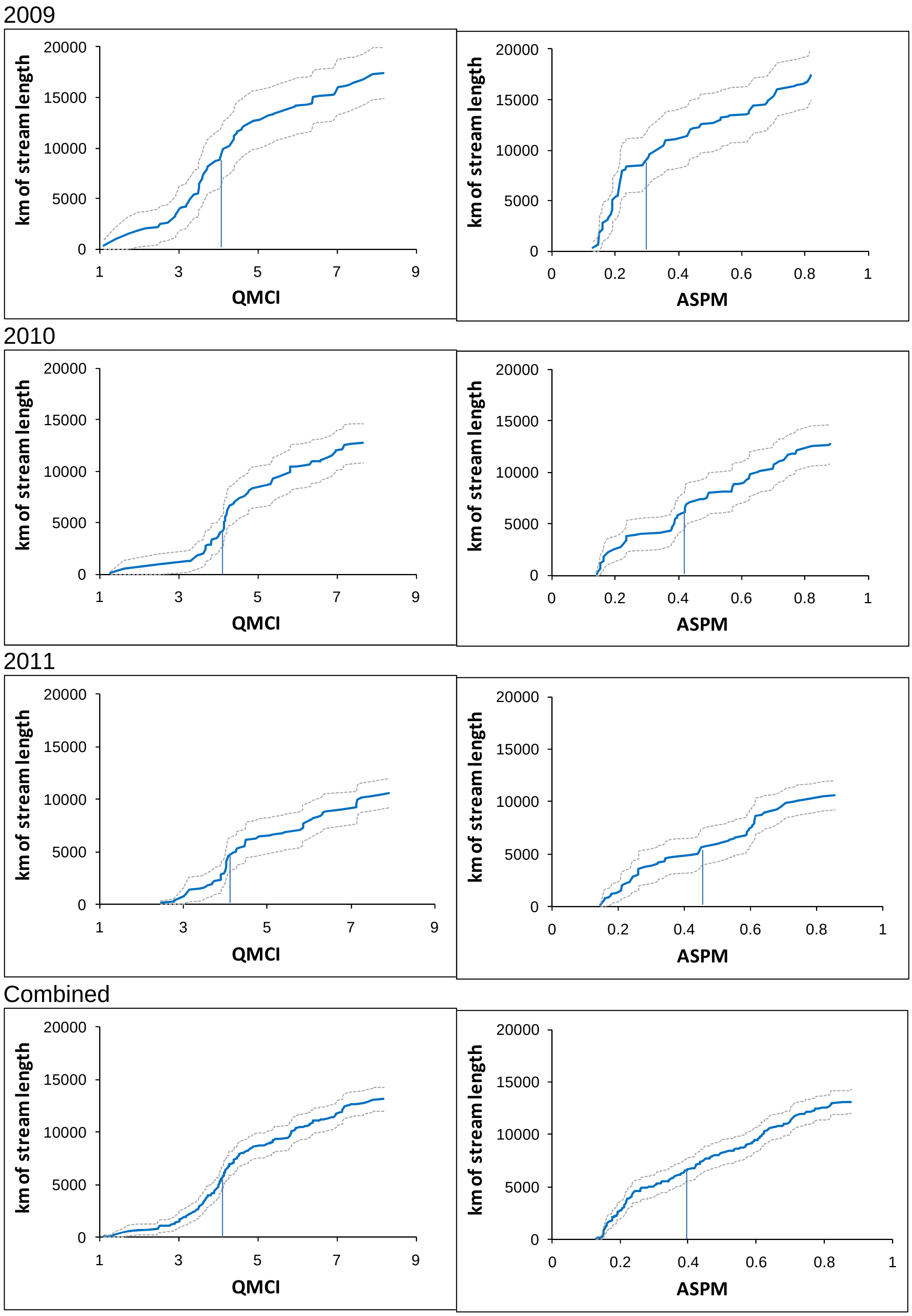
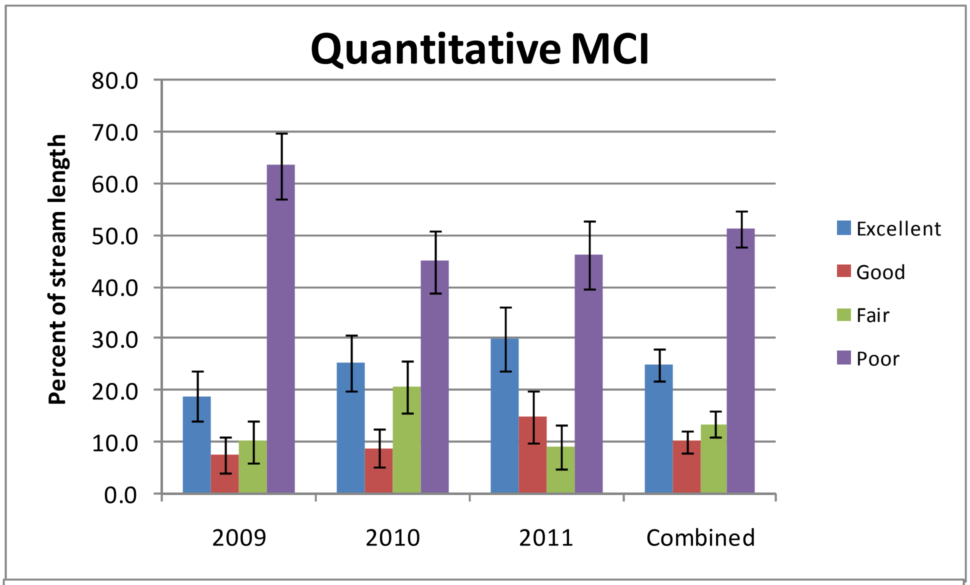


Figure 4: **Cumulative distribution functions (with 95% confidence intervals shown as dashed lines) of stream length (km) for QMCI and ASPM in each year and for combined years. Vertical lines indicate median metric values. Stream lengths for which inferences can be made vary among years because of the random sampling approach.**



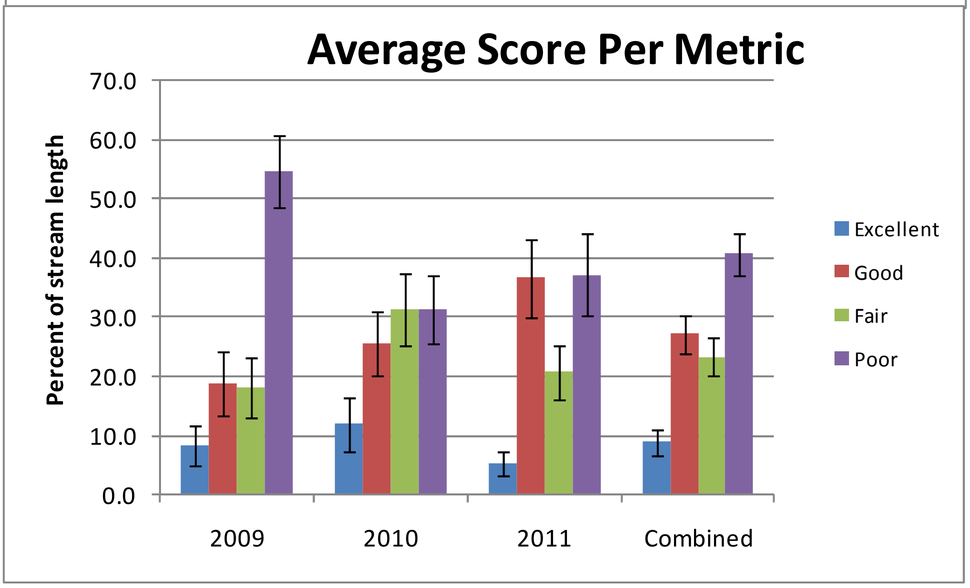


Figure 5: **Mean (±SE) percent of stream length falling into four environmental condition classes for QMCI and interim classes for ASPM. QMCI classes reflect calculations of hard-bottom or soft-bottom metrics as appropriate. The ASPM classes are interim because it uses the hard-bottom MCI and is benchmarked against hard-bottom reference sites.**

4.2 Ecological trends (long-term sites)

4.2.1 Overall trends

Changes in macroinvertebrate metrics over time are shown in Figure 6 for long-term (i) monitoring sites on developed land (i.e., excluding restoration and reference sites), (ii) reference sites (100% upstream native forest; n = 3), and (iii) sites currently undergoing riparian management ('restoration'; sampled since 2002, n = 5). Regional Mann-Kendall statistics for groupings of sites are shown in Table 5. Negative values indicate a decline over time, and positive values indicate an increase.

Overall, there was no trend in ASPM but there was a significant decline in MCI over time across all developed sites (Table 4). This change was equivalent to 8 MCI units over the duration of sampling, and this was not deemed ecologically significant according to the interim criterion of 12% change relative to the developed site median. Sites that had some form of riparian management alongside the monitoring reach ('restoration') showed significant increases in ASPM (0.01 per year or 0.1 over the 10-

year duration of monitoring) and MCI (1.5 units per year or 15 units), equivalent to >12% changes overall relative to the restoration site median (Table 5; see also Figure 6). There were no statistically significant trends for the three long-term reference site metrics, although a 'borderline' (0.05<P<0.1) trend in MCI was indicated representing only a 6% change overall (Table 5). The available reference sites represent a limited geographic spread and range of stream types (see Table 1). Additional reference sites are now monitored as part of the REMS programme (see Collier et al. 2007) and will provide a more robust basis for discriminating long-term changes and defining ecological significance in the future.

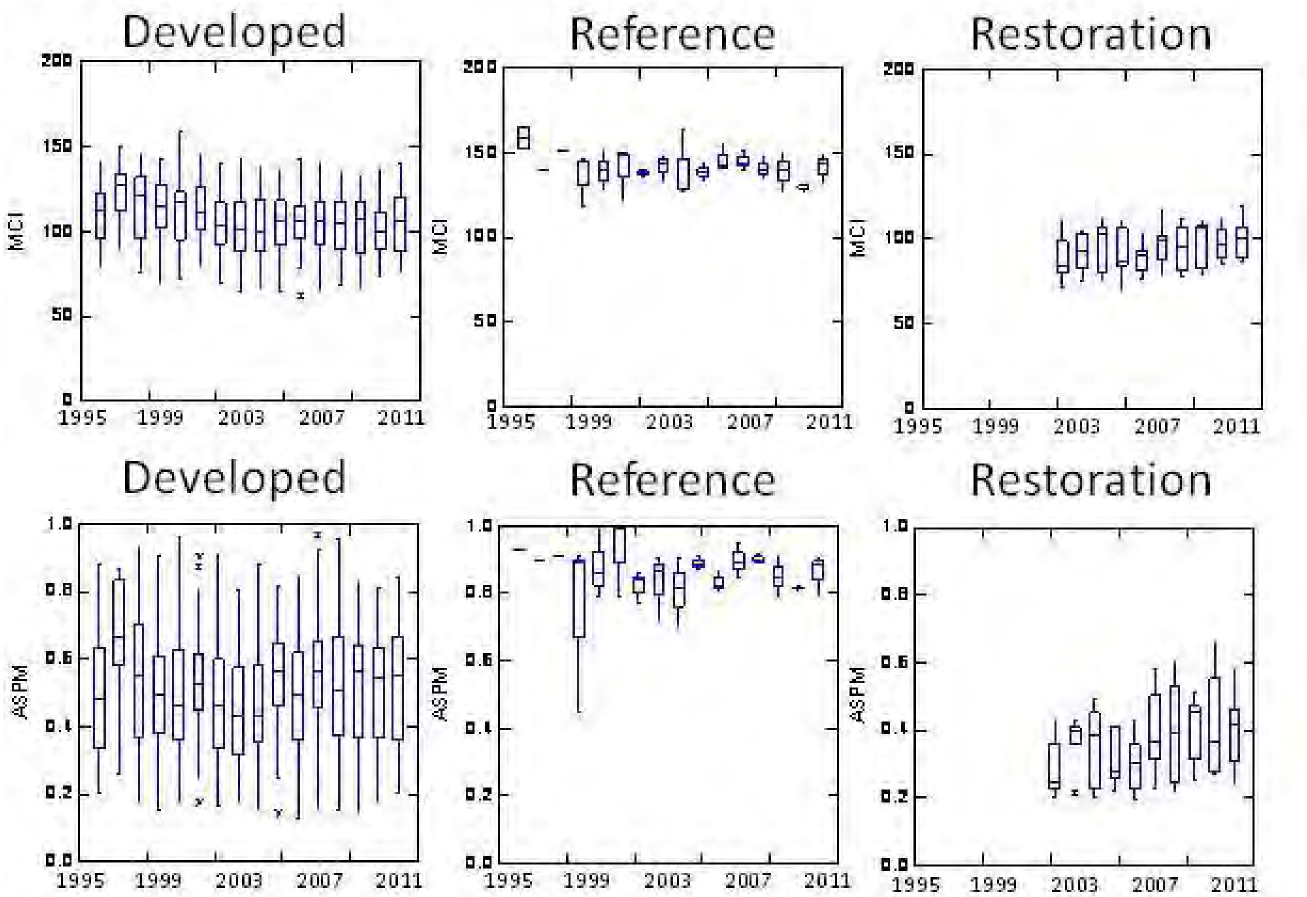


Figure 6: **Boxplots of macroinvertebrate trend metrics at long-term monitoring sites alongside reaches that are (i) developed (i.e., excluding restoration and reference sites), (ii) reference sites (100% upstream native forest) and (iii) undergoing riparian management (sampled since 2002).**

Table 5: Regional Mann-Kendall test statistics applied to (A) MCI and (B) ASPM for long-term monitoring sites alongside reaches that are (i) developed (i.e., excluding restoration and reference sites), (ii) undergoing riparian restoration (sampled since 2002) and (iii) reference sites (100% upstream native forest). Probability values significant at P<0.05 are shown in bold.

A. MCI

	Tau	S	z	P	Trend slope (units y^{-1})
Developed	-0.170	-462	-4.656	**0.000**	-0.50
Restoration	0.320	78	3.017	**0.003**	1.15
Reference	-0.223	-67	-1.955	0.051	-

B. ASPM

	Tau	S	z	P	Trend slope (proportion y^{-1})
Developed	0.064	174	1.738	0.082	-
Restoration	0.348	85	3.301	**0.001**	0.01
Reference	-0.150	-45	-1.298	0.194	-

Footnote: Tau represents the correlation coefficient, *S* is the Kendall test statistic, *z* is the standard normal deviate, *P* denotes the probability value, and the trend slope represents the change in median metric value per unit time (only shown where *S* is statistically significant).

4.2.2 Site trends

Temporal trends for individual monitoring sites that were statistically significant or 'clear' ($P<0.05$), or of 'borderline' significance ($0.05<P<0.1$), are shown in Table 6. Mann-Kendall statistics are presented in Appendix 7, and time series plots are presented in Appendix 8. Eight sites showed clear declines in MCI and 3 showed borderline declines, collectively representing 28% of the long-term monitoring sites, compared to 3 sites showing increasing trends in MCI (2 of these were 'clear' trends). For ASPM, one site showed clear decreases over time and 2 sites showed clear increases (2 borderline decreases and 4 borderline increases in ASPM were also detected). One reference site (1414_1) had a negative trend in MCI and ASPM, as also noted by Collier & Hamer (2008), although this change was not regarded as ecologically significant (Table 6). Three restoration sites showed trends, with ASPM or MCI increasing over time at 2 of these sites and one site showing a borderline decline in MCI, although time series plots indicate an increase in macroinvertebrate metrics over recent years at that site (see Appendix 8). Collectively across both indicators, almost half (46%) of the long-term monitoring sites displayed temporal trends, with 28% trending down and 18% trending up.

Table 6: Summary of temporal trends at long-term (≥10 years record) sampling sites inferred from the Mann-Kendall test for the 2 macroinvertebrate trend metrics. 0.05<*P*<0.1 refers to 'borderline trends'. Bold indicates 'clear' trends significant at *P*<0.05. Empty cells indicate that a trend was not evident for a particular metric. Ecological significance was inferred where the absolute change exceeded 12%, and the trend slope exceeded 1% per annum.

Site	**MCI**			**ASPM**		
	Trend	Statistical	Ecological	Trend	Statistical	Ecological
1043_1	Increase	0.05<P<0.1	Yes			
1055_3	Decrease	**P<0.01**	No	Decrease	0.05<P<0.1	No
1172_6	Decrease	0.05<P<0.1	No			
1174_10	Decrease	**P=0.01**	Yes			
1257_4	Decrease	**P=0.01**	Yes			
1323_1	Increase	**P<0.01**	Yes	Increase	**P<0.001**	Yes
1414_1	Decrease	**P<0.01**	No	Decrease	**P<0.05**	No
220_1	Decrease	**P<0.05**	Yes	Decrease	0.05<P<0.1	Yes
240_5	Decrease	P=0.05	Yes			
256_2	Decrease	**P<0.05**	Yes			
398_1	Increase	**P<0.01**	Yes	Increase	**P<0.01**	Yes
428_3	Decrease	**P<0.05**	Yes			
433_2	Decrease	**P<0.05**	Yes			
556_9				Increase	0.05<P<0.1	Yes
736_2				Increase	0.05<P<0.1	Yes
749_10	Decrease	0.05<P<0.1	Yes			
786_2				Increase	0.05<P<0.1	Yes
976_2				Increase	0.05<P<0.1	No

Figure 7: Location of long-term sites sampled for more that 10 years and over 2009-11, showing sites where macroinvertebrate trend metrics were considered 'stable' (no evidence of change over this period; circles), or where increasing (upward pointing triangles) or decreasing (downward pointing triangles) trends were detected in the named metrics (clear and borderline trends combined).

4.2.3 Relationships with water quality trends

There was little correspondence between trends in macroinvertebrate metrics and water quality at the 14 sites with comparable data, although some did correspond with certain parameters (e.g., 240-5 declining MCI and increasing nutrients; 398-1 improving metrics and lower turbidity; 556-9 improving ASPM and lower turbidity and total phosphorus; 786-2 improving ASPM and lower phosphorous) (Table 7). Such correspondence does not indicate cause or effect, simply an association of patterns, and it is important to consider whether the magnitude of change in water quality is biologically significant (see Appendix 9 for median values). Water quality parameters are indicators of various anthropogenic impacts. Metrics such as the MCI are designed to indicate organic enrichment but incorporate a variety of interacting biological responses that may not respond in a constant fashion directly to any one water quality parameter. Where trends are evident for macroinvertebrate metrics but not for water quality parameters or they indicate a decline while water quality parameters are improving, macroinvertebrate communities may be more strongly affected by other pressures such as habitat quality. Alternatively, trends in water quality parameters without an equivalent response in macroinvertebrate metrics may reflect the fact that thresholds for biological impairment were not exceeded prior to summer sampling. This comparison highlights the need for different types of indicators to more fully evaluate the ecological implications of human activities on stream ecosystems.

Table 7: Summary of temporal trends at long-term (≥10 years record) sampling sites for the 2 macroinvertebrate trend metrics from the REMS programme (clear and borderline trends combined), compared to provisional water quality trends from the RRIMP programme (see Appendix 9). For the RRIMP data only statistically significant trends with slopes of >1% per annum are shown.

☺ = increasing quality, ☹ = decreasing quality.

REMS			RRIMP								
Site	MCI	ASPM	Site	Black disk	Turbid-ity	DO%	TP	DRP	TN	NH4	DIN
240-5	☹		240-5					☹	☹		☹
398-1	☺	☺	398-1		☺		☹	☹			
407-1			407-1	☹			☺	☺	☹		
428-3	☹		428-3								
477-14			477-10		☹				☹		☹
556-9		☺	556-9		☺		☺				
619-20			619-20	☹			☺	☺	☺		☺
749-10	☹		749-10				☺			☺	
786-2		☺	786-2				☺	☺	☹		☹
976-2		☺	976-1								
1249-15			1249-15				☺				
1253-9			1253-7					☹			
1257-4	☹		1257-3		☺						☺
1323-1	☺	☺	1323-1						☹		☹

5 Key findings

- Unbiased estimates of wadeable stream extent based on the probability survey design indicate that, over the 3 years of sampling from 2009 to 2011, 60% of target wadeable stream length was unshaded, 69% had 'clear' water at the time of sampling, and most (50-56% of stream length) had unconsolidated beds with high cover by fine sediment, leading to over half of the regional stream length being classified as 'soft-bottom' for macroinvertebrate sampling purposes.

- Mean regional habitat score for wadeable streams on developed land was 86 compared to 154 at reference sites.

- Macrophyte cover averaged 29% with 3% cover by native species. Periphyton cover by long filaments and thick mats was 8% of substrate surfaces on average at the time of sampling, with 10% of wadeable stream length exceeding 25% cover by long filaments and thick mats.

- The state of the environment assessment based on invertebrate monitoring indicates that around one third (35% QMCI, 36% ASPM) of wadeable stream length on developed land was rated as 'good-excellent' and two-thirds (65% QMCI, 64% ASPM) were rated as 'fair-poor'. Around half (41-51%) of stream length on developed land over the 2009-11 period was considered to have "poor" ecological condition.

- On average, 'fair-poor' sites had significantly more fine sediment on the streambed, lower habitat quality, and higher levels of calcium and phosphorus-bearing rocks and proportions of pasture in upstream catchments, while 'excellent-good' sites had more hard rock geology and more indigenous forest in upstream catchments.

- Of the 37 non-reference long-term sites sampled for at least 10 years, almost half showed clear (P<0.05) or borderline (0.05<P<0.1) trends over time in MCI or ASPM. Of the sites showing clear trends, 2 were increasing in condition and 8 were decreasing in condition.

- Both macroinvertebrate metrics increased at the five monitoring sites where riparian management had been implemented and did not change significantly across the long-term reference sites, suggesting that riparian management was having a quantifiable benefit to stream health at these sites.

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Appendix 1: Effects of sampling substrate on macroinvertebrate metrics

Some REMS sites contain a mix of stony and sand/silt substrates that could be sampled using either 'hard'- or 'soft'-bottom protocols. In these situations both methods were used to assess the effects of sampling different substrates (stones vs wood) in the same streams on invertebrate metrics, and paired t-tests were used to compare metrics. Three reference sites (1965_1, 1971_1, 555_2) were sampled annually using both protocols over 2005-08, and 15 developed sites were sampled over this period at intervals of 1-3 years.

The results show moderate correspondence for macroinvertebrate metrics collected on the two substrate types (Figure A1-1). Statistically significant differences were detected for %EPT* abundance, MCI and ASPM but not for EPT* taxa richness (Table A1-1). These results differ from those presented in Collier & Hamer (2010) where few significant differences between hard and soft substrate samples were detected, and this is attributed to the greater statistical power provided by the more recent dataset. This analysis indicates that substrate type can influence some macroinvertebrate metrics with higher values on hard-bottomed substrates, although except for %EPT* absolute differences were small (means in Table A). This analysis does not differentiate between hard- and soft-bottom protocols, however, as the latter method is likely to be mostly applied in low gradient, lowland waterways where stony substrates may not be expected to occur naturally and where other factors may affect macroinvertebrate community composition.

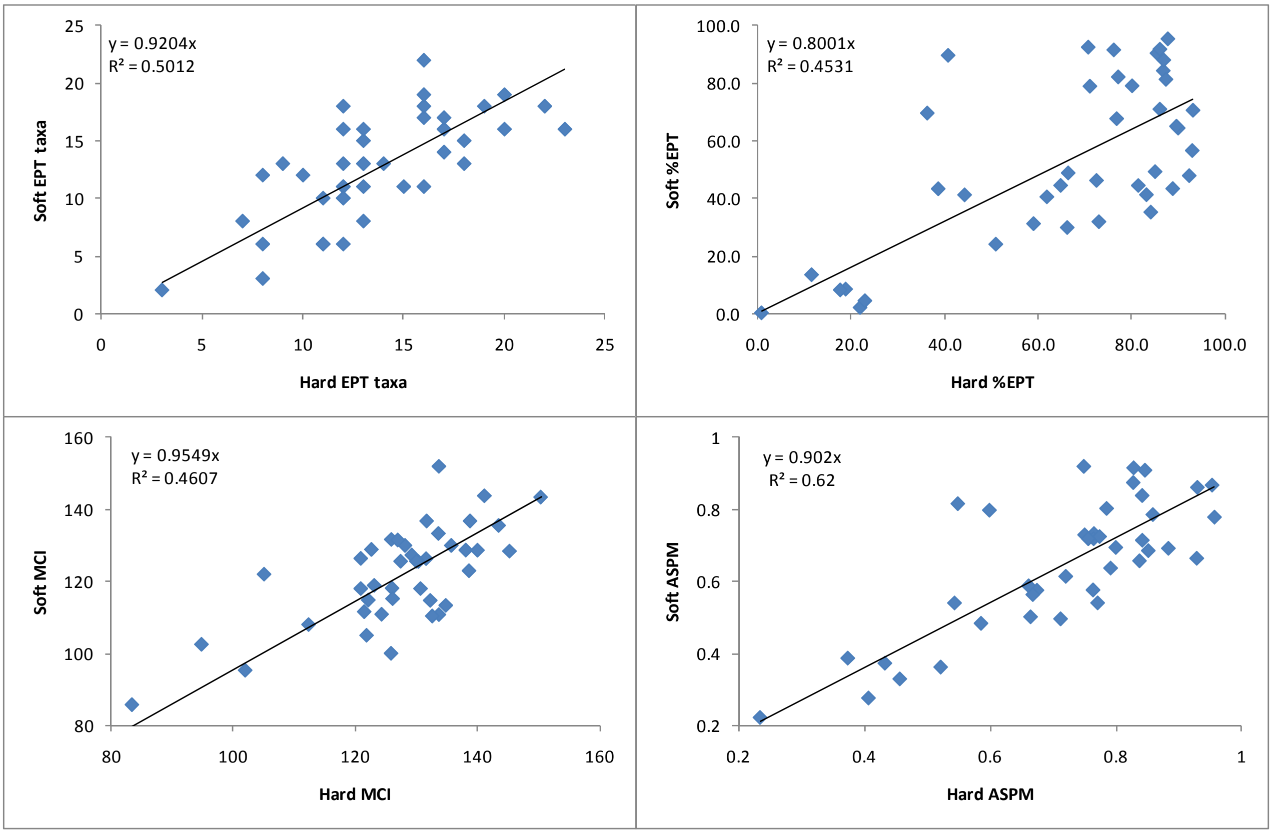


Figure A1-1: Relationships between macroinvertebrate metrics collected from paired hard- and soft-bottom substrates over 2005-11.

Table A1-1: Paired t-test statistics for macroinvertebrate metrics derived from samples collected on hard- and soft-bottom substrates from reference sites (n = 3 over 7 years) and combined reference and developed sites (n = 40-41)

Reference sites only			All sites		
EPT* taxa richness (n = 21)			EPT* taxa richness (n = 41)		
Mean Hard EPT	=	16.476	Mean Hard EPT	=	13.659
Mean Soft EPT	=	15.524	Mean Soft EPT	=	12.732
Mean difference	=	0.952	Mean difference	=	0.927
SD of difference	=	3.232	SD of difference	=	3.327
t	=	1.350	t	=	1.784
df	=	20	df	=	40
p-value	=	0.192	p-value	=	0.082
% EPT* abundance (n=21)			% EPT* abundance (n=41)		
Mean Hard %EPT	=	84.653	Mean Hard %EPT	=	65.987
Mean Sodt %EPT	=	70.279	Mean Soft %EPT	=	53.445
Mean difference	=	14.374	Mean difference	=	12.542
SD of difference	=	21.111	SD of difference	=	22.016
t	=	3.120	t	=	3.648
df	=	20	df	=	40
p-value	=	**0.005**	p-value	=	**0.001**
MCI (n = 21)			MCI (n = 41)		
Mean Hard MCI	=	133.001	Mean Hard MCI	=	127.224
Mean Soft MCI	=	129.491	Mean Soft MCI	=	121.768
Mean difference	=	3.510	Mean difference	=	5.456
SD of difference	=	7.255	SD of difference	=	10.124
t	=	2.217	t	=	3.451
df	=	20	df	=	40
p-value	=	**0.038**	p-value	=	**0.001**
ASPM (n = 21)			ASPM (n = 40)		
Mean Hard ASPM	=	0.839	Mean Hard ASPM	=	0.717
Mean Soft ASPM	=	0.766	Mean Soft ASPM	=	0.649
Mean difference	=	0.073	Mean difference	=	0.068
SD of difference	=	0.109	SD of difference	=	0.115
t	=	3.089	t	=	3.747
df	=	20	df	=	39
p-value	=	**0.006**	p-value	=	**0.001**

Appendix 2: Effects of stand down triggering flood event on macroinvertebrate metrics

On 24 January 2011, a large storm event triggered a 2-week sampling stand down period based on trigger flows at representative regional hydrological monitoring sites. This flood was followed by a second smaller flood on 7 March which did not trigger a stand down (see Figure A2-1). These events provided the opportunity to assess the effects of floods on invertebrate indicators at hard-bottom reference sites and target sites on developed land that had been sampled shortly before the flood (10-14 January). No significant effects of the floods were detected on QMCI or ASPM for sites in native forest or on developed land (Figure A2-1). Based on these analyses, which are limited to hard-bottom streams in the central part of the Region, a flood of sufficient magnitude to trigger a sampling stand down period did not affect estimates of regional wadeable stream state during the 2011 monitoring period.

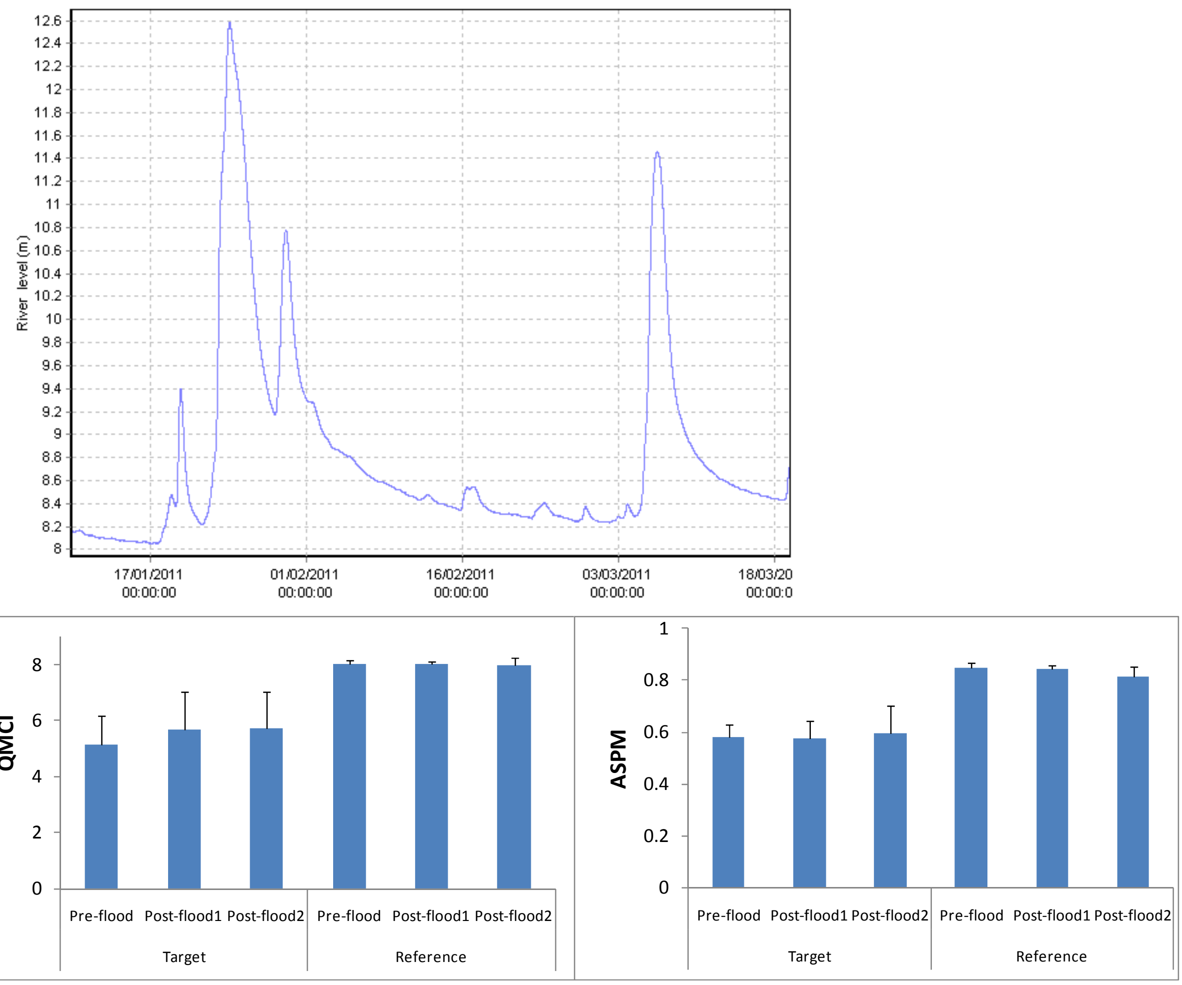


Figure A2-1: Upper panel: Example hydrograph (Punui River) illustrating the January and March 2011 floods. Lower panel: Change in QMCI and ASPM (mean±SE) values measured for reference sites (33_16, 1888_4, 1968_1) and target sites on developed land (2007_2, 2085_1, 410_8) prior to and 9-10 days following a storm event that triggered a 2-week sampling stand-down (post-flood1). A second set of samples was collected 4-11 days after a second smaller flood (post-flood2).

Appendix 3: Summary statistics from spsurvey for physical variables and plant metrics measured at randomly selected sites (probability design) over 2009-11 (all years combined, n = 180).

Variable/ statistic	N	Estimate	StdError	LCB95Pct	UCB95Pct
Percent sand/silt/clay					
5Pct	8	0.00		0.00	6.04
10Pct	16	7.01		0.00	9.06
25Pct	45	19.30		12.88	24.24
50Pct	96	57.29		44.51	69.84
75Pct	140	93.48		85.44	99.07
90Pct	147	99.50		99.21	99.80
95Pct	147	99.75		99.45	100.00
Mean	180	55.95	2.48	51.09	60.81
Variance	180	1321.82	66.23	1192.01	1451.64
Std. Deviation	180	36.36	0.91	34.57	38.14
Channel width:wetted width					
5Pct	10	1.13		1.07	1.16
10Pct	23	1.19		1.16	1.23
25Pct	65	1.52		1.38	1.58
50Pct	114	1.83		1.76	1.98
75Pct	149	2.40		2.24	2.73
90Pct	169	3.79		2.88	4.62
95Pct	174	4.57		3.93	8.61
Mean	180	2.29	0.13	2.03	2.54
Variance	180	2.20	0.69	0.84	3.55
Std. Deviation	180	1.48	0.23	1.02	1.94
Total habitat score					
5Pct	6	36.24		26.66	41.14
10Pct	11	43.18		37.53	49.90
25Pct	32	63.61		52.97	67.84
50Pct	80			78.14	90.93
75Pct	132	107.04		102.38	119.06
90Pct	159	125.45		122.02	135.57
95Pct	170	142.62		128.64	157.27
Mean	180	86.45	2.38	81.78	91.11
Variance	180	991.25	96.32	802.47	1180.03
Std. Deviation	180	31.48	1.53	28.49	34.48
Macrophyte Total Cover					
5Pct	43	0.00		0.00	0.00
10Pct	43	0.00		0.00	0.00
25Pct	48	0.20		0.00	1.23
50Pct	99	9.07		5.29	18.54
75Pct	145	54.74		40.09	73.51
90Pct	165	85.56		80.96	97.24
95Pct	172	97.64		87.72	99.79
Mean	180	29.14	2.63	23.99	34.28
Variance	180	1179.09	104.63	974.03	1384.16
Std. Deviation	180	34.34	1.52	31.35	37.32

Macrophyte Channel Clogginess					
5Pct	45	0.00		0.00	0.00
10Pct	45	0.00		0.00	0.00
25Pct	46	0.17		0.00	0.89
50Pct	96	9.33		5.30	16.98
75Pct	144	55.82		35.90	73.88
90Pct	163	85.81		81.00	93.26
95Pct	171	93.30		85.95	99.51
Mean	180	28.83	2.57	23.80	33.86
Variance	180	1172.42	98.89	978.60	1366.25
Std. Deviation	180	34.24	1.44	31.41	37.07
Macrophyte Native Community					
5Pct	130	0.00		0.00	0.00
10Pct	130	0.00		0.00	0.00
25Pct	130	0.00		0.00	0.00
50Pct	130	0.00		0.00	0.00
75Pct	130	0.00		0.00	1.60
90Pct	157	6.95		4.12	15.54
95Pct	168	18.23		9.25	36.99
Mean	180	2.74	0.56	1.65	3.84
Variance	180	66.16	18.64	29.62	102.69
Std. Deviation	180	8.13	1.15	5.89	10.38
Peripyhton Proliferation Index					
5Pct	73	0.00		0.00	0.00
10Pct	73	0.00		0.00	0.00
25Pct	73	0.00		0.00	0.00
50Pct	85	1.44		0.00	2.81
75Pct	128	9.96		7.53	14.22
90Pct	163	26.42		23.04	31.89
95Pct	171	44.47		27.51	56.04
Mean	180	8.25	1.03	6.24	10.27
Variance	180	189.90	36.29	118.78	261.02
Std. Deviation	180	13.78	1.32	11.20	16.36
Periphyton Slimyness Index					
5Pct	37	0.00		0.00	0.00
10Pct	37	0.00		0.00	0.00
25Pct	37	0.00		0.00	1.49
50Pct	84	5.84		4.44	8.64
75Pct	128	16.02		13.06	20.74
90Pct	158	28.08		24.94	34.90
95Pct	171	40.42		31.09	44.90
Mean	180	10.75	0.89	9.01	12.49
Variance	180	155.57	19.99	116.39	194.75
Std. Deviation	180	12.47	0.80	10.90	14.04

Appendix 4: Summary statistics from spsurvey for macroinvertebrate metrics measured at randomly selected sites (probability design) over 2009-11 (all years combined, n = 180).

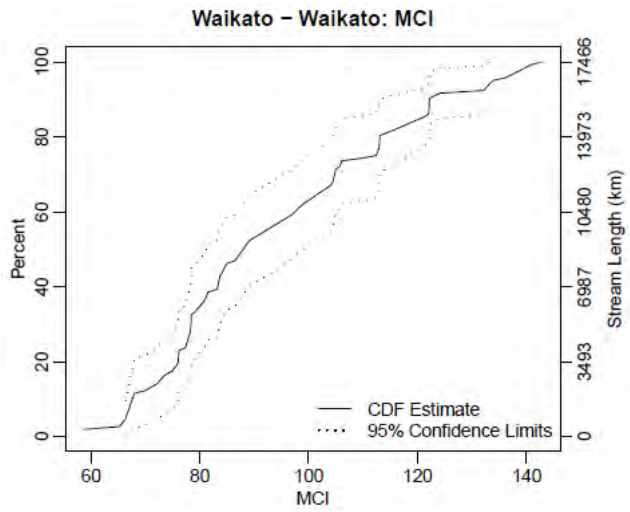
Variable/ percentile	N	Estimate	StdError	LCB95Pct	UCB95Pct
MCI(hb)					
5Pct	8	67.49		66.26	69.31
10Pct	15	72.06		67.70	75.63
25Pct	46	81.63		77.48	83.81
50Pct	84	98.16		94.17	102.25
75Pct	133	114.80		111.26	119.58
90Pct	159	126.93		122.17	133.20
95Pct	170	133.56		129.89	139.33
Mean	180	98.92	1.42	96.13	101.70
Variance	180	423.57	32.23	360.41	486.73
Std. Deviation	180	20.58	0.78	19.05	22.12
QMCI(hb)					
5Pct	5	1.86		1.32	2.78
10Pct	14	2.90		2.12	3.12
25Pct	38	3.61		3.39	3.83
50Pct	87	4.22		4.10	4.45
75Pct	132	5.84		5.37	6.26
90Pct	161	7.01		6.67	7.17
95Pct	168	7.19		7.14	7.72
Mean	180	4.61	0.11	4.39	4.83
Variance	180	2.43	0.23	1.99	2.88
Std. Deviation	180	1.56	0.07	1.42	1.70
Taxa richness					
5Pct	8	12.74		11.04	14.27
10Pct	17	14.79		14.11	16.54
25Pct	53	19.50		17.52	19.95
50Pct	88	22.35		21.49	22.88
75Pct	132	25.66		24.21	26.27
90Pct	160	28.67		27.04	31.11
95Pct	173	31.27		29.43	34.17
Mean	180	22.58	0.39	21.82	23.34
Variance	180	28.70	3.21	22.41	34.99
Std. Deviation	180	5.36	0.30	4.77	5.94
EPT* richness					
5Pct	20	0.00		0.00	0.00
10Pct	20	0.00		0.00	0.26
25Pct	35	1.56		0.78	2.67
50Pct	83	7.15		5.59	8.00
75Pct	129	11.20		10.64	12.23
90Pct	152	13.97		12.93	15.88
95Pct	167	15.83		14.46	17.87
Mean	180	7.30	0.38	6.55	8.05
Variance	180	29.54	2.03	25.56	33.52

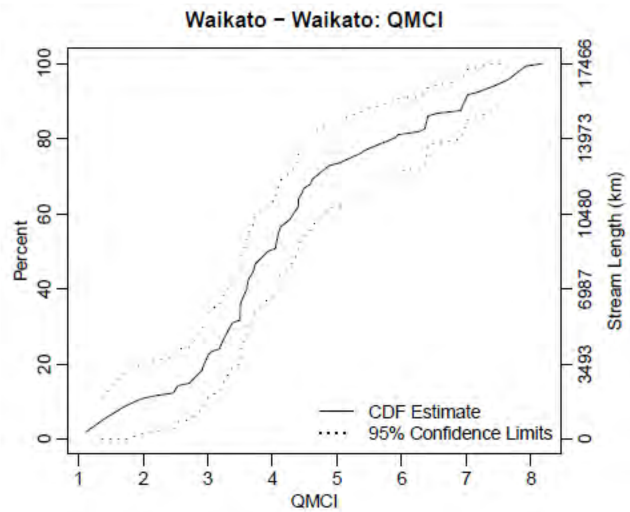
Std. Deviation	180	5.43	0.19	5.07	5.80
Percent EPT* abundance					
5Pct	20	0.00		0.00	0.00
10Pct	20	0.00		0.00	0.23
25Pct	38	0.72		0.57	1.66
50Pct	83	15.52		9.36	25.70
75Pct	132	52.44		48.36	57.21
90Pct	161	72.93		62.73	78.92
95Pct	169	79.22		75.69	87.26
Mean	180	27.76	2.02	23.80	31.73
Variance	180	828.36	54.98	720.61	936.11
Std. Deviation	180	28.78	0.96	26.91	30.65
ASPM					
5Pct	7	0.15		0.15	0.16
10Pct	15	0.16		0.15	0.18
25Pct	41	0.21		0.19	0.23
50Pct	86	0.39		0.34	0.44
75Pct	135	0.61		0.57	0.65
90Pct	160	0.71		0.70	0.77
95Pct	170	0.78		0.74	0.82
Mean	180	0.42	0.02	0.39	0.45
Variance	180	0.05	0.00	0.04	0.05
Std. Deviation	180	0.22	0.01	0.20	0.23

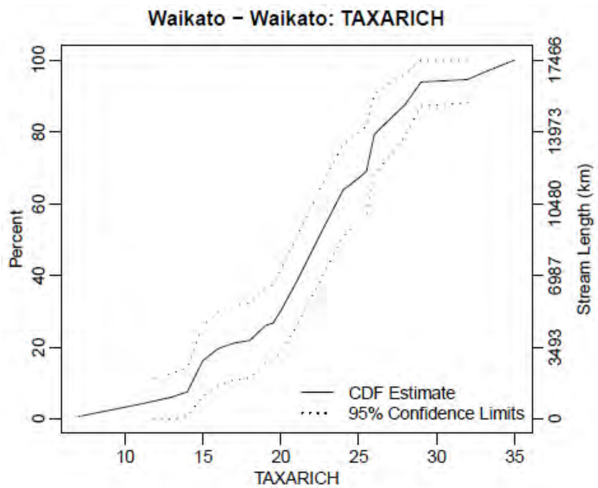
Appendix 5: Cumulative distribution function plots for metrics calculated using spsurvey for each year (2009, 2010, 2011) and for all 3 years combined.

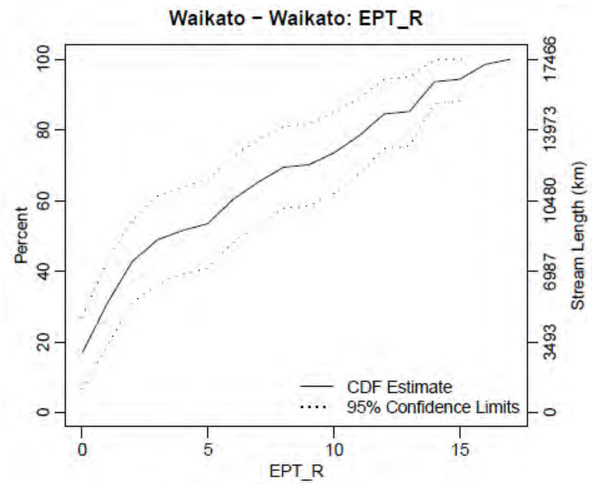
Key to abbreviations:
MCI – Macroinvertebrate Community Index (hard-bottomed)
QMCI – Quantitative Macroinvertebrate Community Index (hard-bottomed)
TAXARICH – Number of taxa
EPT_R – Number of EPT taxa excluding Hydroptilidae
Pct_EPT – Percent EPT abundance excluding Hydroptilidae
ASPM – Average Score Per Metric
Pct_SSC – Percent sand/silt/clay
CW_WW – Channel width:wetted width ratio
HABSCORE – Habitat Quality Score
MTC – Macrophyte Total Cover
MCC – Macrophyte Channel Clogginess
MNC – Macrophyte Native Cover
PPI – Periphyton Proliferation Index
PSI – Periphyton Slimyness Index

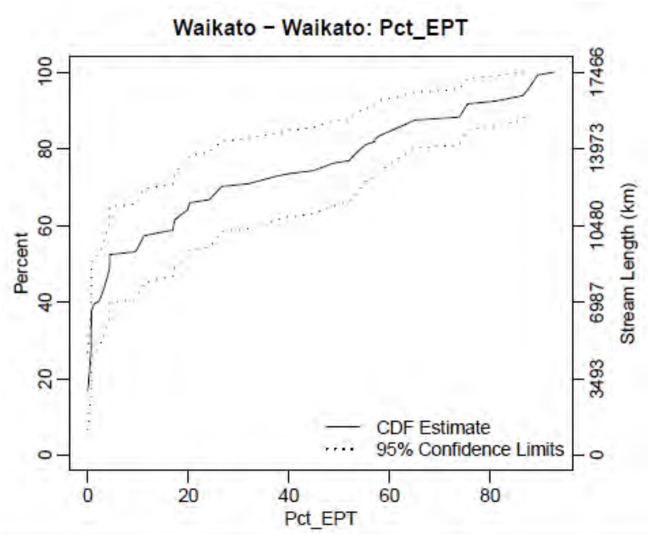
2009


Waikato – Waikato: MCI
Percent
Stream Length (km)
MCI
CDF Estimate
95% Confidence Limits

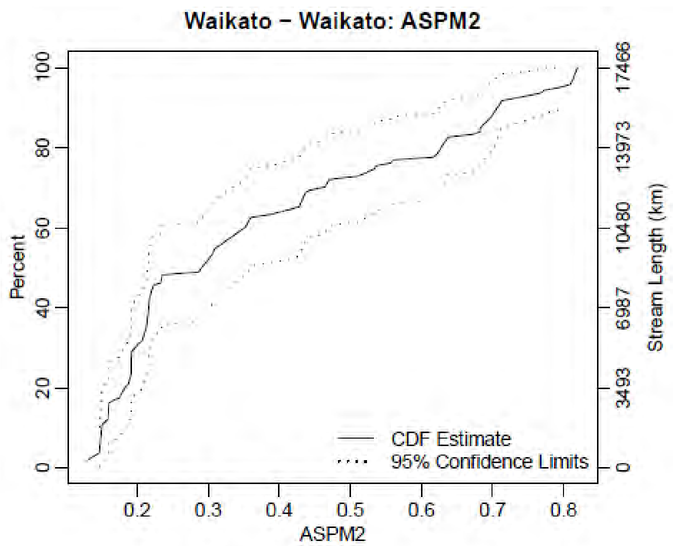

Waikato – Waikato: QMCI
Percent
Stream Length (km)
QMCI
CDF Estimate
95% Confidence Limits


Waikato – Waikato: TAXARICH
Percent
Stream Length (km)
TAXARICH
CDF Estimate
95% Confidence Limits

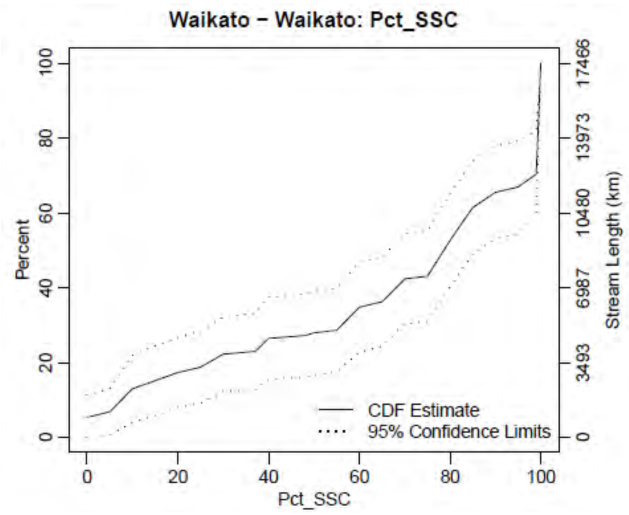

Waikato – Waikato: EPT_R
Percent
Stream Length (km)
EPT_R
CDF Estimate
95% Confidence Limits



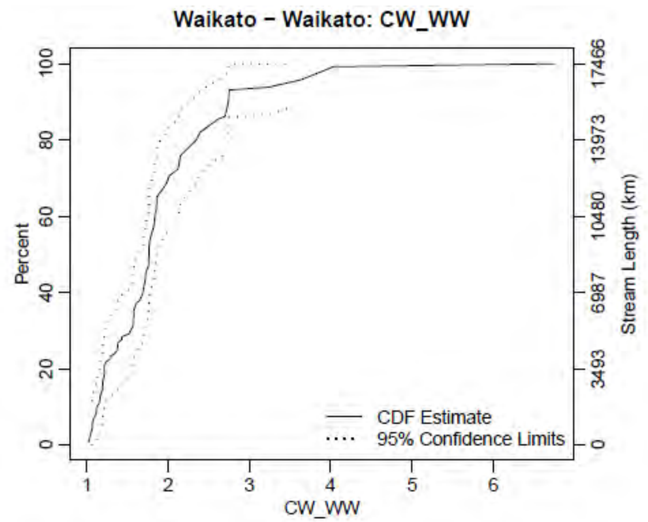
Waikato – Waikato: Pct_EPT
Percent
Stream Length (km)
Pct_EPT
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
3493
6987
10480
13973
17466



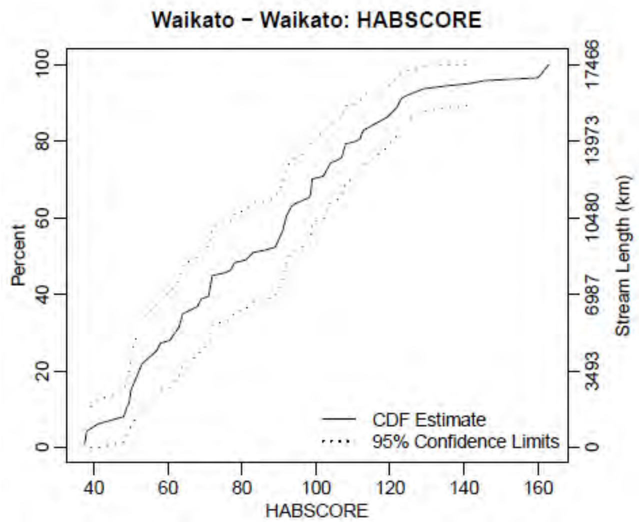
Waikato – Waikato: ASPM2
Percent
Stream Length (km)
ASPM2
CDF Estimate
95% Confidence Limits
0.2
0.3
0.4
0.5
0.6
0.7
0.8
3493
6987
10480
13973
17466



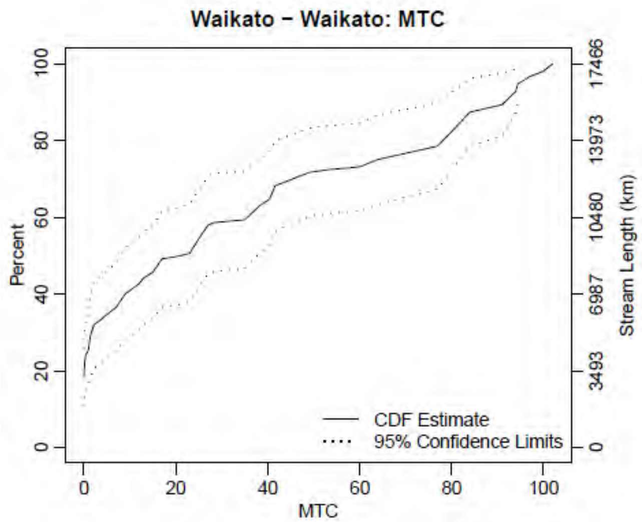
Waikato – Waikato: Pct_SSC
Percent
Stream Length (km)
Pct_SSC
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
3493
6987
10480
13973
17466



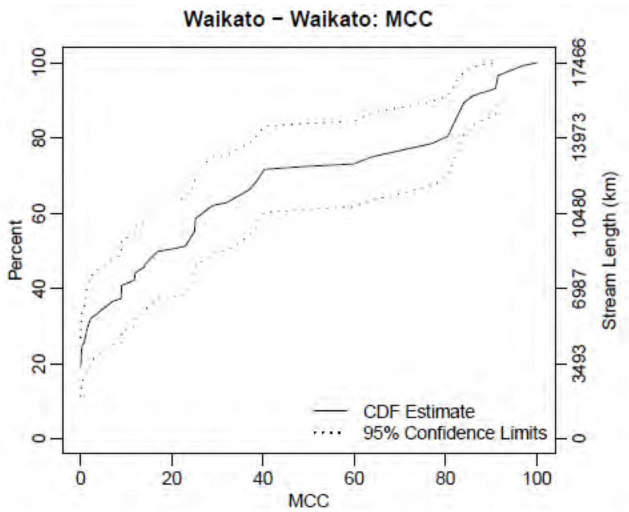
Waikato – Waikato: CW_WW
Percent
Stream Length (km)
CW_WW
CDF Estimate
95% Confidence Limits
1
2
3
4
5
6
3493
6987
10480
13973
17466



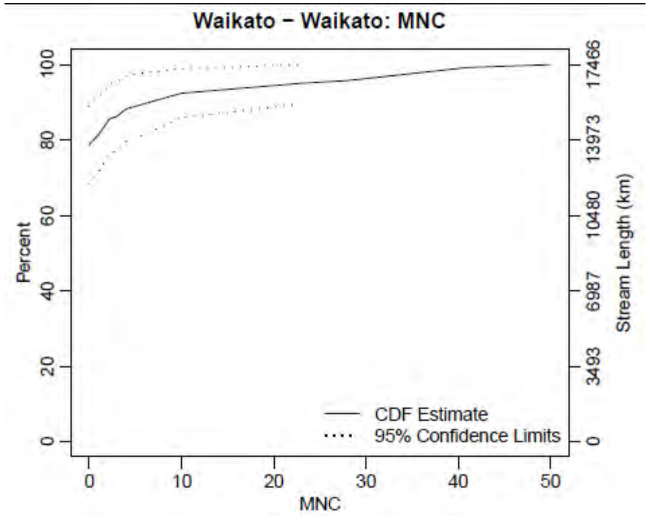
Waikato – Waikato: HABSCORE
Percent
Stream Length (km)
HABSCORE
CDF Estimate
95% Confidence Limits



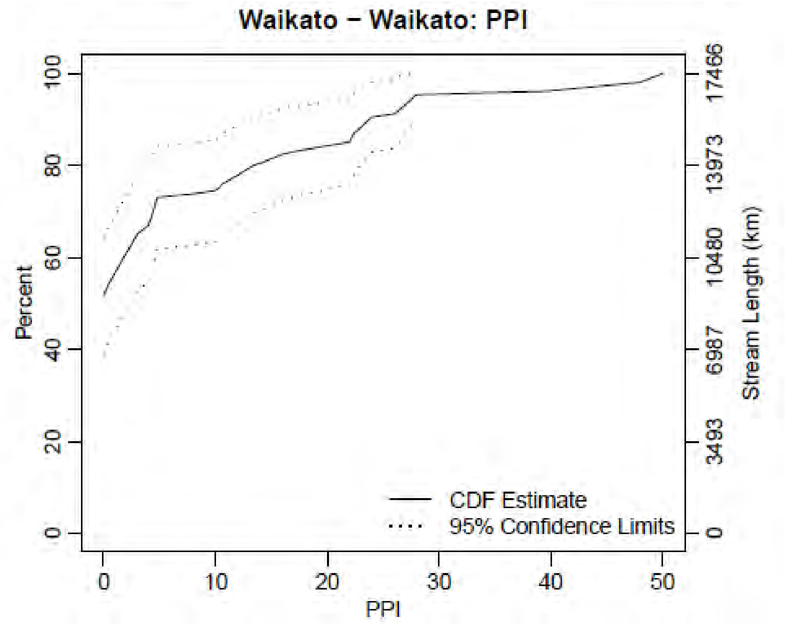
Waikato – Waikato: MTC
Percent
Stream Length (km)
MTC
CDF Estimate
95% Confidence Limits

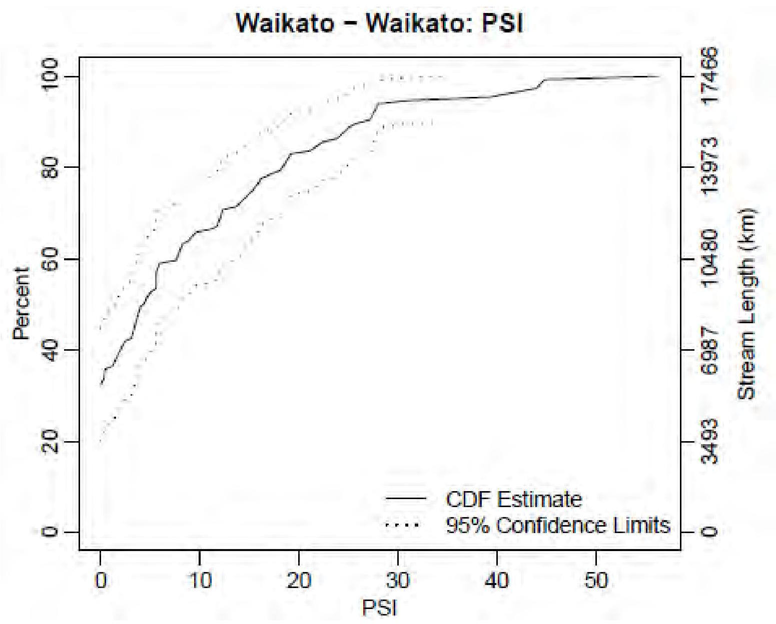


Waikato – Waikato: MCC
Percent
Stream Length (km)
MCC
CDF Estimate
95% Confidence Limits

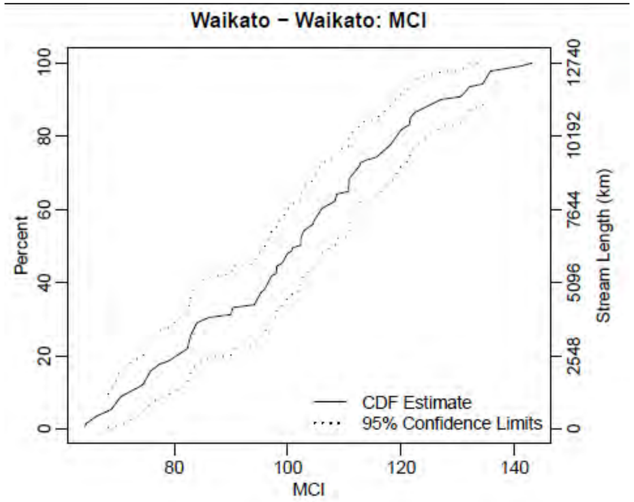


Waikato – Waikato: MNC
Percent
Stream Length (km)
MNC
CDF Estimate
95% Confidence Limits

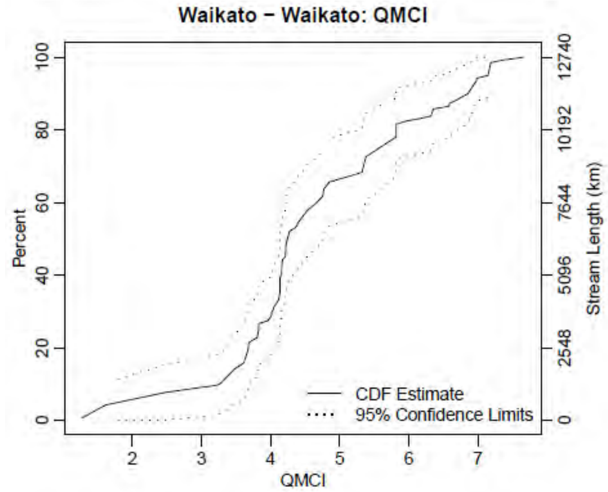

Waikato – Waikato: PPI
Percent
Stream Length (km)
PPI
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
3493
6987
10480
13973
17466
0
10
20
30
40
50


Waikato – Waikato: PSI
Percent
Stream Length (km)
PSI
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
3493
6987
10480
13973
17466
0
10
20
30
40
50

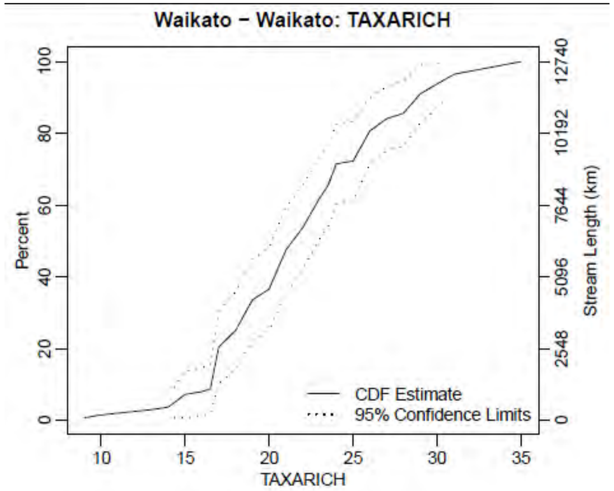
2010



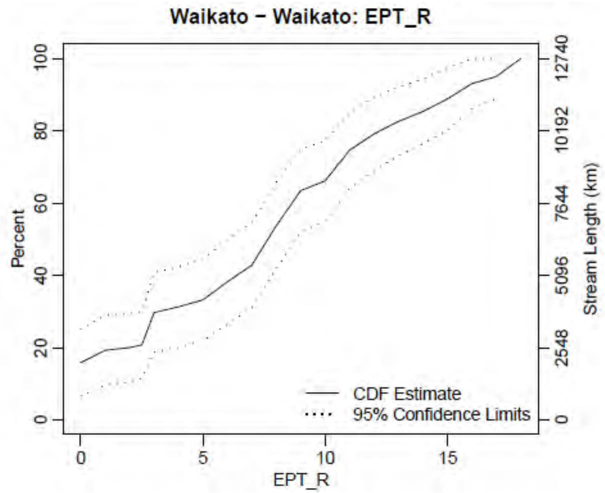
Waikato – Waikato: MCI
Percent
Stream Length (km)
MCI
CDF Estimate
95% Confidence Limits



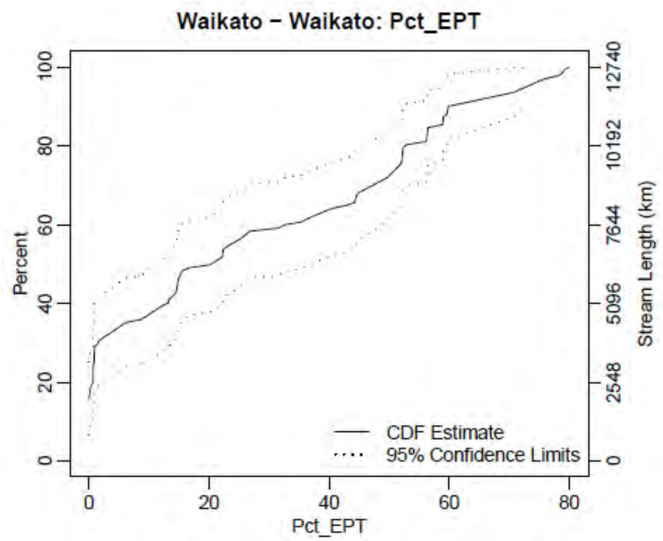
Waikato – Waikato: QMCI
Percent
Stream Length (km)
QMCI
CDF Estimate
95% Confidence Limits

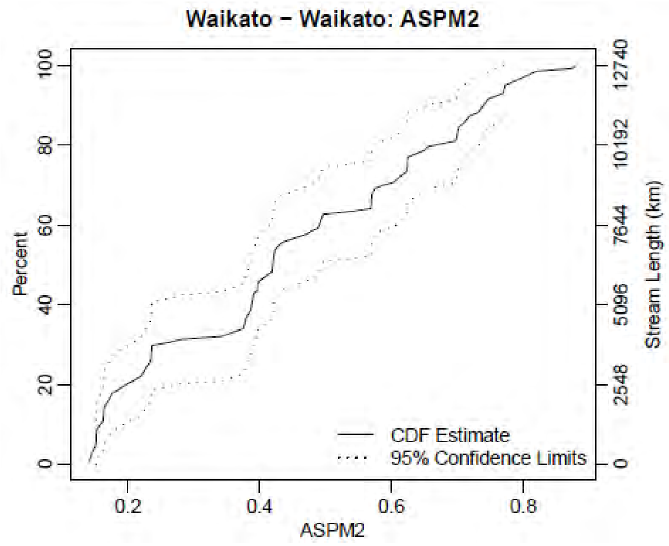


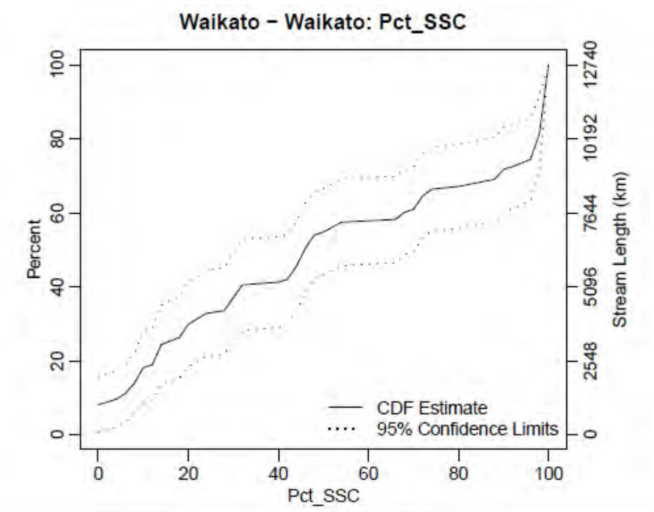
Waikato – Waikato: TAXARICH
Percent
Stream Length (km)
TAXARICH
CDF Estimate
95% Confidence Limits

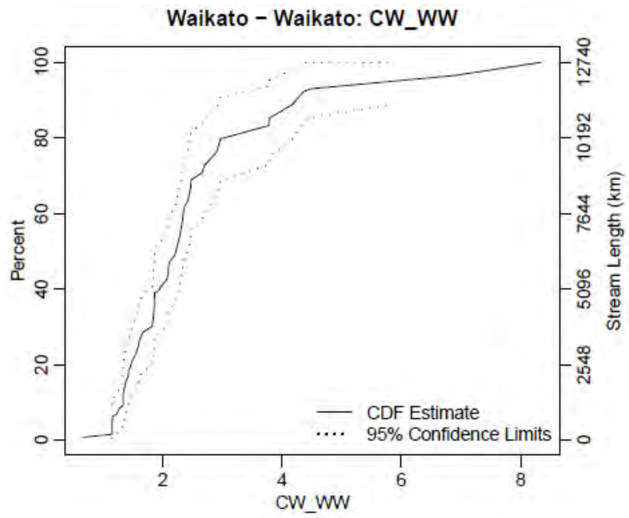


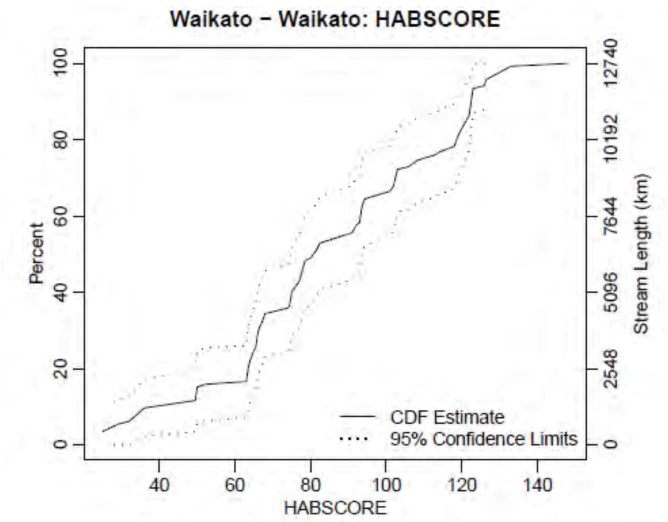
Waikato – Waikato: EPT_R
Percent
Stream Length (km)
EPT_R
CDF Estimate
95% Confidence Limits

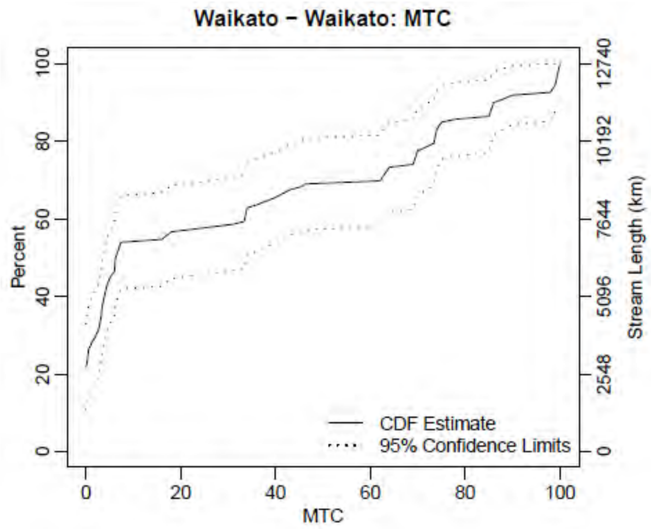

Waikato – Waikato: Pct_EPT
Percent
Stream Length (km)
Pct_EPT
CDF Estimate
95% Confidence Limits

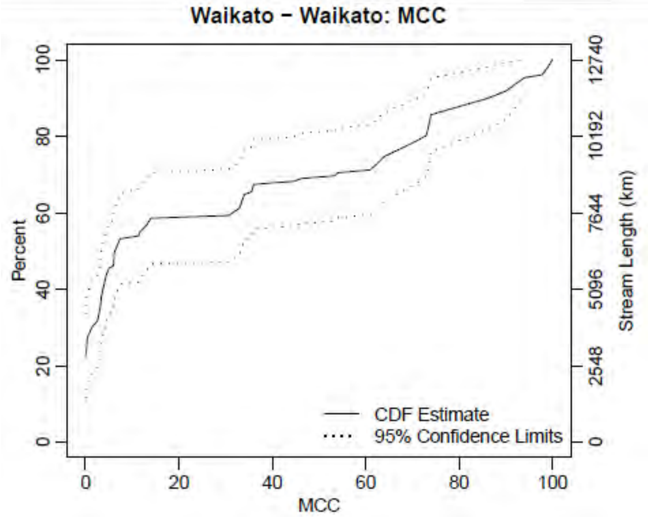

Waikato – Waikato: ASPM2
Percent
Stream Length (km)
ASPM2
CDF Estimate
95% Confidence Limits

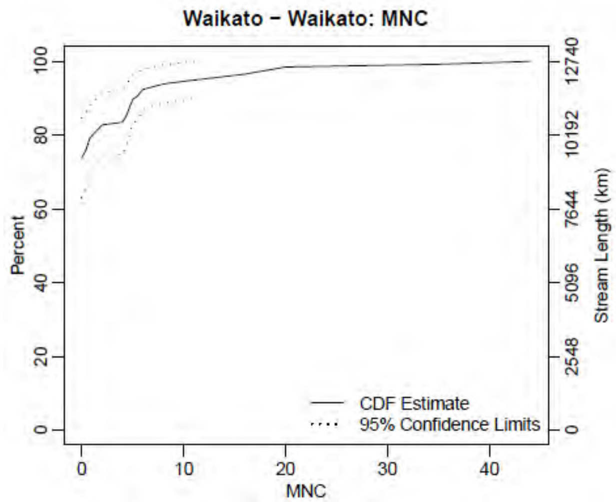

Waikato – Waikato: Pct_SSC
Percent
Stream Length (km)
Pct_SSC
CDF Estimate
95% Confidence Limits

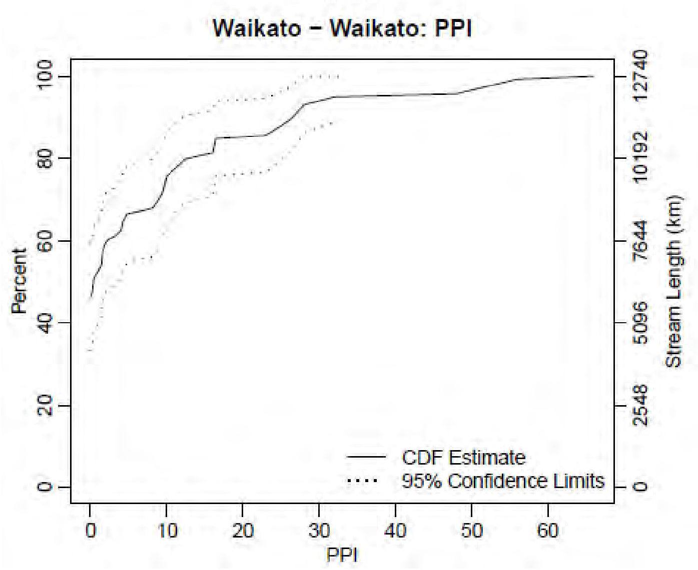

Waikato – Waikato: CW_WW
Percent
Stream Length (km)
CW_WW
CDF Estimate
95% Confidence Limits

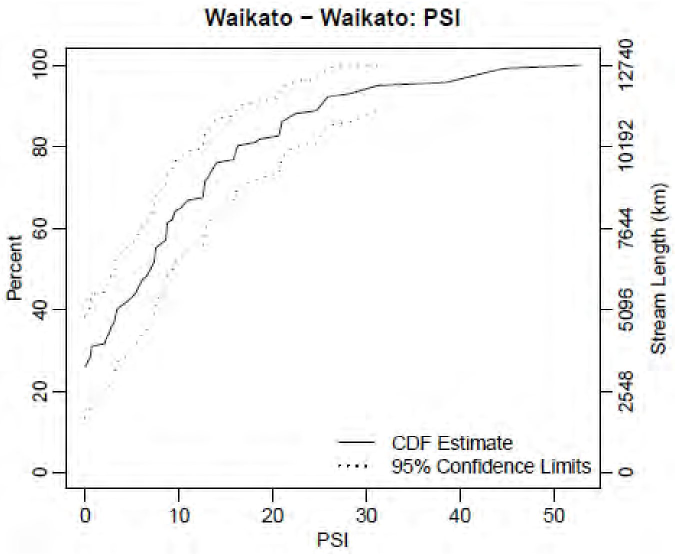

Waikato – Waikato: HABSCORE
Percent
Stream Length (km)
HABSCORE
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2548
5096
7644
10192
12740
40
60
80
100
120
140


Waikato – Waikato: MTC
Percent
Stream Length (km)
MTC
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2548
5096
7644
10192
12740
0
20
40
60
80
100

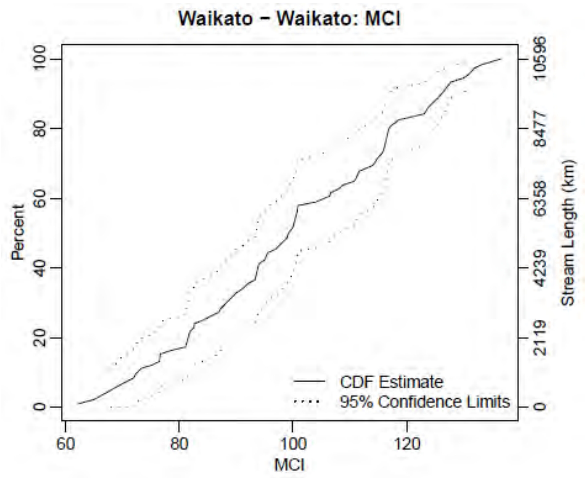

Waikato – Waikato: MCC
Percent
Stream Length (km)
MCC
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2548
5096
7644
10192
12740
0
20
40
60
80
100


Waikato – Waikato: MNC
Percent
Stream Length (km)
MNC
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2548
5096
7644
10192
12740
0
10
20
30
40

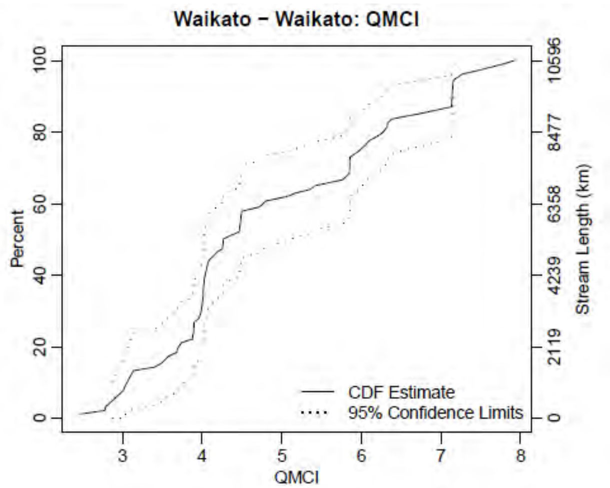

Waikato – Waikato: PPI
Percent
0
20
40
60
80
100
Stream Length (km)
0
2548
5096
7644
10192
12740
0
10
20
30
40
50
60
PPI
CDF Estimate
95% Confidence Limits


Waikato – Waikato: PSI
Percent
0
20
40
60
80
100
Stream Length (km)
0
2548
5096
7644
10192
12740
0
10
20
30
40
50
PSI
CDF Estimate
95% Confidence Limits

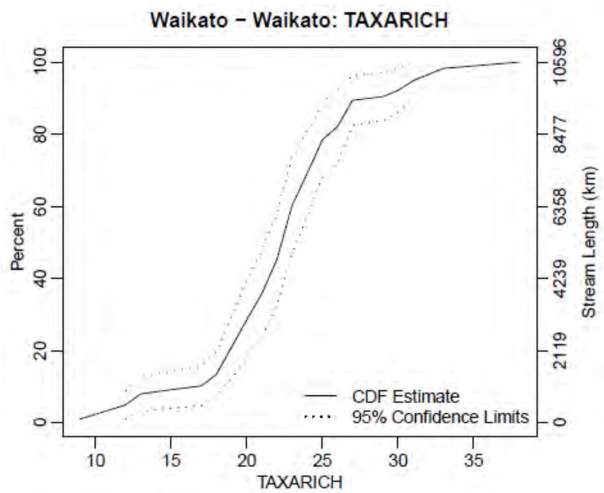
2011



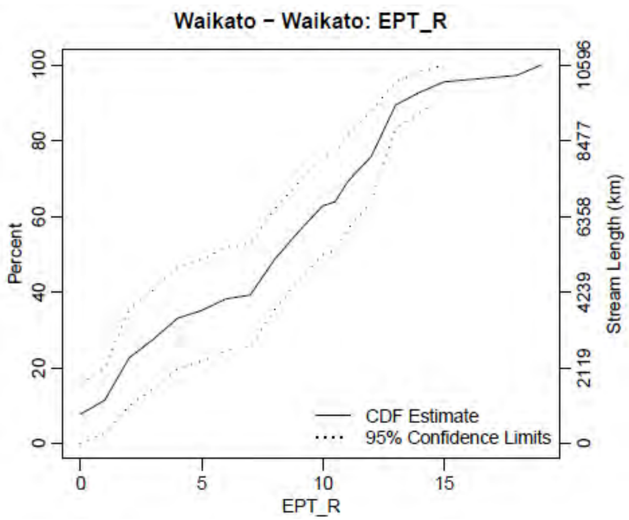
Waikato – Waikato: MCI
Percent
Stream Length (km)
MCI
CDF Estimate
95% Confidence Limits



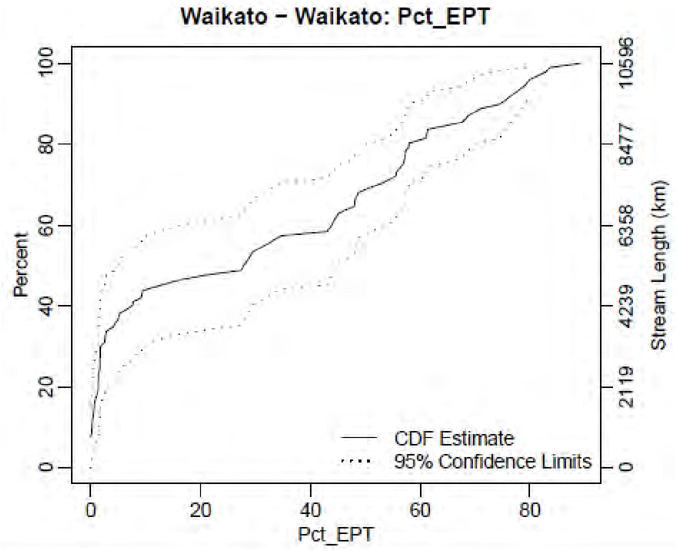
Waikato – Waikato: QMCI
Percent
Stream Length (km)
QMCI
CDF Estimate
95% Confidence Limits

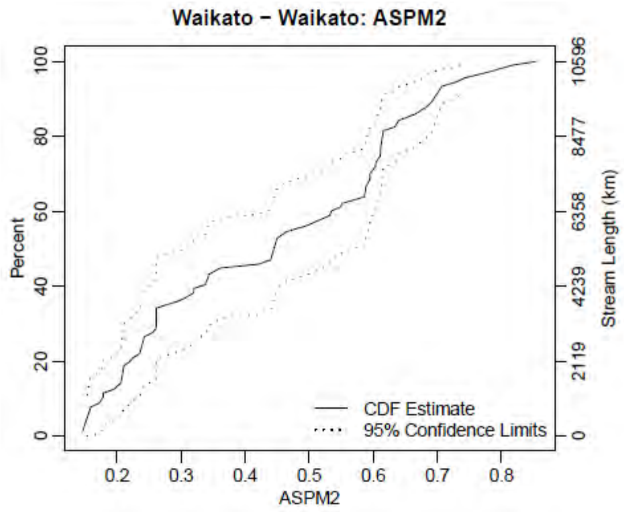


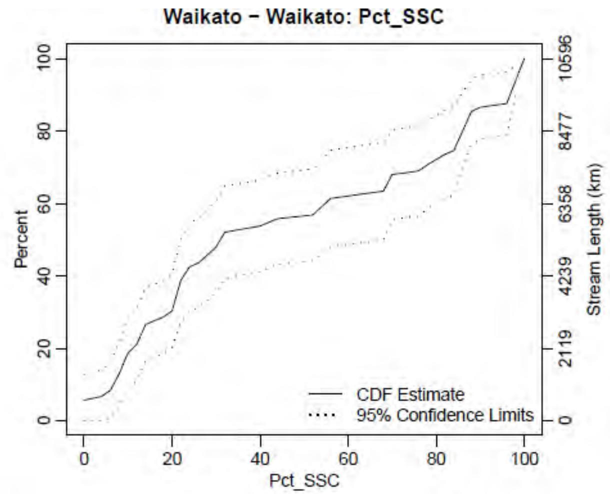
Waikato – Waikato: TAXARICH
Percent
Stream Length (km)
TAXARICH
CDF Estimate
95% Confidence Limits

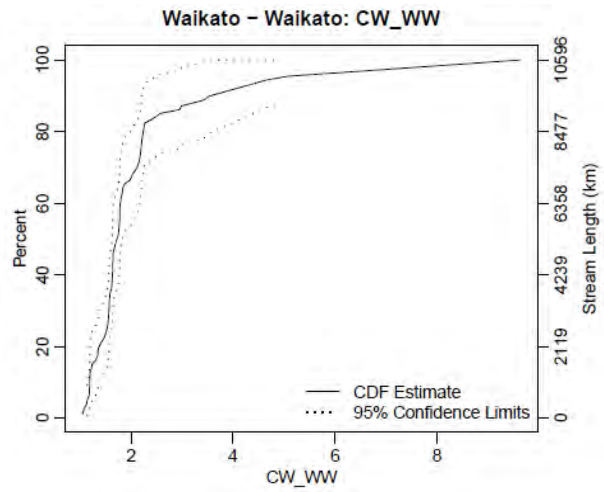


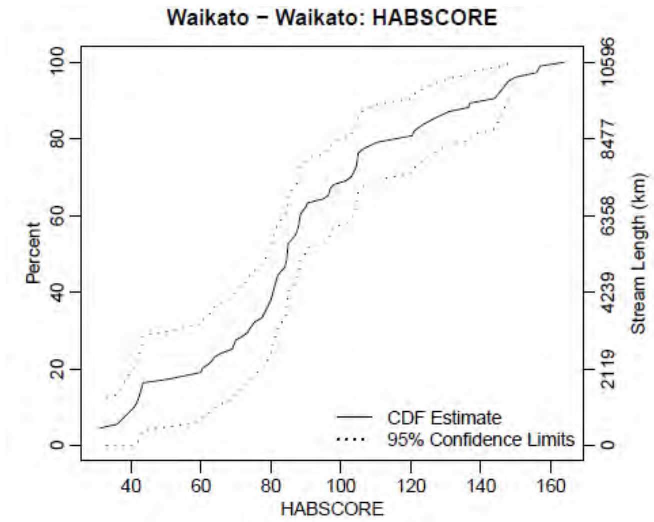
Waikato – Waikato: EPT_R
Percent
Stream Length (km)
EPT_R
CDF Estimate
95% Confidence Limits

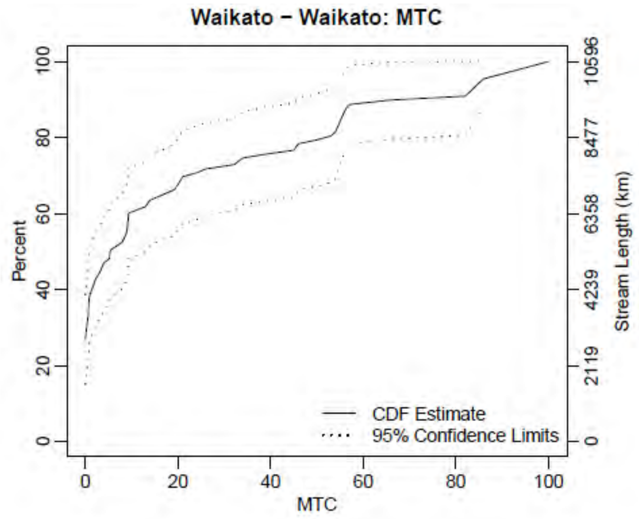

Waikato – Waikato: Pct_EPT
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
Pct_EPT

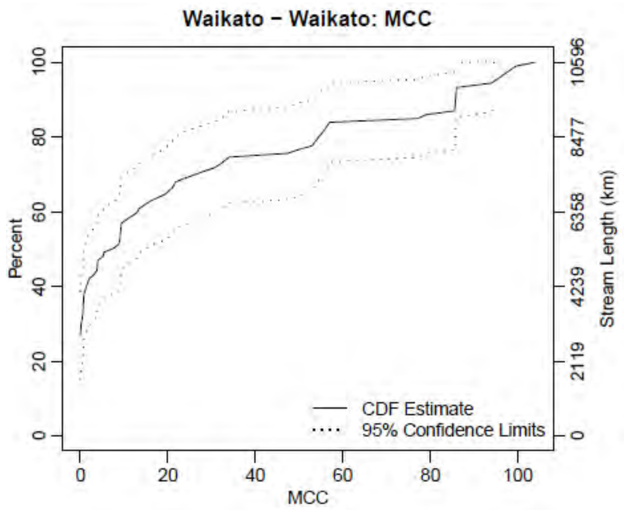

Waikato – Waikato: ASPM2
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
ASPM2

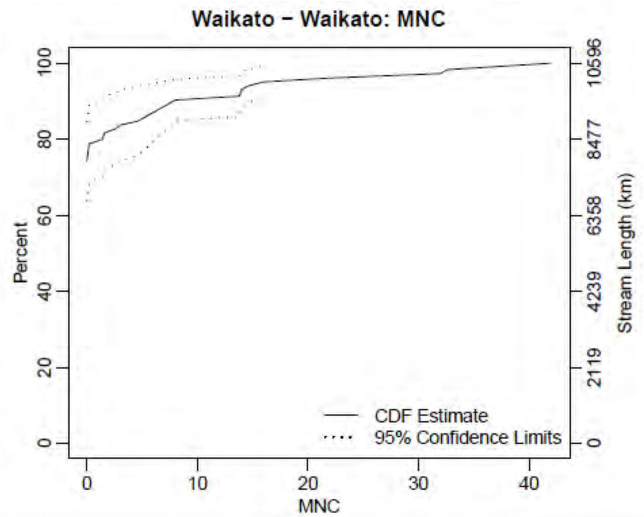

Waikato – Waikato: Pct_SSC
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
Pct_SSC

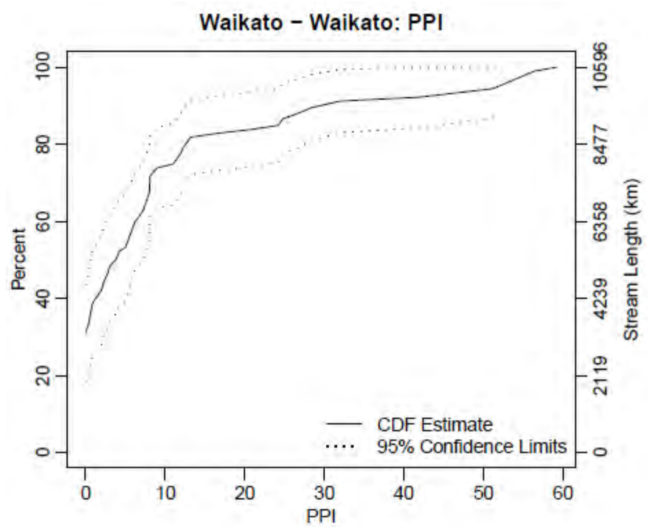

Waikato – Waikato: CW_WW
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
CW_WW

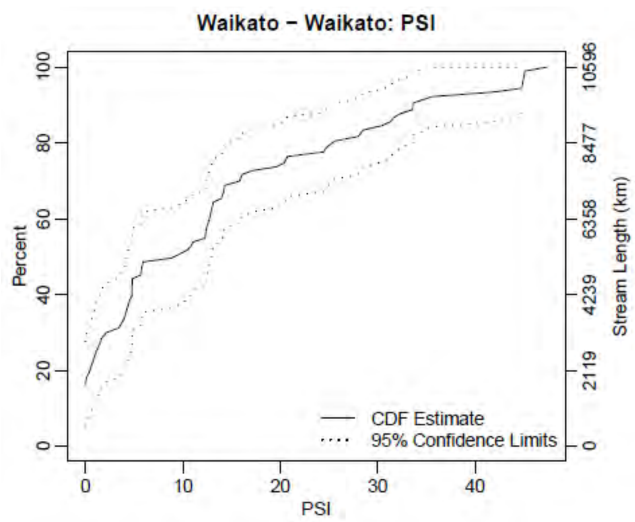

Waikato – Waikato: HABSCORE
Percent
Stream Length (km)
HABSCORE
CDF Estimate
95% Confidence Limits


Waikato – Waikato: MTC
Percent
Stream Length (km)
MTC
CDF Estimate
95% Confidence Limits

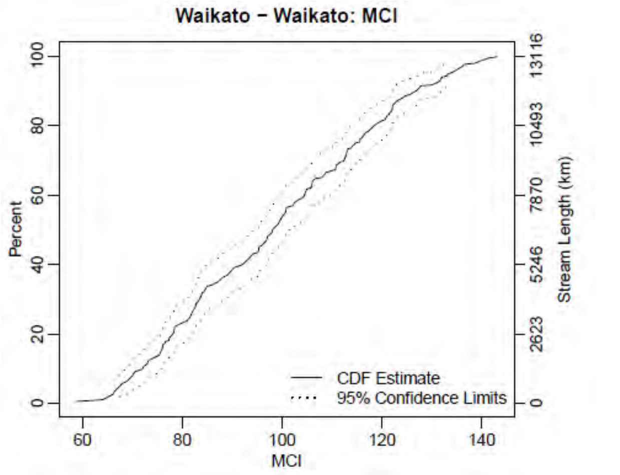

Waikato – Waikato: MCC
Percent
Stream Length (km)
MCC
CDF Estimate
95% Confidence Limits

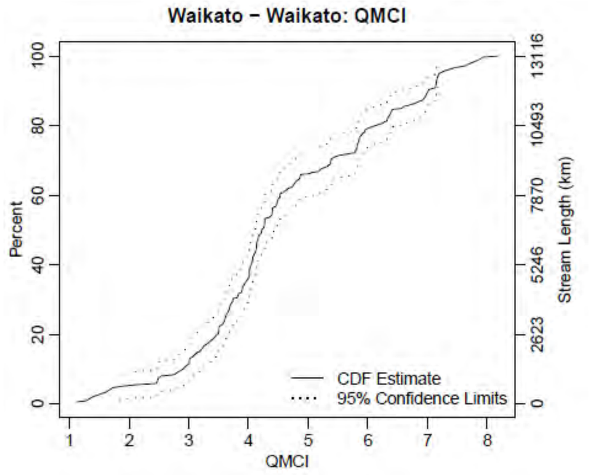

Waikato – Waikato: MNC
Percent
Stream Length (km)
MNC
CDF Estimate
95% Confidence Limits

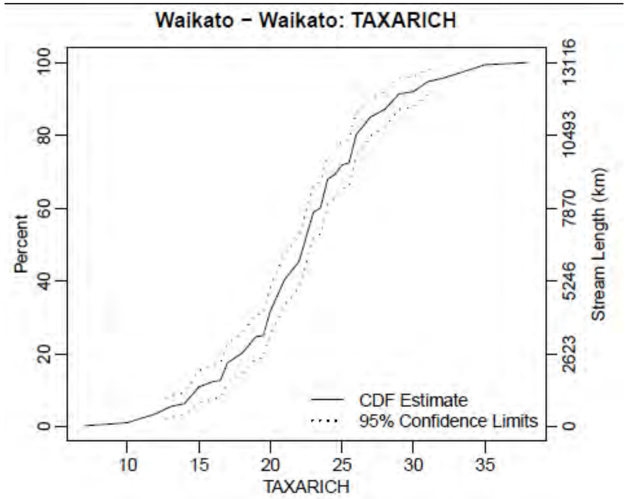

Waikato – Waikato: PPI
Percent
Stream Length (km)
PPI
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2119
4239
6358
8477
10596
0
10
20
30
40
50
60

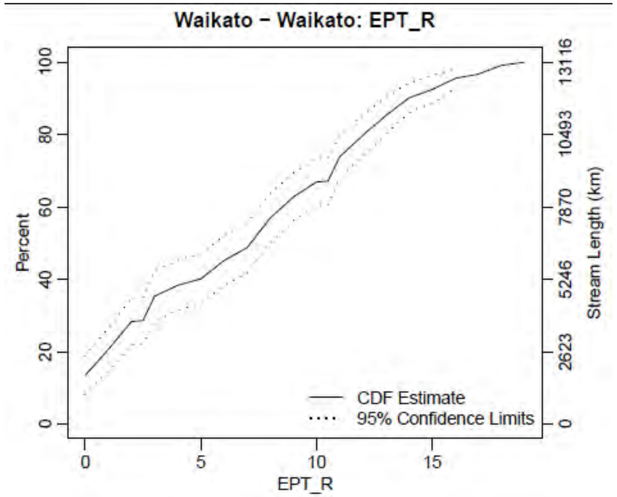

Waikato – Waikato: PSI
Percent
Stream Length (km)
PSI
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2119
4239
6358
8477
10596
0
10
20
30
40

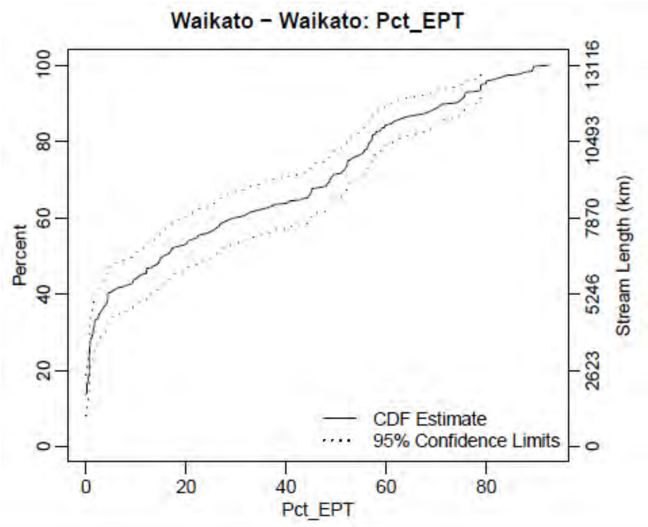
COMBINED

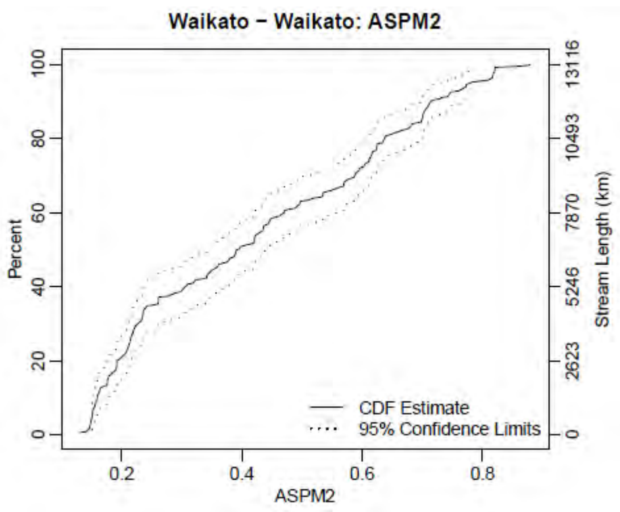

Waikato – Waikato: MCI
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
MCI

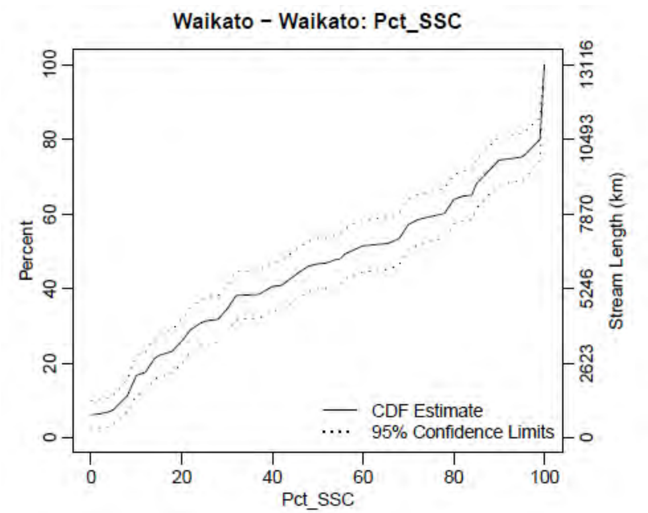

Waikato – Waikato: QMCI
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
QMCI

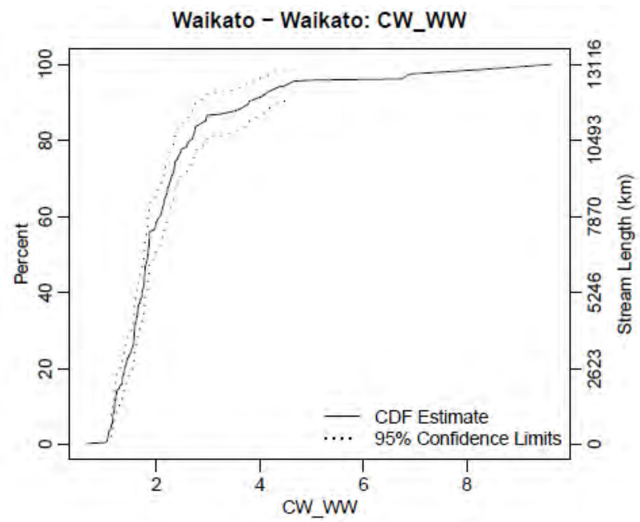

Waikato – Waikato: TAXARICH
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
TAXARICH

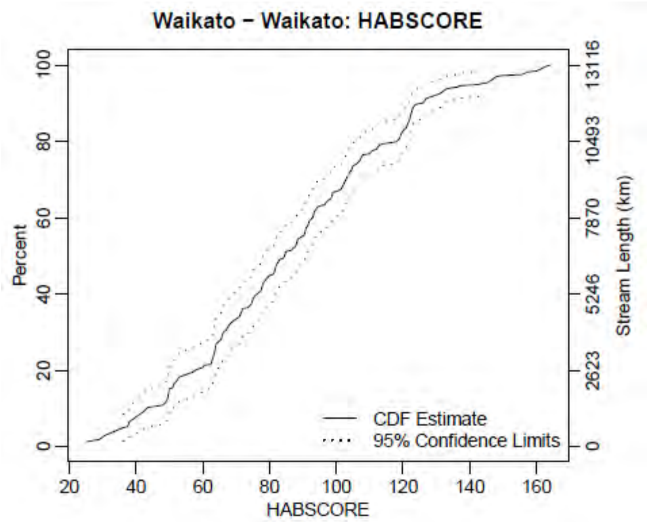

Waikato – Waikato: EPT_R
Percent
Stream Length (km)
CDF Estimate
95% Confidence Limits
EPT_R

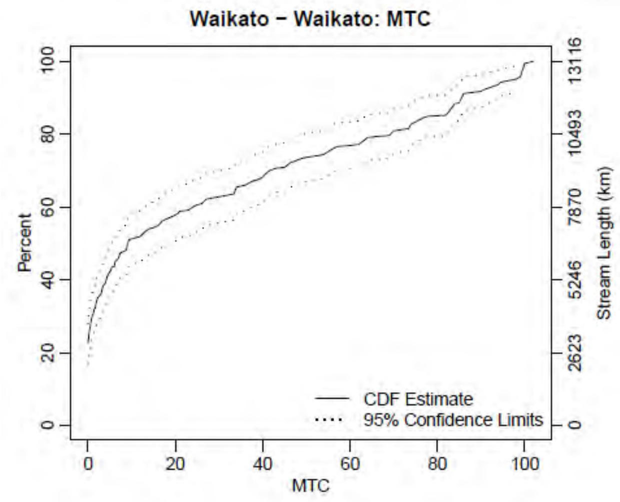

Waikato – Waikato: Pct_EPT
Percent
Stream Length (km)
Pct_EPT
CDF Estimate
95% Confidence Limits

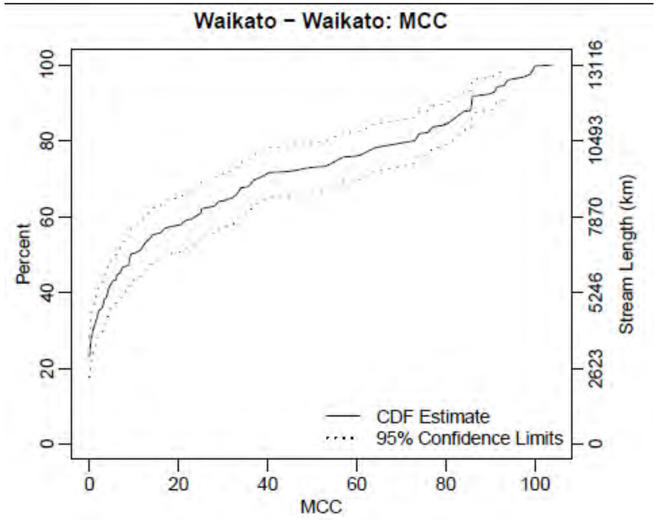

Waikato – Waikato: ASPM2
Percent
Stream Length (km)
ASPM2
CDF Estimate
95% Confidence Limits

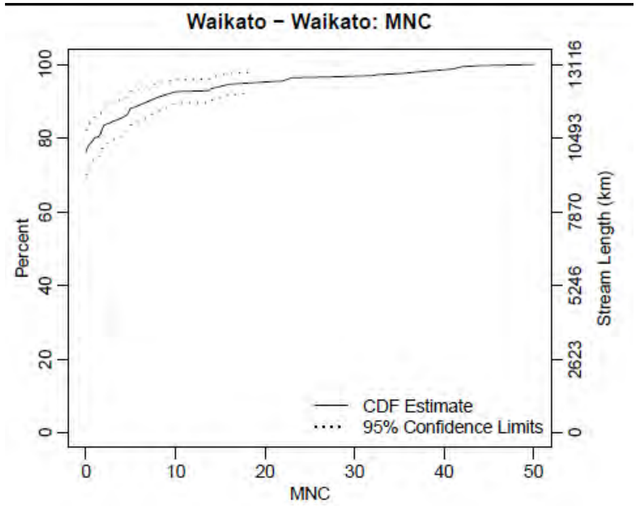

Waikato – Waikato: Pct_SSC
Percent
Stream Length (km)
Pct_SSC
CDF Estimate
95% Confidence Limits

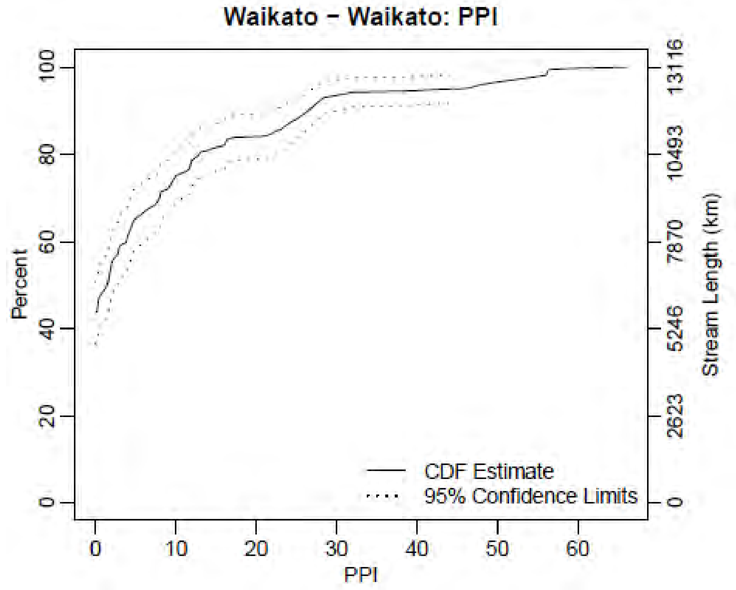

Waikato – Waikato: CW_WW
Percent
Stream Length (km)
CW_WW
CDF Estimate
95% Confidence Limits

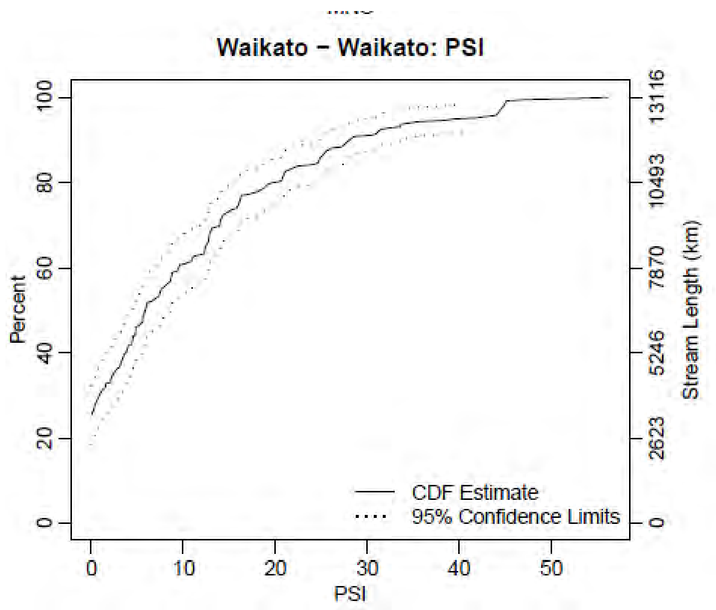

Waikato – Waikato: HABSCORE
Percent
Stream Length (km)
HABSCORE
CDF Estimate
95% Confidence Limits


Waikato – Waikato: MTC
Percent
Stream Length (km)
MTC
CDF Estimate
95% Confidence Limits


Waikato – Waikato: MCC
Percent
Stream Length (km)
MCC
CDF Estimate
95% Confidence Limits


Waikato – Waikato: MNC
Percent
Stream Length (km)
MNC
CDF Estimate
95% Confidence Limits


Waikato − Waikato: PPI
Percent
Stream Length (km)
PPI
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2623
5246
7870
10493
13116
0
10
20
30
40
50
60


Waikato − Waikato: PSI
Percent
Stream Length (km)
PSI
CDF Estimate
95% Confidence Limits
0
20
40
60
80
100
0
2623
5246
7870
10493
13116
0
10
20
30
40
50

Appendix 6: Macroinvertebrate metrics for reference sites sampled over 2009-11.

Duplicate samples in the same year represent multiple samplings as index sites or post-flood events

Site no.	Year	Method	Count	Taxa richness	QMCI	MCI	EPT* richness	%EPT* abundance	ASPM
1051_4	2009	Hard	257	30	7.87	127.33	20	83.27	0.85
125_15	2009	Hard	227.5	26	7.80	127.69	15	86.15	0.79
125_15	2009	Hard	236.5	37	7.84	134.59	21	77.59	0.86
1414_1	2009	Hard	235	26	7.83	139.23	16	91.70	0.85
1132_67	2009	Hard	240.5	41	6.88	121.46	20	73.00	0.80
1513_3	2009	Hard	243	30	7.61	130.00	17	81.69	0.81
1888_4	2009	Hard	232.5	34	7.74	135.88	23	86.02	0.92
1888_4	2009	Hard	231	30	7.95	135.86	18	85.50	0.85
1962_1	2009	Hard	250	35	7.52	129.71	19	76.20	0.82
1965_1	2009	Soft	227.5	27	6.12	128.89	15	64.40	0.72
1965_1	2009	Hard	232	23	8.72	122.61	13	89.87	0.76
1966_1	2009	Hard	234.5	23	8.21	133.04	12	88.91	0.77
1968_1	2009	Hard	217.5	27	7.75	142.22	18	84.14	0.86
1969_1	2009	Hard	250	30	6.79	116.67	14	73.20	0.71
1971_1	2009	Soft	172	27	6.92	122.96	14	70.93	0.71
1971_1	2009	Hard	235	29	7.91	138.62	17	85.96	0.84
234_28	2009	Hard	243	24	6.37	120.83	13	70.58	0.69
234_28	2009	Hard	218	19	7.58	130.53	12	95.87	0.79
33_16	2009	Hard	228	24	7.89	142.50	16	93.86	0.86
33_16	2009	Hard	224.5	28	7.94	141.43	18	84.86	0.86
379_1	2009	Hard	228.5	36	7.86	136.67	24	86.00	0.94
458_1	2009	Hard	241.5	30	7.59	130.67	18	67.49	0.77
471_2	2009	Hard	236	30	7.10	126.67	16	71.82	0.75
474_2	2009	Hard	257.5	36	5.78	121.67	18	45.05	0.68
477_14	2009	Hard	245.5	27	7.96	150.37	20	86.56	0.91
555_2	2009	Soft	236	33	7.56	131.52	22	92.37	0.92
555_2	2009	Hard	216.5	26	6.78	126.92	16	70.67	0.75
754_20	2009	Hard	223.5	26	8.08	123.08	13	91.72	0.77
781_2	2009	Hard	233.5	30	7.86	135.33	18	83.51	0.84
9_4	2009	Hard	242	40	6.64	127.18	21	63.43	0.79
1051_4	2010	Hard	221.5	19	8.16	145.26	14	81.49	0.84
125_15	2010	Hard	215.5	21	7.98	127.62	13	90.95	0.82
125_15	2010	Hard	227.5	23	7.80	135.65	13	90.55	0.83
1132_67	2010	Hard	240.5	27	5.35	127.41	15	33.10	0.64
1414_1	2010	Hard	218.5	21	7.52	130.48	12	92.68	0.81
1513_3	2010	Hard	228.5	26	8.10	140.77	16	89.28	0.89
1888_4	2010	Hard	223	29	8.28	142.76	19	89.69	0.94
1888_4	2010	Hard	245.5	29	8.23	144.14	18	88.39	0.92
1962_1	2010	Hard	243	32	7.65	126.88	15	85.80	0.83

Site no.	Year	Method	Count	Taxa richness	QMCI	MCI	EPT* richness	%EPT* abundance	ASPM
1965_1	2010	Soft	219.5	25	6.91	126.40	13	87.93	0.80
1965_1	2010	Hard	223.5	23	7.25	120.87	13	86.80	0.79
1966_1	2010	Hard	216	21	8.43	130.48	10	90.05	0.77
1968_1	2010	Hard	215.5	19	8.23	150.53	14	80.97	0.85
1969_1	2010	Hard	231.5	28	7.37	135.56	13	88.34	0.82
1971_1	2010	Hard	230.5	31	8.18	132.26	20	88.72	0.93
1971_1	2010	Soft	191	34	5.52	114.71	16	43.46	0.66
234_28	2010	Hard	219.5	19	4.99	103.16	7	57.40	0.55
33_16	2010	Hard	235	24	7.91	137.50	13	80.21	0.80
33_16	2010	Hard	219.5	22	7.70	150.91	15	86.10	0.88
379_1	2010	Hard	217	27	8.18	142.22	16	87.33	0.88
458_1	2010	Hard	214.5	31	5.91	121.29	18	54.31	0.75
471_2	2010	Hard	236.5	31	7.93	138.71	21	82.03	0.93
474_2	2010	Hard	209.5	30	6.36	122.67	14	60.14	0.71
477_14	2010	Hard	231.5	25	8.31	130.40	14	86.18	0.82
555_2	2010	Hard	222	26	7.88	129.23	16	85.36	0.85
555_2	2010	Soft	237	30	6.93	127.33	19	90.30	0.91
754_20	2010	Hard	278	24	8.24	133.33	15	91.37	0.86
781_2	2010	Hard	224.5	29	7.63	136.43	18	85.52	0.89
9_4	2010	Hard	227	34	6.44	130.00	20	57.93	0.81
1051_4	2011	Hard	213.5	34	8.30	139.41	25	91.57	0.96
125_15	2011	Hard	218	29	7.34	131.72	17	78.90	0.79
125_15	2011	Hard	219.5	31	7.56	133.55	19	77.90	0.82
1132_67	2011	Hard	228	33	5.60	121.81	16	43.00	0.63
1414_1	2011	Hard	227.5	26	7.86	148.46	18	96.70	0.91
1513_3	2011	Hard	211.5	25	8.21	141.60	17	93.62	0.87
1888_4	2011	Hard	235	30	8.26	139.33	19	90.85	0.88
1888_4	2011	Hard	226	30	8.36	140.67	20	90.93	0.90
1888_4	2011	Hard	214	28	7.82	136.43	18	82.71	0.83
1962_1	2011	Hard	231	32	7.82	133.55	16	83.33	0.80
1965_1	2011	Hard	225	21	7.83	138.10	13	92.89	0.80
1965_1	2011	Soft	219	23	5.95	128.70	11	56.62	0.63
1966_1	2011	Hard	237	28	7.90	127.14	13	82.91	0.74
1968_1	2011	Hard	215.5	25	7.80	145.60	18	80.97	0.85
1968_1	2011	Hard	220.5	28	7.48	133.57	17	71.66	0.77
1968_1	2011	Hard	224.5	23	8.12	140.87	15	92.43	0.83
1969_1	2011	Hard	227.5	25	7.29	141.60	15	90.99	0.83
1971_1	2011	Hard	219	30	8.33	130.67	17	92.24	0.84
1971_1	2011	Soft	217	30	5.61	118.00	17	47.93	0.66
234_28	2011	Hard	220	27	6.71	124.44	16	73.18	0.74
3008_1	2011	Hard	215	27	5.60	111.85	15	66.98	0.68
33_16	2011	Hard	230.5	21	8.00	148.57	14	88.72	0.83
33_16	2011	Hard	219.5	23	8.17	141.74	13	82.46	0.78
33_16	2011	Hard	221	23	8.09	146.09	16	95.70	0.87
379_1	2011	Hard	212	24	8.18	144.17	15	94.58	0.85
410_10	2011	Hard	231.5	27	7.97	139.26	19	87.47	0.87
410_11	2011	Hard	226.5	27	7.88	136.30	17	91.83	0.85
458_1	2011	Hard	230.5	36	7.83	141.14	24	83.08	0.92

Site no.	Year	Method	Count	Taxa richness	QMCI	MCI	EPT* richness	%EPT* abundance	ASPM
471_2	2011	Hard	237.5	25	7.97	129.60	13	87.58	0.77
474_2	2011	Hard	229.5	41	5.00	120.00	19	35.73	0.65
477_14	2011	Hard	227.5	28	8.42	143.57	19	89.23	0.88
555_2	2011	Hard	228	31	7.85	130.32	19	85.96	0.84
555_2	2011	Soft	222.5	29	7.23	125.52	18	91.69	0.84
754_20	2011	Hard	220	22	8.08	128.18	13	91.82	0.78
781_2	2011	Hard	214.5	28	7.83	138.57	18	91.14	0.87
9_4	2011	Hard	216	31	6.35	129.03	19	62.27	0.76

Appendix 7: Mann Kendall trend results for MCI and ASPM.

Calculated from the computer program TimeTrends (v.3.20; 2011). For P values, Red = significant at $P<0.05$ and Bold = borderline at $0.05<P<0.1$

Mann-Kendall test for Group 1043_1 for MCI

10 observations from 1/01/02 to 1/01/11 with 1 ties

1043_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	80.83	18.00	124.00	1.53	**0.07**	1.43	-0.05	2.32

Mann-Kendall test for Group 1055_3 for MCI

15 observations from 1/01/96 to 1/01/11 with 0 ties

1055_3	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	137.00	-63.00	408.33	-3.07	**0.00**	-1.30	-1.75	-0.80

Mann-Kendall test for Group 1158_7 for MCI

13 observations from 1/01/96 to 1/01/11 with 0 ties

1158_7	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	120.00	0.00	268.67	0.00	1.00	0.02	-1.32	0.99

Mann-Kendall test for Group 1172_6 for MCI

16 observations from 1/01/96 to 1/01/11 with 0 ties

1172_6	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	110.89	-40.00	493.33	-1.76	**0.08**	-0.94	-1.98	-0.03

Mann-Kendall test for Group 1174_10 for MCI

15 observations from 1/01/96 to 1/01/11 with 1 ties

1174_10	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	98.67	-54.00	407.33	-2.63	**0.01**	-1.63	-2.49	-0.73

Mann-Kendall test for Group 1249_15 for MCI

15 observations from 1/01/96 to 1/01/11 with 3 ties

1249_15	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	84.44	1.00	403.67	0.00	1.00	0.00	-1.22	0.83

Mann-Kendall test for Group 1252_3/1252_1 for MCI

14 observations from 1/01/96 to 1/01/10 with 0 ties

	Median value	Kendall statistic	Varian ce	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	88.33	-26.00	332.67	-1.37	0.17	-1.12	-2.74	0.29

Mann-Kendall test for Group 1253_9 for MCI

13 observations from 1/01/97 to 1/01/11 with 0 ties

1253_9	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	108.00	0.00	268.67	0.00	1.00	-0.03	-1.88	1.29

Mann-Kendall test for Group 1257_4 for MCI

14 observations from 1/01/98 to 1/01/11 with 0 ties

1257_4	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	114.06	-49.00	333.67	-2.63	**0.01**	-1.85	-2.64	-0.83

Mann-Kendall test for Group 125_4 for MCI

14 observations from 1/01/97 to 1/01/11 with 4 ties

125_4	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	133.00	10.00	324.00	0.50	0.62	0.22	-0.69	1.37

Mann-Kendall test for Group 1284_1 for MCI

15 observations from 1/01/96 to 1/01/11 with 0 ties

1284_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	135.79	7.00	408.33	0.30	0.77	0.24	-0.60	1.37

Mann-Kendall test for Group 1300_2 for MCI

10 observations from 1/01/02 to 1/01/11 with 0 ties

1300_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	100.03	5.00	125.00	0.36	0.36	0.48	-1.31	2.45

Mann-Kendall test for Group 1323_1 for MCI

10 observations from 1/01/02 to 1/01/11 with 0 ties

1323_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	110.43	29.00	125.00	2.50	**0.00**	2.68	1.80	3.99

Mann-Kendall test for Group 1414_1 for MCI

15 observations from 1/01/96 to 1/01/11 with 1 ties

1414_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	146.32	-60.00	407.33	-2.92	**0.00**	-1.25	-1.91	-0.71

Mann-Kendall test for Group 195_1 for MCI

13 observations from 1/01/96 to 1/01/11 with 0 ties

195_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	106.36	-22.00	268.67	-1.28	0.20	-1.10	-2.52	0.31

Mann-Kendall test for Group 220_1 for MCI

13 observations from 1/01/96 to 1/01/09 with 1 ties

220_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	126.32	-35.00	267.67	-2.08	**0.04**	-1.34	-2.24	-0.46

Mann-Kendall test for Group 240_5 for MCI

14 observations from 1/01/97 to 1/01/11 with 0 ties

240_5	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	108.60	-37.00	333.67	-1.97	0.05	-1.91	-3.21	-0.54

Mann-Kendall test for Group 256_2 for MCI

14 observations from 1/01/96 to 1/01/11 with 1 ties

256_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	106.06	-40.00	332.67	-2.14	**0.03**	-1.67	-2.42	-0.37

Mann-Kendall test for Group 365_1 for MCI

13 observations from 1/01/96 to 1/01/11 with 1 ties

365_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	124.00	-19.00	267.67	-1.10	0.27	-0.37	-1.42	0.28

Mann-Kendall test for Group 36_1 for MCI

13 observations from 1/01/96 to 1/01/11 with 0 ties

36_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	118.10	-14.00	268.67	-0.79	0.43	-0.72	-2.05	0.61

Mann-Kendall test for Group 398_1 for MCI

10 observations from 1/01/02 to 1/01/11 with 0 ties

398_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	80.14	29.00	125.00	2.50	**0.00**	1.58	0.59	3.05

Mann-Kendall test for Group 407_1 for MCI

14 observations from 1/01/96 to 1/01/11 with 2 ties

407_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	76.32	-4.00	330.00	-0.17	0.87	-0.13	-0.56	0.84

Mann-Kendall test for Group 413_2 for MCI

14 observations from 1/01/96 to 1/01/11 with 2 ties

413_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	128.37	0.00	330.00	0.00	1.00	0.00	-1.79	1.11

Mann-Kendall test for Group 428_3 for MCI

15 observations from 1/01/96 to 1/01/11 with 1 ties

428_3	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	102.22	-46.00	407.33	-2.23	**0.03**	-1.29	-2.07	-0.34

Mann-Kendall test for Group 433_2 for MCI

15 observations from 1/01/96 to 1/01/11 with 0 ties

433_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	88.57	-45.00	408.33	-2.18	**0.03**	-1.06	-1.96	-0.41

Mann-Kendall test for Group 453_8 for MCI

14 observations from 1/01/96 to 1/01/11 with 1 ties

453_8	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	92.42	12.00	332.67	0.60	0.55	0.27	-0.75	1.39

Mann-Kendall test for Group 476_1 for MCI

13 observations from 1/01/97 to 1/01/11 with 0 ties

476_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	110.77	-12.00	268.67	-0.67	0.50	-0.45	-2.01	1.17

Mann-Kendall test for Group 477_14 for MCI

15 observations from 1/01/96 to 1/01/11 with 0 ties

477_14	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	144.44	-17.00	408.33	-0.79	0.43	-0.37	-1.55	0.47

Mann-Kendall test for Group 477_5 for MCI

14 observations from 1/01/96 to 1/01/11 with 0 ties

477_5	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	103.68	5.00	333.67	0.22	0.83	0.22	-0.73	1.45

Mann-Kendall test for Group 47_2 for MCI

10 observations from 1/01/02 to 1/01/11 with 1 ties

47_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	79.09	0.00	124.00	0.00	0.50	0.00	-0.96	0.71

Mann-Kendall test for Group 481_11 for MCI

13 observations from 1/01/97 to 1/01/10 with 2 ties

481_11	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	107.86	-16.00	266.67	-0.92	0.36	-0.76	-2.44	1.01

Mann-Kendall test for Group 493_1 for MCI

13 observations from 1/01/97 to 1/01/11 with 0 ties

493_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	83.33	-12.00	268.67	-0.67	0.50	-0.47	-1.80	0.85

Mann-Kendall test for Group 495_1 for MCI

12 observations from 1/01/97 to 1/01/11 with 0 ties

495_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	124.38	6.00	212.67	0.34	0.73	0.54	-0.98	1.74

Mann-Kendall test for Group 514_1 for MCI

13 observations from 1/01/96 to 1/01/11 with 1 ties

514_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	132.73	-3.00	267.67	-0.12	0.90	-0.04	-0.73	0.66

Mann-Kendall test for Group 556_9 for MCI

13 observations from 1/01/96 to 1/01/11 with 0 ties

556_9	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	103.20	-8.00	268.67	-0.43	0.67	-0.24	-1.79	0.78

Mann-Kendall test for Group 619_20 for MCI

14 observations from 1/01/96 to 1/01/11 with 2 ties

619_20	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	85.83	-5.00	331.67	-0.22	0.83	-0.38	-0.97	1.41

Mann-Kendall test for Group 736_2 for MCI

11 observations from 1/01/2000 to 1/01/2011 with 0 ties

736_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	105.263	-17.000	165.000	-1.246	0.213	-1.111	-2.465	0.454

Mann-Kendall test for Group 749_10 for MCI

15 observations from 1/01/96 to 1/01/11 with 1 ties

749_10	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	73.75	-38.00	407.33	-1.83	**0.07**	-1.38	-2.43	-0.25

Mann-Kendall test for Group 786_2 for MCI

15 observations from 1/01/96 to 1/01/11 with 0 ties

786_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	102.11	23.00	408.33	1.09	0.28	0.93	-0.42	2.18

Mann-Kendall test for Group 976_2 for MCI

14 observations from 1/01/96 to 1/01/11 with 0 ties

976_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	120.52	-29.00	333.67	-1.53	0.13	-0.77	-1.45	0.11

Mann-Kendall test for Group 1043_1 for ASPM

10 observations from 1/01/02 to 1/01/11 with 0 ties

1043_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.228	5.000	125.000	0.358	0.364	0.003	-0.006	0.010

Mann-Kendall test for Group 1055_3 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

1055_3	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.850	-37.000	408.333	-1.782	**0.075**	-0.008	-0.018	-0.001

Mann-Kendall test for Group 1158_7 for ASPM

13 observations from 1/01/96 to 1/01/11 with 0 ties

1158_7	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.671	12.000	268.667	0.671	0.502	0.005	-0.006	0.019

Mann-Kendall test for Group 1172_6 for ASPM

16 observations from 1/01/96 to 1/01/11 with 0 ties

1172_6	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.513	-24.000	493.333	-1.036	0.300	-0.010	-0.020	0.004

Mann-Kendall test for Group 1174_10 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

1174_10	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.539	-27.000	408.333	-1.287	0.198	-0.009	-0.022	0.002

Mann-Kendall test for Group 1249_15 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

1249_15	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.259	-5.000	408.333	-0.198	0.843	-0.001	-0.010	0.006

Mann-Kendall test for Group 125_4 for ASPM

14 observations from 1/01/97 to 1/01/11 with 0 ties

125_4	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.793	17.000	333.667	0.876	0.381	0.003	-0.008	0.016

Mann-Kendall test for Group 1252_3/1253_1 for ASPM

14 observations from 1/01/96 to 1/01/10 with 0 ties

1252_3	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.293	5.000	333.667	0.219	0.827	0.000	-0.012	0.010

Mann-Kendall test for Group 1253_9 for ASPM

13 observations from 1/01/97 to 1/01/11 with 0 ties

1253_9	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.469	14.000	268.667	0.793	0.428	0.005	-0.009	0.024

Mann-Kendall test for Group 1257_4 for ASPM

14 observations from 1/01/98 to 1/01/11 with 0 ties

1257_4	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.643	-17.000	333.667	-0.876	0.381	-0.004	-0.009	0.002

Mann-Kendall test for Group 1284_1 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

1284_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.828	13.000	408.333	0.594	0.553	0.008	-0.011	0.035

Mann-Kendall test for Group 1300_2 for ASPM

10 observations from 1/01/02 to 1/01/11 with 0 ties

1300_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.420	11.000	125.000	0.894	0.190	0.007	-0.013	0.024

Mann-Kendall test for Group 1323_1 for ASPM

10 observations from 1/01/02 to 1/01/11 with 0 ties

1323_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.563	41.000	125.000	3.578	**0.000**	0.034	0.023	0.046

Mann-Kendall test for Group 1414_1 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

1414_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.904	-41.000	408.333	-1.979	**0.048**	-0.004	-0.011	-0.001

Mann-Kendall test for Group 195_1 for ASPM

13 observations from 1/01/96 to 1/01/11 with 0 ties

195_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.534	6.000	268.667	0.305	0.760	0.002	-0.012	0.015

Mann-Kendall test for Group 220_1 for ASPM

13 observations from 1/01/96 to 1/01/09 with 0 ties

220_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.702	-30.000	268.667	-1.769	**0.077**	-0.011	-0.019	-0.003

Mann-Kendall test for Group 240_5 for ASPM

14 observations from 1/01/97 to 1/01/11 with 0 ties

240_5	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.622	-1.000	333.667	0.000	1.000	0.000	-0.009	0.012

Mann-Kendall test for Group 256_2 for ASPM

14 observations from 1/01/96 to 1/01/11 with 0 ties

256_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.375	-15.000	333.667	-0.766	0.443	-0.005	-0.012	0.003

Mann-Kendall test for Group 36_1 for ASPM

13 observations from 1/01/96 to 1/01/11 with 0 ties

36_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.633	10.000	268.667	0.549	0.583	0.007	-0.007	0.026

Mann-Kendall test for Group 365_1 for ASPM

13 observations from 1/01/96 to 1/01/11 with 0 ties

365_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.678	10.000	268.667	0.549	0.583	0.003	-0.003	0.009

Mann-Kendall test for Group 398_1 for ASPM

10 observations from 1/01/02 to 1/01/11 with 0 ties

398_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.260	27.000	125.000	2.326	**0.008**	0.012	0.005	0.017

Mann-Kendall test for Group 407_1 for ASPM

14 observations from 1/01/96 to 1/01/11 with 0 ties

407_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.278	27.000	333.667	1.423	0.155	0.008	-0.001	0.016

Mann-Kendall test for Group 413_2 for ASPM

14 observations from 1/01/96 to 1/01/11 with 0 ties

413_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.675	9.000	333.667	0.438	0.661	0.004	-0.012	0.017

Mann-Kendall test for Group 428_3 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

428_3	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.457	-31.000	408.333	-1.485	0.138	-0.011	-0.029	0.001

Mann-Kendall test for Group 433_2 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

433_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.444	11.000	408.333	0.495	0.621	0.003	-0.009	0.011

Mann-Kendall test for Group 453_8 for ASPM

15 observations from 1/01/95 to 1/01/11 with 0 ties

453_8	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.436	17.000	408.333	0.792	0.428	0.006	-0.006	0.014

Mann-Kendall test for Group 47_2 for ASPM

10 observations from 1/01/02 to 1/01/11 with 0 ties

47_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.236	-3.000	125.000	-0.179	0.500	-0.001	-0.004	0.004

Mann-Kendall test for Group 476_1 for ASPM

13 observations from 1/01/97 to 1/01/11 with 0 ties

476_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.529	4.000	268.667	0.183	0.855	0.002	-0.011	0.016

Mann-Kendall test for Group 477_14 for ASPM

15 observations from 1/01/96 to 1/01/11 with 0 ties

477_14	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.888	-23.000	408.333	-1.089	0.276	-0.006	-0.011	0.002

Mann-Kendall test for Group 477_5 for ASPM

14 observations from 1/01/96 to 1/01/11 with 0 ties

477_5	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.494	29.000	333.667	1.533	0.125	0.010	-0.001	0.021

Mann-Kendall test for Group 481_11 for ASPM

13 observations from 1/01/97 to 1/01/10 with 0 ties

481_11	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.526	12.000	268.667	0.671	0.502	0.012	-0.014	0.026

Mann-Kendall test for Group 493_1 for ASPM

13 observations from 1/01/97 to 1/01/11 with 0 ties

493_1	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.236	-16.000	268.667	-0.915	0.360	-0.003	-0.009	0.003

Mann-Kendall test for Group 495_1 for ASPM

12 observations from 1/01/97 to 1/01/11 with 0 ties

495_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.694	8.000	212.667	0.480	0.631	0.005	-0.006	0.024

Mann-Kendall test for Group 514_1 for ASPM

13 observations from 1/01/96 to 1/01/11 with 0 ties

514_1	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.625	2.000	268.667	0.061	0.951	0.000	-0.010	0.013

Mann-Kendall test for Group 556_9 for ASPM

13 observations from 1/01/96 to 1/01/11 with 0 ties

556_9	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.433	32.000	268.667	1.891	**0.059**	0.011	0.001	0.017

Mann-Kendall test for Group 619_20 for ASPM

14 observations from 1/01/96 to 1/01/11 with 0 ties

619_20	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.358	21.000	333.667	1.095	0.274	0.008	-0.004	0.015

Mann-Kendall test for Group 736_2 for ASPM

11 observations from 1/01/2000 to 1/01/2011 with 0 ties

736_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.453	23.000	165.000	1.713	0.087	0.009	0.001	0.021

Mann-Kendall test for Group 749_10 for ASPM

15 observations from 1/01/96 to 1/01/11 with 1 ties

749_10	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.168	-28.000	407.333	-1.338	0.181	-0.003	-0.007	0.001

Mann-Kendall test for Group 786_2 for ASPM

16 observations from 1/01/95 to 1/01/11 with 0 ties

786_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.528	42.000	493.333	1.846	**0.065**	0.016	0.002	0.028

Mann-Kendall test for Group 976_2 for ASPM

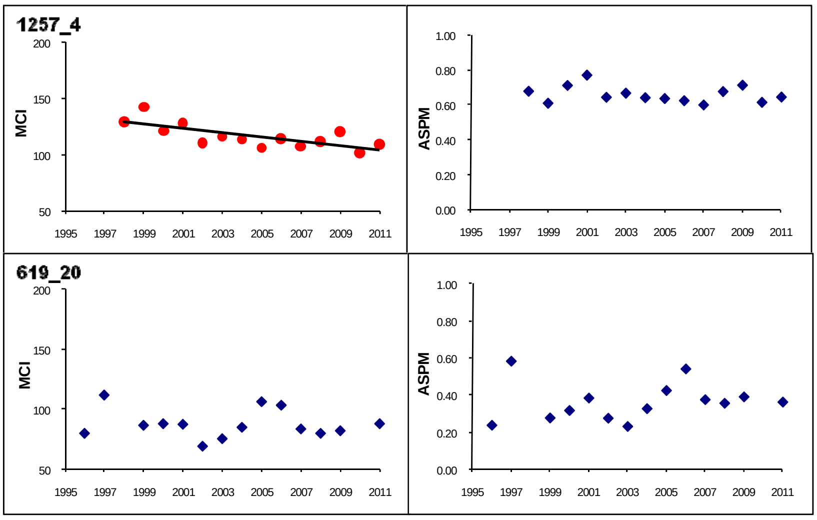
14 observations from 1/01/96 to 1/01/11 with 0 ties

976_2	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.568	33.000	333.667	1.752	**0.080**	0.005	0.000	0.014

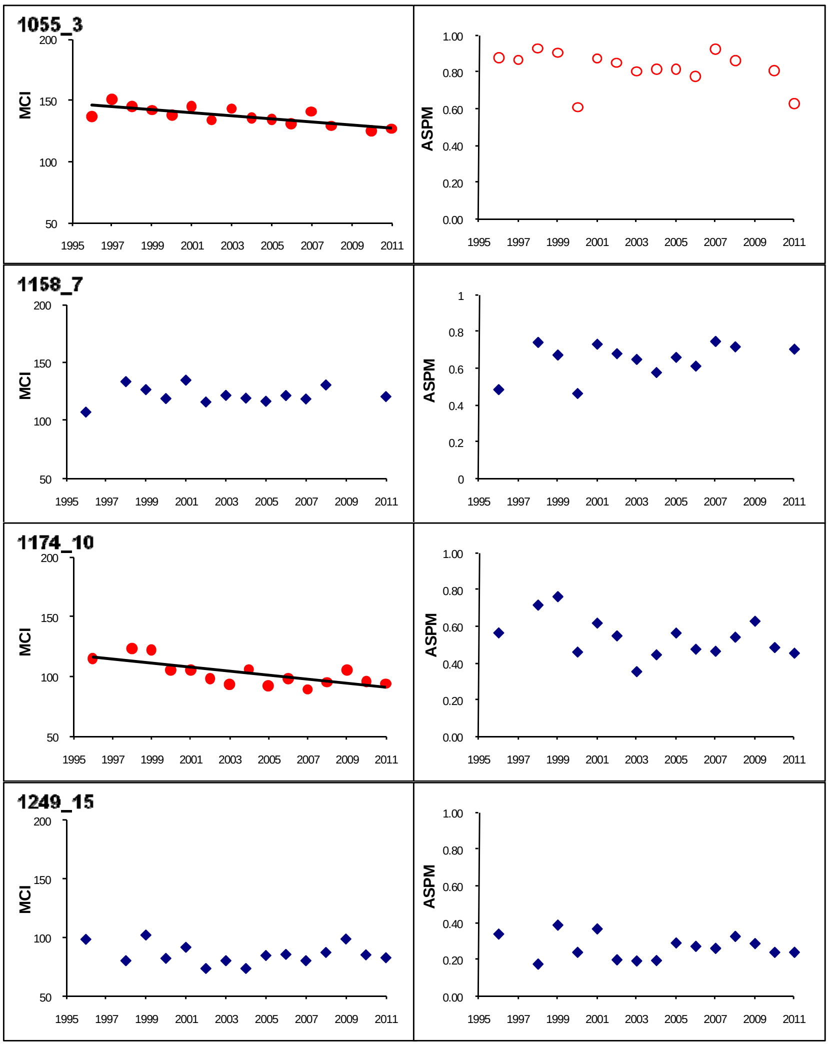
Appendix 8: Time-series plots of invertebrate trend metrics.

Linear interpolations are shown for sites showing temporal trends based on the Mann Kendall test at *P*<0.05 ('clear'; closed circles with trendline) or 0.05<*P*<0.1 ('borderline'; open circles).

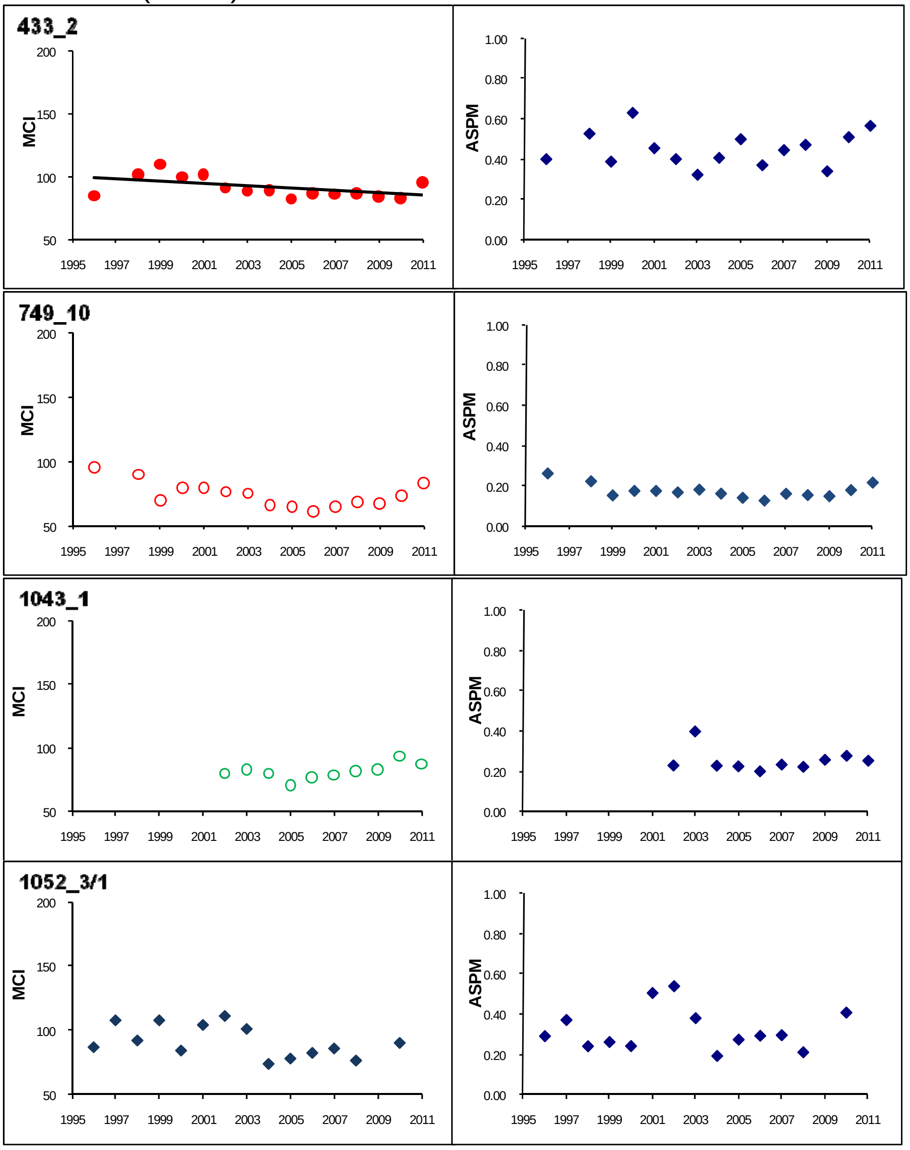
COROMANDEL



HAURAKI



HAURAKI (condt.)



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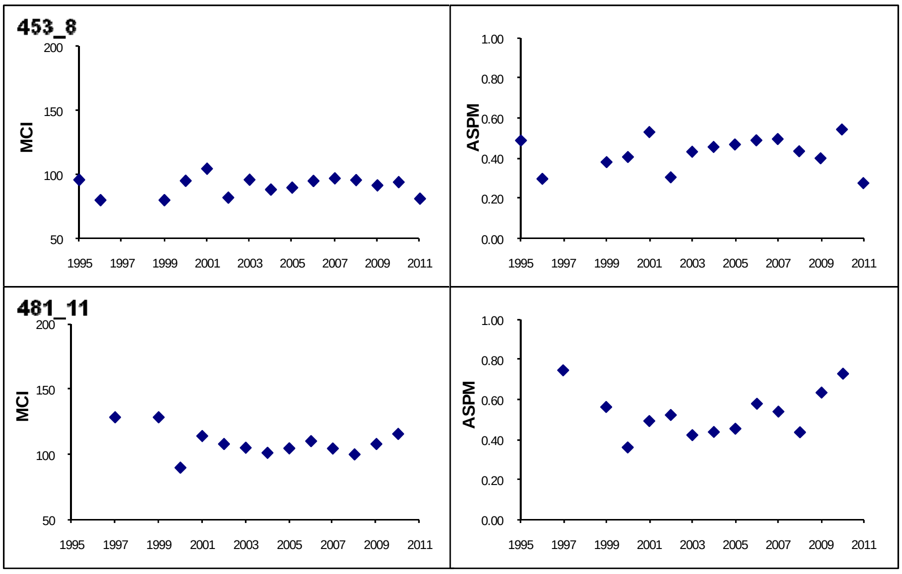

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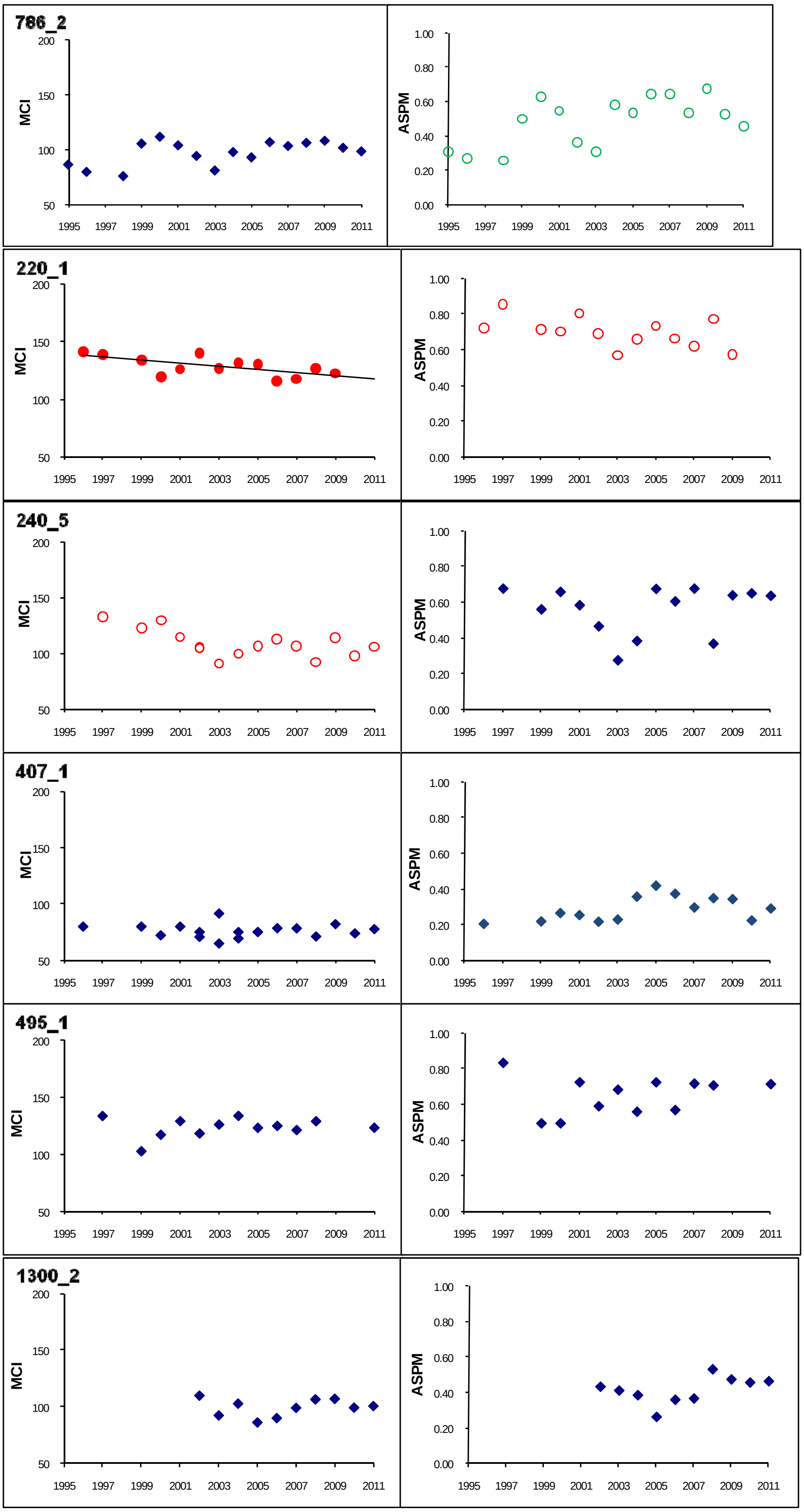

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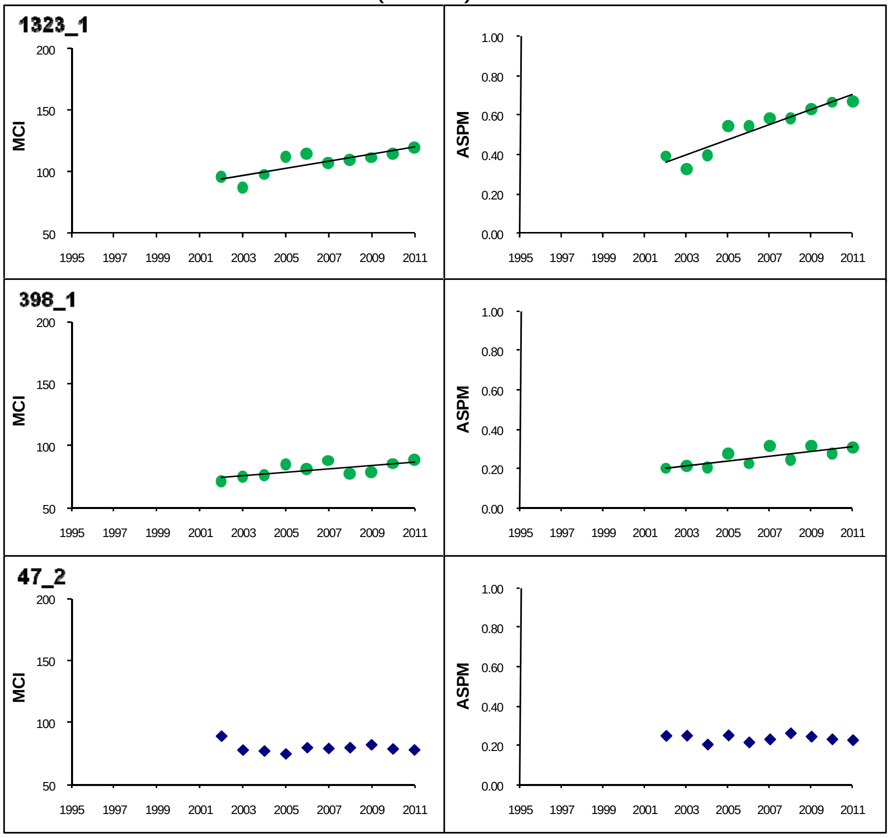
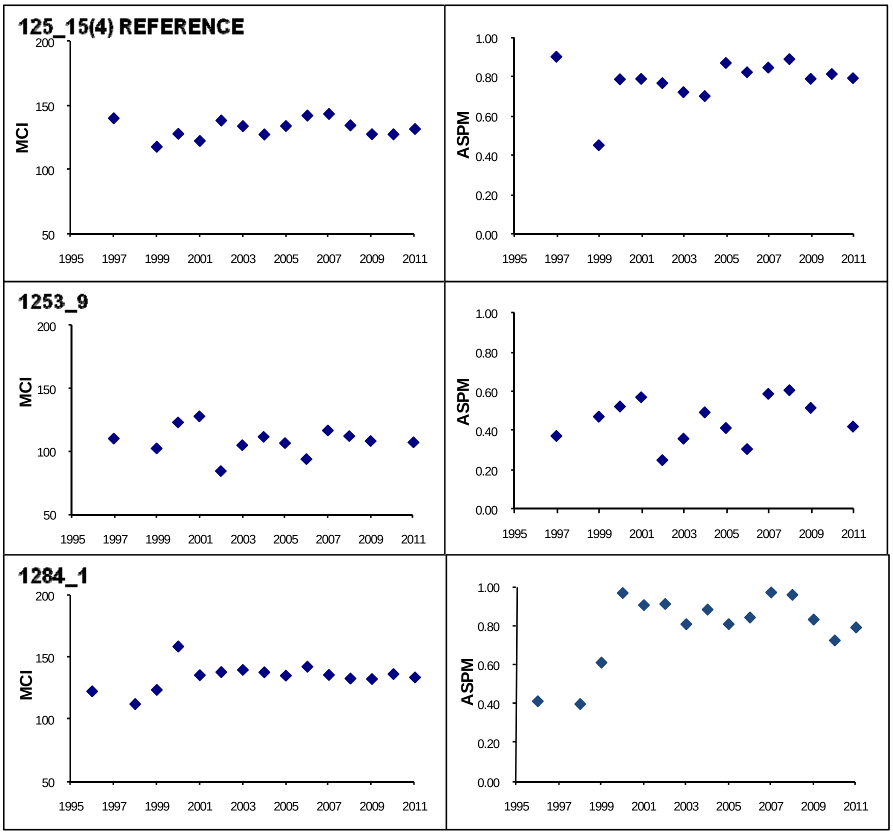


WAIPA



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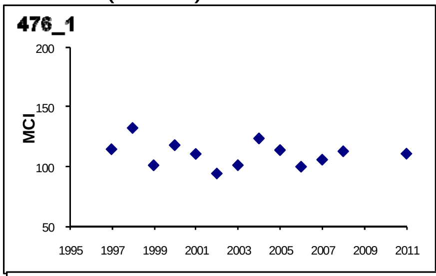
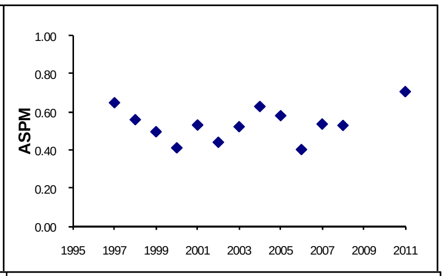
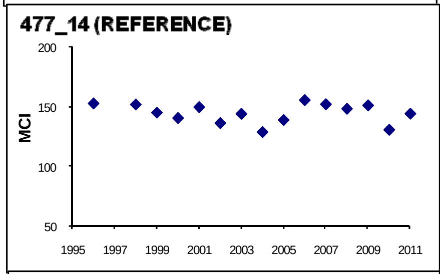
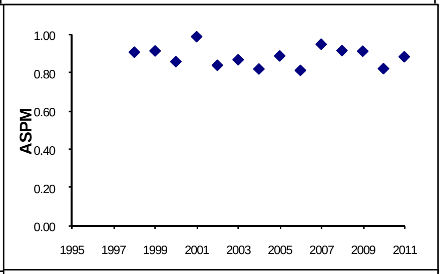
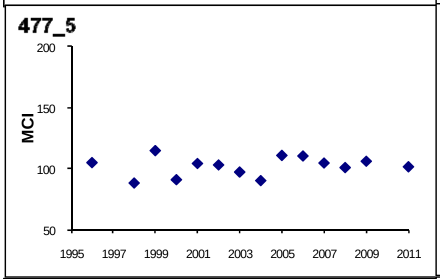
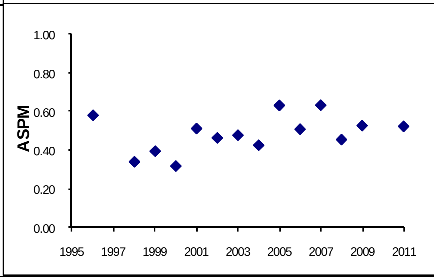


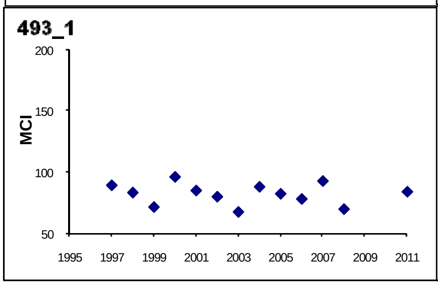


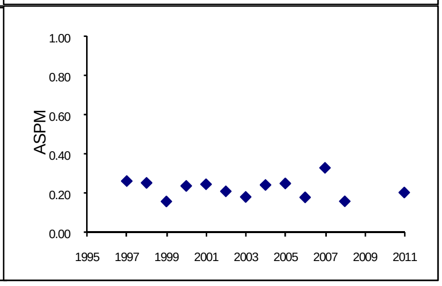




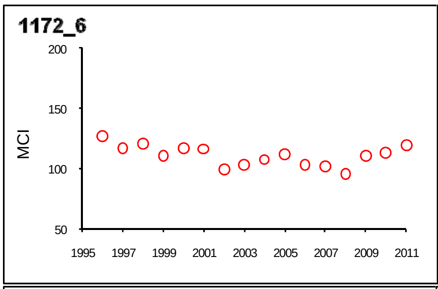


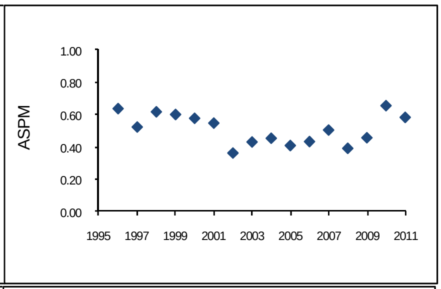


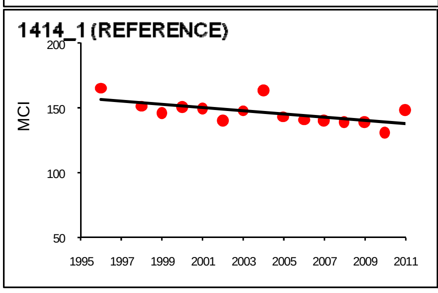


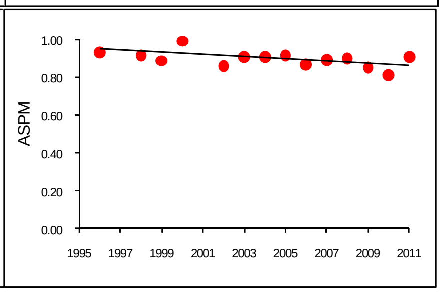


WEST COAST

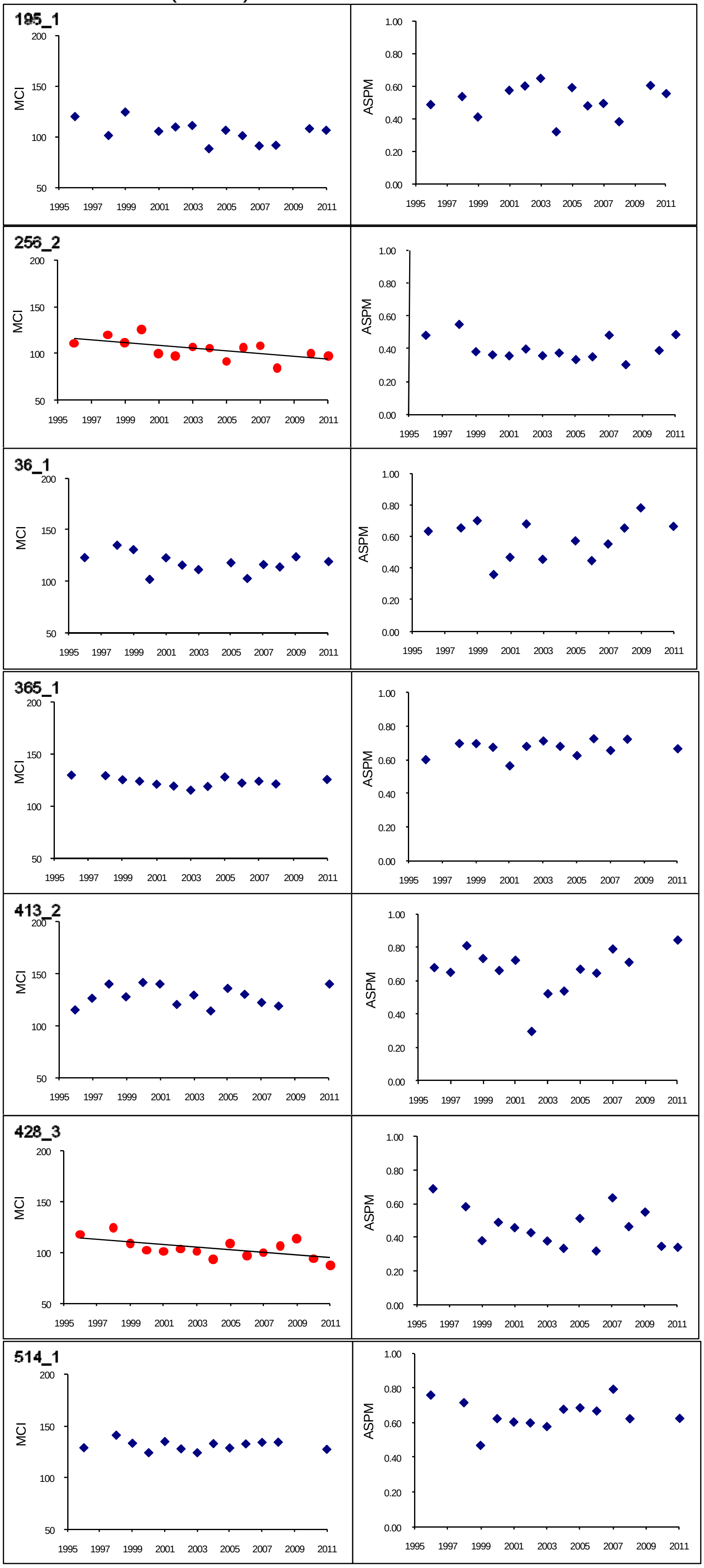




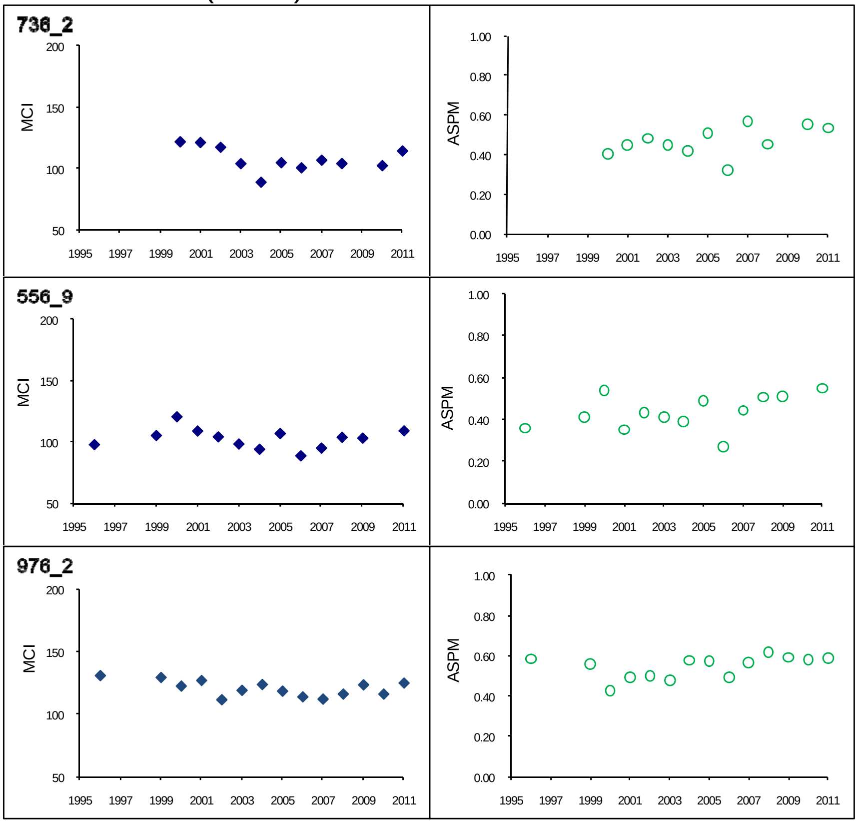




WEST COAST (condt.)



WEST COAST (condt.)



Appendix 9: Provisional water quality trends (not flow-adjusted) at sites where water quality (RRIMP) and ecological (REMS) monitoring overlap.

Yellow shading indicates statistically significant trends at P<0.05; for 'slope' beige = declining trend for ecological health and green = increasing trend for ecological health. Darker beige and green shadings represent slopes >1% per annum which is considered an environmentally important trend. For REMS, + and ++ = borderline and clear (P<0.05) positive trends, respectively, and - and -- = borderline and clear (P<0.05) negative trends, respectively.

REMS			RRIMP	Black disc				Turbidity			
Site	MCI	ASPM	Site	median	P(%)_raw	SKSE_raw	slope(%pa)	median	P(%)_raw	SKSE_raw	slope(%pa)
240-5	-	Stable	240-5	1.13	88.29	-0.0008	-0.1	4.3	71.97	-0.0125	-0.3
398-1	++	++	398-1	0.39	57.96	-0.0009	-0.2	24.8	1.93	-0.3323	-1.3
407-1	Stable	Stable	407-1	1.08	4.89	-0.0150	-1.4	3.3	13.67	0.0430	1.3
428-3	--	Stable	428-3	0.83	68.25	0.0040	0.5	6.0	36.95	-0.0401	-0.7
477-14	Stable	Stable	477-10	3.70	78.55	-0.0052	-0.1	1.2	0.03	0.0350	2.9
556-9	Stable	+	556-9	0.69	25.42	0.0071	1.0	8.5	1.87	-0.1889	-2.2
619-20	Stable	Stable	619-20	3.40	0.07	-0.1157	-3.4	1.1	8.59	-0.0125	-1.1
749-10	-	Stable	749-10	1.30	70.20	-0.0044	-0.3	4.9	9.39	-0.0613	-1.3
786-2	Stable	+	786-2	1.38	6.66	-0.0150	-1.1	2.4	99.99	0.0000	0.0
976-2	Stable	+	976-1	1.07	17.91	-0.0117	-1.1	4.0	28.16	-0.0350	-0.9
1249-15	Stable	Stable	1249-15	1.11	16.31	-0.0207	-1.9	5.4	20.34	-0.0638	-1.2
1253-9	Stable	Stable	1253-7	0.90	87.92	-0.0014	-0.2	5.7	7.07	-0.0859	-1.5
1257-4	--	Stable	1257-3	2.63	12.35	-0.0300	-1.1	1.5	3.04	-0.0200	-1.4
1323-1	++	++	1323-1	ND	ND	ND	ND	0.5	23.14	-0.0050	-1.0

	REMS		RRIMP	DO%				TP			
Site	MCI	ASPM	Site	median	P(%)_raw	SKSE_raw	slope(%pa)	median	P(%)_raw	SKSE_raw	slope(%pa)
240-5	-	Stable	240-5	86.8	0.00	-0.2475	-0.3	0.130	15.61	0.0012	0.9
398-1	++	++	398-1	90.2	0.13	-0.1598	-0.2	0.380	0.50	0.0081	2.1
407-1	Stable	Stable	407-1	102.5	84.54	0.0191	0.0	0.579	0.00	-0.0140	-2.4
428-3	--	Stable	428-3	101.9	32.56	-0.0429	0.0	0.032	67.44	0.0010	3.1
477-14	Stable	Stable	477-10	100.0	0.68	-0.1249	-0.1	0.008	46.76	0.0000	0.0
556-9	Stable	+	556-9	103.2	1.12	-0.1006	-0.1	0.041	2.69	-0.0008	-2.0
619-20	Stable	Stable	619-20	105.1	8.87	-0.1753	-0.2	0.015	0.07	-0.0004	-2.7
749-10	-	Stable	749-10	90.4	0.00	-0.8239	-0.9	0.107	0.93	-0.0015	-1.4
786-2	Stable	+	786-2	98.6	0.00	0.3157	0.3	0.139	0.00	-0.0027	-1.9
976-2	Stable	+	976-1	102.9	10.98	-0.0825	-0.1	0.030	96.86	0.0000	0.0
1249-15	Stable	Stable	1249-15	88.0	8.87	0.1641	0.2	0.075	3.24	-0.0010	-1.3
1253-9	Stable	Stable	1253-7	100.2	9.88	-0.0779	-0.1	0.026	61.72	0.0000	0.0
1257-4	--	Stable	1257-3	101.6	0.37	-0.1663	-0.2	0.005	29.77	0.0000	0.0
1323-1	++	++	1323-1	97.8	0.08	-0.1490	-0.2	0.070	82.42	0.0000	0.0

	REMS		RRIMP	DRP				TN			
Site	MCI	ASPM	site	median	P(%)_raw	SKSE_raw	slope(%pa)	median	P(%)_raw	SKSE_raw	slope(%pa)
240-5	-	Stable	240-5	0.068	0.02	0.0014	2.1	2.41	0.00	0.1275	5.3
398-1	++	++	398-1	0.119	0.00	0.0052	4.4	2.22	11.19	0.0159	0.7
407-1	Stable	Stable	407-1	0.519	0.04	-0.0110	-2.1	3.34	0.04	0.0342	1.0
428-3	--	Stable	428-3	0.012	32.17	0.0000	0.0	0.83	1.14	0.0050	0.6
477-14	Stable	Stable	477-10	0.004	0.02	0.0000	0.0	0.21	0.00	0.0079	3.8
556-9	Stable	+	556-9	0.010	43.11	0.0000	0.0	0.75	13.83	0.0034	0.5
619-20	Stable	Stable	619-20	0.007	0.00	-0.0003	-4.3	0.65	0.93	-0.0065	-1.0
749-10	-	Stable	749-10	0.054	60.24	0.0002	0.4	1.67	56.73	-0.0045	-0.3
786-2	Stable	+	786-2	0.110	0.00	-0.0021	-1.9	1.74	0.00	0.0248	1.4
976-2	Stable	+	976-1	0.014	4.63	0.0001	0.7	0.43	4.09	0.0032	0.7
1249-15	Stable	Stable	1249-15	0.030	99.99	0.0000	0.0	1.97	57.91	0.0025	0.1
1253-9	Stable	Stable	1253-7	0.009	0.02	0.0002	2.2	0.74	0.64	0.0045	0.6
1257-4	--	Stable	1257-3	0.002	1.27	0.0000	0.0	0.10	42.75	-0.0006	-0.6
1323-1	++	++	1323-1	0.066	28.98	-0.0001	-0.2	0.67	0.00	0.0159	2.4

REMS			RRIMP	NH_4				DIN			
Site	MCI	ASPM	Site	median	P(%)_raw	SKSE_raw	slope(%pa)	median	P(%)_raw	SKSE_raw	slope(%pa)
240-5	-	Stable	240-5	0.029	78.15	0.000000	0.0	1.930	0.00	0.1173	6.1
398-1	++	++	398-1	0.270	33.48	-0.001100	-0.4	1.260	72.15	0.0021	0.2
407-1	Stable	Stable	407-1	0.090	7.18	-0.004500	-5.0	2.950	14.54	0.0154	0.5
428-3	--	Stable	428-3	0.005	0.22	0.000000	0.0	0.665	71.38	0.0007	0.1
477-14	Stable	Stable	477-10	0.005	0.05	0.000000	0.0	0.165	0.00	0.0063	3.8
556-9	Stable	+	556-9	0.010	0.80	0.000000	0.0	0.517	11.56	0.0024	0.5
619-20	Stable	Stable	619-20	0.005	0.00	0.000000	0.0	0.508	0.03	-0.0092	-1.8
749-10	-	Stable	749-10	0.030	0.90	-0.000591	-2.0	1.114	71.59	-0.0035	-0.3
786-2	Stable	+	786-2	0.010	0.05	0.000000	0.0	1.525	0.00	0.0196	1.3
976-2	Stable	+	976-1	0.005	0.00	0.000000	0.0	0.276	4.93	0.0014	0.5
1249-15	Stable	Stable	1249-15	0.020	5.43	0.000000	0.0	1.540	99.99	0.0000	0.0
1253-9	Stable	Stable	1253-7	0.005	0.00	0.000000	0.0	0.597	0.00	0.0055	0.9
1257-4	--	Stable	1257-3	0.005	0.46	0.000000	0.0	0.019	0.02	-0.0006	-3.2
1323-1	++	++	1323-1	0.005	0.06	0.000000	0.0	0.604	0.00	0.0157	2.6