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Ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) Programme 2012 – 2014 report

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Executive summary

As part of its Environmental Indicators Programme, the Waikato Regional Council has been conducting annual surveys of aquatic invertebrates and stream habitat to document the state and trend of the ecological condition of streams and rivers in the region since 1994 (Regional Ecological Monitoring of Streams—REMS). This report presents the second complete set of results for the three-year 'rotating panel' of randomly selected sites used to assess waterway 'state' (developed land only), and also reports updated trends for sites with ten or more years of data (across a range of land uses, restoration sites, and reference condition). Results are interpreted relative to the Reference Network of 24 sites in undeveloped catchments. There are c.70 sites for which the council now has ten or more years of survey data. These include the majority of the 41 sites on developed land ('long-term sites') and the 24 in more pristine catchments ('reference sites'). Each of these sites was sampled 1 to 3 times between 2012 and 2014, depending on which network they are part of (i.e. random vs. reference vs. long-term).

The principal aims of this report were to provide an update on the 2009-2011 data reported in Collier & Hamer (2012) by:

(i) providing 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 for the years 2012-2014,

(ii) identifying **temporal trends in key invertebrate metrics at sites considered to have robust long-term data**, including an increased number of reference condition sites.

This report will also provide brief comment regarding seven additional sites recently sampled and make recommendations regarding their possible future inclusion in the REMS programme.

Based on stream monitoring between 2012 and 2014, the majority of streams on developed land are estimated to have high levels of deposited fine sediment, and little riparian vegetation (reflected by low shade and habitat scores), these are likely to be contributing factors to the observed overall poor ecological state of the regions streams, based on certain indices of ecological health. The state of the environment assessment based on invertebrate monitoring indicates that around one third of wadeable stream length on developed land was rated as 'good-excellent' and two-thirds were rated as 'fair-poor'. Based on the quantitative macroinvertebrate community index around half of the length of wadeable streams on developed land over the 2012 to 2014 period was considered to have "poor" ecological condition in any given year. Overall these results are similar to those from estimates produced from the same monitoring network sampled three years prior over 2009 to 2011.

Unbiased estimates of wadeable stream extent based on the probability survey design indicate that for, perennial, non-tidal, $\leq 5^{th}$ order streams on developed land from 2012 to 2014, 60% of target wadeable stream length was unshaded, 76% had clear water at the time of sampling, and most (73% of stream length) had fine sediment cover above threshold values for benthic macroinvertebrates. Over half of the regional stream length was classified as 'soft-bottom' for macroinvertebrate sampling, as evidenced by the high proportion of sites with little compaction, and high proportion of sand, silt, and clay substrates. On average, sites on developed land scored markedly lower for habitat assessments compared to reference sites in native forest. On streams flowing through developed land, macrophyte cover averaged 31% of the channel, while periphyton cover by long filaments and thick mats averaged 9% of substrate surfaces at the time of sampling, with 11% of wadeable stream length exceeding 25% cover by long filaments and thick mats.

Mann-Kendall statistical tests indicated that of the 30 non-reference long-term sites sampled for at least 10 years about a third showed clear ($P<0.05$) or borderline ($0.05<P<0.1$) trends over time for macroinvertebrate metrics. Of the sites showing clear trends, three were increasing in condition and eight were decreasing in condition. After false discovery rate corrections, only one long-term site, Whirinaki Stream at Corbertt Road, was considered to show a statistically significant trend. This site had improving macroinvertebrate metrics, and although the reasons for this are unclear they may be related to the effectiveness of fencing and shading in the immediate sampling reach and upstream fencing and planting.

Further exploration of sample information collected from the REMS network is planned to investigate pressure – response relationships for biological and habitat measures. This will improve our understanding of how stream ecological health responds to pressures (e.g. sediment, riparian landuse), and how reporting, tool development, efficiency, and predictive power of the network might be increased. As sampling of fish communities is now a regular part of State of the Environment monitoring at Waikato Regional Council, work is being undertaken to meld habitat, macroinvertebrate, and fish sampling data for the random network to provide a more holistic assessment of site ecology, and improve our estimates of the ecological health of streams at both regional and site scales.

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1 Introduction

As part of its Environmental Indicators Programme, the Waikato Regional Council has been conducting annual surveys of aquatic invertebrates and stream habitat to document the state and trend of the ecological condition of streams and rivers in the region since 1994 (Regional Ecological Monitoring of Streams – REMS). The history and objectives of this monitoring programme were reviewed by Collier (2005), and results up to 2011 were reported by Collier & Hamer (2012). The composition of invertebrate communities provides an integrated measure of a stream's ecological health which is influenced by local and upstream activities that affect water quality and the physical stream environment. Invertebrate community composition is condensed into metrics that can be used as indicators to report changes over time (trends) or patterns across the region (state). Similar monitoring approaches are 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 can provide a holistic and cumulative understanding of ecosystem condition, and augments other measures such as water quality (e.g., chemistry, microbes). Aspects of habitat and in-stream plant cover are assessed concurrently with macroinvertebrate collections (for details see Collier & Kelly 2005; Collier et al. 2014).

The REMS network was modified in 2005 to incorporate (i) a network of reference sites on streams in unmodified (native forest) catchments (see Collier et al. 2007), and (ii) a range of sites around the region reflecting different levels of upstream catchment development (see Collier 2005). In the sampling season 2005/06, 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. The landcover assessment (reported in Collier & Hamer 2010) was replaced in 2009 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. The first set of results on waterway 'state' derived from this design was presented in Collier & Hamer (2012).

This report presents the second complete set of results for the three-year 'rotating panel' of randomly selected sites used to assess waterway 'state' (developed land only). This report also provides updated 'trends' for sites with ten or more years of data (across a range of land uses, restoration sites, and reference condition). Results are interpreted relative to the reference network of 24 sites in undeveloped catchments A small percentage of reference 'index sites' are also 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, there are c.70 sites for which the council now has ten or more years of survey data. These include the majority of the 41 sites on developed land (long-term sites) and the 24 in more pristine catchments (reference sites). Each of these sites was sampled 1 to 3 times between 2012 and 2014, depending on which network they are part of (i.e. random vs. reference vs. long-term).

The principal aims of this report were to provide an update on the 2009-2011 data reported in Collier & Hamer (2012) by:

(iii) providing 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 for the years 2012-2014,

(iv) identifying **temporal trends in key invertebrate metrics at sites considered to have robust long-term data**, including at an increased number of reference condition sites.

This report will also provide brief comment regarding seven additional sites recently sampled and make recommendations regarding their possible future inclusion in the REMS programme.

2 Network Design

Since the inception of the REMS programme in 1994, a total of 2780 samples have been collected from 608 different sites. These sites have been sampled for various reasons over the 20 year history of the programme. There have also been variations in the timing of sample collection (although most sampling has been conducted sometime over summer months), and field protocols and laboratory processing procedures which were altered in 2002 to conform to standardised Ministry for the Environment (MfE) protocols for wadeable stream monitoring (Stark et al. 2001). Of the total of 2708 samples, 1990 samples have been collected as part of the REMS programme since 2002 using these standard protocols. Historically sites were positioned downstream of discharges, at road bridges, downstream of restoration works or based on catchment landuse. There are currently 252 sites in the network design with up to 132 sites being sampled in any one year. The sites are part of three complimentary sub-networks, the reference (24 sites, sampled annually), long-term (47 sites, with 38 sampled in any one year) and random (180 sites, with 60 sampled in any one year) monitoring networks (see Figure 1).

2.1 Reference site monitoring network

In 2005, a regional network of wadeable stream reference sites was established whose catchments were in >85% unmodified native vegetation cover (see Collier et al 2007). 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). 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).

The reference network is comprised of 24 sites that have been sampled annually since 2005. Reference sites now have ten or more years worth of data allowing trends to be analysed at all 24 sites, an increase of 21 sites since the REMS programme was reported on in 2012 (TR 2012/27; Collier & Hamer, 2012). To establish trends and determine the influence of substrate type on macroinvertebrate metric scores, three reference sites which were c. 50% soft bottomed have had concurrent samples collected from ‘hard’ (stones) and ‘soft’ (mainly wood) substrates and these results were reported in TR 2012/27 (Collier & Hamer, 2012). Since 2009, 3 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 (see Appendix 1 for analysis from Collier & Hamer (2012)). The sites are spread across management zones with 2 reference sites in the Coromandel Zone, 4 in the Waihou Piako Zone, 2 in the Lake Taupo Zone, 2 in the Upper Waikato Zone, 0 in the Central Waikato Zone, 2 in the Lower Waikato Zone, 6 in the Waipa Zone and 7 in the West Coast Zone (Figure 1; Table 1).

2.2 Long-term site monitoring network

Forty eight long-term sites were established for various reasons in the past and include 10 sites that continue to be sampled as non-wadeable sites using appropriate methods for these sites (i.e. sampling a stony riffle or macrophytes from the bank). The 10 non-wadeable sites have been maintained as part of the network because they generally have both, flow and water quality monitoring data as well (Table 1).The remainder of the 38 sites are wadeable and have been sampled in a consistent manner using the MfE protocols of Stark et al. (2001). Data from 41 long-term sites are presented in this report, with the focus on 30 sites which have been sampled at least 10 times between 2002 and 2014, (Table 1). Sixty-eight percent of long-term sites are hard bottomed and

32% are soft bottomed waterways. A number of sites have regular water quality monitoring undertaken at or nearby the site as outlined in Tulagi (2014), or are near flow recorder sites (Table 1). In total long-term trend sites are spread across management zones with 4 current long-term sites in the Coromandel Zone, 11 in the Waihou Piako Zone, 1 in the Lake Taupo Zone, 5 in the Upper Waikato Zone, 3 in the Central Waikato Zone, 2 in the Lower Waikato Zone, 6 in the Waipa Zone and 11 in the West Coast Zone (Figure 1; Table 1).

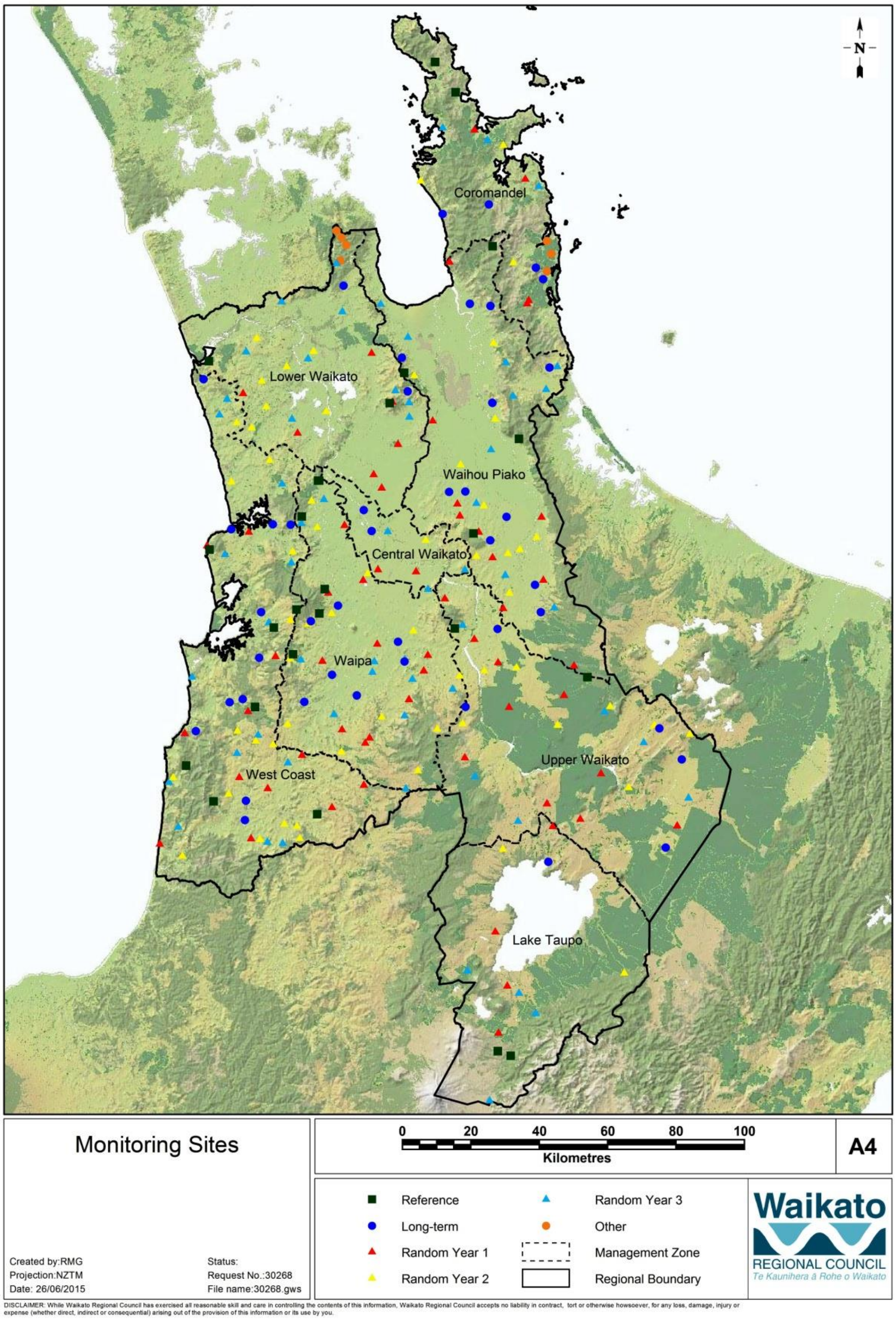

Figure 1. Map of the region showing long-term, reference and random sites sampled during summer over 2011 – 2014.

2.3 Additional sites

Four sites, previously in the Auckland region, have been included in this report, as have three sites previously monitored by NIWA in the Coromandel (Figure 1; Table 1). These sites are shown in Figure 1 as “other” and are treated separately to other long-term and reference sites in the analysis. The additional sites located in the Hunua ranges were monitored by Auckland Council from 2004 up until a recent boundary change placed the sites into the Waikato Region. Until 2014, these sites were sampled using the same collection protocol as used by Waikato Regional Council, however the invertebrate samples were processed using P1 instead of P2 protocols (as used by Waikato Regional Council; Stark et al., 2001). For the purpose of this report, these sites are assessed regarding their possible inclusion in the REMS programme in the future. Three plantation forestry sites in the Coromandel were also sampled in 2013 and 2014 in conjunction with NIWA. These three sites have been sampled since 1993 by NIWA for a forestry company and this long-term dataset was considered important enough to be continued, as the NIWA monitoring was to end. It was decided that Waikato Regional Council and NIWA would sample the sites together for three years (2013 – 2015) to calibrate the differing sampling protocols employed by NIWA and Waikato Regional Council, due to the different purposes of the two monitoring programmes (i.e. effects based and SOE reporting, respectively). NIWA sampling differed from Waikato Regional Council methods in that it consisted of 5 Surber samples collected from run habitats and pooled into one sample per site, all invertebrates counted until 2002 and P2 protocols from Stark et al. (2001) were used from 2003 onwards (Wright-Stow & Quinn 2011. As the sampling for the three year comparison was completed during the 2015 sampling period, these results will be reported at a later date. Given the length of this dataset, it is likely that they will be included into the long-term monitoring network to provide additional plantation forestry sites in the dataset.

Table 1: Description and location of 41 long-term (black text), 24 reference (green text) and 7 ‘Investigation’ (blue text) invertebrate monitoring sites sampled up to 2014. In the Site code column, H = Hard bottom samples collected; S = Soft Bottom sample collected; NW = non-wadeable; WQ = RERIMP water quality monitoring sites reported on by Tulagi (2014); F = flow monitoring site; CI = Coromandel forestry investigation site; AI = Auckland Council monitoring site now in the Waikato region. Easting and Northing units are NZTM. Integrated Catchment Management (ICM) management zones, REC group relates to Climate class/Source of flow/Geology class (Snelder & Biggs 2002). FENZ groups from Leathwick et al (2010). Percent native vegetation cover upstream based on the LINZ LCDB4 GIS layer. Years sampled shows the total number of years the site has been sampled and the number of years sampled in a consistent way using the MfE protocols outlined by Stark et al (2001).

Site Code	Waterway	Location	Easting	Northing	ICM ZONE	REC GROUP	FENZ Group (100/250)	% Native Vegetation Upstream	Years Sampled (with MfE protocols/Total)
Long-term Sites									
1300_2 S, WQ	Whangamata Stm	Kinloch	1853536	5717011	Lake Taupo	CW/H/VA	17/45	6	13/17
1323_1 H, WQ	Whirinaki Stm	Corbett Rd	1885583	5755559	Upper Waikato	CW/H/VA	17/45	23	12/17
220_1 H	Kaiwhitwhiti Stm	Tiverton Downs	1887414	5721104	Upper Waikato	CW/H/VA	17/45	3	10/15
240_5 S, WQ	Kawaunui Stm	SH5 Bridge	1891999	5746560	Upper Waikato	CW/H/VA	17/45	18	12/16
495_1 H	Mangawhio Stm Trib	Taupaki Rd	1829692	5761934	Upper Waikato	CW/H/VA	19/54	55	9/13
786_2 H, NW, WQ, F	Pokaiwhenua Stm	Arapuni Rd	1838866	5784259	Upper Waikato	CW/L/VA	28/83	5	13/19
398_1 S, WQ	Mangakotukutuku Stm	Peacockes Rd	1802507	5812574	Central Waikato	WW/L/M	12/31	2	13/18
398_6 H	Mangakotukutuku Stm	Pelorus Street	1801962	5811272	Central Waikato	WW/L/SS	12/33	2	7/12
47_2 S	Bankwood Stm	Emerald Tce	1800251	5818671	Central Waikato	WD/L/M	12/31	9	13/18
453_8 H, WQ, F	Mangatangi River	Stubbs Rd	1794438	5883474	Lower Waikato	WW/L/HS	11/30	70	12/17
481_11 H, WQ, F	Mangawara Stm	Mangawara Rd	1812968	5853028	Lower Waikato	WW/L/HS	18/47	52	11/15
1253_8 S, NW	Waitomo Stm	Waitomo Valley Rd	1791116	5771047	Waipa	WW/L/VA	28/83	30	11/17
1253_9 S, NW, WQ, F	Waitomo Stm	Tumutumu Rd	1783079	5763172	Waipa	WW/L/VA	30/90	37	11/16
1284_1 H	Whakarautawa Stm	Mangati Rd	1784994	5786442	Waipa	CX/H/VA	5/11	85	12/17
476_1 H, WQ	Mangatutu Stm	Lethbridge Rd	1812017	5774875	Waipa	CW/L/VA	30/90	57	9/14
477_5 H	Mangauika Stm	Mangauika Rd	1792790	5791054	Waipa	WW/L/VA	19/56	54	11/17
493_1 S	Mangawhero Stm Trib	Mangawhero Rd	1798239	5765080	Waipa	WW/L/VA	11/26	1	9/14
1257_4 H, WQ	Waiwawa River	U/S Toranoho Stm	1836201	5906962	Coromandel	WW/L/VA	3/6	99	13/18
954_5 H, WQ, F	Tapu River	Tapu-Coroglen Rd	1822967	5904237	Coromandel	WW/L/VA	2/4	94	9/10
1043_1 S	Toenepi Stm	Tahuroa Rd	1824850	5823912	Waihou Piako	WD/L/VA	12/33	0	13/18
1055_3 H	Torehape Stm	Torehape West Rd	1811289	5862707	Waihou Piako	WW/L/HS	18/47	51	12/18
1158_7 H	Waimakariri Stm	Waimakariri Rd	1851341	5789140	Waihou Piako	WW/H/VA	11/26	56	9/14

Site Code	Waterway	Location	Easting	Northing	ICM ZONE	REC GROUP	FENZ Group (100/250)	% Native Vegetation Upstream	Years Sampled (with MfE protocols/Total)
1174_10 S, NW, WQ	Waiomou Stm	Waiomou Rd	1849703	5797037	Waihou Piako	WW/H/VA	28/83	45	13/18
1249_15 S, NW, WQ, F	Waitoa River	Landsdowne Rd	1841469	5816735	Waihou Piako	WW/L/VA	28/83	1	13/18
1252_3 H	Waitoki Stm	Rawhiti Rd	1837312	5849643	Waihou Piako	WW/L/VA	20/59	21	10/16
23_2 H	Apakura Stm	Puriri Valley Rd	1836860	5877653	Waihou Piako	WW/L/VA	20/59	65	9/14
433_2 H	Mangapapa Stm	Henry Watson Rd	1836777	5809924	Waihou Piako	WW/L/VA	11/26	28	13/18
531_4 H	Matatoki Stm	Matatoki Rd	1830950	5878339	Waihou Piako	WW/L/VA	23/71	51	9/14
619_20 H, WQ, F	Ohinemuri River	SH25 Bridge	1853801	5859777	Waihou Piako	WW/L/VA	11/26	38	11/16
749_10 S, NW, WQ, F	Piako River	Kiwitahi	1829552	5824019	Waihou Piako	WW/L/VA	28/83	15	13/18
1172_6 H	Wainui Stm	Wainui Reserve	1761922	5813014	West Coast	WW/L/VA	3/6	72	13/19
195_1 H	Huriwai Stm	Waikaretu Rd	1754069	5856542	West Coast	WW/L/SS	18/49	21	11/16
256_2 S, NW	Kiritihere Stm	Mangatoa Rd	1751731	5754796	West Coast	WW/L/HS	23/74	88	12/17
36_1 H, F	Awaroa River	Hauturu Road	1770096	5775917	West Coast	WW/L/HS	30/88	54	12/17
365_1 H	Mangahoanga Stm	Moerangi Rd	1770643	5789129	West Coast	WW/L/SS	18/49	55	9/14
413_2 H	Mangaokahu Stm	Cogswell Road	1779188	5814377	West Coast	WW/L/HS	18/49	87	9/15
428_3 H, NW, WQ	Mangaotaki River	SH3 Br	1766255	5734611	West Coast	WW/L/VA	28/83	16	12/17
514_1 H	Marokopa Stm	Te Anga Rd	1765321	5764013	West Coast	WW/L/VA	30/88	61	9/14
556_9 H, NW, WQ, F	Mokau River	Totoro Rd	1765761	5729010	West Coast	WW/L/VA	30/92	17	12/17
736_2 H	Parawai Stm	Ohautira Rd	1774020	5814517	West Coast	WW/L/HS	23/70	10	11/13
976_2 H, NW, WQ	Tawarau River	Speedies Rd	1761522	5762908	West Coast	WW/L/VA	30/88	50	13/17
Reference Sites									
1051_4 H	Tongariro River Trib	Tree Trunk Gorge	1842636	5660936	Lake Taupo	CX/M/HS	16/44	91	10/10
458_1 H	Mangatawai Stm	U/S SH1	1838912	5662264	Lake Taupo	CX/M/VA	65/186	60	12/16
1888_4 H	Otautora Stm	Akatarere Rd	1826451	5784438	Upper Waikato	CW/H/VA	19/55	99	10/10
555_2 H&S	Mokaihaha Stm	Galaxy Road	1864718	5770433	Upper Waikato	CW/H/VA	11/26	97	10/10
1132_67 H	Waikato River Trib	Port Waikato	1755512	5861701	Lower Waikato	WW/L/SS	18/49	90	10/10
1961_1 H	Mangatea Stream Trib	Mangatea Rd	1807721	5849573	Lower Waikato	WW/L/HS	18/47	87	10/10
125_15 H	Firewood Creek Trib	Off Walkway	1787051	5827170	Waipa	WW/L/HS	18/47	99	10/10
1966_1 H	Purangirangi Stream	Oamaru Road	1779813	5776998	Waipa	WW/L/HS	19/56	98	10/10
1968_1 H	Whakakai Stream	Research Stn	1782350	5816843	Waipa	WW/L/HS	11/30	100	10/10

Site Code	Waterway	Location	Easting	Northing	ICM ZONE	REC GROUP	FENZ Group (100/250)	% Native Vegetation Upstream	Years Sampled (with MfE protocols/Total)
379_1 H	Mangakara Stm	Bushline	1788985	5795826	Waipa	CW/H/VA	19/55	83	10/10
477_14 H, WQ	Mangauika Stm	U/S Weir	1787392	5788746	Waipa	CX/H/VA	5/11	97	13/18
474_2 H	Mangatu Stm	Mangatu Rd	1826765	5939438	Coromandel	WW/L/SS	20/60	97	10/10
9_4 H	Ahirau Stm	Port Charles Rd	1820809	5947839	Coromandel	WW/L/HS	1/1	98	10/10
1962_1 H	Waiwhata Stream	Ohinewai Road	1811877	5858344	Waihou Piako	WW/L/HS	18/47	84	10/10
234_28 H, WQ	Kauaeranga River	U/S from Road End	1837446	5894967	Waihou Piako	CW/H/VA	18/49	100	11/11
754_20 H	Piakonui Stm Trib	Piakonui Road	1831880	5811927	Waihou Piako	WW/L/VA	11/27	99	10/10
781_2 H	Pohomihi Stm	U/S MPDC Intake	1845033	5839251	Waihou Piako	WW/L/VA	19/54	100	10/10
1414_1 H	Omanawa Stm Trib	Pirongia West Rd	1780796	5789915	West Coast	CX/H/VA	54/156	100	13/18
1513_3 H	Te Rekereke Stm	Karioi at Papanui	1755682	5807255	West Coast	WW/L/VA	3/6	77	10/10
1965_1 H&S	Waikuku Stream	Te Kauri Lodge	1774267	5784726	West Coast	WW/L/VA	20/59	75	10/10
1969_1 H	Mangawhata Stream	Puhunga Road	1786807	5730780	West Coast	WW/L/SS	20/59	98	10/10
1971_1 H&S	Mangapohue Stream	Te Anga Rd	1768833	5761760	West Coast	WW/L/VA	20/61	100	10/10
33_16 H, WQ	Awakino River	Gribbon Road	1756873	5734495	West Coast	CX/H/HS	16/42	99	11/11
471_2 H	Mangatoa Stm	Mangatoa Rd	1748948	5744787	West Coast	WW/L/HS	18/48	100	10/10
Additional Sites									
145_2 H, CI	Gumdigger Gully Stm	NIWA Report 14	1853130	5896393	Coromandel	WW/L/VA	22/65	4	2/11
1101_7 H, CI	Wahitapu Stm	NIWA Report 8	1854438	5892794	Coromandel	WW/L/VA	22/65	0	2/11
977_4 H, CI	Tawatawa Stm	NIWA Report 9	1853081	5887611	Coromandel	WW/L/VA	22/65	30	2/11
3103_1 H, AI	Konini Stream	Rata Ridge Track	1795198	5895283	Lower Waikato	WW/L/HS	18/47	100	10/10
3104_1 H, AI	Milnes Stream	Mangatangi Hill Rd	1793462	5890730	Lower Waikato	WW/L/HS	18/47	100	11/11
460_35 H, AI	Mangatawhiri Trib	St Pauls	1792356	5899357	Lower Waikato	WW/H/HS	18/47	16	10/10
460_36 H, AI	Mangatawhiri Trib	Mine Rd	1793861	5897352	Lower Waikato	WW/H/HS	18/47	100	10/10

Footnote: Red text show where site numbers don't correspond exactly the following water quality (WQ) or flow recording (F) sites are considered applicable to the long-term REMS sites: 1300_2 = 1300_1 (WQ), 1257_4 = 1257_3 (WQ); 1249_15 = 1249_38 (F); 1253_9 = 1253_7 (WQ), 1253_3 (F); 477_14 = 477_10 (WQ); 976_2 = 976_1 (WQ); 453_8 = 453_6 (WQ,F); 481_11 = 481_7 (WQ), 481_2 (F); 1174_10 = 1174_4 (WQ); 476_1 = 476_7 (F), 33-16 = 33_6(WQ), 234_28 = 234_11 (WQ) .

2.4 Random site monitoring network

This survey design was first implemented by Waikato Regional Council in 2009 and the first complete set of results was presented in Collier and Hamer (2012). The description of this network is described below (reproduced from the previous report), including an explanation of minor changes which were required during the 2012-2014 survey period. A comparison of monitoring network designs can also be found in Collier & Olsen (2013).

The 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 (https://www.nemi.gov/methods/sams_method_summary/11950/). 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 by an unknown quantity. A key benefit of this type of 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. 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).

In the first round of sampling, between 2009-11, potential sites were screened and defined as non-target if they were non-wadeable, non-perennial, drained catchments entirely in native forest (already represented by the reference network), or represented non-target habitats (e.g. lakes, wetlands) or sample frame inaccuracies (see Appendix 1 for estimated network lengths). Candidate sites were initially screened initially using aerial photos to determine whether they could form part of the target population. A total of 491 sites were screened to arrive at 228 target sites, of which 48 were not sampled mainly because of access difficulties. Sixty target sites are sampled each year on a rotating 3-yearly basis. This provides 180 samples from 180 different sites over a given three year period, originally 2009-11, and then these same 180 sites were sampled again over 2012-14 (Figure 2). Estimated target and non-target 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).

Minor variations to the survey network have been implemented between the two three year rotations (i.e. 2009-2011 and 2012-2014). This was due to two sites being inaccessible as a result of land owner permission issues, and one site being dry between 2012 and 2014. If these sites remain inaccessible or dry in the upcoming three yearly rotation (i.e. 2015 to 2017) they will be replaced by the next suitable randomly selected site. These temporary small reductions in sample size do not affect the robustness of the network, as the number of sites selected provides resilience to occasional missing sites. A fourth site, 796_9, on a tributary of the Pouraureroa Stream is no longer in the Waikato Region due to a political boundary change. This site has subsequently been replaced by site 2098_1 a tributary of the Maire Stream, which was the next suitable (target) site on the list of random sites generated in 2009. For use in this report extent estimates for 2009-2011 have been recalculated for the reduced data set of 179 sites, to exclude 796_9 (i.e. 59 sites in 2010; Appendix 1). Due to this site change there are minor changes to the estimated lengths of stream types in Table 2, when compared to those reported in Collier and Hamer (2012).

Table 2: Estimated target and non-target river network lengths (km; SE in parentheses) represented by target and non-target (excluded) sites from the random monitoring network for each year and combined years (based on sites forming the network 2012 – 2014). Length is calculated using the R package 'spsurvey' by adjusting site values for their probability of selection based on the REC sample frame.

	Year 1 (n=60)	Year 2 (n=60)	Year 3 (n=60)	Combined (n=180)
Target				
Sampled	16728 (1357)	11684 (958)	10415 (955)	12506 (623)
Inaccessible	3151 (699)	2763 (565)	3073 (562)	2978 (376)
Other	0 (0)	0 (0)	125 (104)	39 (36)
Dry	0 (0)	0 (0)	181 (163)	78 (69)
Total	19879 (1328)	14447 (965)	13794 (773)	15601 (590)
Non-target				
Reference	6766 (1174)	6628 (1033)	7124 (1183)	6862 (605)
Non-wadeable	3297 (698)	3249 (401)	2682 (570)	3091 (306)
Tidal	248 (150)	90 (76)	181 (147)	184 (83)
Drain	1111 (548)	870 (355)	1723 (558)	1247 (286)
Dry	2469 (827)	4753 (905)	8975 (1184)	5625 (617)
Lentic	460 (298)	2151 (611)	1269 (570)	1394 (313)
Wetland	1885 (797)	4163 (1058)	1326 (622)	2567 (493)
Network inaccuracy[1]	1548 (803)	1084 (559)	590 (393)	1015 (324)
Boundary change	0 (0)	230 (195)	0 (0)	78 (69)
Total	17785 (1313)	23217 (1282)	23870 (1333)	22063 (759)
Total				37664

[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).

3 Methods

3.1 Sample collection and data compilation

Prior to 2002, field sampling protocols differed from those used currently, notably in terms of habitats sampled, net mesh size and minimum number of invertebrates counted. From 2002, macroinvertebrate data were collected in line with Ministry for the Environment protocols as described by Stark et al. (2001) and refined for the Waikato region by Collier & Kelly (2005). Change from earlier protocols involved focussing on hard- or soft- bottom habitats at particular sites, use of a coarser mesh size for the sampling net (from 0.25mm to 0.5mm), increasing the fixed count from 100 to 200+ individuals (and recording of rare taxa; P2), and increasing the level of taxonomic resolution (notably for Chironomidae). MCI tolerance values for all sites and over time period are based on those presented in Table 1 of Stark & Maxted (2007). Collier et al. (2005) discusses the implications of these changes for assessing long-term trends. Although some sites have data collected prior to 2002, we have chosen to present data for sites with 10 or more sampling occasions but only undertake trend analysis for sites with 10 sampling occasions or more using the Stark et al. (2001) methods for reasons discussed below.

Five metrics are calculated from sorted and identified macroinvertebrate samples: EPT* richness, %EPT* abundance, the Macroinvertebrate Community Index (MCI), the quantitative MCI (QMCI), and the Average Score Per Metric (ASPM) which is an aggregation of the two EPT metrics and MCI benchmarked to reference condition (Table 3) in a particular year (see Collier 2008). The acronym EPT refers to the sensitive groups Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). Mertics derived from EPT 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 Table 1 of Stark & Maxted (2007), except for *Dolomedes* which have traditionally been omitted from calculations by Waikato Regional Council. For taxa with no score listed the score at the next taxonomic level up was used, where these were available, otherwise taxa were excluded from MCI and QMCI calculations.

For long-term data collected prior to 2002, Chironomidae taxa were not differentiated and the combined chironomid taxon was allocated a tolerance score of 2 but after 2002 greater taxonomic resolution of Chironomidae was used. As described above, 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 mean of the annual maximums over 2005-14 was used because few reference sites had been sampled (Table 3).

Table 3: Maximum values from reference sites that were used in ASPM calculations. The average annual maximum was used for 2002-2004 as relatively few reference sites were sampled. The same applies for 1994-2001, except for EPT* taxa which was multiplied by 0.68 to take account of the 100 invertebrate count sorting procedure used (see Collier & Hamer 2012).

Year	EPT* taxa	%EPT*	MCI
1994 - 2001	15	94	151
2002 - 2004	22	94	151
2005	22	91	153
2006	23	96	161
2007	20	94	152
2008	21	93	148
2009	24	96	150
2010	21	93	151
2011	25	97	149
2012	21	94	149
2013	22	97	156
2014	20	89	138

Soft-bottom or hard-bottom MCI and QMCI values were calculated based on the sampling protocol used at individual sites, and scores were then assigned to the degradation classes listed in the MCI user guide (Table 4; Stark & Maxted 2007). Hard-bottomed MCI scores were used in the ASPM calculation for all sites as there was not enough Soft-bottomed reference site data to compare to.

Table 4: Interpretation of MCI-type biotic indices (Transcribed from Stark & Maxted, 2007)

Stark & Maxted (2004, 2007) quality class	Stark (1998) descriptions	MCI MCI-sb	SQMCI & QMCI SQMCI-sb & QMCI-sb
Excellent	Clean water	> 119	> 5.99
Good	Doubtful quality or possible mild pollution	100 – 119	5.00 – 5.90
Fair	Probable moderate pollution	80 – 99	4.00 – 4.99
Poor	Probable severe pollution	< 80	< 4.00

At sites where both hard and soft bottom samples were collected (i.e. sites that were approximately half soft and half hard bottomed), the sample types were analysed for trends separately. At index sites, where 2 samples were collected in any one year the 2 metric scores were averaged to give one value for that site in that year. Interim quality classes for ASPM follow the same narrative descriptions as those for MCI, and are respective values the same as those used in Collier & Hamer (2012) which were derived from the average annual mean reference score for 2005-2011 data; “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 little is known of what to expect in unmodified low-gradient soft-bottom streams which are now only present in highly developed landscapes.

The current qualitative habitat assessment method has been conducted on most occasions since 2005 (Collier 2005) (corresponding to 80% of macroinvertebrate samples reported on here). Long-term trends in habitat quality can be investigated for sites sampled annually since 2005 (at least 10 years). At present this equates to 12 long-term sites and 23 reference sites. 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) (see Collier & Kelly 2005). Reference sites average 149 and non-reference long-term sites 106 since 2005, while random sites on developed land have averaged 94 over the 2009-2014 (the period they have been monitored for). 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, 2014). 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). A number of physical habitat assessments are also made including measuring channel width and a substrate assessment of 100 streambed particles although prior to 2009 a rapid bankside % estimate of streambed substrate was made.

3.2 Statistical analyses

3.2.1 Trend analysis (long-term & reference sites)

Trend analysis was only applied to currently sampled sites where macroinvertebrate monitoring had ≥10 years of data and samples were collected using the consistent methodologies of Stark et al (2001; i.e. 2002 to 2014). We inferred likely trends in metric data with the Mann-Kendall trend test (Helsel et al. 2006), using TimeTrends software (version 5; 2014). Statistically significant trends were identified at P <0.05 and borderline trends were inferred where P values fell between 0.05 and 0.1. This analysis was followed by False Discovery Rate (FDR) controlling procedures to remove any Type 1 errors following Stark & Maxted (2007). Any trends after the FDR were interpreted as clear (i.e. true rejection of the null hypothesis) and not due to chance alone. Trends of long-term restoration sites where riparian management had been implemented are not specifically included in this report but are reported on in Stansfield & Van der Zwan (2015).

A statistically significant trend may be detected but the magnitude of change in metric values over time may be small and within the range of variation encountered naturally. Collier (2006) and Stark & Fowles (2006) raised this issue of ecological relevance versus statistical significance of observed trends. As a basis for inferring ecological relevance of statistically significant trends at non-reference sites, Collier & Hamer (2012) estimated that this equated to changes of 15% for MCI and 12% for ASPM scores. For both metrics, in this report 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, it was necessary to adjust the data for the known probability of site selection, rather than being a simple random sample. This adjustment enabled calculation of an unbiased estimate of stream length represented by particular metric values for the target population of streams. Standard error (SE) estimates were based on the local neighbourhood method described by Stevens & Olsen (2003). Tables in Appendix 2 show the summary statistics (including percentile outputs) for physical habitat and macroinvertebrate metrics, cumulative distribution plots of metrics against regional stream length are also provided in Appendix 2.

4 Results & Discussion

4.1 Ecological state (random sites)

4.1.1 Physical characteristics

Wadeable stream channels on developed land sampled over the summer months between 2012 – 2014 (random site network), averaged around 5m in width with water occupying about half the active channel at the time of sampling (i.e., channel width:wetted width ratio about 2.5; Table 5). Based on categorical observations, 60% of wadeable stream length on developed land in the Region can be considered as having no overhead shade with around 10% having riparian vegetation that provided full shade. Stream water was mostly clear (c. 75% overall), and estimates varied slightly between 2012 and 2014, possibly reflecting antecedent flow conditions (71 to 81% of stream length was 'clear'; Table 5). Streambed substrates are estimated to be dominated on average by fine particles (>50%), although this appeared to vary between years and was likely related to the level of compaction (substrates at >70% of streams were estimated to be either loose or completely unpacked; Table 5) and embeddedness (>50% of streams were recorded as being covered by >50% fine sediment; Table 5). A slightly greater proportion of stream length was consequently sampled using soft, as opposed to hard-bottom macroinvertebrate protocols. Previous monitoring designs, prior to 2009, not involving random selection have tended to sample a higher proportion of hard bottomed streams, thereby potentially not providing an accurate assessment of stream habitat and condition at a regional scale.

In other studies, deposited fine sediment (measured both as embeddedness, and as percent sand/silt/clay) has been shown to be related with macroinvertebrate communities by reducing instream habitat. Burdon et al. (2013) demonstrated that fine sediment cover of greater than 20% of the stream bed is correlated with a rapid decline in sensitive macroinvertebrate taxa. Vegetated riparian buffer zones play a key role in stream ecosystems, including regulation of organic matter inputs, water temperature, shade, and instream plant growth (Collier et al. 1995). Based on our monitoring network the majority of streams on developed land are estimated to have high levels of deposited fine sediment, and little riparian vegetation (reflected by low shade and habitat scores). These parameters are likely to be contributing to the overall poor ecological state of the regions streams on developed land in terms of QMCI (Figure 3), although further interrogation of the data may be needed to more conclusively elucidate these relationships for the present monitoring network.

Habitat quality scores were fairly consistent across years, as was the extent of macrophyte cover and channel clogginess; native macrophyte species were poorly represented in terms of cover (<5% overall; Table 5). 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 2). Shade and habitat quality scores were considerably higher at reference sites than on developed land, while percent sand/silt/clay, macrophyte and periphyton cover were much lower at reference sites (Table 5). The overall difference in physical characteristics between streams on developed land compared to reference condition highlights the changes that land development has had on the region's streams. It also partially reflects the fact that all reference sites are located on hill-country streams in native forest, as reference condition sites for lowland streams in the Waikato region no longer exist. These results are generally similar to those presented for 2009-2011 (Collier & Hamer 2012).

Table 5: Mean (SE) regional percentage estimates of characteristics for wadeable streams on developed land based on the probability survey design analysis for (A)

categorical classifications expressed as % of wadeable stream length (proportions); and (B) continuous variables (averages). Reference site data are shown as % of samples for categorical variables and absolute values for continuous variables.

Variable	Category	2012 (n=58)	2013 (n=59)	2014 (n=59)	Combined (n=176)	Reference Samples
A. Categorical habitat variables						
Shade	None	67.2 (5.8)	61.9 (5.6)	41.4 (6.4)	57.7 (3.8)	4.2
	Partial	22.1 (5.6)	27.3 (5.1)	51.9 (6.6)	32.6 (3.6)	16.9
	Full	10.7 (3.3)	10.8 (4.6)	6.7 (2.5)	9.7 (2.3)	78.9
Turbidity	Clear	75.2 (4.9)	71.4 (5.6)	81.4 (5)	75.7 (3.1)	98.6
	Slight	21 (4.9)	10.3 (3.1)	12.6 (4.6)	14.5 (2.4)	1.4
	High	3.9 (1.5)	10 (4.3)	2.1 (1.3)	5.6 (1.6)	0
	Stained	0 (0)	8.2 (4.4)	4 (1.8)	4.2 (1.7)	0
Compaction (packing of substrate)	Tight	9.4 (3.5)	1.6 (1)	3.1 (1.5)	4.8 (1.4)	26.8
	Moderate	12.2 (4.3)	19.8 (5.1)	28.3 (5.9)	20.1 (3.0)	49.3
	Loose	30.0 (6.4)	26.7 (5.4)	36.9 (6.3)	30.9 (3.3)	22.5
	None	48.4 (6.8)	51.9 (6.1)	31.7 (6.6)	44.2 (3.6)	1.4
Embeddedness (cover by fine sediment)	<5%	6.7 (3.1)	6.4 (3.6)	6.7 (2.7)	6.8 (1.9)	45.1
	5-25%	19 (5.3)	17.5 (4.3)	22.7 (5.8)	19.6 (3)	29.6
	26-50%	9.9 (3.9)	19.8 (4.9)	22.8 (5.7)	17.9 (2.9)	19.7
	51-75%	15.5 (4.6)	18.6 (4.8)	9.7 (3.2)	14.6 (2.6)	5.6
	>75%	48.9 (6.3)	37.7 (6.1)	38 (7)	41.1 (3.5)	0
Sampling method	Hard (H)	26.4 (5.9)	42.9 (5.6)	53 (6.2)	41.1 (3.3)	91.7
	Soft (S)	68.8 (6.2)	51.9 (5.7)	42.4 (6.8)	54.3 (3.5)	0
	H+S	4.8 (2.5)	5 (2)	5 (4)	4.6 (1.6)	8.3
B. Continuous habitat variables						
Percent sand/silt/clay		63.7 (4.9)	58 (4)	48.1 (5.4)	56.4 (2.6)	14.4
Channel width:wetted width		1.8 (0.1)	3.1 (0.5)	1.8 (0.1)	2.3 (0.2)	1.9
Habitat quality score		98.3 (3.5)	88.3 (3.3)	95.4 (3.9)	94.3 (2.1)	146.4
Macrophyte total cover (%)		25.3 (4)	32.2 (4.4)	35 (5.5)	30.6 (2.7)	0.2
Macrophyte channel clogginess (%)		24.2 (3.9)	31.4 (4.3)	32.6 (5.4)	29.2 (2.6)	0
Macrophyte native cover (%)		3.3 (1.1)	4 (0.9)	8.1 (2.3)	4.9 (0.9)	0
Periphyton proliferation index		8.5 (1.5)	9.8 (1.8)	7.9 (1.7)	8.7 (1.1)	1.8
Periphyton slimyness index		10.7 (2)	11.2 (1.6)	11.2 (1.5)	11 (1)	4.7

4.1.2 Macroinvertebrate condition metrics

Cumulative distribution functions for the two invertebrate state metrics, QMCI and ASPM, are shown in Figure 2 (see Appendix 2 for percentile values). The estimated median QMCI and ASPM values for target wadeable streams on developed land in the Region are 3.9 and 0.39, respectively. For MCI, the estimated median value was 98 (hard and soft bottom as appropriate). While for EPT taxa, invertebrates sensitive to pollution, median EPT* richness (number of EPT taxa present) was 6.7, the %EPT* (proportion of individuals in sample) was 17.3, the median number of taxa present at sites was estimated to be 22 (Appendix 2).

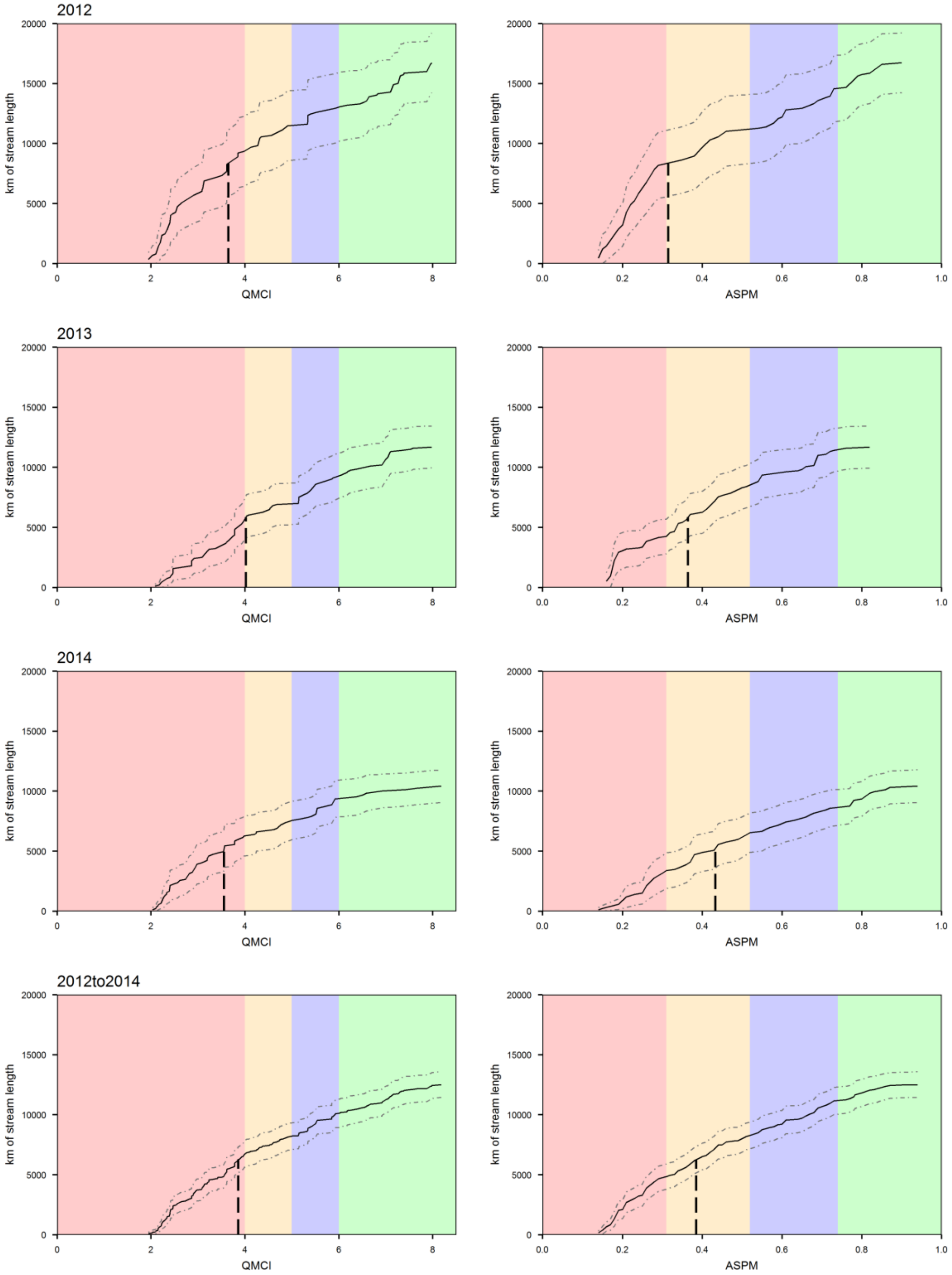

Figure 2: Cumulative frequency distributions for QMCI and ASPM based on sites sampled in 2012, 2013, 2014, and all sites 2012 to 2014. Solid lines indicate estimated stream length, grey dotted lines indicate upper and lower 95th percentiles. Dashed vertical lines indicate median values. Coloured bands indicate poor, fair, good, and excellent quality classes (red through to green).

The proportion of stream length in each condition class for QMCI and ASPM (interim classes only) varied among years and partly reflected differences in the percentage of soft-bottom streams sampled in any given year, although QMCI class designations took this into account. When estimated for each individual year, proportional QMCI estimates over 2012-14 rated 10-23% of wadeable stream length (non-tidal, perennial) on developed land as ‘excellent’, 9-19% as ‘good’, 11-13% as ‘fair’, and 47-60% as ‘poor’ (Figure 3). Across all three years combined (2012 to 2014 summers), 65 % of the region’s wadeable stream length on developed land was estimated to be in a fair-poor ecological condition based on the QMCI scores of their macroinvertebrate communities. Similar results are also found for the ASPM scores. Based on the interim ASPM condition classes across all three years, which are relative to reference condition (presented in Collier & Hamer 2012), 11% fall into the 'excellent' class, 23% into the 'good' class, 28% into 'fair' class, and 38% into the 'poor' class.

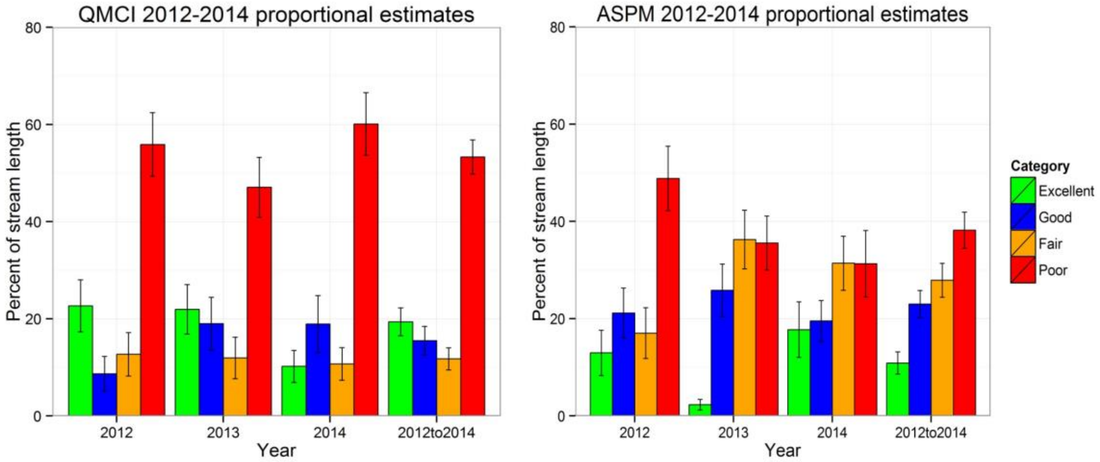

Figure 3: Mean (±1 SE) percent of stream length falling into four environmental condition classes for QMCI and interim classes for ASPM based on sites sampled in 2012, 2013, 2014, and all sites 2012 to 2014. QMCI classes reflect calculations of hard-bottom or soft-bottom metrics as appropriate. The ASPM classes are interim because it uses the hard-bottom MCI and is benchmarked against hard-bottom reference sites.

Based on both metrics used to assess state, around one-third of target wadeable stream length on developed land defined by the REC network layer was rated as good-excellent and two-thirds were rated as fair-poor. This pattern appears to be relatively consistent across every three year rotation completed since 2009 (Figure 4). Results presented for the period 2009 to 2011 (Collier & Hamer 2102), identified that 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 currently underway to determine the relative importance and interaction of these factors.

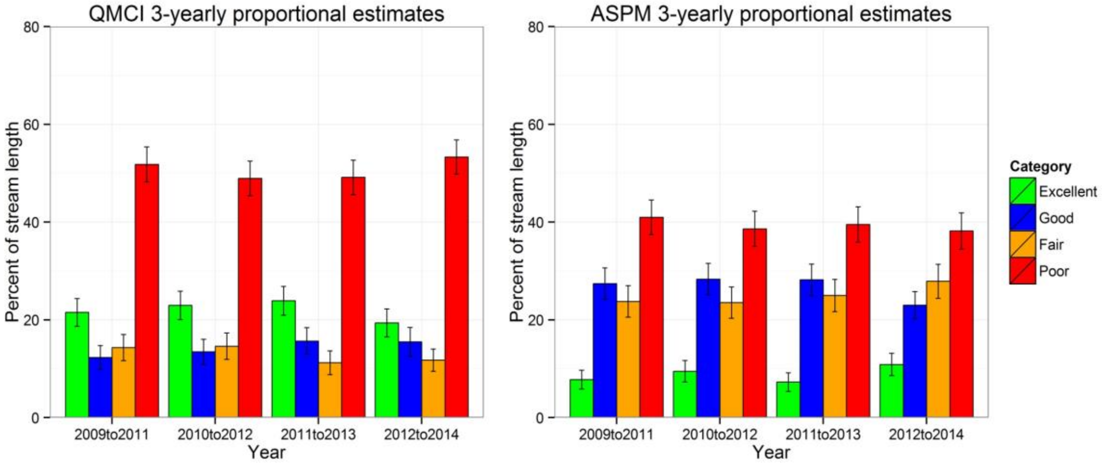

Figure 4: Mean (±1 SE) percent of stream length falling into four environmental condition classes for QMCI and interim classes for ASPM, presented for each complete rotation from 2009 to 2014. QMCI classes reflect calculations of hard-bottom or soft-bottom metrics as appropriate. The ASPM classes are 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

When analysed for the last 10 years (since 2002) neither of the macroinvertebrate metrics used to investigate trends, MCI and ASPM, showed any trend when all the long-term sites on developed land were grouped together. There was a negative trend, however, with regard to MCI at reference sites based on the regional Mann-Kendall test (Table 6; Figure 5). This relates to reduction of 5 MCI units at reference sites overall, over the 10 year period from 2005 – 2014. While it is of some concern that reference sites appear to exhibit a statistical decline in MCI scores overall, this decline is lower than that required to be considered ecologically significant (12%; see Collier 2006 and Stark & Fowles 2006). While there may not have been a statistically significant trend for long-term sites overall, some individual sites do show improving or declining trends, and these are discussed in Section 5.2.3, below. Overall trends for the long-term and reference networks are presented in Table 6. For each metric, negative values indicate a decline over time, and positive values indicate an improvement.

Table 6: Regional Mann-Kendall test statistics applied to (A) MCI and (B) ASPM for data collected since January 2002 from long-term monitoring sites that are (i) long-term (i.e. on developed land), (ii) reference sites. Probability values significant at P<0.05 are shown in bold.

	N	Tau	S	z	P	Trend slope (units y^{-1})
A MCI						
Long-term	470	-0.02	-1625	-0.50	0.62	
Reference	277	-0.16	-5665	-3.69	**0.00**	-0.48
B ASPM						
Long-term	470	0.06	6237	1.91	0.06	
Reference	277	0.01	382	0.25	0.80	

Footnote: Tau represents the non-parametric Kendall 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 statistically significant).

Between 2002 and 2014 MCI scores at long-term sites ranged from 39 to 143 with a median value of 105 (using soft-bottomed and hard-bottomed tolerance scores as appropriate). Of the sites currently monitored as part of the long-term network, and with 10 or more years of data since 2002, 50% were classified in the “good” category for MCI most of the time (18 of 36; see Table 4 for bands). The 3 top ranked long-term sites (based on maximum MCI) showed declines in MCI over the 2002-2014 time period (Waikato Regional Council unpublished data). This seems to show that better long-term sites tend to have decreasing trends in terms of MCI, but are still within the “excellent” quality class. Only 1 of the trends at these 3 sites was found to be ecologically significant and none were statistically significant after correction for FDR (false discovery rate; Table 8). Two long-term sites were equivalent to reference condition in having median MCI values above 133 and therefore considered “excellent” (1284_1 Whakarautawa, 1055_3 Torehape). A similar finding was noted for reference sites with 6 of the 24 reference sites having declining MCI trends over the last 10 years while still remaining in the “excellent” quality class (however 4 of the 6 were ecologically relevant declines; see section 5.2.3 below).

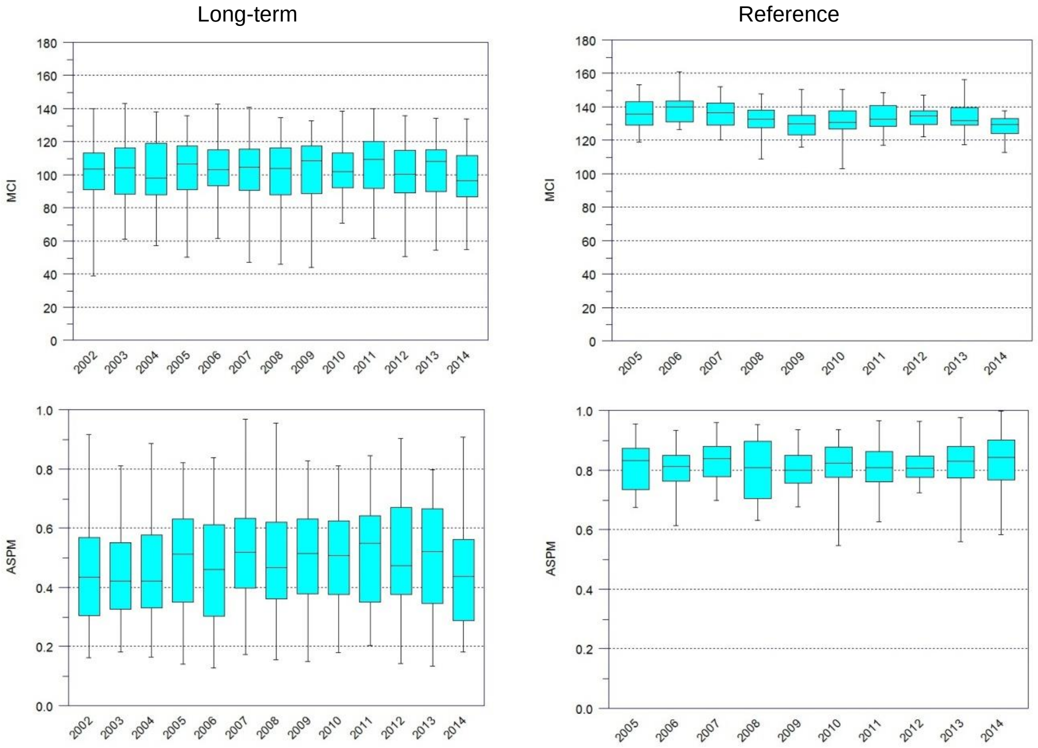

Figure 5: Boxplots of long-term (left) and reference (right) sites for the two invertebrate metrics of MCI (top) and ASPM (bottom) over time at all long-term and reference sites combined. Boxplots show; minimum and maximum, 25th and 75th percentile and median. There was a significant negative trend for MCI at reference sites only (top right graph).

Measured habitat parameters were also investigated for trends over the 2005 to 2014. Conductivity, canopy cover, substrate embeddedness, periphyton and macrophyte metrics showed no trends over time. However, total habitat scores, percentage of the bed covered by sand, silt, or clay, and the stream width ratio (channel width:wetted width) did show trends (Table 7). These indicate that long-term sites appear to have less fine substrate (sand/silt/clay) than previously, although this could relate to a change in methodology from visually estimating fine substrate cover to counting substrate particles across transects. Channel width ratio (channel width:wetted width) has an increasing trend overtime (Table 6), and this appears to be largely driven by channels getting wider as there was no change in wetted widths (Waikato Regional Council unpublished data). Previous studies have shown that stream channels in pasture are narrower than in forested streams (see Davies-Colley 1997). As streams and rivers are fenced off and planted with trees and shrubs the shade could well be causing a period of stream widening as stream bank grasses are shaded out (Davies-Colley 1997). However, this is not always the case and the underlying substrate and cohesiveness can have a greater influence on channel morphology (Ballie & Davies 2002).

Table 7: Regional Mann-Kendall test statistics applied to (A) Habitat Score, (B) % Sand Silt/Clay and (C) Width ratio (Channel width divided by Wetted width) for data collected since January 2005 from long-term monitoring sites that are (i) long-term (i.e., on developed land), (ii) reference sites. Probability values significant at P<0.05 are shown in bold.

	N	Tau	S	z	P	Trend slope (units y^{-1})
A Habitat score						
Long-term	349	-0.01	-772	-0.37	0.71	
Reference	255	-0.10	-3262	-2.27	**0.02**	-0.38
B %Sand/Silt/Clay						
Long-term	429	-0.09	-3724	-2.16	**0.03**	-3.07
Reference	266	-0.17	-5660	-3.93	**0.00**	-8.36
C Width ratio						
Long-term	323	0.16	7186	3.91	**0.00**	1.71
Reference	255	0.08	2772	1.93	**0.05**	1.08

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 statistically significant).

In this report, long-term sites were not separated from sites with active restoration as the majority of long-term sites now have some level of riparian fencing and planting to manage the impacts of the surrounding landuse practices. Sites included in the Clean Streams and Catchment Environmental Monitoring Restoration Programmes were reported on recently by Stansfield & Van der Zwan (2015), and as such are not included in this report.

4.2.2 Reference site trends

Reference sites draining native forested catchments are sampled to provide a benchmark against which to compare changes in other sites. Reference site MCI scores ranged from 103 to 163 with a median of 133. This implies that reference condition is synonymous with the “excellent” health categories presented in Table 4. Across all reference sites combined there was a negative statistical trend with regard to MCI, but not ASPM (Table 6; Figure 5). This appears to be largely driven by statistically significant declining trends at several streams; Te Rekereke (1513_3), Mangatea (1961_1), Mangatoa (471_2), Pohomihi (781_2) and Mokaihaha (555_2H) (Table 8; Figure 6; see Appendix 3 for plots of individual sites). There is no direct evidence that would suggest a reason for this decline, however, anecdotal observations made at these sites by field staff imply that Te Rekereke is increasingly affected by cattle, while the Mangatea (<1m wide) and Mangatoa (1.5m) streams are very small, and potential pest issues have been identified in these catchments (Brett Bailey, Pers. Comm.). The Pohomihi stream site is just upstream of the water take for Te Aroha, and the Mokaihaha has had some exotic forestry harvested and replaced with farmland around the native forest reserve. The Otautora stream is within the Maungatautari Ecological reserve and also appears to be declining in MCI scores, despite being in a catchment subject to intensive pest control. Further analysis of the dataset is currently underway and is focused on a more mechanistic approach to explain the declining trends at the above sites.

Table 8: Summary of temporal trends at long-term (black) and reference (green) sites with ≥10 records since 2002 at sampling sites inferred from the Mann-Kendall test for MCI and ASPM metrics. Statistical significance is indicated for 'Borderline trends' (not bold) if the P value is between 0.05 and 0.1. Significant trends at *P*<0.05 are indicated by bold text. If a trend was found following the False Discovery Rate (FDR) test this is in italics. Empty cells indicate that a trend was not evident. Ecological significance was inferred where the absolute change exceeded 12%, and the trend slope exceeded 1% per annum.

Site number	MCI			ASPM		
	Trend	Statistical	Ecological	Trend	Statistical	Ecological
Long-term						
1055_3	Decrease	*P* = 0.1	No			
1253_8				**Increase**	***P* = 0.02**	**Yes**
1253_9				Increase	*P* = 0.06	Yes
1284_1	Decrease	***P* = 0.04**	No			
1323_1	***Increase***	***P < 0.01***	***Yes***	***Increase***	***P < 0.01***	***Yes***
220_1	**Decrease**	***P* = 0.02**	**Yes**			
240_5	**Increase**	***P* = 0.01**	**Yes**	**Increase**	***P* = 0.03**	**Yes**
36_1				**Increase**	***P* = 0.03**	**Yes**
433_2				Increase	*P* = 0.08	Yes
481_11				**Increase**	***P* = 0.01**	**Yes**
619_20				Increase	*P* = 0.06	Yes
Reference						
1051_4				**Increase**	***P* = 0.01**	**Yes**
1513_3	**Decrease**	***P* = 0.02**	**Yes**			
1888_4	Decrease	*P* = 0.07	No			
1962_1	**Decrease**	***P* = 0.01**	**No**			
1966_1				Increase	*P* = 0.07	No
471_2	**Decrease**	***P* = 0.02**	**Yes**			
555_2H	**Decrease**	***P* = 0.02**	**Yes**	**Decrease**	***P* = 0.02**	**Yes**
781_2	**Decrease**	***P* = 0.01**	**Yes**			

The decline in MCI overtime at reference sites has implications for ASPM calculations, as MCI is one of the three metrics (MCI, %EPT*, EPT* taxa) used to determine ASPM. The ASPM is also standardised by using the maximum MCI value from reference sites each year. Thus, ASPM scores are relative to the reference state of the region in any given year. Therefore, it is important that potential causes for declining MCI scores at reference sites are investigated further, to determine the relative impact of climatic or local scale drivers. It could well be that three dry summers in four years have influenced these sites and continuous sampling over a longer time scales may reveal if the observed patterns can be partially attributed to natural climactic cycles. It is reasonable to assume that smaller sites, such as the Mangatea (1961_1) and Mangatoa (471_2) streams, may be affected more by climatic influences on flow and temperature, and could return to previous condition in time (thereby highlighting the value of long-term datasets). If some reference sites become no longer representative of reference condition due to increased human activity, their use as part of the reference network will need to be revised (e.g. for calculating metrics such as ASPM). That said, reference site, condition is still "excellent" overall, whereas, only 10-20% of sites randomly selected on developed land are comparable in terms of ecological health based on invertebrate metrics. The remainder of the random site network often fall markedly below reference condition.

In terms of ASPM, the increasing trends for reference sites Tongariro River trib (1051_4) and Purangirangi Stream (1966_1) imply these two sites are improving relative to other reference sites (Table 8; Figure 7). Conversely, the hard bottomed sample collected from the Mokaihaha Stream (555_2H) has declined relative to other reference sites. For example in 2005 and 2006 EPT* taxa richness from the hard bottomed sample at this site was used in the ASPM equation. In subsequent years other sites have had higher EPT* taxa richness therefore this site has had relatively low scores. At the Mokaihaha site both hard bottomed samples from a bedrock riffle and soft bottomed samples from woody debris in the reach have been sampled for 10 years and only the hard bottomed samples are showing a negative trend. The Mokaihaha

Stream was also the only reference site that had an ecologically significant trend for both macroinvertebrate metrics (MCI & ASPM) for hard bottom samples.

Three reference sites (Awakino River trib 33_16, Firewood Creek trib 125_15, Otautora Stream 1888_4) are sampled as index sites at the beginning and end of each monitoring season. The results from these sites indicate that there is no ecologically relevant difference (i.e. within 12%) between samples collected early or late in the season at reference sites (Waikato Regional Council unpublished data). In terms of physical habitat trends, a small number of reference sites appear to be driving the overall observed site trends (Table 7). Three of the four sites with borderline negative (less fine sediment) trends for percent Sand/Silt/Clay were reference sites (125_15, 234_28, 471_2; Table 8). This result could relate to native forest catchments recovering from past erosion or fine sediment deposition events. Habitat scores were declining at reference sites overall (Table 8) but only the Ahirau (9_4), Mangatawai (458_1), Waikuku (1965_1) streams had statistically significant declines.

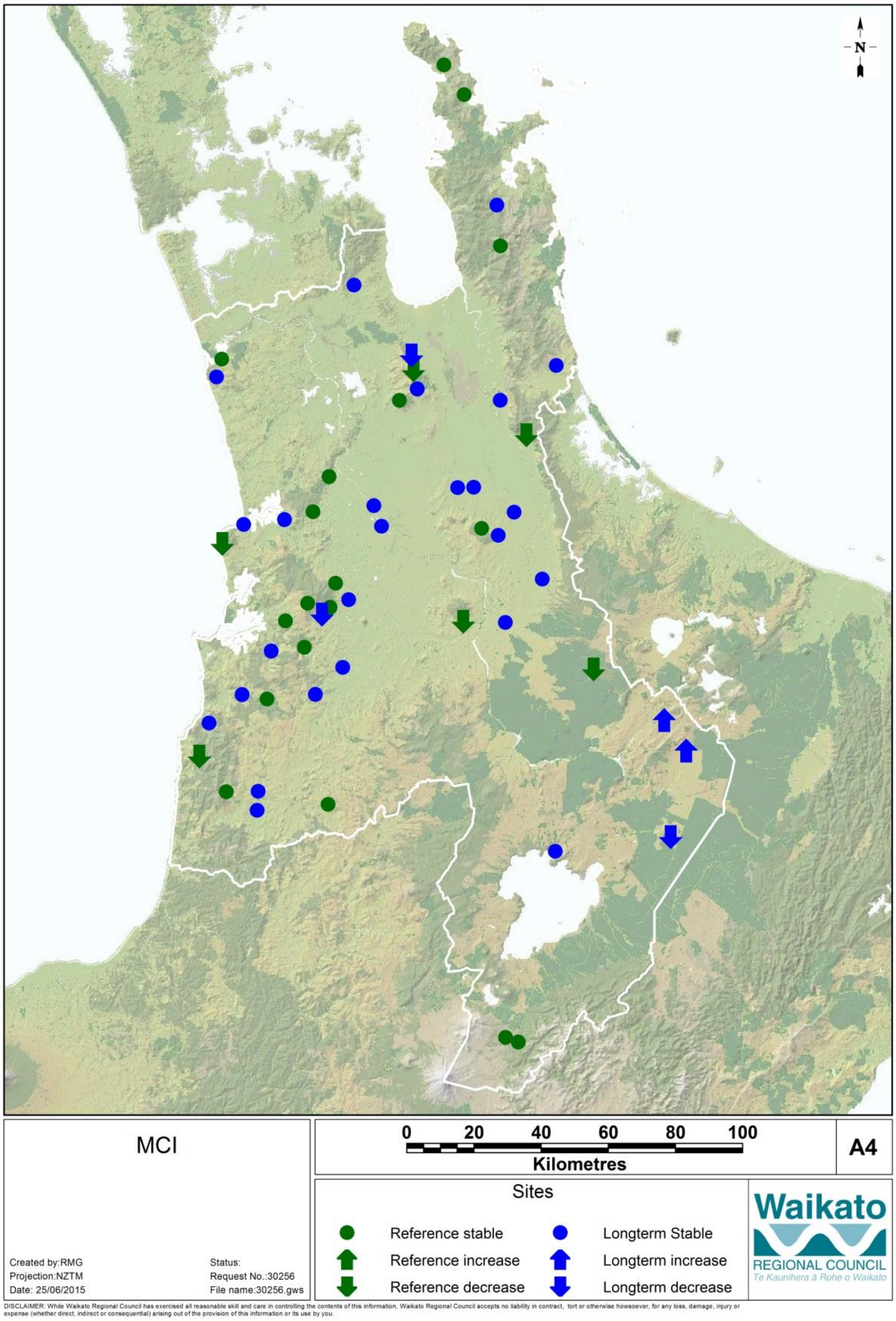

Figure 6: Map showing long-term (blue) and reference site (green) locations. Statistically significant trends for MCI (Macroinvertebrate Community Index) at sites with greater than 10 years data sampled between 2002 and 2014 using MfE protocols are shown.

4.2.3 Long-term site trends

The only long-term sites on developed lab which showed trends for increasing MCI scores were the Whirinaki (1323_1) and Kawaunui (240_5) Streams just 11km apart on either side of the Waikite Valley, South of Rotorua, draining Tumunui Hill and the Paeroa Range (Table 8; Figure 6). The Whirinaki Stream was the only site to have a significant trend after the FDR correction. Both catchments have had about 4km of riparian fencing undertaken upstream of the monitoring sites. The Kawaunui Stream has had four consented dairy effluent discharges to water changed to discharges to land over the study period, and phosphorus concentrations appear to be decreasing (TP), although nitrogen concentrations are either stable or increasing (TN and DIN respectively; Table 9). Furthermore, a greater amount of riparian shade has been recorded and has potentially contributed to the improvement in MCI at this site over time. At the Whirinaki Stream sampling site, around 800m has been retired and re-planted, including at the sampling locality and upstream. Shade provided from riparian trees and blackberry may well contribute to the improvement at this site over time. The water quality trends at this site show a trend for increasing nitrogen concentrations (TN and DIN) and decreasing phosphorus concentrations (TP; Table 9). At this site, however, a general lack of light due to riparian shading and cooler water temperatures has the potential to limit algal growth. The invertebrate community may thus be somewhat buffered from the effects of increasing nitrogen concentrations.

An increase in ASPM for long-term sites implies development towards reference condition of the three macroinvertebrate metrics which make up the ASPM score. Both long-term sites on the Waitomo Stream have improving trends for ASPM (Figure 7). Interestingly, only one of these sites has undergone restoration by planting. In both cases, the MCI has remained stable, thus the improving trend is driven generally by improvements in EPT proportions. There has been notable investment into riparian planting in this catchment with 114km of stream being fenced and the number of discharges to water has reduced from 10 to none over the study period. The Ohinemuri River (619_20) has had the number of discharges to water reduced from 11 to 3 over the monitoring period and has also had 13km of riparian fencing undertaken in the catchment so this may help explain the improving trend there. Three long-term sites with decreasing MCI scores, namely Torehape Stream (1055_1), Kaiwhitiwhiti Stream (220_1) and Whakarautawa Stream (1284_1), are potentially influenced by landuse intensification, and limited riparian vegetation in those catchments. In the Kaiwhitiwhiti, introduced riparian plants were removed and replaced with native plants, potentially reducing the shade provided by riparian vegetation temporarily as new plants establish. Additionally, there is a water take for town supply and forestry operations are taking place upstream.

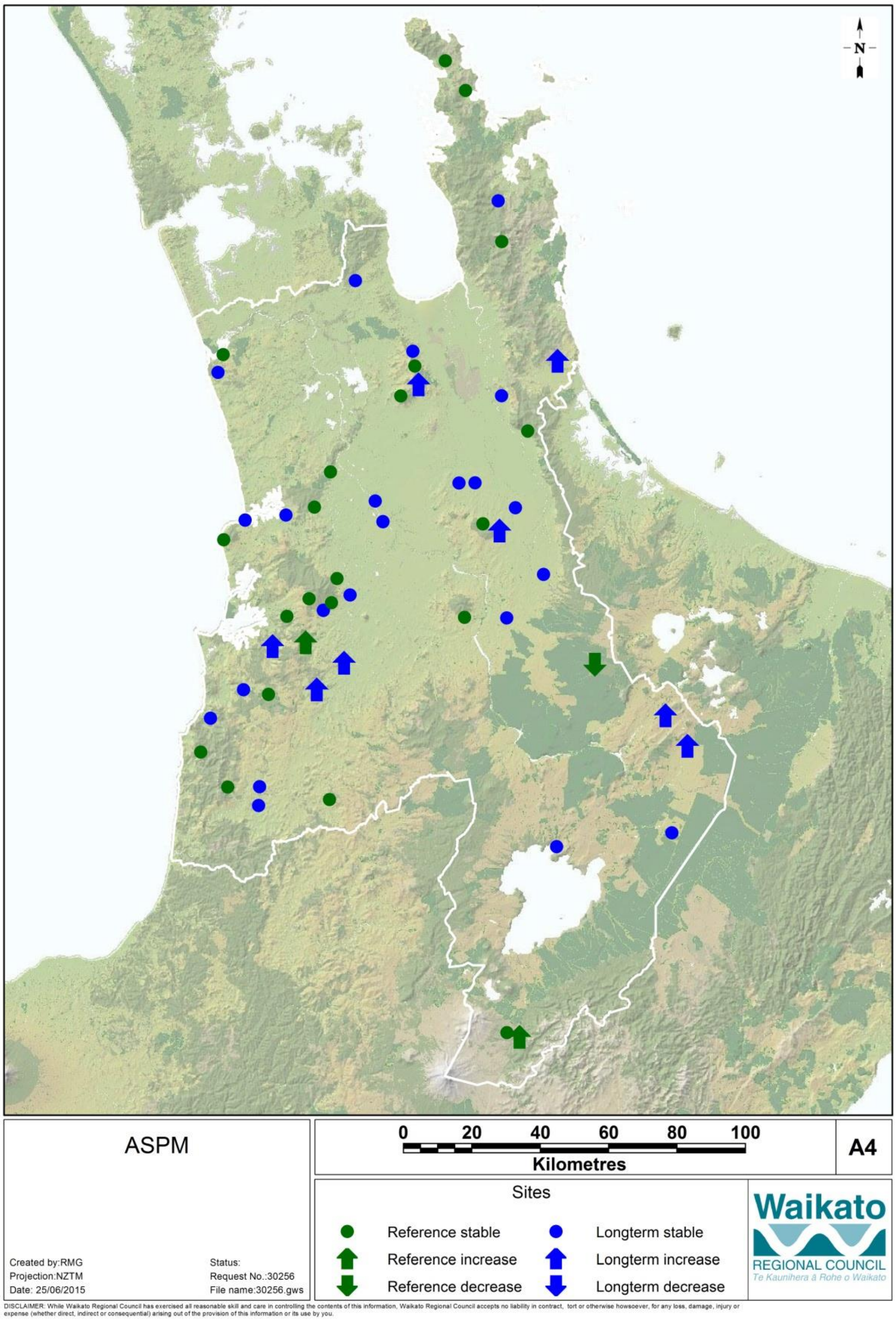

Figure 7: Map showing long-term (blue) and reference site (green) locations with ASPM (Average Score Per Metric) trend direction shown with arrows for sites with greater than 10 years data sampled between 2002 and 2014 using MfE protocols.

4.2.4 Additional sites

Four sites from the Hunua Ranges south of Auckland were monitored by Auckland Council up until 2013 and then by the Waikato Regional Council in 2014. Three of these sites were part of the Auckland Councils reference site network and one was in plantation forestry. While a 10-year data set for these 4 sites exists we have treated them separately in this analysis due to a different sorting protocol being used. There were no trends observed at these sites (Appendix 3) and all were classified as “excellent” for MCI. We recommend including one of the four sites into the Waikato

Regional Councils reference site network. The site would complement the 2 reference sites currently in the Lower Waikato management zone, and meets site criteria related to access. The most suitable of these reference sites in terms of access is Milnes Stream (3104_1), which is easily accessed from the southern entry to the Hunua Ranges.

4.2.5 Relationships with water quality

Few of the long-term and reference sites with regular water quality data collected at the same (or nearby) sites showed trends for invertebrate metrics (Table 9). There was little correspondence between trends in macroinvertebrate metrics and water quality at the 20 sites with comparable data. At two sites, water quality and macroinvertebrate metrics both showed improvements (sites 240_5 and 481_11; Table 9). This does not necessarily indicate causal relationships but merely an association of patterns, and it is important to consider whether the magnitude of change in water quality is biologically significant (see Appendix 6 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 were evident for macroinvertebrate metrics but not for water quality parameters, macroinvertebrate communities may be more affected by other pressures such as habitat quality or fine sediment deposition. Alternatively, trends in water quality parameters without an equivalent response in macroinvertebrate metrics may reflect 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 (Collier & Hamer 2012).

Table 9: Comparison of long-term (REMS) site trends with Water quality (RERIMP) trends at the same or nearby sites. Upward arrows (green) indicate improving trends, downward arrows (red) indicate declining trends, blank boxes indicate no significant trend in quality or health. Grey arrows indicate that a trend is present but that the data may be doubtful. Trends are based on Mann-Kendall test for REMS data and Seasonal Mann-Kendall test for water quality (RERIMP) data. Arrow direction and colour indicates improving/declining trend not the actual direction of change in the data e.g. a trend of declining turbidity measurements would receive an upward green arrow, as this is an improvement in water quality.

REMS					RERIMP								
Site	**MCI**	**ASPM**	**River**	**Site**	**Black disc**	**Turbidity**	**DO%**	**TP**	**DRP**	**TN**	**NH4**	**DIN**	**Temp**
1257_2	Stable	Stable	Waiwawa	1257_3		↑			↑	↑		↑	↓
619_20	Stable	↑	Ohinemuri	619_20	↓				↑				
1249_15	Stable	Stable	Waitoa	1249_15		↑	↑	↑	↑	↑	↑	↑	
749_10	Stable	Stable	Piako	749_10				↑	↑	↑	↑	↑	
1323_1	↑	↑	Whirinaki	1323_1				↑	↑	↓		↓	
398_1	Stable	Stable	Mangakotukutuku	398_1			↑		↓	↑	↑	↑	
240_5	↑	↑	Kawaunui	240_5	↑	↑		↑	↑		↑	↓	↓
786_2	Stable	Stable	Pokaiwhenua	786_2			↑	↑	↑	↓		↓	
1253_9	Stable	↑	Waitomo	1253_7				↑					↓
477_14	Stable	Stable	Mangauika	477_10		↓			↑	↓		↓	↓
428_3	Stable	Stable	Mangaotaki	428_3				↑	↑	↑		↑	↓
556_9	Stable	Stable	Mokau	556_9				↑	↑				↓
976_2	Stable	Stable	Tawarau	976_1				↑					↓
453_8	Stable	Stable	Mangatangi	453_6	↓	↓		↑	↑		↑	↑	↓
481_11	Stable	↑	Mangawara	481_7			↑	↑		↑	↑	↑	↓
954_5	Stable	Stable	Tapu	954_5					↑				↓
1174_10	Stable	Stable	Waiomou	1174_4	↓	↓	↑	↑	↑				
234_28	Stable	Stable	Kauaeranga	234_11		↑			↑				↓
33_16	Stable	Stable	Awakino	33_6	↓			↑	↑	↑		↑	
476_7	Stable	Stable	Mangatutu	476_7				↑	↑				

5 Key findings and recommendations

- Unbiased estimates of wadeable stream extent based on the probability survey design indicate that for, perennial, non-tidal, $\leq 5^{th}$ order streams on developed land, over the 3 years of sampling from 2012 to 2014, around 60% of target wadeable stream length was unshaded, 76% had ‘clear’ water at the time of sampling, and most (73% of stream length) had a level of fine sediment above threshold values for benthic macroinvertebrates. Over half of the regional stream length was classified as ‘soft-bottom’ for macroinvertebrate sampling purposes, as evidenced by the high proportion of sites with little compaction, and high proportion of sand, silt, and clay substrates.

- The mean regional habitat score for wadeable streams on developed land was 94 compared to 146 at reference sites.

- Macrophyte cover averaged 31% with 5% cover by native species. Periphyton cover by long filaments and thick mats averaged 9% of substrate surfaces at the time of sampling, with 11% 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, 34% ASPM) of wadeable stream length on developed land was rated as ‘good-excellent’ and two-thirds (65% QMCI, 66% ASPM) were rated as ‘fair-poor’. Around half (47-60%) of stream length on developed land over the 2012 to 2014 period was considered to have “poor” ecological condition based on QMCI in any given year.

- Overall these results are similar to those from estimates produced from the same monitoring network, but sampled three years prior over 2009 to 2012.

- Of the 30 long-term sites (non-reference) sampled for at least 10 years, a third 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, 3 were increasing in condition and 8 were decreasing in condition.

- One of the formerly Auckland Council sites in the Hunua Ranges will be incorporated into the reference site network of Waikato Regional councils REMS programme. The most suitable site is Milnes Stream (3104_1).

- Additional analyses of sample information collected from the REMS network, and the probabilistic network in particular, is planned to investigate pressure – response relationships This will improve our mechanistic understanding of how stream ecological health responds to pressures (e.g. sediment, riparian landuse), and how we might increase the reporting and predictive power of the network.

- Work will be undertaken to combine habitat, macroinvertebrate, and fish sampling data for the ‘random’ network to provide a more holistic assessment of site ecology, and improve our estimates of the ecological health of streams at regional scale.

6 References

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Appendix 1: Additional information for 2009 to 2011 monitoring period

Table A1.1: Re-calculated estimates of target and non-target river network lengths (km; SE in parentheses) represented by target and non-target (excluded) sites from the random monitoring network for each year and combined years (based on sites forming the network 2009 – 2012). Length is calculated using the R package spsurvey by adjusting site values by their probability of selection based on the REC sample frame.

	Year 1 (n=60)	Year 2 (n=59)	Year 3 (n=60)	Combined (n=179)
Target				
Sampled	17466 (1376)	12153 (1015)	10596 (952)	12966 (644)
Inaccessible	2412 (553)	2628 (564)	3073 (562)	2728 (350)
Other	0 (0)	0 (0)	125 (104)	39 (36)
Dry	0 (0)	0 (0)	0 (0)	0 (0)
Total	19879 (1328)	14781 (1024)	13794 (773)	15733 (603)
Non-target				
Reference	6766 (1174)	6822 (1078)	7124 (1183)	6935 (614)
Non-wadeable	3297 (698)	3274 (396)	2682 (570)	3106 (306)
Tidal	248 (150)	92 (78)	181 (147)	186 (84)
Drain	1111 (548)	667 (310)	1723 (558)	1186 (285)
Dry	2469 (827)	4522 (842)	8975 (1184)	5551 (613)
Lentic	460 (298)	2217 (639)	1269 (570)	1412 (318)
Wetland	1885 (797)	4360 (1104)	1326 (622)	2612 (505)
Network inaccuracy[1]	1548 (803)	689 (442)	590 (393)	865 (299)
Boundary change	0 (0)	241 (205)	0 (0)	79 (70)
Total	17785 (1313)	22883 (1346)	23870 (1333)	21931 (774)

[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).

Table A1.2: Re-calculated mean (SE) regional percentage estimates of characteristics for wadeable streams 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) 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=59)	2011 (n=60)	Combined (n=179)	Reference Samples
A. Categorical habitat variables						
Shade	None	62.9 (6)	60.7 (5.7)	59 (6.1)	61.1 (3.6)	4.2
	Partial	26.8 (5.8)	27.6 (5.3)	36.4 (5.8)	29.7 (3.2)	13.7
	Full	10.3 (3.3)	11.6 (4.7)	4.6 (2.4)	9.2 (2.2)	82.1
Turbidity	Clear	82.1 (3.9)	53.9 (6.9)	68.1 (5.5)	68.5 (3.5)	92.6
	Slight	14.1 (3.7)	30.8 (6.6)	18.1 (4.9)	20.9 (3)	6.4
	High	3 (1.2)	9.2 (3.9)	4.2 (1.9)	5.4 (1.5)	0
	Stained	0.7 (0.6)	6.1 (3.3)	9.5 (4.2)	5.3 (1.7)	1.1
Compaction (packing of substrate)	Tight	6 (2.7)	7.9 (3.5)	9.5 (4.3)	7.5 (1.9)	23.2
	Moderate	11.3 (3.1)	13.4 (4.4)	22.1 (5)	16 (2.5)	45.3
	Loose	11.4 (4.1)	34.8 (6.5)	32 (6.3)	25.7 (3.3)	23.2
	None	71.3 (5.6)	43.9 (5.9)	36.4 (6.9)	50.8 (3.5)	8.4
Embeddedness (cover by fine sediment)	<5%	7.5 (3.2)	7.1 (2.8)	11.8 (4.3)	8.5 (2)	42.1
	5-25%	15.4 (4.3)	20.4 (4.9)	20.3 (4.5)	19.3 (2.7)	32.6
	26-50%	10.6 (4.2)	16.8 (5.2)	20.9 (5.2)	16.2 (2.8)	116.8
	51-75%	16.7 (4.7)	11.7 (4.5)	17.4 (5.8)	15.1 (2.7)	5.3
	>75%	49.7 (6.2)	44 (6.2)	29.6 (6.5)	41 (3.5)	3.2
Sampling method	Hard (H)	27.2 (5.6)	45.6 (5.7)	54.8 (6.4)	42.5 (3.4)	89.3
	Soft (S)	70.1 (5.9)	52.2 (5.8)	39.6 (6.8)	54.2 (3.5)	0
	H+S	2.6 (1.7)	2.3 (1.2)	5.6 (3.8)	3.3 (1.2)	9.5
B. Continuous habitat variables						
Percent sand/silt/clay		68.2 (4.4)	54.3 (4.2)	47 (4.6)	56.6 (2.5)	10
Channel width:wetted width		1.9 (0.1)	2.7 (0.2)	2.3 (0.3)	2.3 (0.1)	1.8
Habitat quality score		84.9 (4)	83.7 (3.5)	88.6 (4.8)	86 (2.4)	154
Macrophyte total cover (%)		34.2 (4.5)	32.7 (4.5)	21.9 (4.8)	29.5 (2.7)	<0.1
Macrophyte channel clogginess (%)		32.4 (4.4)	31.3 (4.4)	24.6 (4.9)	29.2 (2.6)	0
Macrophyte native cover (%)		3.2 (1.3)	2.1 (0.6)	2.9 (0.8)	2.8 (0.6)	0
Periphyton proliferation index		7.1 (1.6)	8.5 (2)	10 (2.3)	8.4 (1.1)	0.5 (0.2)
Periphyton slimyness index		9.6 (1.4)	10.4 (1.6)	13.2 (2)	10.9 (0.9)	2.9 (0.6)

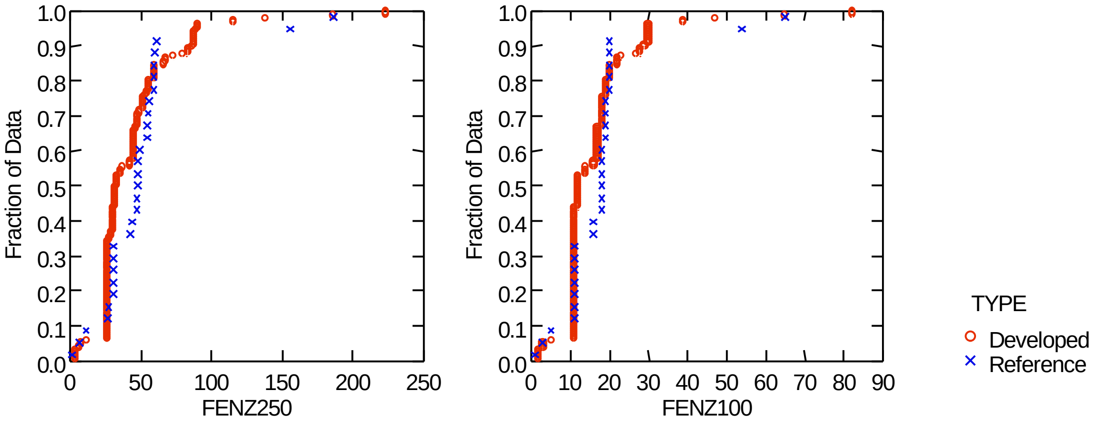


Figure A1.1: Representativeness of reference sites relative to random sites on developed land for FENZ100-and 250-groups in the REMS monitoring network over 2009–11 (reproduced from Collier & Hamer (2012).

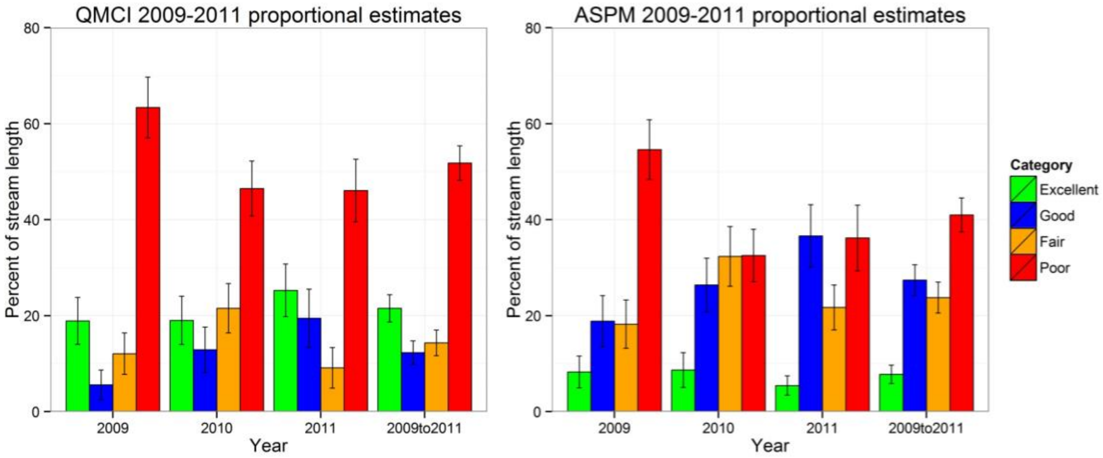


Figure A1.2: Re-calculated mean (±1 SE) percent of stream length falling into four environmental condition classes for QMCI and interim classes for ASPM for the period 2009 to 2011. QMCI classes reflect calculations of hard-bottom or soft-bottom metrics as appropriate. The ASPM classes are interim because it uses the hard-bottom MCI and is benchmarked against hard-bottom reference sites.

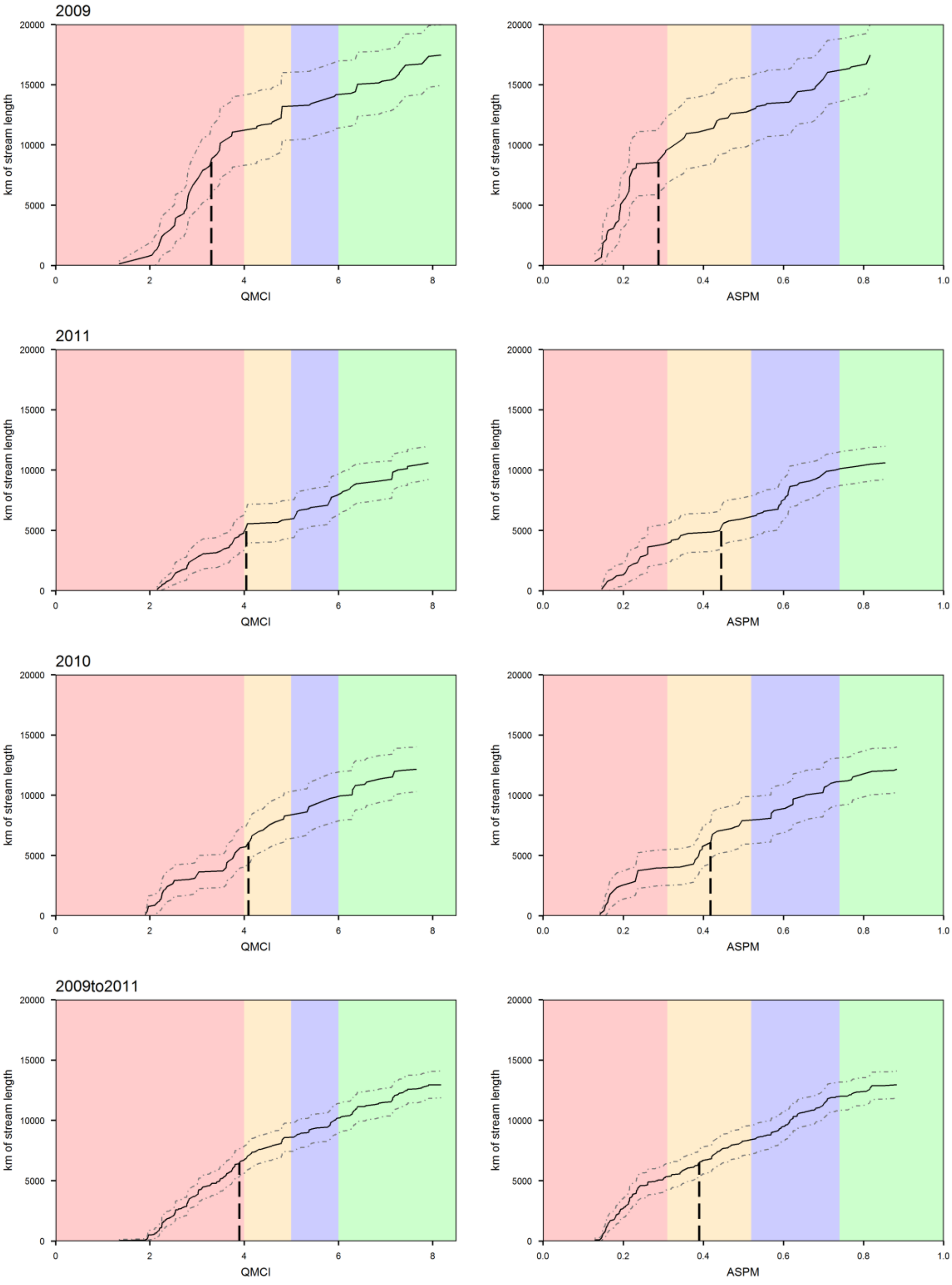


Figure A1.3: Cumulative frequency distributions for QMCI and ASPM, re-calculated for 2009 to 2011. Solid lines indicate estimated stream length, grey dotted lines indicate upper and lower 95th percentiles. Dashed vertical lines indicate median values. Coloured bands indicate poor, fair, good, and excellent quality classes (red through to green).

Appendix 2: Additional information for 2012 to 2014 monitoring period

Table A2.1: Summary statistics for extent estimates of habitat indices for the probabilistic network – wadeable streams on developed land, 2009 to 2011 and 2012 to 2014. 5th to 95th percentiles, mean and standard deviation are presented.

Indicator	Rotation	5Pct	25Pct	50Pct	75Pct	95Pct	Mean	Std. Deviation
Conductivity	2012to2014	5.3	8.3	12.0	16.4	29.7	14.3	9.7
Channel width:wetted width	2009to2011	1.1	1.5	1.8	2.4	4.6	2.3	1.5
	2012to2014	1.2	1.4	1.7	2.2	3.6	2.3	2.1
Habitat quality score	2009to2011	35.9	63.5	84.0	105.9	143.1	86.0	31.4
	2012to2014	43.0	73.9	95.4	112.3	137.0	94.3	27.6
Macrophyte channel clogginess (%)	2009to2011	0.0	0.2	10.6	56.4	93.3	29.2	34.3
	2012to2014	0.0	0.8	12.5	52.1	93.9	29.2	32.5
Macrophyte total cover (%)	2009to2011	0.0	0.3	9.3	55.2	97.9	29.5	34.4
	2012to2014	0.0	1.1	15.1	52.9	96.4	30.6	33.5
Percent sand/silt/clay	2009to2011	0.0	20.0	58.5	95.1	99.8	56.6	36.2
	2012to2014	2.4	18.7	56.6	96.1	99.7	56.4	37.0
Periphyton proliferation index	2009to2011	0.0	0.0	1.5	10.2	45.6	8.4	13.8
	2012to2014	0.0	0.0	1.0	9.8	42.8	8.7	15.0
Periphyton slimyness index	2009to2011	0.0	0.1	5.9	16.1	41.0	10.9	12.5
	2012to2014	0.0	1.0	6.5	15.2	42.7	11.2	13.7

Table A2.2: Summary statistics for extent estimates of macroinvertebrate indices for the probabilistic network – wadeable streams on developed land, 2009 to 2011 and 2012 to 2014. 5th to 95th percentiles, mean and standard deviation are presented. "^"denotes the use of hard and soft bottom tolerance scores where appropriate. "*" denotes that these metrics exclude Hydroptilidae.

Indicator	Year	5Pct	25Pct	50Pct	75Pct	95Pct	Mean	Std. Deviation
MCI^	2009to2011	56.2	73.5	100.1	116.3	131.8	96.5	24.4
	2012to2014	59.9	76.9	98.4	114.1	127.3	96.7	22.1
QMCI^	2009to2011	2.1	2.8	3.9	5.8	7.4	4.3	1.7
	2012to2014	2.2	2.9	3.9	5.5	7.3	4.3	1.7
EPT* richness	2009to2011	0.0	1.5	7.1	11.3	15.8	7.2	5.5
	2012to2014	0.0	2.2	6.7	11.3	16.0	7.5	5.3
Percent EPT* abundance	2009to2011	0.0	0.7	14.9	52.2	79.4	27.1	28.4
	2012to2014	0.0	1.5	17.3	52.1	81.0	27.9	29.4
ASPM	2009to2011	0.2	0.2	0.4	0.6	0.8	0.4	0.2
	2012to2014	0.2	0.2	0.4	0.6	0.8	0.4	0.2
Taxa richness	2009to2011	12.7	19.6	22.4	25.7	31.3	22.6	5.4
	2012to2014	13.2	17.8	21.9	26.0	31.5	22.5	5.6

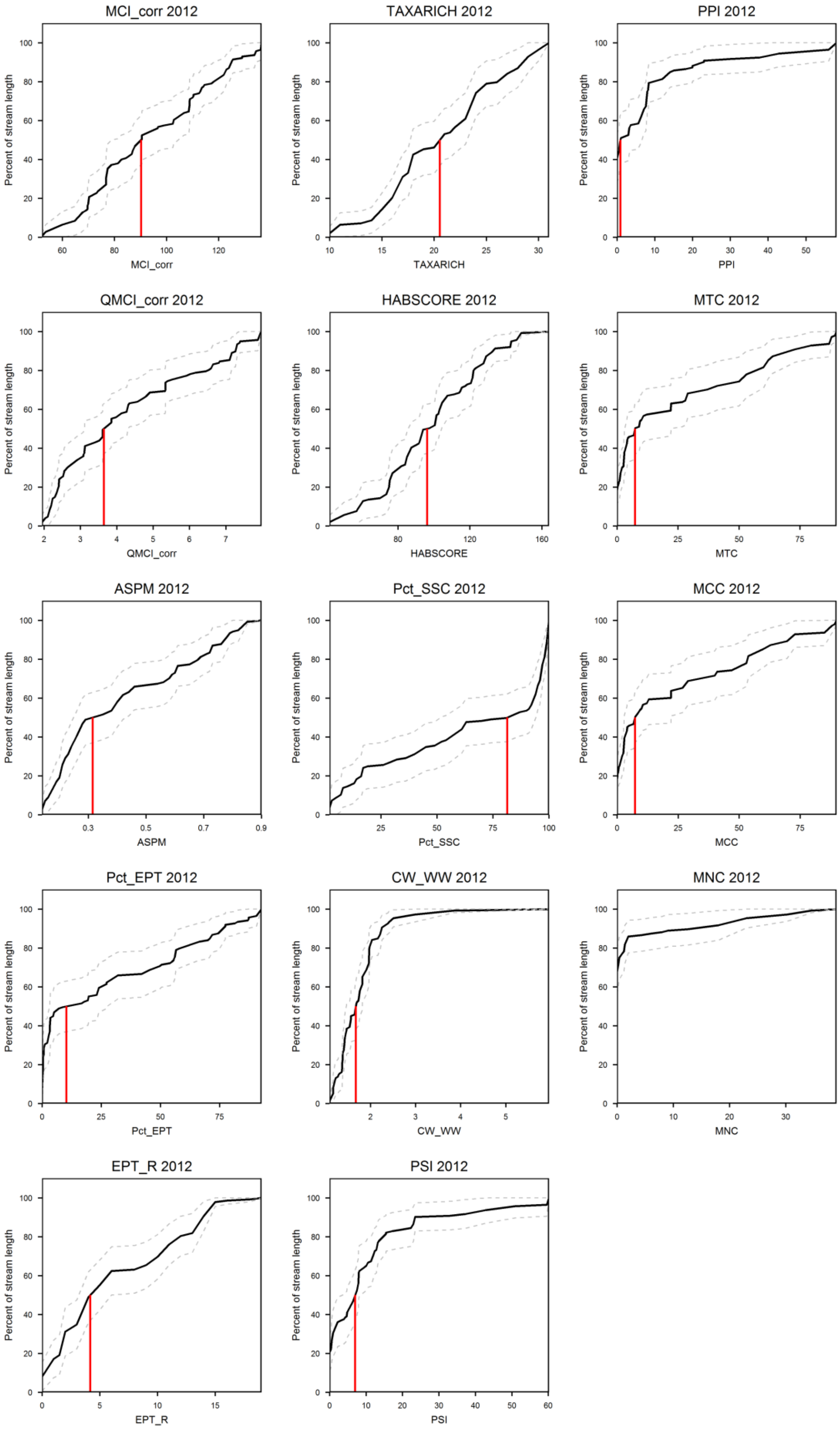


Figure A2.1: Cumulative frequency distributions of extent estimates for physical and biological indices, for 2012. Red vertical lines indicate median values. MCI (MCI_corr), QMCI (QMCI_corr), Channel width:wetted width (CW_WW), Habitat quality score (HABSCORE), Macrophyte channel clogginess (MCC), Macrophyte total cover (MTC), Percent sand/silt/clay (Pct_SSC), Periphyton proliferation index (PPI), Periphyton slimyness index (PSI), EPT* richness (EPT_R), Percent EPT* abundance (Pct_EPT), ASPM, taxa richness (TAXARICH).

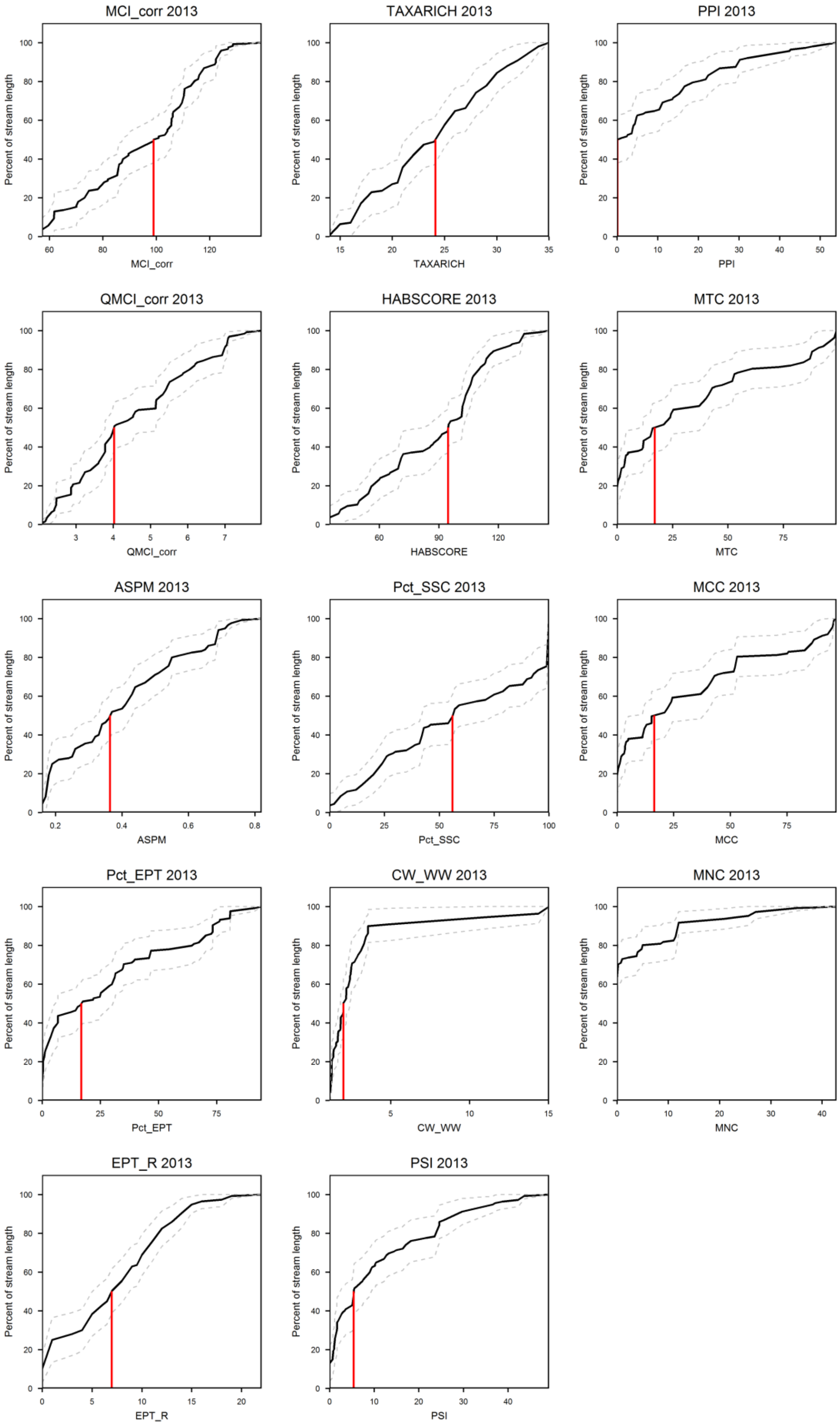


Figure A2.2: Cumulative frequency distributions of extent estimates for physical and biological indices, for 2013. Red vertical lines indicate median values. MCI (MCI_corr), QMCI (QMCI_corr), Channel width:wetted width (CW_WW), Habitat quality score (HABSCORE), Macrophyte channel clogginess (MCC), Macrophyte total cover (MTC), Percent sand/silt/clay (Pct_SSC), Periphyton proliferation index (PPI), Periphyton slimyness index (PSI), EPT* richness (EPT_R), Percent EPT* abundance (Pct_EPT), ASPM, taxa richness (TAXARICH).

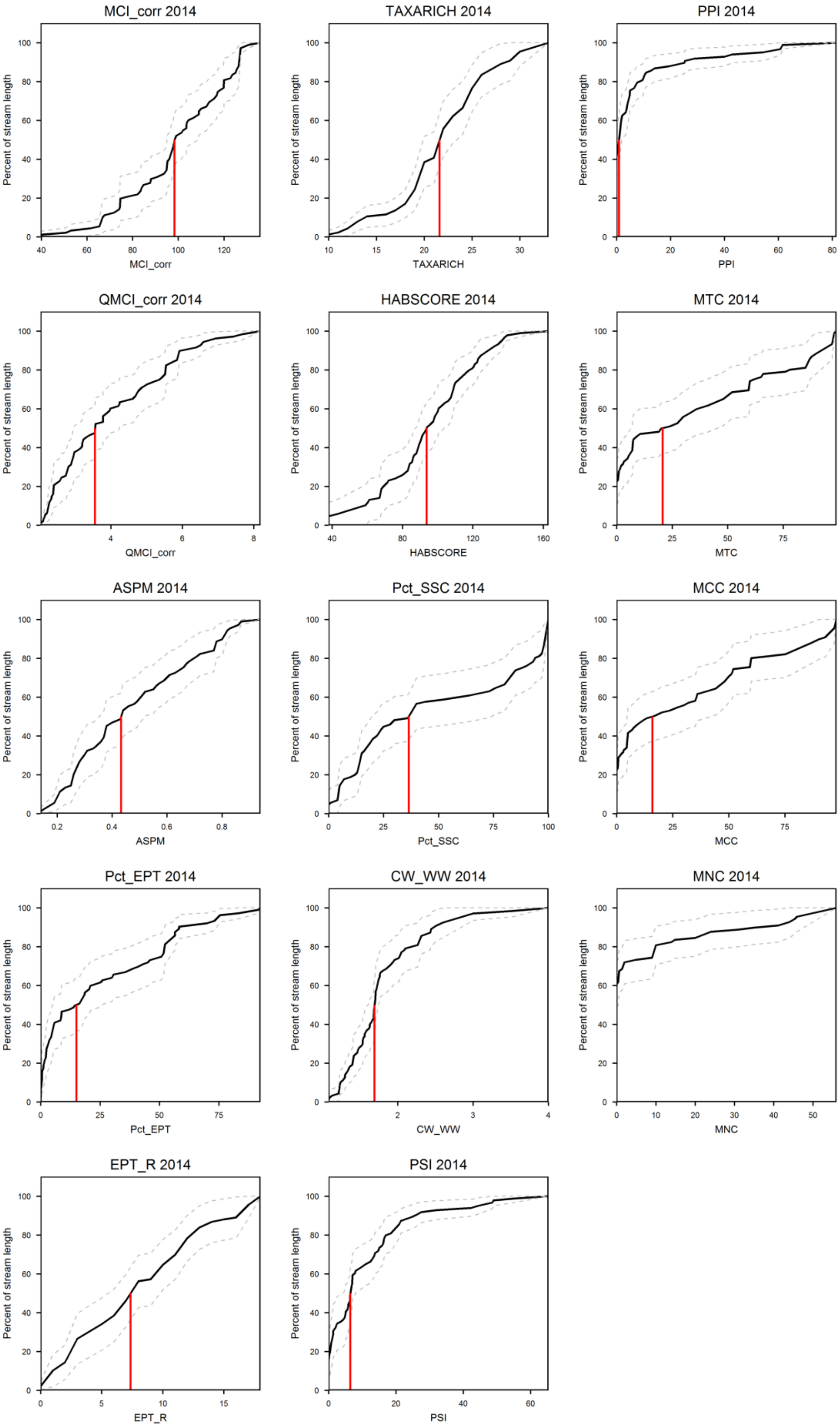


Figure A2.3: Cumulative frequency distributions of extent estimates for physical and biological indices, for 2014. Red vertical lines indicate median values. MCI (MCI_corr), QMCI (QMCI_corr), Channel width:wetted width (CW_WW), Habitat quality score (HABSCORE), Macrophyte channel clogginess (MCC), Macrophyte total cover (MTC), Percent sand/silt/clay (Pct_SSC), Periphyton proliferation index (PPI), Periphyton slimyness index (PSI), EPT* richness (EPT_R), Percent EPT* abundance (Pct_EPT), ASPM, taxa richness (TAXARICH).

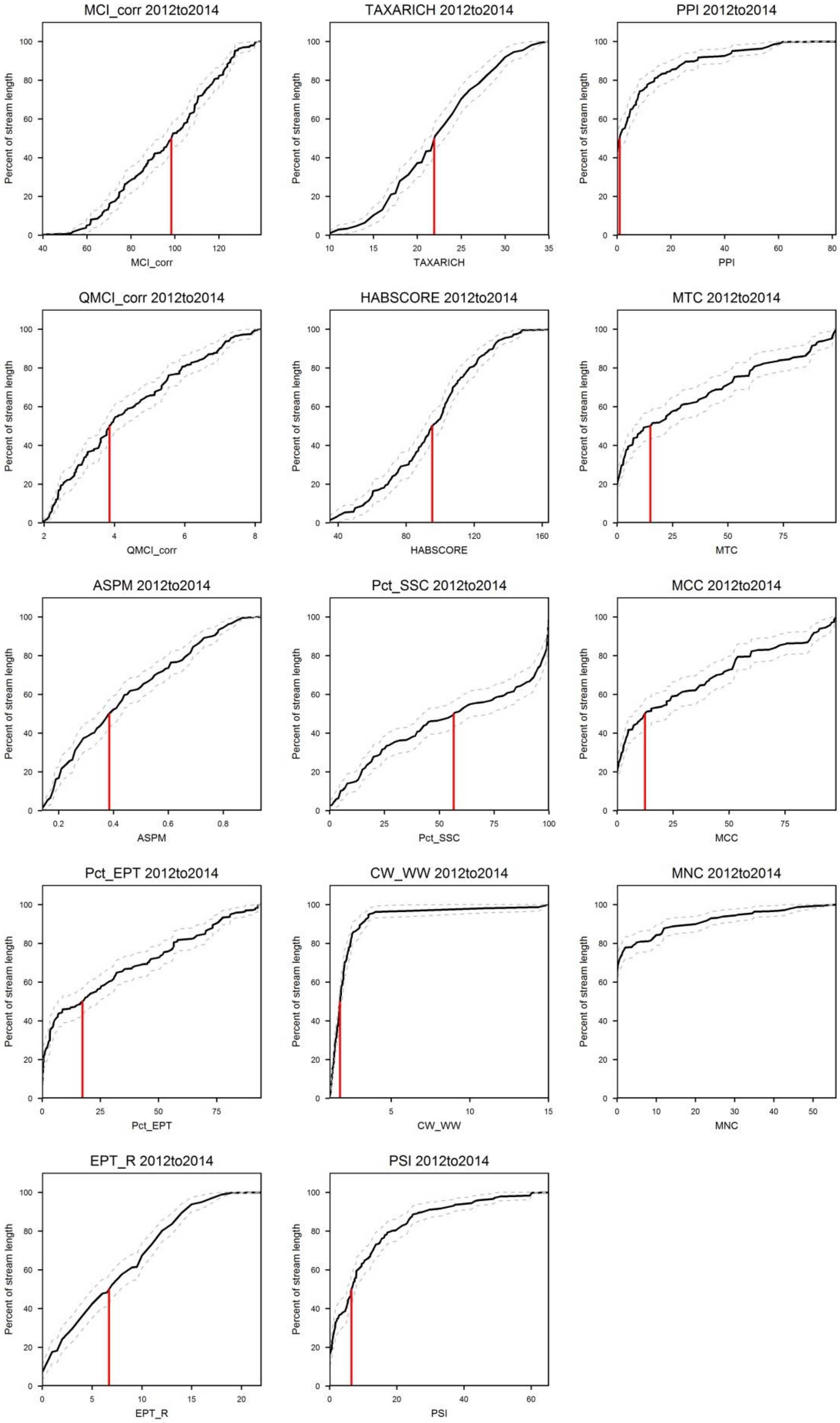


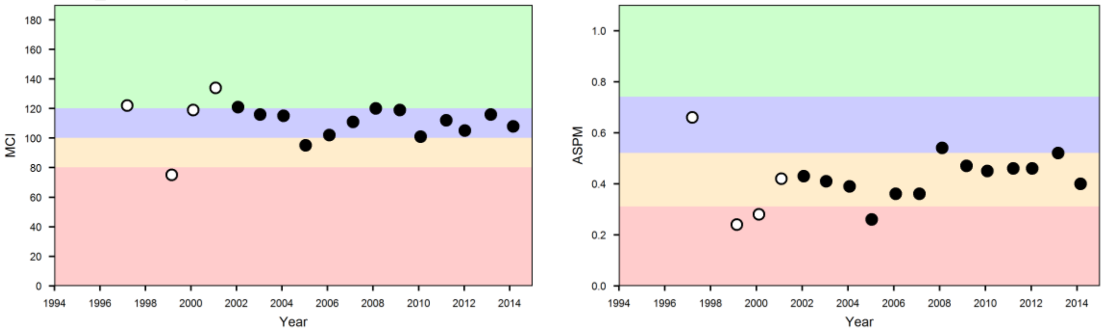
Figure A2.4: Cumulative frequency distributions of extent estimates for physical and biological indices, for 2012 to 2014. Red vertical lines indicate median values. MCI (MCI_corr), QMCI (QMCI_corr), Channel width:wetted width (CW_WW), Habitat quality score (HABSCORE), Macrophyte channel clogginess (MCC), Macrophyte total cover (MTC), Percent sand/silt/clay (Pct_SSC), Periphyton proliferation index (PPI), Periphyton slimyness index (PSI), EPT* richness (EPT_R), Percent EPT* abundance (Pct_EPT), ASPM, taxa richness (TAXARICH).

Appendix 3: Long-term and reference site trend graphs for Macroinvertebrate Community Index and Average Score Per Metric

Trend graphs for Macroinvertebrate Community Index (MCI) and Average Score Per Metric (ASPM), arranged by network and management zone. Band colours relate to; Green = excellent, Blue = good, Orange = fair, Red = poor quality classes based on Stark & Maxted (2007) for MCI and Collier & Hamer (2012) for ASPM. White dots show the results prior to 2002 and the use MfE collection protocols (also not included in trend analysis). Trendlines are shown as a solid line if Significant and dotted line if a boarderline trend.

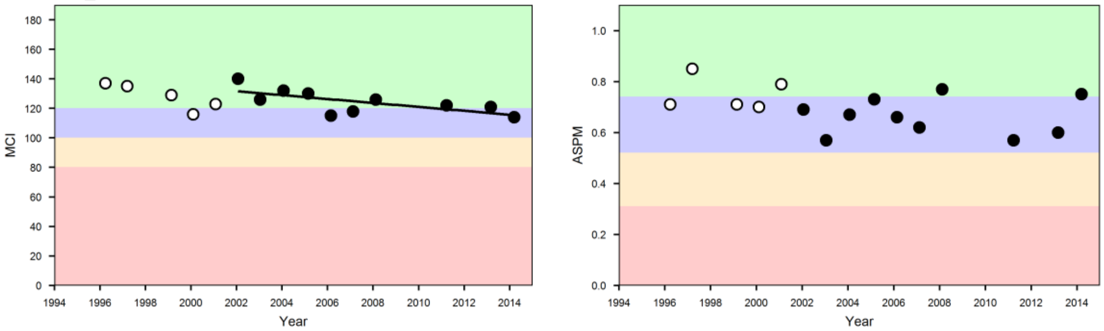
Long-term – Lake Taupo

1300_2 - Whangamata Stm - Soft bottomed

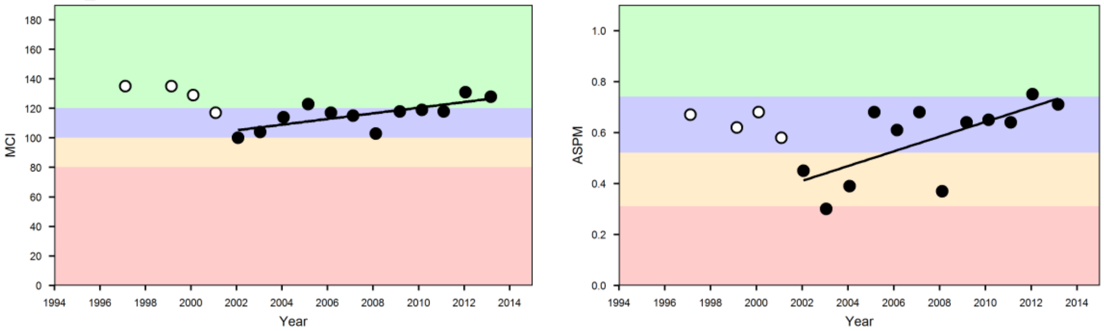


Long-term – Upper Waikato

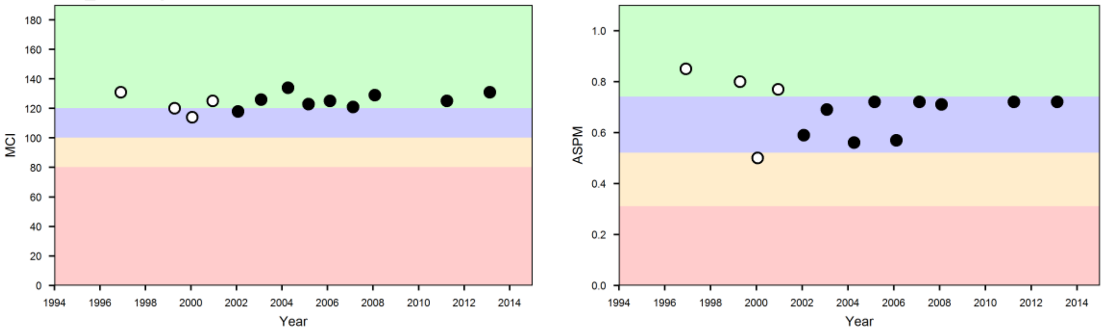
220_1 - Kaiwhitwhiti Stm - Hard bottomed



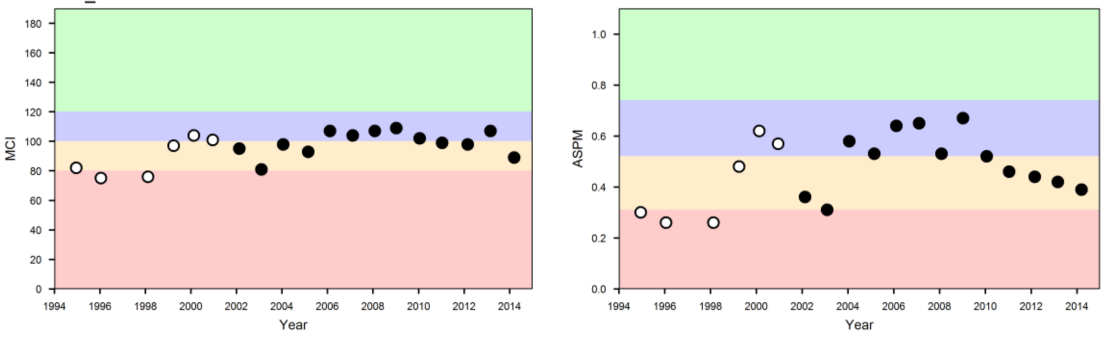
240_5 - Kawaunui Stm - Soft bottomed



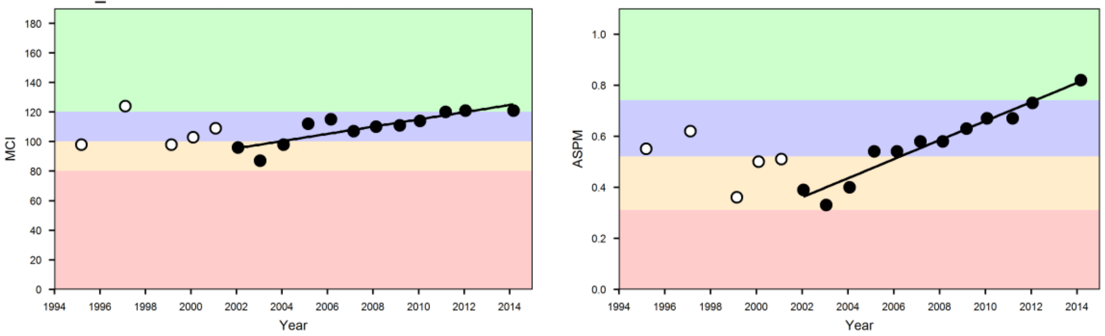
495_1 - Mangawhio Stm Trib - Hard bottomed



786_2 - Pokaiwhenua Stm - Hard bottomed

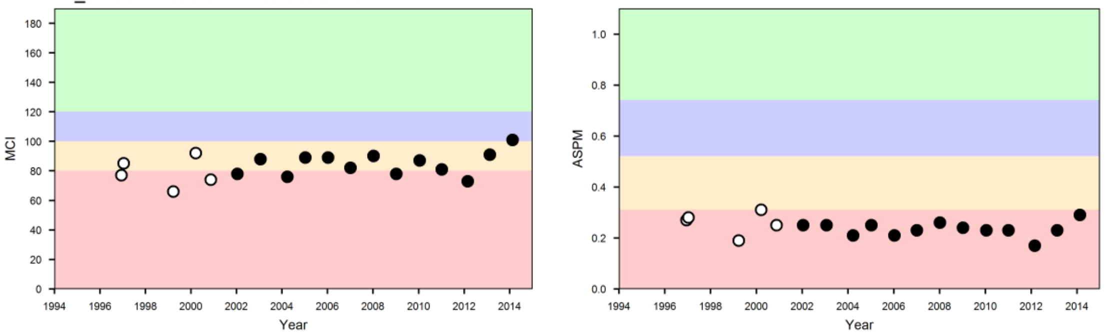


1323_1 - Whirinaki Stm - Hard bottomed

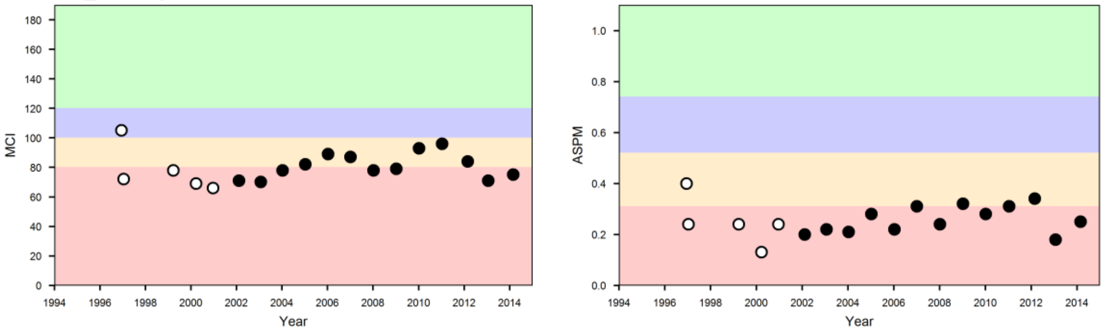


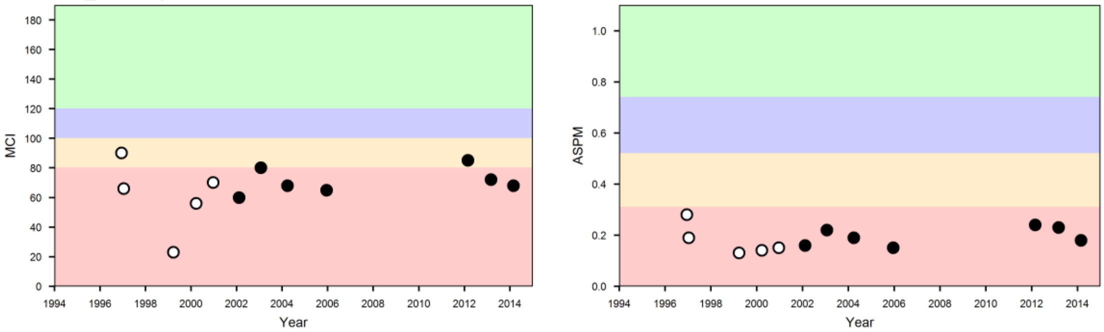
Long-term – Central Waikato

47_2 - Bankwood Stm - Soft bottomed



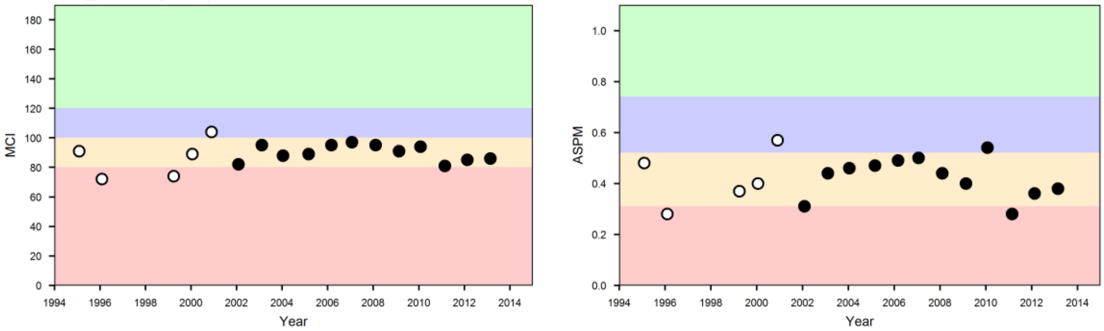
398_1 - Mangakotukutuku Stm - Soft bottomed



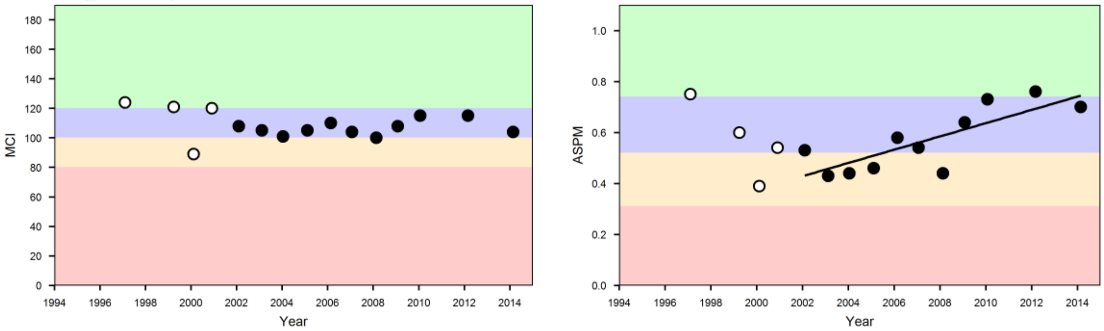


398_6 - Mangakotukutuku Stm - Soft bottomed

Long-term – Lower Waikato

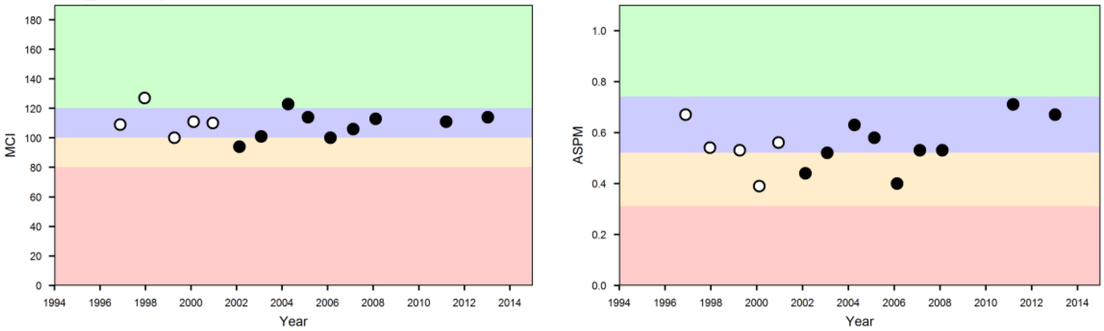


453_8 - Mangatangi River - Hard bottomed

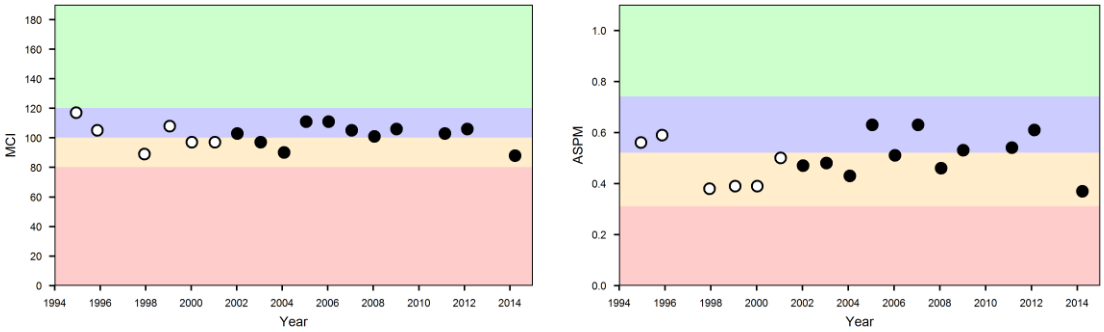


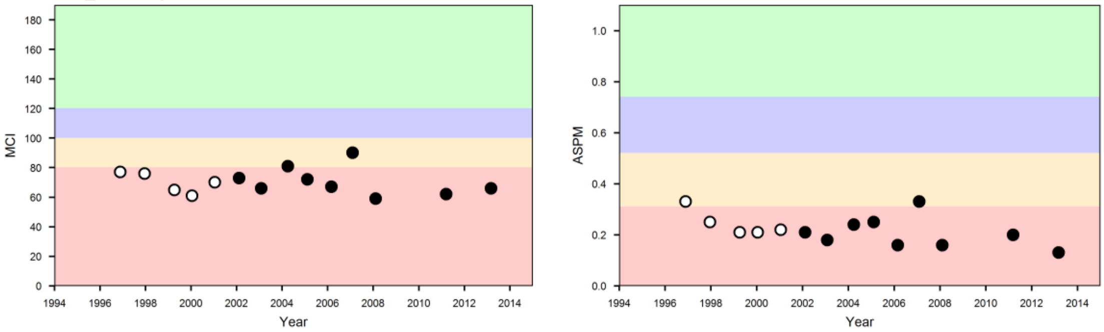
481_11 - Mangawara Stm - Hard bottomed

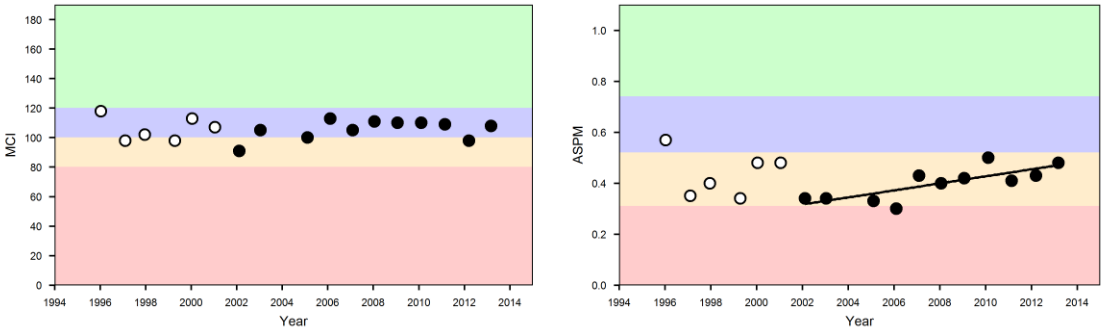
Long-term – Waipa

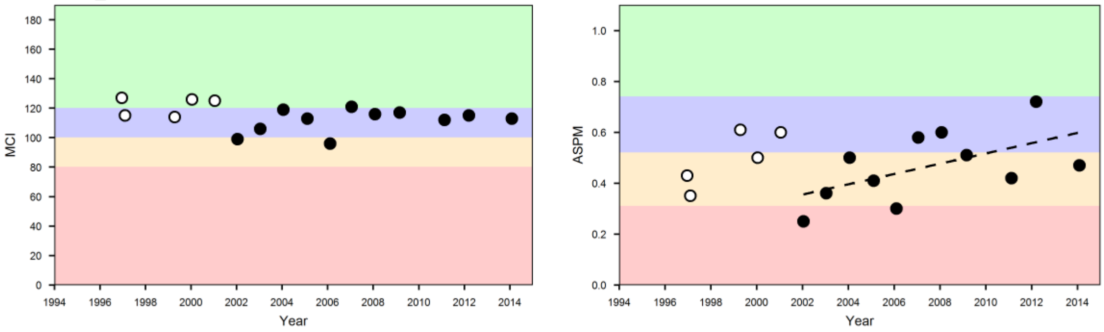


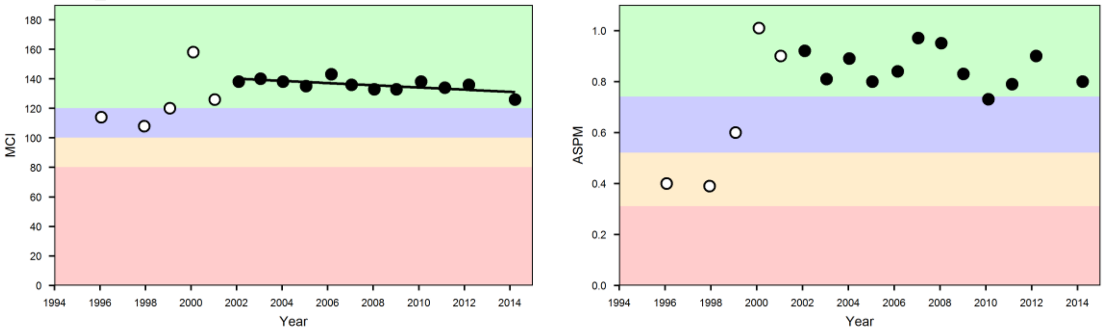
476_1 - Mangatutu Stm - Hard bottomed


477_5 - Mangauika Stm - Hard bottomed


493_1 - Mangawhero Stm Trib - Soft bottomed

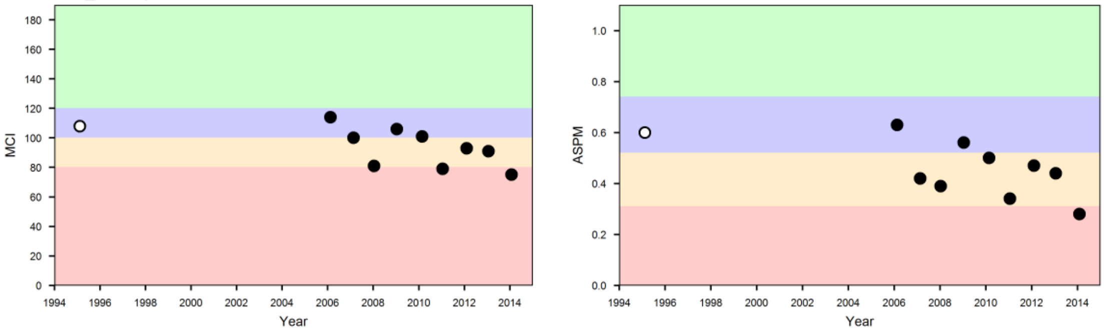

1253_8 - Waitomo Stm - Soft bottomed


1253_9 - Waitomo Stm - Soft bottomed

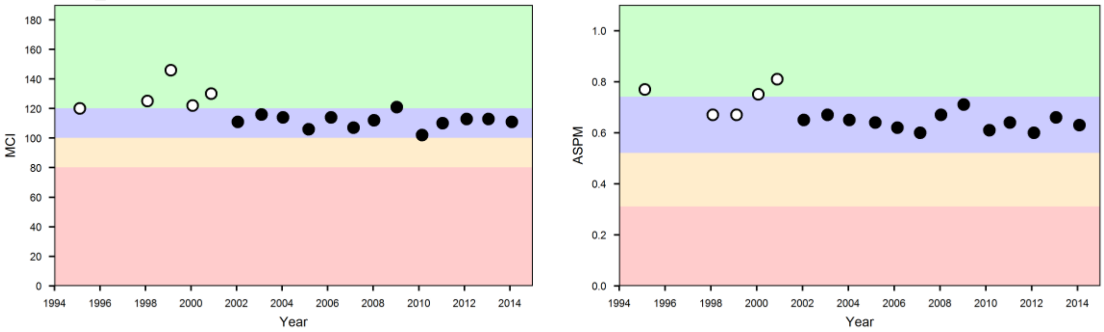

1284_1 - Whakarautawa Stm - Hard bottomed

Long-term – Coromandel

954_5 - Tapu River - Hard bottomed

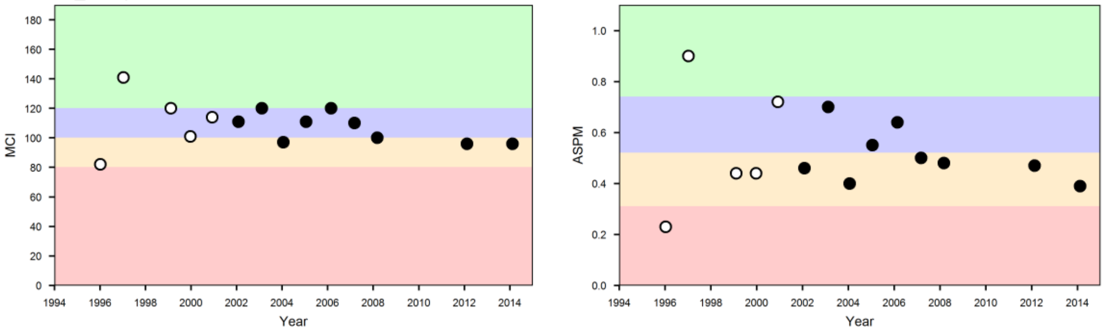


1257_4 - Waiwawa River - Hard bottomed

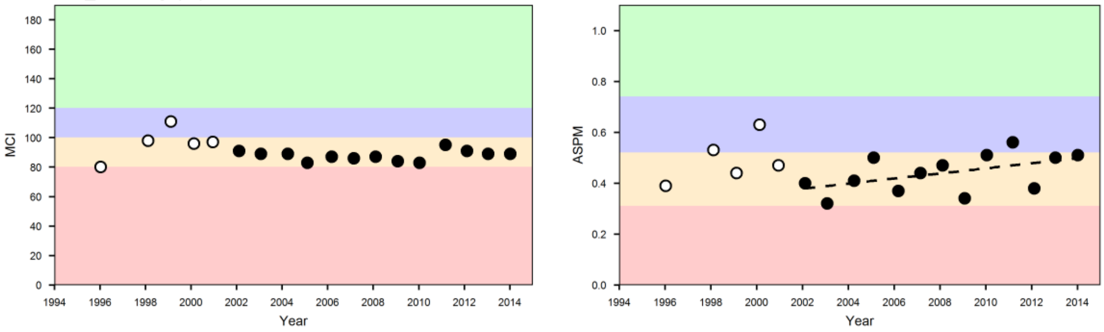


Long-term – Waihou – Piako

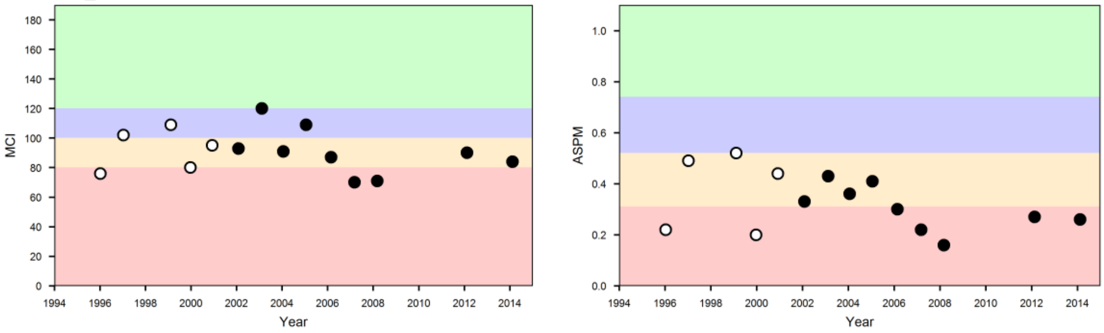
23_2 - Apakura Stm - Hard bottomed



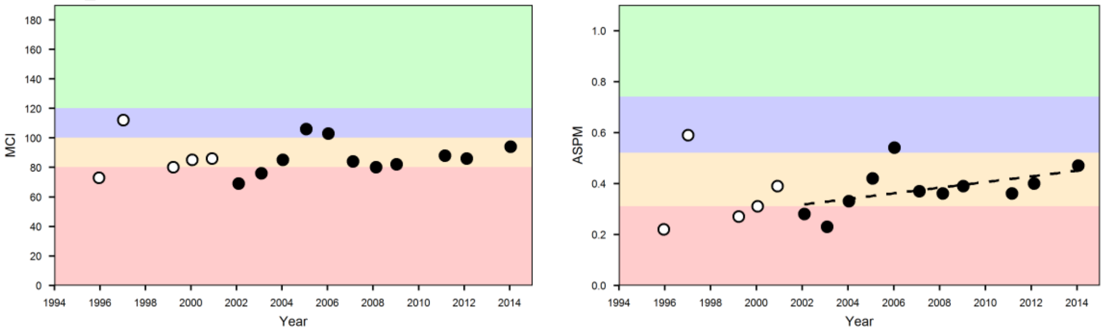
433_2 - Mangapapa Stm - Hard bottomed



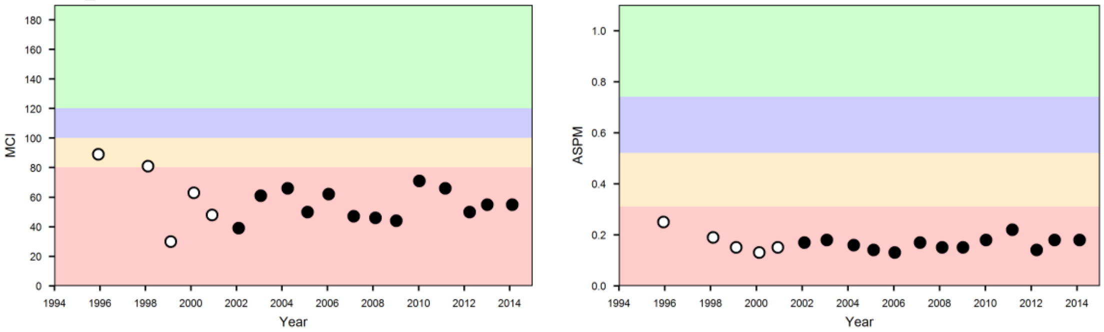
531_4 - Matatoki Stm - Hard bottomed



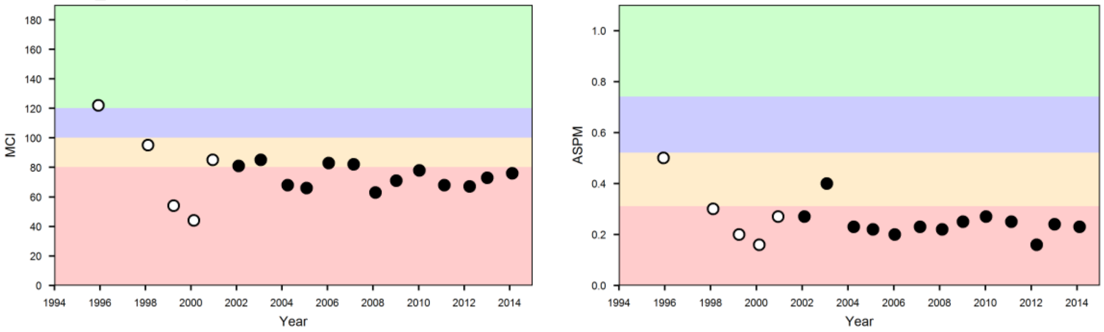
619_20 - Ohinemuri River - Hard bottomed



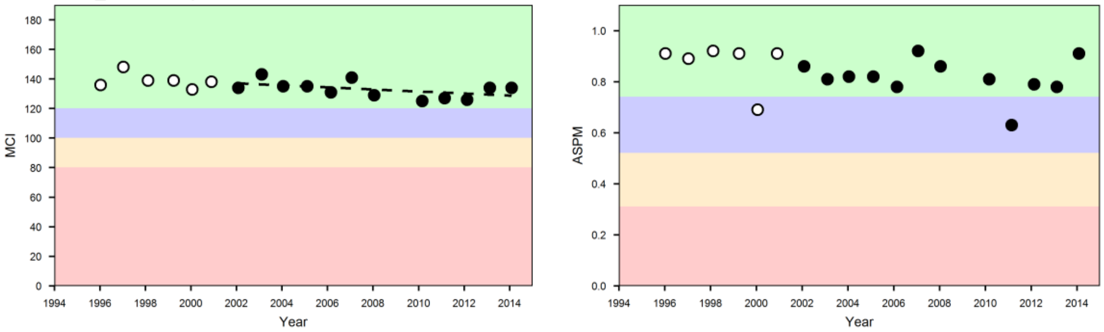
749_10 - Piako River - Soft bottomed



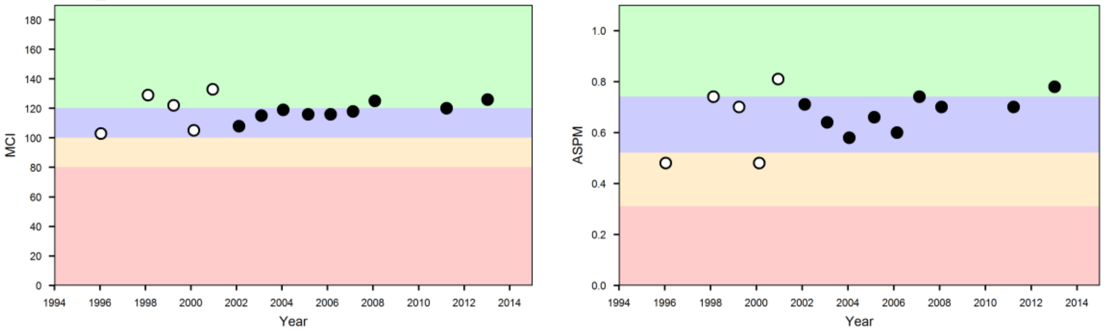
1043_1 - Toenepi Stm - Soft bottomed



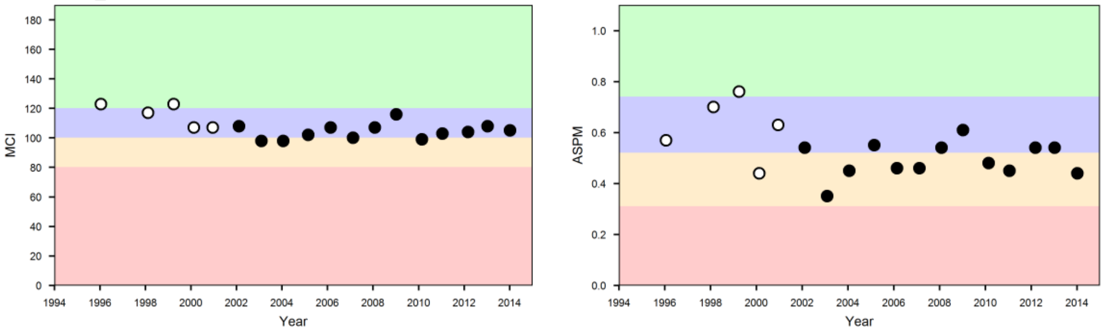
1055_3 - Torehape Stm - Hard bottomed



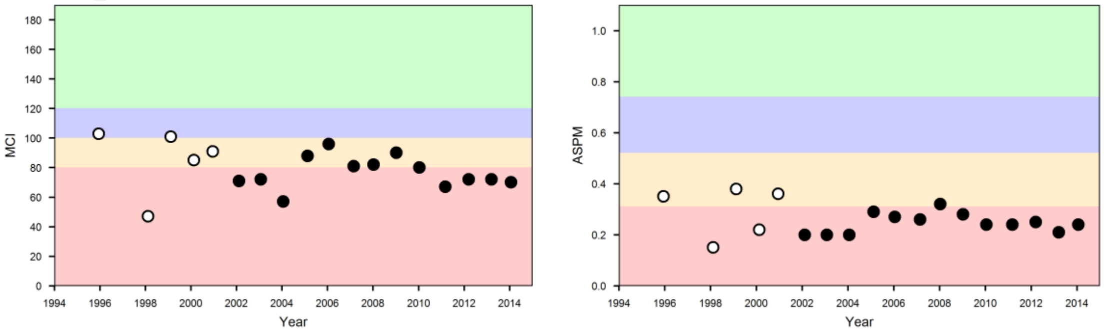
1158_7 - Waimakariri Stm - Hard bottomed



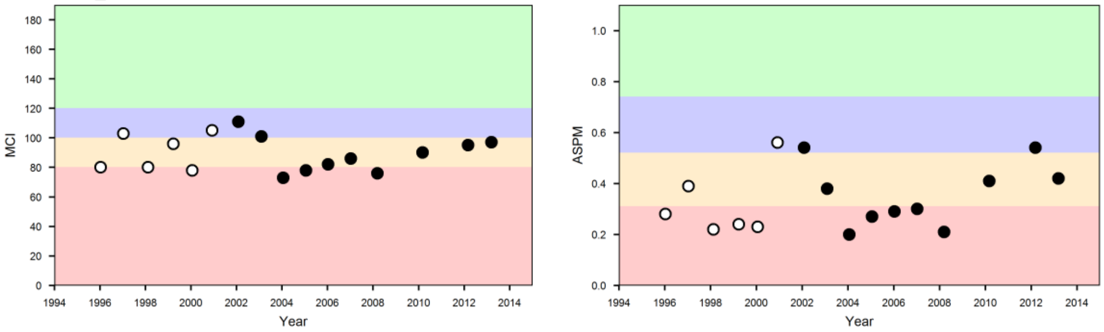
1174_10 - Waiomou Stm - Soft bottomed



1249_15 - Waitoa River - Soft bottomed

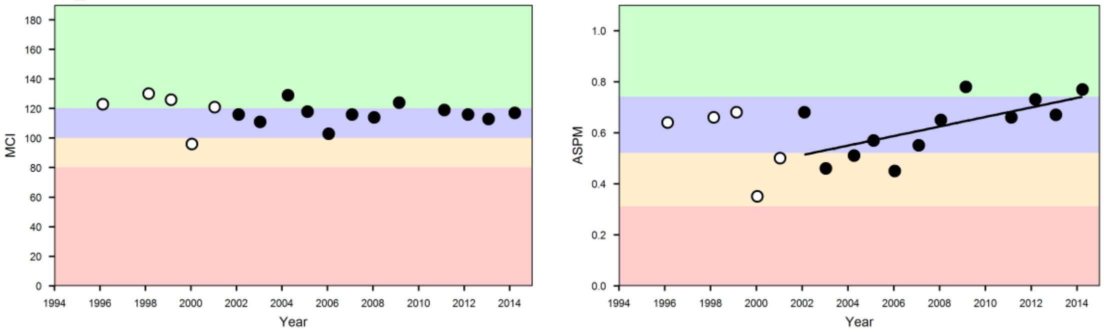


1252_3 - Waitoki Stm - Hard bottomed

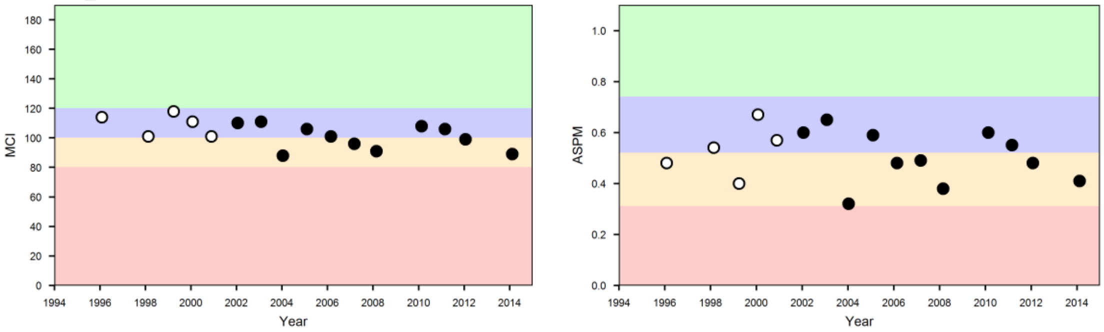


Long-term – West Coast

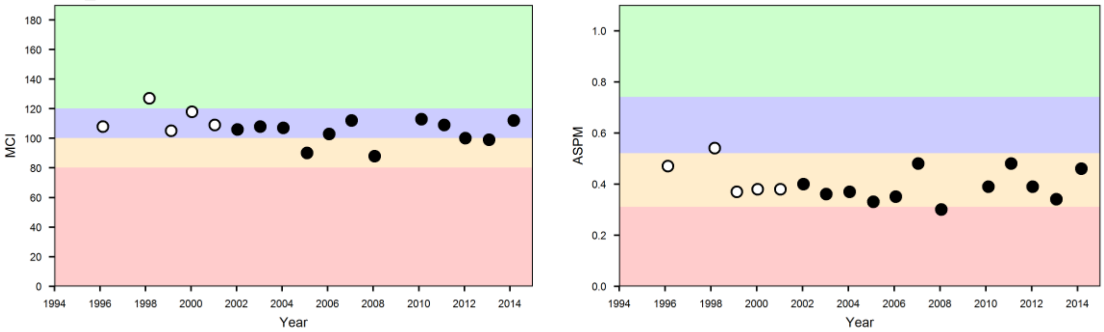
36_1 - Awaroa River - Hard bottomed



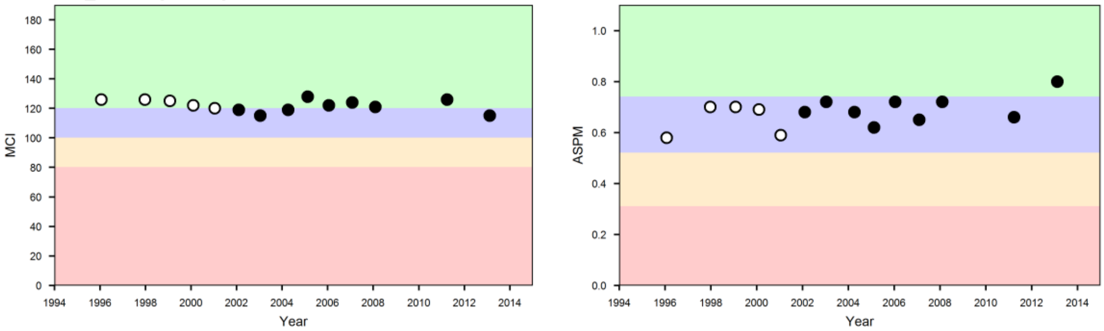
195_1 - Huriwai Stm - Hard bottomed



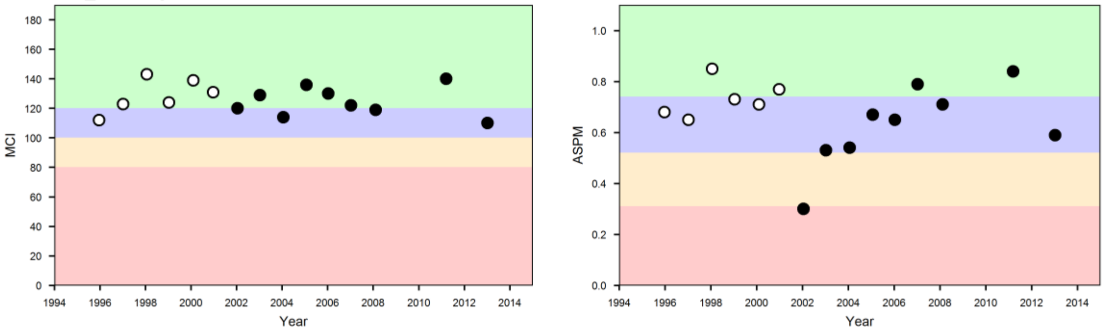
256_2 - Kiritihere Stm - Soft bottomed



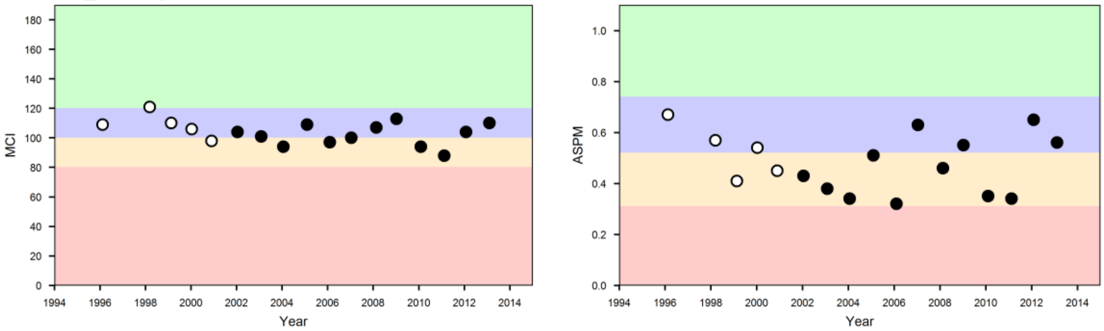
365_1 - Mangahoanga Stm - Hard bottomed



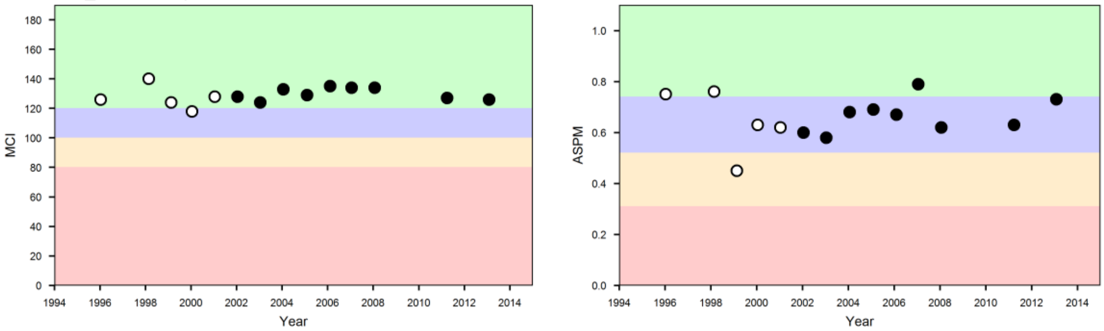
413_2 - Mangaokahu Stm - Hard bottomed



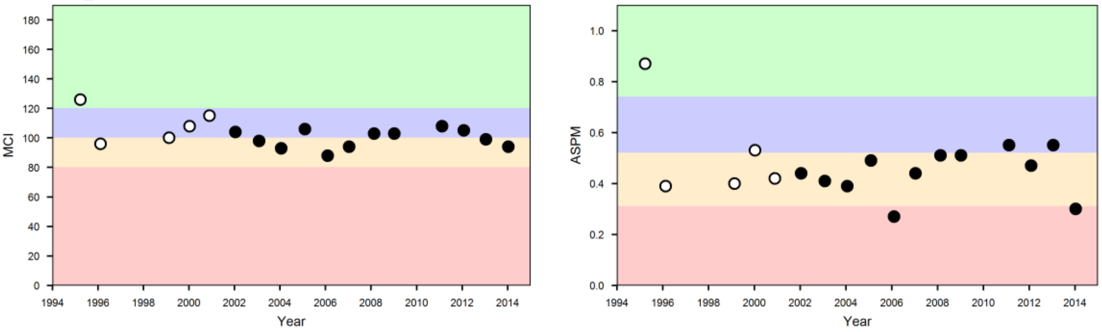
428_3 - Mangaotaki River - Hard bottomed



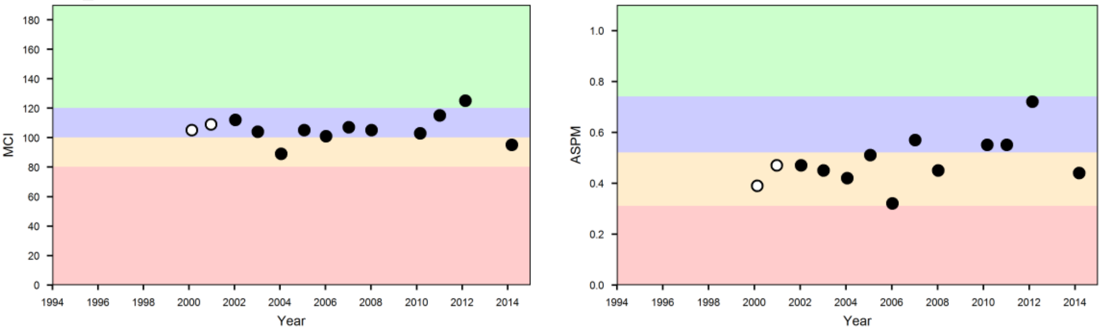
514_1 - Marokopa Stm - Hard bottomed



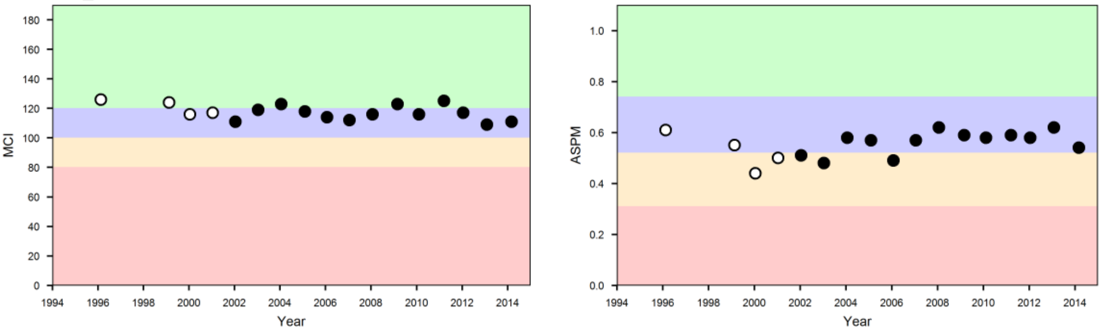
556_9 - Mokau River - Hard bottomed



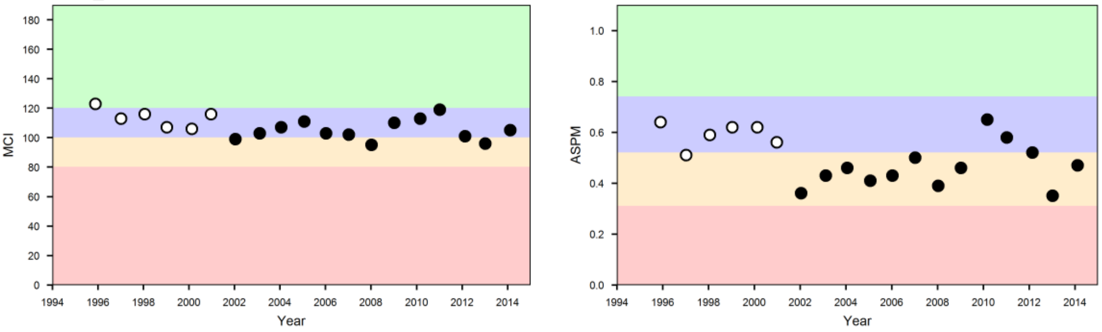
736_2 - Parawai Stm - Hard bottomed



976_2 - Tawarau River - Hard bottomed

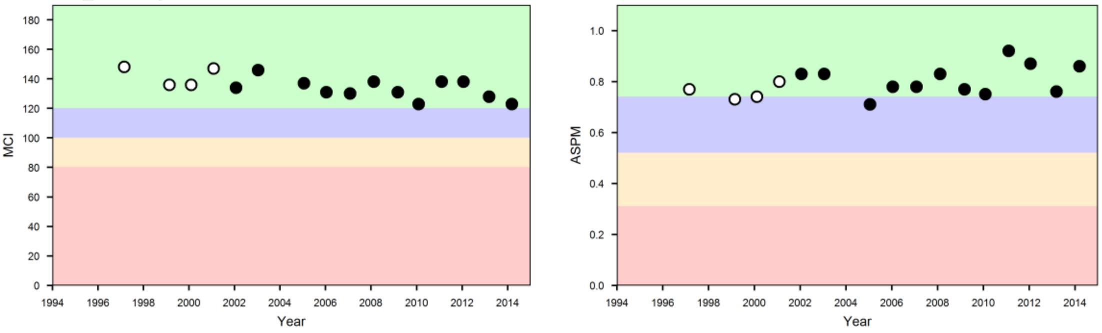


1172_6 - Wainui Stm - Hard bottomed

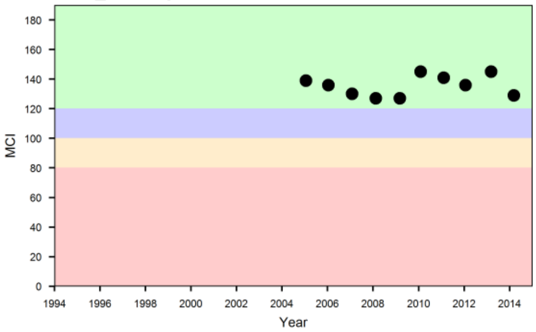


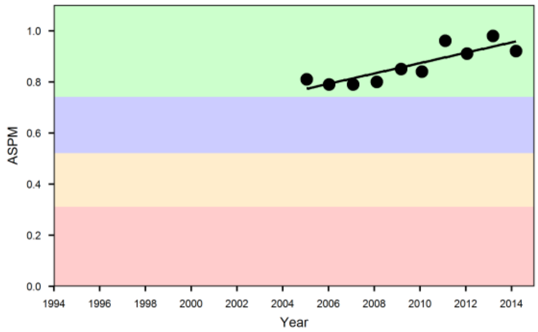
Reference – Lake Taupo

458_1 - Mangatawai Stm - Hard bottomed



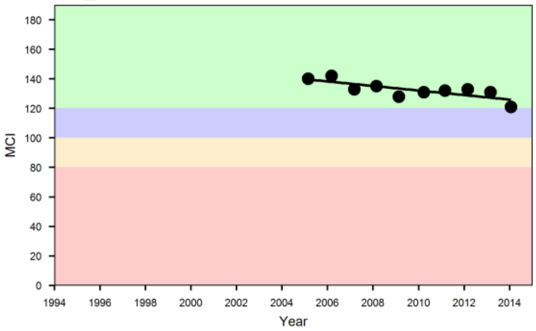
1051_4 - Tongariro River Trib - Hard bottomed

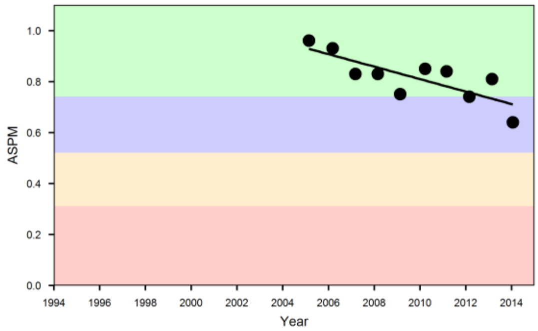




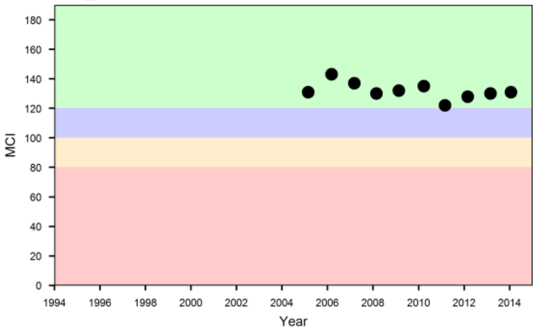
Reference – Upper Waikato

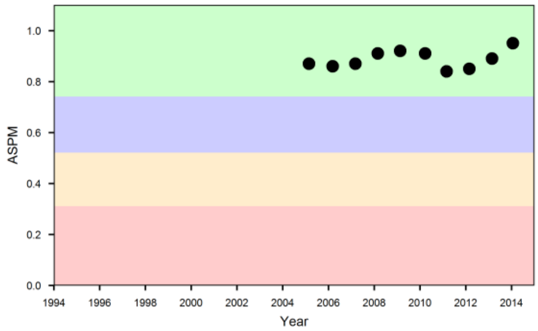
555_2H - Mokaihaha Stm - Hard bottomed



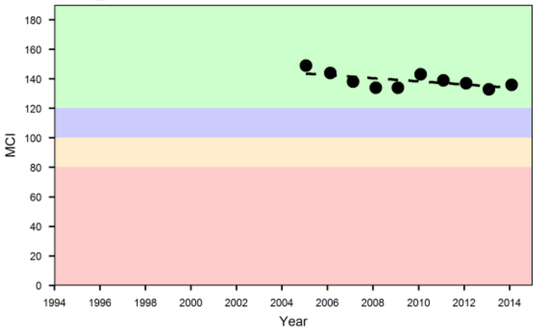


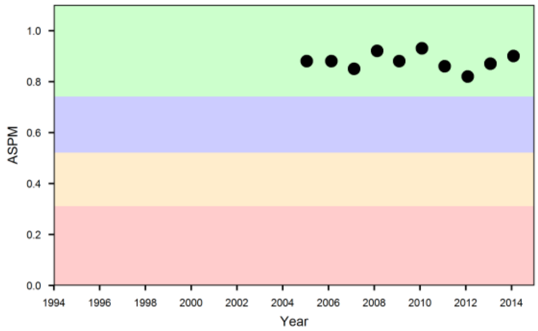
555_2S - Mokaihaha Stm - Soft bottomed





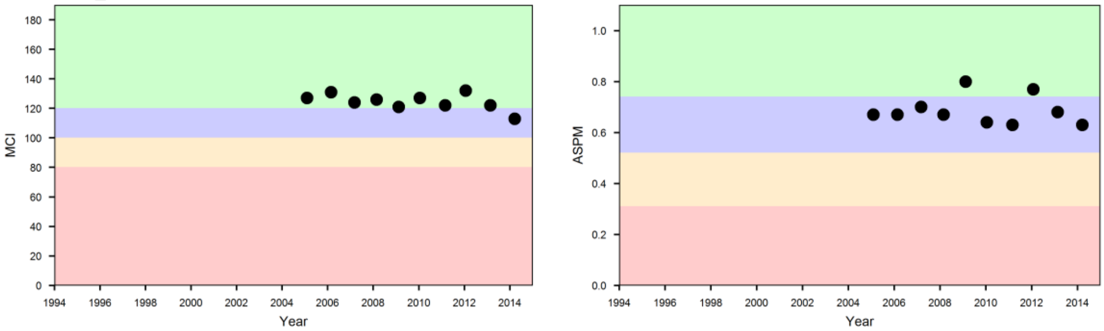
1888_4 - Otautora Stm - Hard bottomed



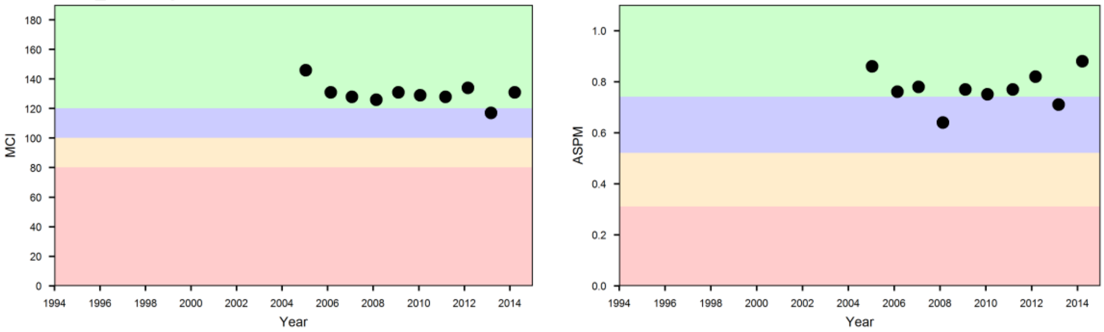


Reference – Lower Waikato

1132_67 - Waikato River Trib - Hard bottomed

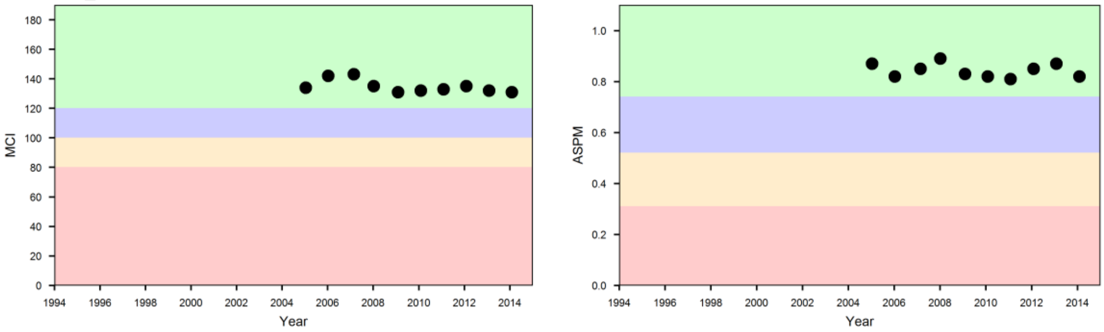


1961_1 - Mangatea Stream Trib - Hard bottomed

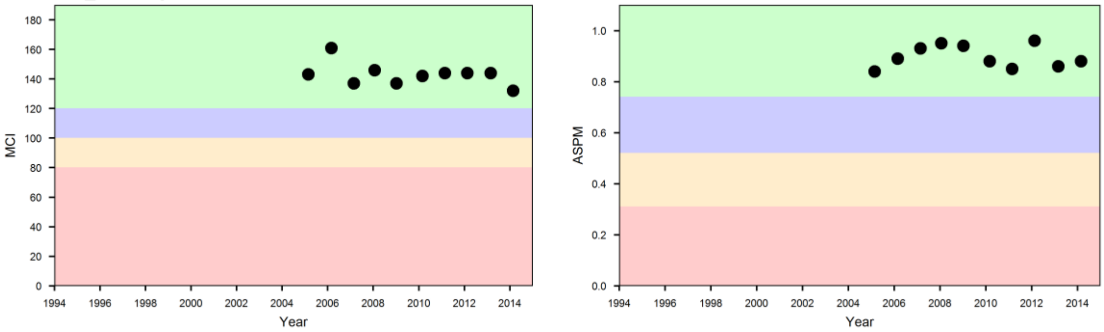


Reference – Waipa

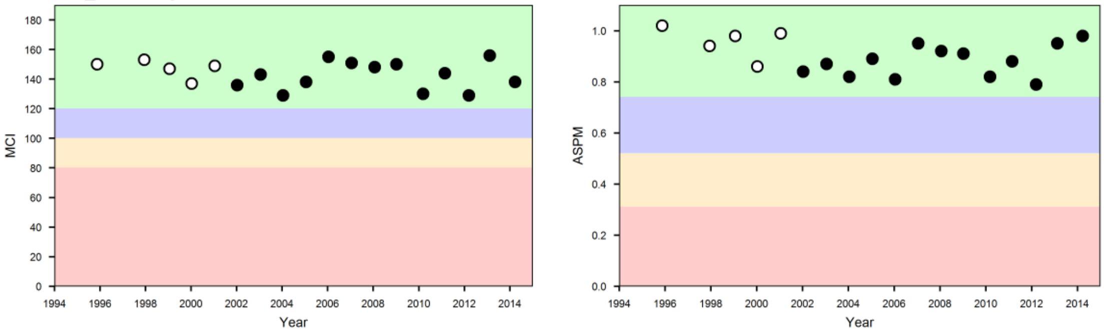
125_15 - Firewood Creek Trib - Hard bottomed



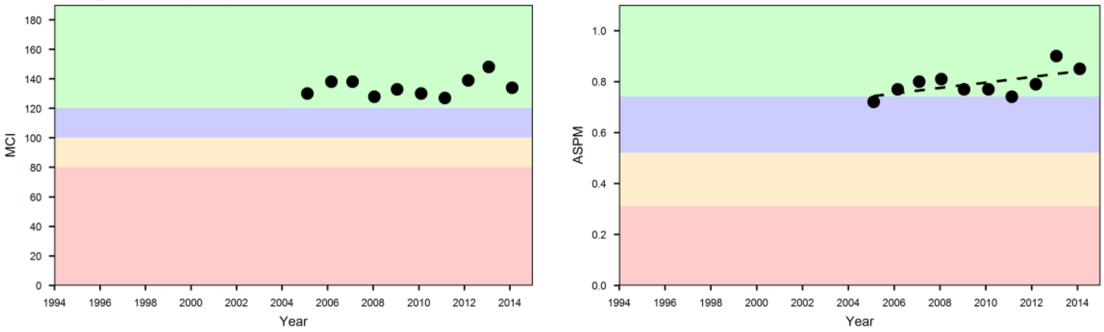
379_1 - Mangakara Stm - Hard bottomed



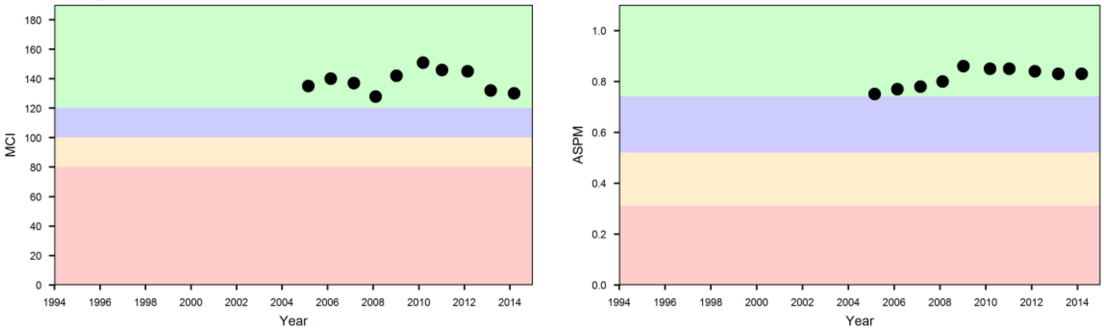
477_14 - Mangauika Stm - Hard bottomed



1966_1 - Purangirangi Stream - Hard bottomed

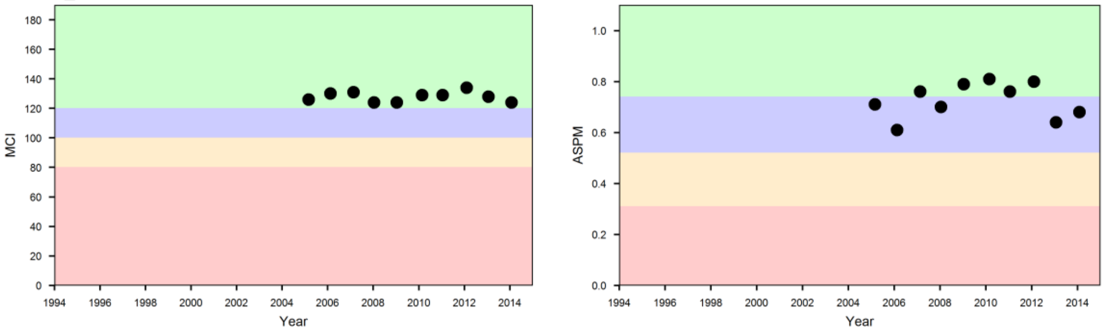


1968_1 - Whakakai Stream - Hard bottomed

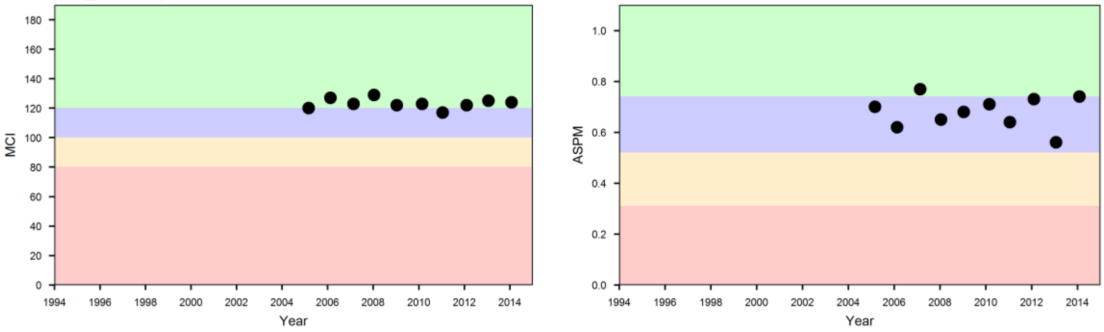


Reference – Coromandel

9_4 - Ahirau Stm - Hard bottomed

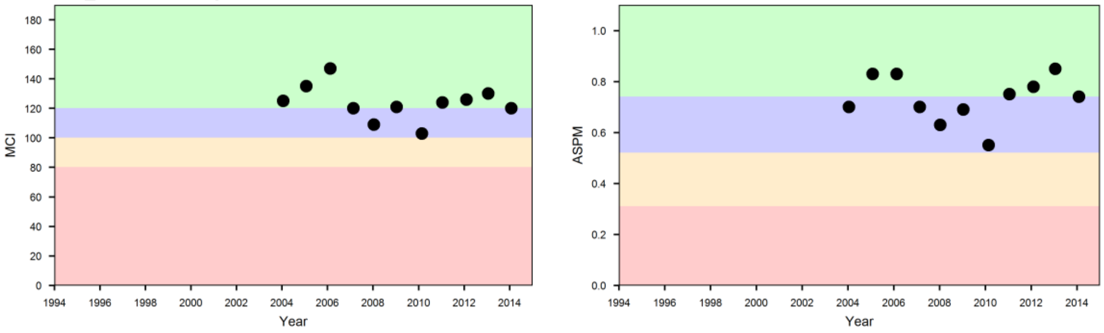


474_2 - Mangatu Stm - Hard bottomed

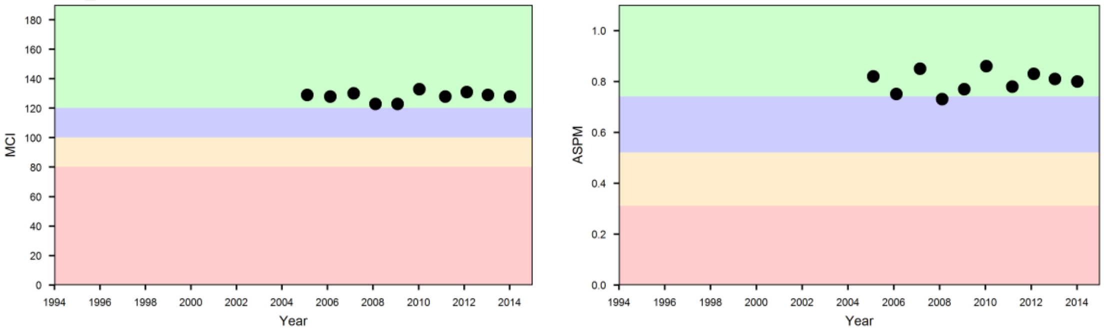


Reference – Waihou Piako

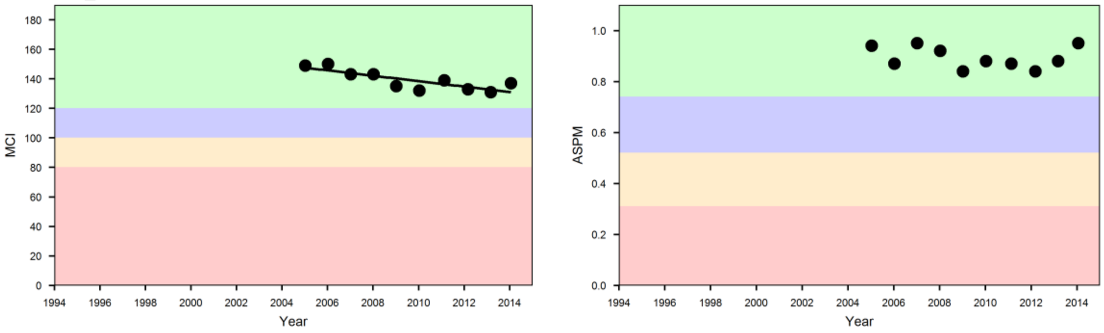
234_28 - Kauaeranga River - Hard bottomed



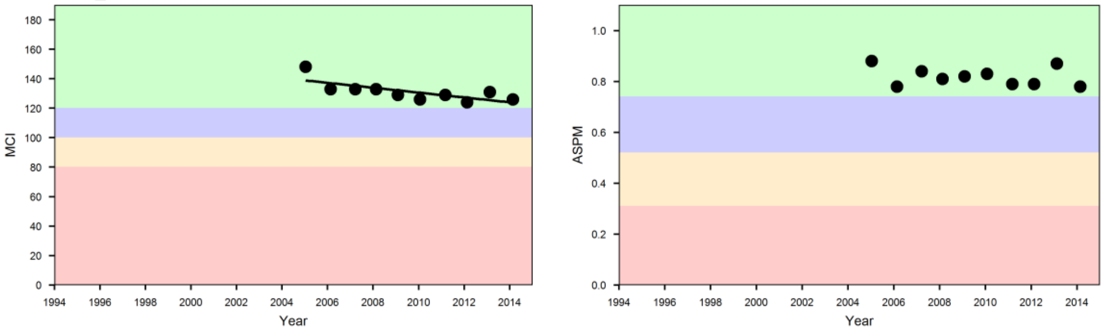
754_20 - Piakonui Stm Trib - Hard bottomed



781_2 - Pohomihi Stm - Hard bottomed

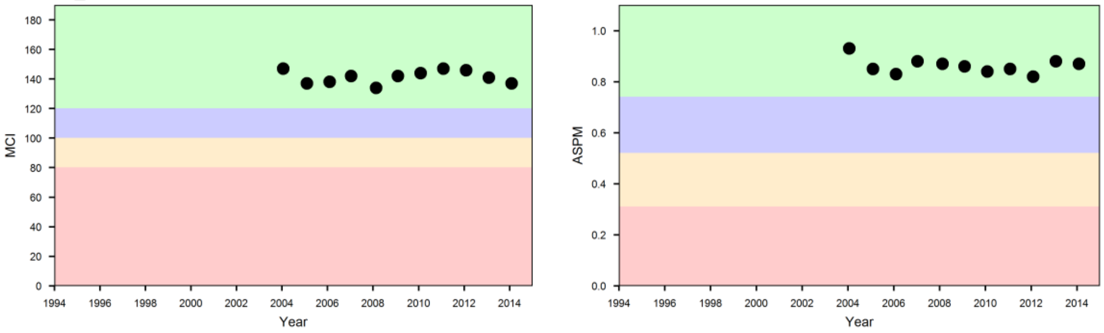


1962_1 - Waiwhata Stream - Hard bottomed

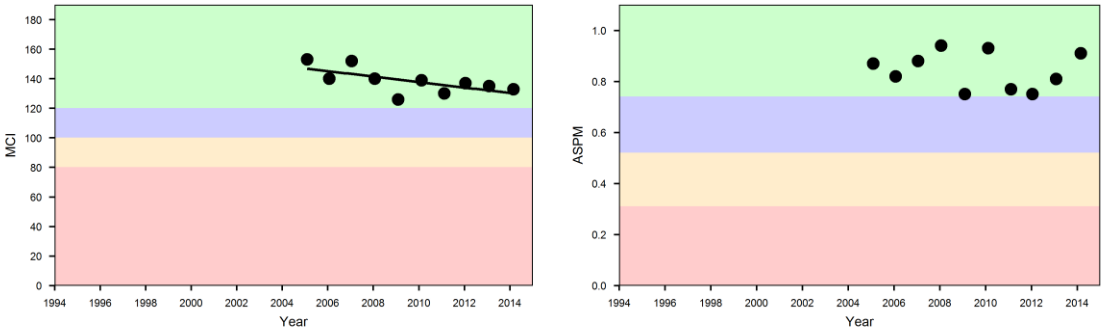


Reference – West Coast

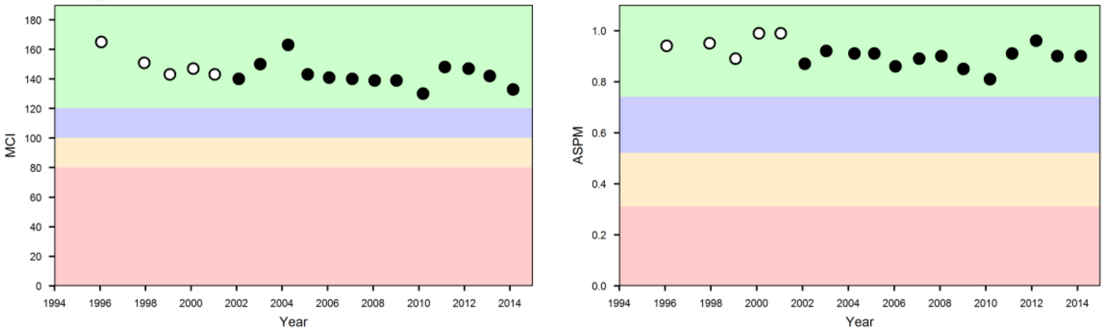
33_16 - Awakino River - Hard bottomed



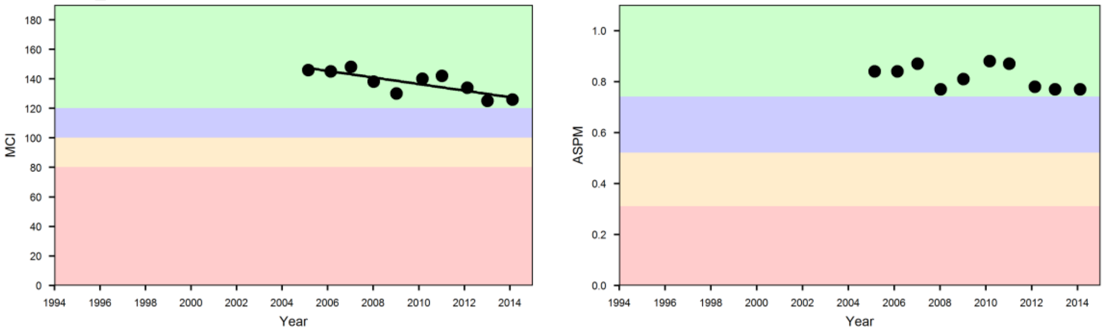
471_2 - Mangatoa Stm - Hard bottomed



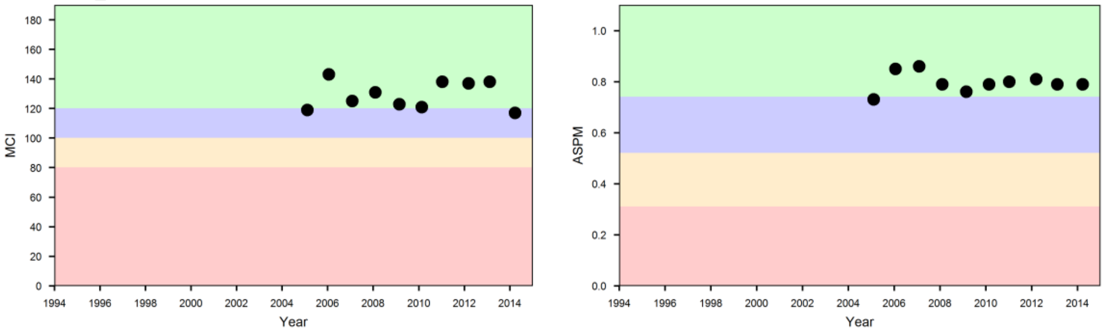
1414_1 - Omanawa Stm Trib - Hard bottomed



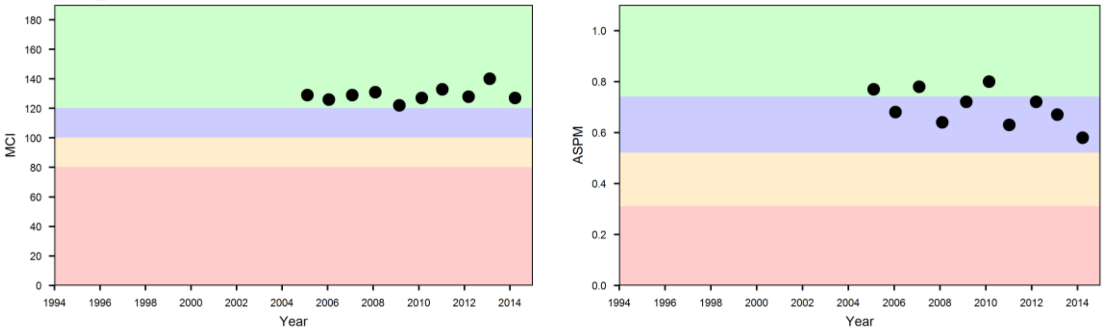
1513_3 - Te Rekereke Stm - Hard bottomed



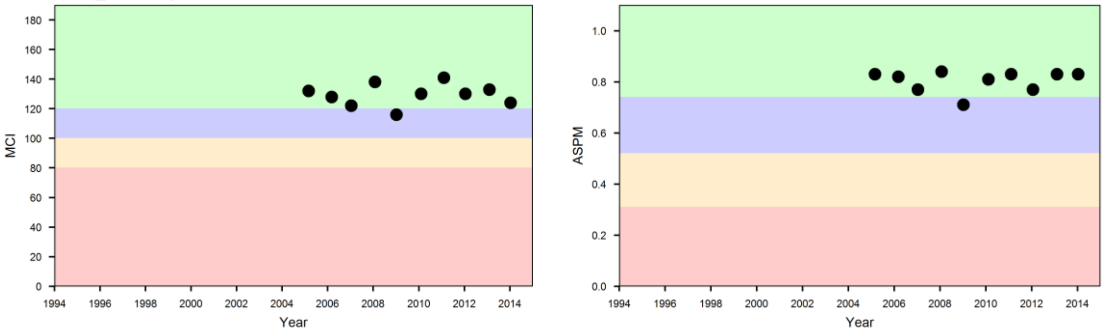
1965_1H - Waikuku Stream - Hard bottomed



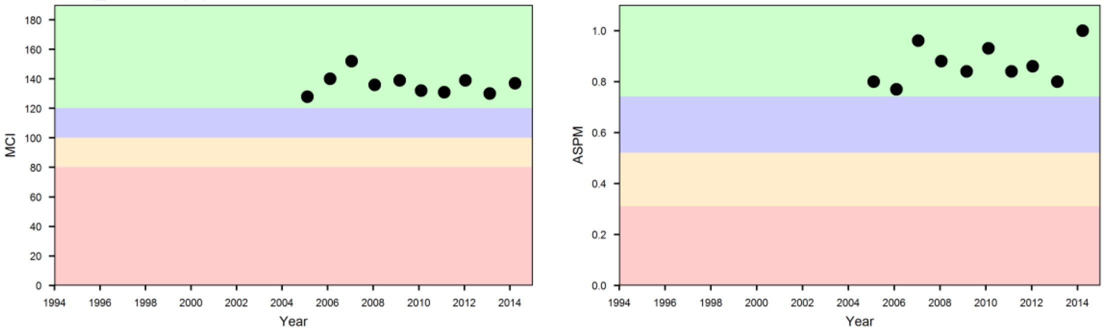
1965_1S - Waikuku Stream - Soft bottomed



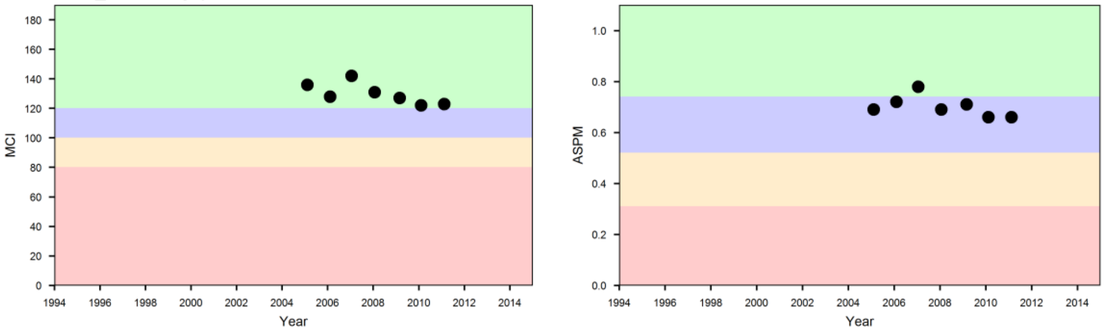
1969_1 - Mangawhata Stream - Hard bottomed



1971_1H - Mangapohue Stream - Hard bottomed

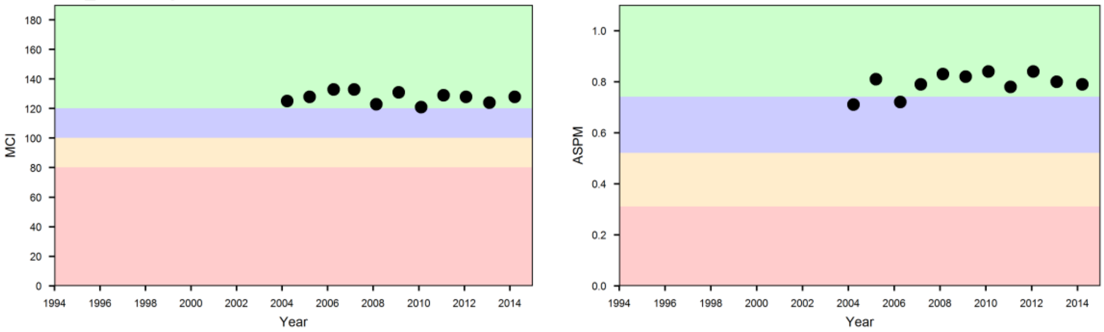


1971_1S - Mangapohue Stream - Soft bottomed

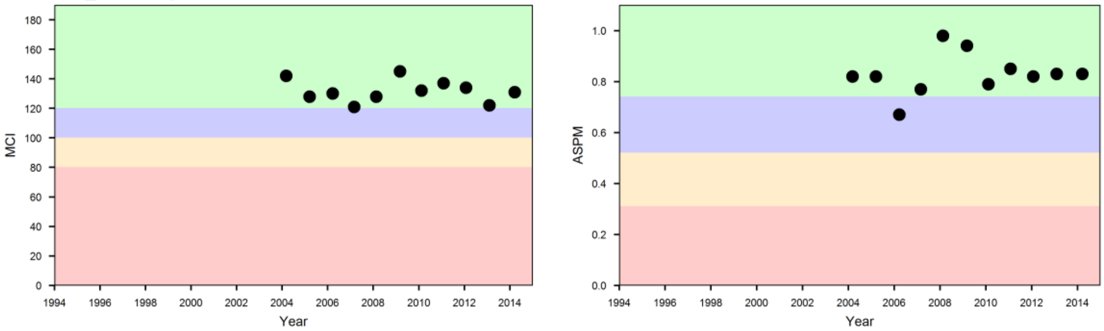


Other – Auckland Council sites - Hunua ranges

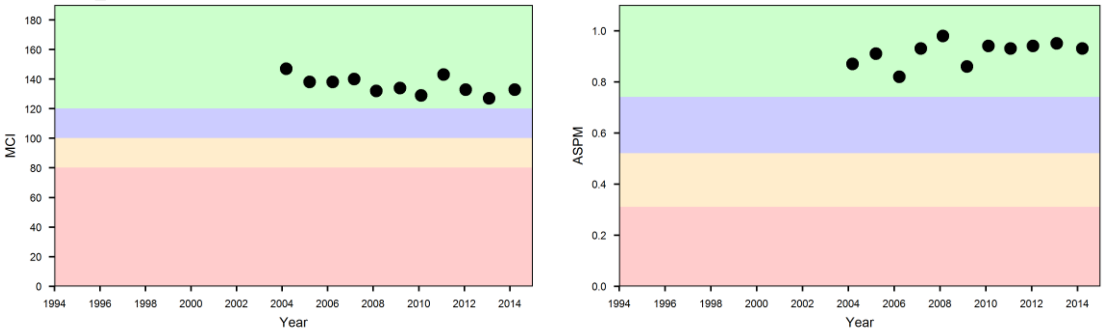
460_35 - Mangatawhiri River Trib - Hard bottomed



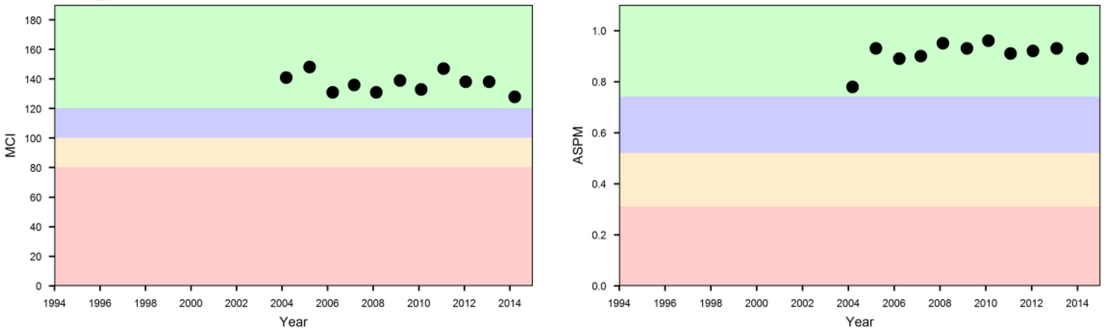
460_36 - Mangatawhiri River Trib - Hard bottomed



3103_1 - Konini Stream - Hard bottomed



3104_1 - Milnes Stream - Hard bottomed



Appendix 4: Mann Kendall trend results for MCI

Calculated from the computer program TimeTrends (v.3.20; 2011). For P values, Red = significant at *P*<0.05 and Bold = borderline *P 0.05* - 0.1, Red and bold if significant after False Discovery Rate (FDR) analysis. Note: trend analysis not undertaken for sites with a sample size of less than 10 records.

Site	Sample size	Median value	Kendall statistic	Variance	Z	P	Median Sen slope (annual)	5% confidence limit for slope	95% confidence limit for slope	Percent annual change
Long-term										
1043_1	13	73.3	-14	268.67	-0.79	0.43	-0.81	-1.46	0.61	-1.11
1055_3	12	133.75	-25	211.67	-1.65	**0.1**	-0.79	-1.4	0	-0.59
1158_7	9	117.9	26	92	2.61	0	1.3	0.49	2.23	1.11
1172_6	13	102.7	5	267.67	0.24	0.81	0.22	-0.9	1.62	0.21
1174_10	13	104.1	16	268.67	0.92	0.36	0.48	-0.33	0.96	0.46
1249_15	13	72.1	-7	267.67	-0.37	0.71	-0.42	-2.3	1.29	-0.58
1252_3	10	87.8	5	125	0.36	0.72	1.57	-3.62	2.54	1.78
1253_8	11	107.9	6	164	0.39	0.7	0.51	-0.71	2.01	0.47
1253_9	11	113	9	165	0.62	0.53	0.65	-0.8	2.15	0.58
1257_4	13	112.8	-14	268.67	-0.79	0.43	-0.28	-0.88	0.51	-0.25
1284_1	12	135.85	-31	211.67	-2.06	0.04	-0.77	-1.24	-0.24	-0.57
1300_2	13	112.2	-14	268.67	-0.79	0.43	-0.51	-1.55	0.79	-0.46
1312_10	12	94.5	-22	212.67	-1.44	0.15	-1.1	-2.53	0.12	-1.16
1323_1	12	111.85	48	212.67	3.22	**0**	2.4	1.64	3.11	2.15
195_1	11	101	-16	164	-1.17	0.24	-1.05	-3.31	0.52	-1.04
220_1	10	124.35	-26	124	-2.25	0.02	-1.28	-2.73	-0.53	-1.03
23_2	9	109.6	-19	91	-1.89	0.03	-1.55	-3.38	-0.04	-1.42
240_5	12	117.85	39	211.67	2.61	0.01	2.06	0.57	2.87	1.75
256_2	12	106.45	2	212.67	0.07	0.95	0.13	-0.94	1.11	0.13
36_1	12	116.1	0	212.67	0	1	0.05	-1.28	0.76	0.04
365_1	9	121.4	6	92	0.52	0.31	0.53	-1.15	1.36	0.44
398_1	13	79.4	14	268.67	0.79	0.43	1.06	-0.8	2.37	1.34
398_6	7	68.3	5	44.33	0.6	0.28	0.41	-5.07	2.18	0.61
413_2	9	121.9	-2	92	-0.1	0.46	-0.31	-3.13	2.47	-0.25
428_3	12	102.25	6	212.67	0.34	0.73	0.2	-1.29	1.62	0.19
433_2	13	88.6	5	267.67	0.24	0.81	0.06	-0.86	0.53	0.06
453_8	12	90.35	-10	212.67	-0.62	0.54	-0.3	-1.34	0.93	-0.33
47_2	13	87.3	18	268.67	1.04	0.3	0.4	-0.65	1.62	0.46
476_1	9	110.8	12	92	1.15	0.13	1.31	-0.6	2.28	1.18
477_5	11	103.1	-5	165	-0.31	0.76	-0.22	-1.59	0.96	-0.21
481_11	11	105	4	164	0.23	0.81	0.49	-0.71	1.42	0.46
493_1	9	66.5	-12	92	-1.15	0.13	-0.91	-4.01	1.15	-1.37
495_1	9	125.2	8	92	0.73	0.24	0.59	-1.18	1.65	0.47
514_1	9	128.7	2	92	0.1	0.46	0.21	-0.79	1.61	0.16
531_4	9	90	-18	92	-1.77	0.04	-2.73	-7.77	-0.15	-3.04
556_9	12	100.95	2	212.67	0.07	0.95	0.11	-0.97	0.92	0.11
619_20	11	85	17	165	1.25	0.21	1.33	-1.12	2.22	1.56

Site	**Sample size**	**Median value**	**Kendall statistic**	**Variance**	**Z**	**P**	**Median Sen slope (annual)**	**5% confidence limit for slope**	**95% confidence limit for slope**	**Percent annual change**
736_2	11	104.5	5	165	0.31	0.76	0.44	-1.18	2.29	0.42
749_10	13	54.5	8	268.67	0.43	0.67	0.55	-1.52	1.5	1.01
786_2	13	98.9	10	268.67	0.55	0.58	0.5	-1.02	1.83	0.51
954_5	9	92.5	-20	92	-1.98	0.02	-3.55	-6.6	-1	-3.84
976_2	13	115.9	-12	268.67	-0.67	0.5	-0.22	-1.14	0.56	-0.19
Reference										
1051_4	10	136	3	125	0.18	0.86	0.25	-3.44	2.24	0.18
1132_67	10	124.9	-15	125	-1.25	0.21	-1.2	-2.05	0.33	-0.96
125_15	10	133.3	-15	125	-1.25	0.21	-0.47	-1.77	0.14	-0.36
1414_1	13	140.8	-24	266.67	-1.41	0.16	-0.81	-2.1	0.14	-0.57
1513_3	10	138.95	-27	125	-2.33	0.02	-2.38	-3.71	-0.96	-1.72
1888_4	10	137.5	-21	125	-1.79	**0.07**	-1.14	-3.24	-0.12	-0.83
1961_1	10	130.15	-11	125	-0.89	0.37	-1.17	-2.7	0.49	-0.9
1962_1	10	129.85	-30	124	-2.6	0.01	-1.22	-2.72	-0.43	-0.94
1965_1H	10	127.9	-1	125	0	1	-0.05	-1.64	2.58	-0.04
1965_1S	10	128.4	6	124	0.45	0.65	0.28	-0.68	1.81	0.22
1966_1	10	133.55	7	125	0.54	0.59	0.22	-1.84	2.2	0.16
1968_1	10	138.25	1	125	0	1	0.31	-2.41	1.79	0.23
1969_1	10	129.8	1	125	0	1	0.1	-3.06	1.69	0.08
1971_1H	10	136.2	-7	125	-0.54	0.59	-0.41	-2.03	0.99	-0.3
1971_1S	7	127.5	-13	44.33	-1.8	0.04	-2.3	-6.47	-0.12	-1.81
234_28	11	124.4	-6	164	-0.39	0.7	-0.5	-3.58	1.69	-0.4
33_16	11	142	3	165	0.16	0.88	0.4	-1.02	1.26	0.28
379_1	10	143.2	-7	125	-0.54	0.59	-0.31	-2.77	0.82	-0.21
458_1	12	132.25	-20	212.67	-1.3	0.19	-0.89	-2.06	0.18	-0.67
471_2	10	137.65	-26	124	-2.25	0.02	-1.51	-3.28	-0.65	-1.1
474_2	10	122.95	1	125	0	1	0.07	-0.89	0.63	0.05
477_14	13	143.5	6	268.67	0.31	0.76	0.18	-1.73	1.89	0.12
555_2H	10	132.3	-27	125	-2.33	0.02	-1.58	-2.58	-0.44	-1.2
555_2S	10	131.2	-17	125	-1.43	0.15	-0.66	-2.25	0.12	-0.5
754_20	10	128.4	3	125	0.18	0.86	0.04	-1.06	0.95	0.03
781_2	10	137.95	-29	125	-2.5	0.01	-2.1	-3.44	-0.9	-1.52
9_4	10	128.25	-3	125	-0.18	0.86	-0.14	-0.66	0.85	-0.11
Auckland										
3103_1	10	135.81	-21	125	-1.79	**0.07**	-1.54	-2.8	-0.5	-1.13
3104_1	10	137.81	-3	125	-0.18	0.86	-0.13	-1.6	1.36	-0.09
460_35	10	128.33	-10	124	-0.81	0.42	-0.66	-1.24	0.66	-0.52
460_36	10	131.14	1	125	0	1	0.04	-3.5	1.6	0.03

Appendix 5: Mann Kendall trend results for ASPM

Calculated from the computer program TimeTrends (v.3.20; 2011). For P values, Red = significant at *P*<0.05 and Bold = borderline *P 0.05* - 0.1, Red and bold if significant after False Discovery Rate (FDR) analysis. Note: trend analysis not undertaken for sites with a sample size of less than 10 records.

Site	Sample size	Median value	Kendall statistic	Variance	Z	P	Median Sen slope (annual)	5% confidence limit for slope	95% confidence limit for slope	Percent annual change
Long-term										
1043_1	13	0.23	-18	268.67	-1.04	0.3	0	-0.01	0	-1.54
1055_3	12	0.81	-10	212.67	-0.62	0.54	0	-0.02	0.01	-0.32
1158_7	9	0.7	12	92	1.15	0.13	0.01	-0.01	0.02	1.32
1172_6	13	0.46	20	268.67	1.16	0.25	0.01	-0.01	0.02	1.79
1174_10	13	0.48	10	268.67	0.55	0.58	0	-0.01	0.01	0.2
1249_15	13	0.24	4	268.67	0.18	0.85	0	-0.01	0.01	0.36
1252_3	10	0.34	11	125	0.89	0.37	0	-0.03	0.03	1.18
1253_8	11	0.41	31	165	2.34	0.02	0.01	0.01	0.02	3.21
1253_9	11	0.47	25	165	1.87	**0.06**	0.02	0	0.05	5.2
1257_4	13	0.64	-14	268.67	-0.79	0.43	0	-0.01	0	-0.37
1284_1	12	0.83	-16	212.67	-1.03	0.3	-0.01	-0.02	0.01	-0.68
1300_2	13	0.43	20	268.67	1.16	0.25	0.01	0	0.02	1.32
1312_10	12	0.41	22	212.67	1.44	0.15	0.01	-0.01	0.03	3.14
1323_1	12	0.58	62	212.67	4.18	**0**	0.04	0.03	0.04	6.07
195_1	11	0.49	-15	165	-1.09	0.28	-0.01	-0.04	0.01	-2.38
220_1	10	0.66	-1	125	0	1	0	-0.01	0.01	-0.02
23_2	9	0.48	-12	92	-1.15	0.13	-0.02	-0.03	0.01	-3.31
240_5	12	0.64	32	212.67	2.13	0.03	0.02	0	0.05	3.88
256_2	12	0.38	8	212.67	0.48	0.63	0	-0.01	0.01	0.65
36_1	12	0.66	32	212.67	2.13	0.03	0.02	0	0.04	3.38
365_1	9	0.68	6	92	0.52	0.31	0	-0.01	0.01	0.63
398_1	13	0.25	26	268.67	1.53	0.13	0.01	0	0.01	2.73
398_6	7	0.19	3	44.33	0.3	0.39	0	-0.02	0.01	0.94
413_2	9	0.65	22	92	2.19	0.01	0.04	0.01	0.07	6.05
428_3	12	0.45	16	212.67	1.03	0.3	0.01	-0.01	0.03	1.85
433_2	13	0.44	30	268.67	1.77	**0.08**	0.01	0	0.02	2.37
453_8	12	0.44	-6	212.67	-0.34	0.73	-0.01	-0.02	0.01	-1.15
47_2	13	0.23	-4	268.67	-0.18	0.85	0	0	0	-0.34
476_1	9	0.53	14	92	1.36	0.09	0.02	-0.02	0.04	3.1
477_5	11	0.51	7	165	0.47	0.64	0.01	-0.02	0.01	1.19
481_11	11	0.54	33	165	2.49	0.01	0.03	0.01	0.04	4.65
493_1	9	0.2	-10	92	-0.94	0.18	0	-0.02	0.01	-2.31
495_1	9	0.71	18	92	1.77	0.04	0	0	0.02	0.54
514_1	9	0.67	12	92	1.15	0.13	0.01	-0.01	0.03	0.81
531_4	9	0.3	-20	92	-1.98	0.02	-0.02	-0.05	-0.01	-5.47
556_9	12	0.46	22	212.67	1.44	0.15	0.01	-0.01	0.02	1.77
619_20	11	0.37	25	165	1.87	**0.06**	0.01	0	0.02	3.45

Site	**Sample size**	**Median value**	**Kendall statistic**	**Variance**	**Z**	**P**	**Median Sen slope (annual)**	**5% confidence limit for slope**	**95% confidence limit for slope**	**Percent annual change**
Long-term										
736_2	11	0.47	13	165	0.93	0.35	0.01	0	0.03	2.11
749_10	13	0.17	14	268.67	0.79	0.43	0	0	0	0.6
786_2	13	0.52	-14	268.67	-0.79	0.43	-0.01	-0.03	0.01	-2.71
954_5	9	0.44	-16	92	-1.56	0.06	-0.03	-0.05	0	-6.1
976_2	13	0.58	24	268.67	1.4	0.16	0.01	0	0.01	0.88
Reference										
1051_4	10	0.84	31	125	2.68	0.01	0.02	0.01	0.03	2.22
1132_67	10	0.67	-9	125	-0.72	0.47	0	-0.01	0.01	-0.4
125_15	10	0.84	-11	125	-0.89	0.37	0	-0.01	0	-0.23
1414_1	13	0.9	-6	268.67	-0.31	0.76	0	0	0	-0.09
1513_3	10	0.82	-15	125	-1.25	0.21	-0.01	-0.02	0	-0.99
1888_4	10	0.9	5	108.33	0.38	0.7	0	0	0	0
1961_1	10	0.77	1	125	0	1	0	-0.02	0.02	0.26
1962_1	10	0.81	-11	125	-0.89	0.37	-0.01	-0.01	0.01	-0.67
1965_1H	10	0.79	3	125	0.18	0.86	0	-0.01	0.01	0.07
1965_1S	10	0.7	-15	125	-1.25	0.21	-0.01	-0.04	0.01	-1.69
1966_1	10	0.78	21	125	1.79	**0.07**	0.01	0	0.02	1.24
1968_1	10	0.83	17	125	1.43	0.15	0.01	0	0.02	1.16
1969_1	10	0.82	7	125	0.54	0.59	0	-0.01	0.01	0.11
1971_1H	10	0.85	9	125	0.72	0.47	0.01	-0.02	0.02	0.76
1971_1S	7	0.69	-11	44.33	-1.5	0.07	-0.01	-0.03	0.01	-1.56
234_28	11	0.74	3	165	0.16	0.88	0	-0.02	0.03	0.32
33_16	11	0.87	-5	157.67	-0.32	0.75	0	-0.02	0.01	0
379_1	10	0.89	1	125	0	1	0	-0.01	0.01	0.17
458_1	12	0.81	6	212.67	0.34	0.73	0	-0.01	0.01	0.4
471_2	10	0.84	-5	125	-0.36	0.72	0	-0.02	0.02	-0.28
474_2	10	0.69	3	125	0.18	0.86	0	-0.02	0.02	0.36
477_14	13	0.88	18	268.67	1.04	0.3	0.01	0	0.01	0.83
555_2H	10	0.83	-27	125	-2.33	0.02	-0.02	-0.05	-0.01	-2.69
555_2S	10	0.88	9	125	0.72	0.47	0.01	-0.01	0.01	0.66
754_20	10	0.81	5	125	0.36	0.72	0	-0.01	0.01	0.36
781_2	10	0.88	-5	125	-0.36	0.72	0	-0.02	0.01	-0.45
9_4	10	0.74	3	125	0.18	0.86	0	-0.02	0.02	0.51
Auckland										
3103_1	10	0.93	23	125	1.97	0.05	0.01	0	0.02	0.81
3104_1	10	0.92	13	125	1.07	0.28	0.01	0	0.02	0.74
460_35	10	0.81	17	125	1.43	0.15	0.01	0	0.02	1.15
460_36	10	0.82	9	125	0.72	0.47	0	-0.02	0.02	0.44

Appendix 6: WQ trend analysis undertaken by Bill Vant using a Seasonal Mann-Kendal test in Timetrends software.

Site	River	Location		Black disc				Turbidity			
			start	n_raw	median	P(%)_raw	slope(%pa)	n_raw	median	P(%)_raw	slope(%pa)
1257-3	Waiwawa	Coroglen	2002	150	2.7	56.4	-0.8	156	1.4	1.65	-2.6
619-20	Ohinemuri	SH25	2002	151	3.1	0	-4.8	156	1	80.5	-0.2
1249-15	Waitoa	Landsdowne	2002	152	1.1	36.09	1.4	156	5.3	0.57	-2.5
749-10	Piako	Kiwitahi	2002	153	1.3	35.61	-1.7	156	4.5	22.43	-1
1323-1	Whirinaki	Corbett	2002					156	0.5	21.01	1.3
398-1	Mangakotukutuku	Peacockes	2002	148	0.4	15.39	1.4	149	23	16.33	-0.9
240-5	Kawaunui	SH5	2002	153	1.2	0.09	3.2	156	3.9	0.95	-2.4
407-1	Mangamingi	Paraonui Rd	2002	152	1	0.01	-4	156	3.8	0	5.9
786-2	Pokaiwhenua	Arapuni-Putaruru Rd	2002	153	1.3	46.9	-0.8	156	2.8	88.78	-0.1
1253-7	Waitomo	Tumutumu	2002	142	0.8	29.53	-1.2	154	5.7	34.19	-0.9
477-10	Mangauika	Te Awamutu W/S	2002	149	3.7	23.67	-1.3	154	1.5	0	4.7
428-3	Mangaotaki	SH3	2002	154	0.8	25.05	-1.5	156	5.8	83.25	0.3
556-9	Mokau	Totoro	2002	154	0.7	61.52	0.6	156	8	58.5	-0.4
976-1	Tawarau	Speedies	2002	153	1	52.61	-0.8	155	3.5	65.65	-0.3
453-6	Mangatangi	SH25	2002	149	0.6	0	-9.9	156	11	0	5.8
481-7	Mangawara	Rutherford Rd	2002	154	0.2	10.88	1.3	156	41.7	34.11	-0.4
954-5	Tapu	Tapu-Coroglen Rd	2002	152	3.5	75.64	-0.4	156	1.1	25.95	-1.9
1174-4	Waiomou	Matamata-Tauranga Rd	2002	154	1.2	0.24	-2.2	156	4	0.16	2.5
234-11	Kauaeranga	Smiths	2002	151	3	42.94	1.3	155	1.2	3.44	-3.2
33-6	Awakino	Gribbon Rd	2002	153	1.8	1.63	-3.1	156	1.6	62.17	0.6
476-7	Mangatutu	Walker Rd	2002	150	1.5	32.35	-0.6	155	3	9.11	-1.6

Site	River	Location		NH4				DIN			
			start	n_raw	median	P(%)_raw	slope(%pa)	n_raw	median	P(%)_raw	slope(%pa)
1257-3	Waiwawa	Coroglen	2002	156	0.005	0.32	0	156	0.015	0.07	-2.7
619-20	Ohinemuri	SH25	2002	156	0.005	0.11	0	156	0.475	40.75	-0.6
1249-15	Waitoa	Landsdowne	2002	156	0.02	0	-8.9	156	1.551	0.87	-1.1
749-10	Piako	Kiwitahi	2002	156	0.021	0	-6.1	156	0.993	0	-4.3
1323-1	Whirinaki	Corbett	2002	156	0.005	0.78	0	156	0.705	0	2.5
398-1	Mangakotukutuku	Peacockes	2002	149	0.23	0	-5.8	149	1.22	0	-4.1
240-5	Kawaunui	SH5	2002	156	0.02	0	-9.4	156	2.538	0.18	1.5
407-1	Mangamingi	Paraonui Rd	2002	156	0.098	0.45	6.4	156	3.008	94.38	0
786-2	Pokaiwhenua	Arapuni-Putaruru Rd	2002	156	0.005	0	0	156	1.678	0	1.6
1253-7	Waitomo	Tumutumu	2002	154	0.005	0.7	0	154	0.63	65.37	0.1
477-10	Mangauika	Te Awamutu W/S	2002	154	0.005	0.09	0	154	0.2	0	2.3
428-3	Mangaotaki	SH3	2002	156	0.005	7.45	0	156	0.665	1.57	-1
556-9	Mokau	Totoro	2002	156	0.01	0.05	0	156	0.524	23.79	-0.6
976-1	Tawarau	Speedies	2002	155	0.005	0.83	0	155	0.295	64.36	-0.1
453-6	Mangatangi	SH25	2002	156	0.008	91.61	0	156	0.178	0.2	-2.7
481-7	Mangawara	Rutherford Rd	2002	156	0.305	0	-3.9	156	1.26	0	-3
954-5	Tapu	Tapu-Coroglen Rd	2002	156	0.005	1.82	0	156	0.008	8.87	0
1174-4	Waiomou	Matamata-Tauranga Rd	2002	156	0.012	0.2	0	156	0.5	54.91	-0.3
234-11	Kauaeranga	Smiths	2002	155	0.005	0.07	0	155	0.025	30.79	-0.6
33-6	Awakino	Gribbon Rd	2002	156	0.005	0	0	156	0.116	0	-3.6
476-7	Mangatutu	Walker Rd	2002	155	0.01	0.05	0	155	0.372	76.26	-0.3

Site	**River**	**Location**		**DO%**				**Temp**			
			start	**n_raw**	**median**	**P(%)_raw**	**slope(%pa)**	**n_raw**	**median**	**P(%)_raw**	**slope(%pa)**
1257-3	Waiwawa	Coroglen	2002	156	101.2	81.86	0	156	15.2	0.04	0.9
619-20	Ohinemuri	SH25	2002	155	105.4	81.72	0	155	16	6.64	0.4
1249-15	Waitoa	Landsdowne	2002	155	88.5	4.45	0.3	155	15	7.8	0.4
749-10	Piako	Kiwitahi	2002	156	86.9	12.1	0.5	156	15.5	77.75	0
1323-1	Whirinaki	Corbett	2002	156	97.6	35.91	-0.1	156	12.1	16.57	0.1
398-1	Mangakotukutuku	Peacockes	2002	148	89.8	3.37	0.2	149	15.1	66.48	0.1
240-5	Kawaunui	SH5	2002	156	85.7	6.41	0.2	156	14.6	1.95	0.3
407-1	Mangamingi	Paraonui Rd	2002	156	102.3	23.74	-0.1	156	14.2	69.77	0.1
786-2	Pokaiwhenua	Arapuni-Putaruru Rd	2002	156	100.5	0.11	0.4	156	13.9	80.43	0
1253-7	Waitomo	Tumutumu	2002	153	100.2	14.27	0.2	154	13.8	0.06	0.6
477-10	Mangauika	Te Awamutu W/S	2002	153	99.7	49.12	-0.1	154	12.2	0	0.8
428-3	Mangaotaki	SH3	2002	156	101.9	67.22	0	156	13.1	4.39	0.5
556-9	Mokau	Totoro	2002	156	102.6	49.19	-0.1	156	14	1.48	0.5
976-1	Tawarau	Speedies	2002	154	102.9	60.28	0.1	155	13.6	0.54	0.6
453-6	Mangatangi	SH25	2002	156	86.8	65.94	0.1	156	16	0	0.9
481-7	Mangawara	Rutherford Rd	2002	155	74.3	0.18	0.7	156	14.9	0.15	0.7
954-5	Tapu	Tapu-Coroglen Rd	2002	156	102.6	58.46	0	156	14.7	0.85	0.7
1174-4	Waiomou	Matamata-Tauranga Rd	2002	156	95.3	39.72	-0.1	156	13.6	55.98	0.1
234-11	Kauaeranga	Smiths	2002	155	99.6	26.27	-0.1	155	14.8	4.41	0.6
33-6	Awakino	Gribbon Rd	2002	155	101.1	77.62	0	156	12.6	21.01	0.3
476-7	Mangatutu	Walker Rd	2002	154	95.1	42.96	0.1	155	13.9	18.13	0.4

Site	River	Location		TP				DRP				TN			
			start	**n_raw**	**median**	**P(%)_raw**	**slope(%pa)**	**n_raw**	**median**	**P(%)_raw**	**slope(%pa)**	**n_raw**	**median**	**P(%)_raw**	**slope(%pa)**
1257-3	Waiwawa	Coroglen	2002	156	0.005	1.03	0	156	0.002	0	0	156	0.097	0	-5.4
619-20	Ohinemuri	SH25	2002	156	0.014	0.01	-4.8	156	0.005	0	-6.7	156	0.62	26.69	-0.6
1249-15	Waitoa	Landsdowne	2002	156	0.069	0	-5.2	156	0.029	1.63	-1.8	156	1.93	0.05	-1.5
749-10	Piako	Kiwitahi	2002	156	0.095	0	-4.3	156	0.052	0.8	-1.7	156	1.488	0	-3.6
1323-1	Whirinaki	Corbett	2002	156	0.069	0	-1.6	156	0.064	0	-1.6	156	0.765	0	1.8
398-1	Mangakotukutuku	Peacockes	2002	149	0.416	9.42	-1.1	149	0.175	2.78	2.1	149	2.12	0	-3.3
240-5	Kawaunui	SH5	2002	156	0.118	0	-9.6	156	0.069	0	-7.6	156	2.96	5.46	0.8
407-1	Mangamingi	Paraonui Rd	2002	156	0.44	0	-6.8	156	0.383	0	-6.7	156	3.415	88.79	0.1
786-2	Pokaiwhenua	Arapuni-Putaruru Rd	2002	156	0.123	0	-4.2	156	0.097	0	-3.1	156	1.91	0	1.2
1253-7	Waitomo	Tumutumu	2002	154	0.024	0.02	-3.4	154	0.01	86.91	0	154	0.772	98.57	0
477-10	Mangauika	Te Awamutu W/S	2002	154	0.008	7.31	-1.8	154	0.002	0	0	154	0.249	0	2.3
428-3	Mangaotaki	SH3	2002	156	0.032	0.02	-4.4	156	0.012	0.01	-2.8	156	0.881	1.29	-0.8
556-9	Mokau	Totoro	2002	156	0.035	0	-5.1	156	0.01	0.07	-2.7	156	0.809	25.93	-0.7
976-1	Tawarau	Speedies	2002	155	0.029	0	-3.5	155	0.014	13.8	-0.6	155	0.45	35.46	-0.2
453-6	Mangatangi	SH25	2002	156	0.083	0.04	-2.1	156	0.025	1.94	-1.5	156	0.571	14.86	-1
481-7	Mangawara	Rutherford Rd	2002	156	0.228	0	-2.8	156	0.045	7.77	1.6	156	2.12	0	-2.2
954-5	Tapu	Tapu-Coroglen Rd	2002	156	0.004	0.47	0	156	0.002	0	0	156	0.073	13.32	-1
1174-4	Waiomou	Matamata-Tauranga Rd	2002	156	0.043	0	-3.5	156	0.023	0	-4.3	156	0.71	65.94	-0.2
234-11	Kauaeranga	Smiths	2002	155	0.004	20.01	0	155	0.002	0	0	155	0.103	29.42	-1
33-6	Awakino	Gribbon Rd	2002	156	0.018	0.54	-2.8	156	0.013	0	-1.9	156	0.186	0.01	-2.7
476-7	Mangatutu	Walker Rd	2002	155	0.026	0	-5.3	155	0.01	0.01	-3.4	155	0.51	35.53	-0.6