An interpretation of the reasons for statistically significant temporal trends in macroinvertebrate (MCI) SEM data in the Taranaki region, 1995-2005

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Executive summary

Trend analysis performed upon macroinvertebrate data collected from 60 sites using SEM protocols over the ten year period from 1995 to 2005 found nine sites with statistically significant temporal trends in Macroinvertebrate Community Index (MCI) scores (Stark and Fowles, 2006). Two other sites had statistically significant temporal trends but the monitoring period covered a shorter (six year) period. The ecological significance of these trends and discussion of the reasons for the statistical trends have been presented in this report along with assessments of stream / river 'health' for each site over the ten year period, based on a modified MCI grading system.

In some cases specific events or actions (eg, improvements to point source discharges) accounted for the trends evaluated for individual sites, whereas other trends were either coincident with maintenance of, or improvement in, aspects of physicochemical water quality, variability in catchment hydrology, or postulated to be consistent with increased surveillance monitoring and / or improved consents' compliance in catchments for some distance upstream of monitored sites. It is not anticipated that riparian initiatives (Regional Council and / or Fonterra Dairying and Clean Streams Accord) will yet have had significant impacts on stream 'health'. These impacts will more likely be discernible when greater proportions of catchments are fenced and planted, and as shading of waterways increases with growth of vegetation. These impacts should be determined by analyses of trends over longer term (say 20 year) programmes of similar nature to the existing programme.

Overall, there was a general improvement in stream / river 'health' as determined by MCI bands, at the start and end of the ten year period. This occurred mainly at sites in the middle and lower reaches of catchments where the cumulative effects of upstream activities would be expected to have had the greatest influence on macroinvertebrate communities as indicators of surface water quality.

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1. Introduction

State of the environment (SEM) macroinvertebrate data, together with selected compliance monitoring data, collected at 60 sites in the region over the ten year period (1995-2005) under standard TRC programme protocols, recently have been statistically analysed for trends (Stark and Fowles, 2006). The significance of any (positive or negative) trends found has been provided for each of four indices measured by these programmes. However, the principal index of stream 'health', the MCI, has been selected as the most appropriate for use in the assessment of temporal trends in the macroinvertebrate biological quality of regional surface freshwaters.

The significance of any site's trend (i.e. the strength of the trend) can be ranked according to the statistical probability of occurrence, as long as similar numbers of samples were collected for analysis (G McBride, pers comm) which has been the case with the TRC programme.

Following LOWESS smoothing of the temporal MCI data for each site (Stark and Fowles, 2006), the statistical significance of all sites' trends may now be ordered (from strongest to weakest) for all sites, with a short-list of sites provided in terms of the strengths of significant trends. The 'cut-off' point has been chosen as those sites' trends with probabilities significant at the 5% level (followed by false discovery rate (FDR) analysis). Those sites can be ranked in order beginning at the lowest p value. This approach is statistically defensible and should identify sites having trends with valid ecological significance. However, a trend may be statistically significant but have no ecological significance or vice versa. The consideration of ecological significance requires the best professional judgment (BPJ) of a freshwater ecologist with knowledge of the region's rivers and streams. It is likely that the strongest trends (lowest p-values) would have the greatest ecological significance.

In relation to the indicator of stream health, the MCI, the estimation error for this index is 10.8 units (Stark 1998) for the sampling protocols used by TRC. Therefore although a statistically significant temporal trend may be found for a site's data, if the LOWESS range of MCI scores is less than 10.8 units, the best professional judgment may eliminate this from a list of significant results. Also, to place these trends in perspective, each site may be assessed against graduations (bands of MCI values) of stream health. In this instance, Stark's (1985) categories have been modified (using BPJ) as follows:

MCI values	Grading
>140	Excellent
120 – 140	Very good
100 – 119	Good
80 – 99	Fair
60 – 79	Poor
<60	Very poor

Having identified significant (negative and positive) temporal trends at sites in the region, it is timely to determine the reasons for these trends and attempt to assess them in terms of ecological significance. Additional information necessary for such purposes includes catchment hydrology, erosion history, physicochemical water quality trends, and changes in land or water management practices which may have resulted from TRC initiatives, farm practices and/or industrial and municipal

activities. There may be other reasons for these trends beyond the influence of water management initiatives.

In brief, trends may occur in response to:

- physical disturbances
- flow regulation
- changes in land usage
- waste assimilation variability
- physicochemical water quality
- biotic interactions
- management initiatives
  - increased monitoring surveillance
  - upgrading of point source discharges
  - riparian retirement, fencing and planting
  - non-point source discharges.

2. Results and discussion

The sites which showed statistically significant temporal trends in MCI values for the ten year (1995 – 2005) period are listed in Table 1 in descending order of p-values.

Table 1 Sites in the Taranaki region showing significant temporal (1995 to 2005) MCI trends ($p < 0.05$, FDS applied) ranked by statistical strength

Code	Site location	Statistical significance of trend		LOWESS MCI range	Ecological significance (>10.8 MCI units)
		(p-level)	(+ve/-ve)		
KRP000660	Kurapete S : 6 km d/s of Inglewood WWTP	0.00022	+ve	70 –103	Yes
MGH000950	Mangaehu R : Raupuha Road	0.00023	+ve	79 – 96	Yes
WGA000450	Waiongana S : Devon Road	0.00037	+ve	75 – 95	Yes
KPK000660	Kaupokonui R : u/s Fonterra Kapuni factory	0.00131	+ve	81 – 112	Yes
KRP000300	Kurapete S : u/s of Inglewood WWTP	0.00156	+ve	82 – 95	Yes
MRK000420	Mangaoraka S : Corbett Road	0.00300	+ve	80 - 99	Yes
TMR000375	Timaru S : SH 45	0.00588	+ve	90 – 113	Yes
HTK000425	Huatoki S : Huatoki Domain	0.00702	+ve	93 – 110	Yes
WTR000850	Waitara R : Mamaku Road	0.00864	+ve	67 – 92	Yes
*KPA000700	Kapoaiaia S : Whataroa Road	0.00345	+ve	78 – 97	Yes
*KTK000248	Katikara S : near mouth	0.00397	+ve	85 – 110	Yes

[Note * = 5 years data (2000 – 2005) to date]

Nine sites showed significant temporal trends over the full ten year period and each of these trends was positive, ie, an increase in MCI score indicative of improvements in biological stream 'health'. Two other sites also showed significant positive trends but over a shorter (five year (2000-2005)) period as these sites were later inclusions in the SEM programme. All eleven sites' LOWESS-smoothed MCI ranges (minimum to maximum values from the smoothed trend) were ecologically significant (ie >10.8 units) over the periods trended.

It was apparent that none of the eleven 'reference' sites monitored in the upper reaches of rivers or streams (ie near or within the National Park) showed significant temporal MCI trends indicating that factors other than headwater catchment hydrology, climatic or erosion events, were more likely to have impacted on those sites showing significant temporal trends located further downstream in the mid to lower reaches of the region's surface water.

The following discussion presents an assessment of possible influences on trends at each of the nine sites.

2.1 Site KRP000660 : Kurapete Stream – 6 km downstream of Inglewood WWTP

A very strong improvement in MCI scores was found for this relatively small ringplain stream in its lower reaches.

While some improvement also was recorded at the site (KRP000300) 6 km upstream (above the WWTP), this was less significant (see below), and therefore contributed only in part to the downstream site's increase in MCI scores eg LOWESS smoothed scores ranged over 13 units at the upstream site increasing to 33 units for the same period at the downstream site. The principal improvement occurred following the diversion of all Inglewood treated wastewater discharges out of the stream (to the New Plymouth WWT Plant). In more recent years this rapid improvement has levelled off with maintenance of good stream 'health' conditions in the absence of consented overflows from the system. Overall the trend has improved the stream 'health' grading from 'poor' through 'fair' into 'good' where it remains. A contributing (but more minor) factor to this improvement is referenced in the discussion of the upstream site's trend.

2.2 Site MGH000950 : Mangaehu River – Raupuha Road

This site in the lower reaches of one of the largest eastern hill country river catchments showed a strong trend of temporal improvement, a similar trend (although stronger) to that, also at a lower reach site, in the only other large eastern hill country catchment (Waitara River) monitored. The most realistic explanation for this trend is related to the impacts of flood events (eg reduction in frequency / severity) and less sedimentation over the period, but more particularly since 2000. Visual assessments of river substrate composition have suggested some reduction in fine sediment composition of the river bed at the monitoring site in more recent years. Physicochemical water quality data from this site over the 1995-2005 period showed no significant positive or negative trends in any parameters likely to be linked with the trend in improvement in the biological communities. The trend in increasing MCI score was considered ecologically significant (ie greater than 11 units when LOWESS-smoothed).

Overall the trend has seen improvement in the river 'health' grading from originally bordering on 'poor / fair', through mainly 'fair', to occasionally 'good' in recent years.

2.3 Site WGA000450 : Waiongana Stream – Devon Road

A strong trend in temporal improvement shown at this site toward the lower reaches in this ringplain stream was coincident with a reduction in consented water abstraction by NPDC over the last five years and more rigorous control of a large piggery's wastes disposal loadings to the stream. This improvement in biological communities appears to have levelled off in recent years but the range in LOWESS-smoothed MCI values has been ecologically significant for the ten year period. A trend of improvement in stream 'health' has also been apparent at the site monitored some 15 km upstream, particularly over the last three years. However, this trend is much weaker ($p = 0.196$) indicating that activities in the vicinity (and upstream) of the upper site have not contributed substantially to the improvements in steam health at the lower site.

Overall stream 'health' grading for this site has moved from consistently 'poor' for the period 1995 to 2000 through 'fair' bordering on 'good' during the last five years.

2.4 Site KPK000660 : Kaupokonui River – upstream of Fonterra, Kapuni ('lactose') factory

This site in the mid reach of a ringplain river showed a relatively strong trend of temporal improvement which was not shown by either of two other sites further upstream over the period. The range of LOWESS-smoothed MCI values was ecologically significant, further indicative of relatively localised impacts on the biological communities of this site immediately upstream of the Fonterra lactose factory. Factory wastewater irrigation in the catchment a short distance upstream of this site has been better managed throughout this period and surveillance monitoring of a local dairy wastes treatment ponds system has reported better consent compliance in recent years. Two sites further downstream have also shown coincidental temporal improvements but not to the same degree (i.e. weaker trends ($p = 0.024$ and $p = 0.125$)).

Overall the trend has been from a river 'health' grade fluctuating between 'poor' and 'fair' during the first three years to 'fair' for five years, and 'good' during the last two years. (Note: both sites (10 and 16 km further downstream) fluctuated between 'poor' and 'fair' gradings through the ten year period; more consistently in the 'fair' range over the last three years).

2.5 Site KRP000300 : Kurapete Stream – upstream of Inglewood WWTP discharge

A moderately strong improvement in MCI scores was found in this small ringplain stream immediately upstream of the Inglewood WWTP discharge but below the inflowing tributary draining the old Inglewood landfill site. This improvement was coincident with diversion of the small inflow tributary into the WWTP ponds system which eliminated the obvious iron oxide deposition common on the main stream bed in the early part of the period. The LOWESS-smoothed range of MCI scores over the period was only just ecologically significant (13 units) and the trend appears to have seen MCI scores level off more recently.

Overall, the trend has retained a grade of 'fair' stream 'health' in terms of MCI scores throughout the ten year period.

2.6 Site MRK000420 : Mangaoraka Stream – Corbett Road

This site in the lower reaches of a ringplain stream (with its source outside of the National Park) has shown a moderately strong trend of temporal improvement, particularly since 1999. Physicochemical trend monitoring data for this site has shown no significant temporal changes for most parameters, but significant improvements in BOD_5 and ammonia nitrogen concentrations indicative of a reduction in organic loadings monitored in the lower reach of this stream. The range in LOWESS-smoothed MCI scores for the ten year period was ecologically significant and this trend shows a steady increase in MCI scores still occurring since 1999. More rigorous surveillance monitoring of quarrying activities (2 km upstream) and good consents' compliance performance have been coincidental with this period.

Overall, the trend shows stream 'health' fluctuating between 'poor' and 'fair' during the first half of the period improving through 'fair' just into the 'good' grade, in terms of MCI scores, at the end of the ten year period.

2.7 Site TMR000375 : Timaru Stream – SH45

A moderately strong temporal trend of improvement was found at this site toward the lower reaches of the river. The LOWESS-smoothed range of scores was indicative of a significant ecological trend. No obvious explanations are apparent but a possible reason may relate to improved dairy shed wastes disposal management in the catchment upstream of SH45. The trend of improvement has been particularly apparent since 2001 and scores are still trending upwards.

Overall, this trend has shown an improvement in terms of stream 'health' grades from 'fair' to 'good' where it currently remains.

2.8 Site HTK000425 : Huatoki Stream – Huatoki Domain

This site in the mid reaches of a ringplain stream, which rises below the National Park, has shown a moderately strong temporal trend of improvement. This site within the Huatoki Domain had a LOWESS-smoothed range of MCI scores (17 units) which was indicative of a significant ecological trend. No obvious reasons are apparent for this trend although a weaker temporal improvement (not statistically significant) was present at the site (HTK000350) some 3 km upstream prior to the stream's entry into the Huatoki Domain, indicative of possible influences of farming practices in the upper catchment. Both sites have shown a steady improvement since about 2000.

Overall, the trend shows stream 'health' fluctuating between 'fair' and 'good' during the first half of the period improving into the 'good' grade consistently throughout the remaining period.

2.9 Site WTR000850 : Waitara River – Mamaku Road

This site in the lower reaches of the region's largest river catchment (with the greatest proportion from the eastern hill country), showed a moderately strong trend of temporal improvement. This trend was also apparent (but of stronger significance) in the only other eastern hill country river (Mangaehu River) monitored by the SEM programme (see earlier). There has been a steady improvement throughout the ten year period and an explanation may be related to a reduction in sedimentation effects and/or disturbances associated with larger flood events and the frequency of such events. The trend was also ecologically significant with a LOWESS-smoothed range of 25 units in MCI scores.

The overall trend has seen river 'health' move from a grade of 'poor' to 'fair' where it has remained consistently since 2002.

2.10 Other sites

Two sites showed relatively strong positive temporal trends but the monitoring period has been limited to a shorter 2000-2005 period. These sites are in the mid reaches of the Kapoaiaia Stream and lower reaches of the Katikara Stream. Due to the relatively short monitoring period to date, these trends were not analysed any further at this stage other than to record that they appear to be ecologically significant and, in the Katikara Stream, the trend shows an improving grade of stream 'health' from

'fair' to 'good'. A longer monitoring period will allow for a full assessment of these trends.

One site, the Waingongoro River in its upper reaches at Opunake Road (some 7 km below the National Park), was the only site which showed a moderately strong trend of a temporal decline in MCI scores (although this was not statistically significant at the 5% level with FDR applied ($p = 0.027$)). However, the LOWESS-smoothed MCI scores showed a range of less than the 11 units variation considered to be ecologically significant. It also showed that an initial improvement (over 3 years) was followed by a five year deterioration and subsequent three year improvement to an identical score (127 units) recorded at the start of the programme. No statistically significant temporal trends in MCI scores were found at the upstream site, 6.5 km closer to the National Park although an apparent temporal improvement ($p < 0.05$, without FDR applied) was detected, but this was not ecologically significant (ie, less than 11 units variation in the LOWESS-smoothed MCI). However, the difference in MCI scores between these two sites (Figure 1), further illustrates the variability described above.

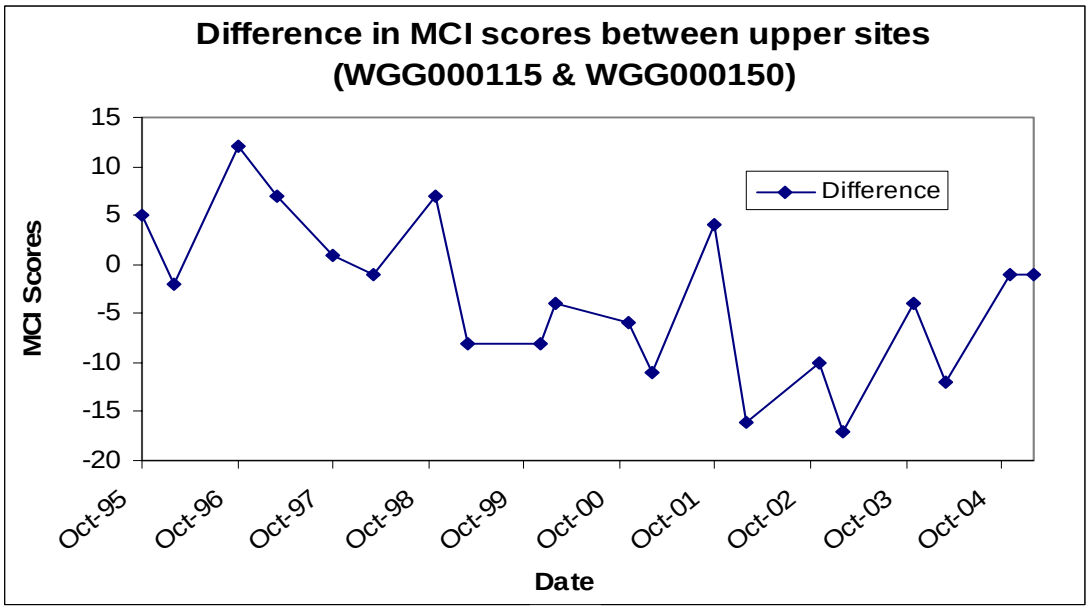

Figure 1 Difference in MCI scores between the two sites in the upper reaches of the Waingongoro River

Localised erosion of the true right bank of the river with sediment deposition on the riverbed was recorded by field observations consistent with the decline in MCI scores in 1999, with no further recurrence of the erosion noted since 2002. Some recovery in MCI scores has followed in recent years. This site-specific erosion event was very localised, as corresponding biological and physicochemical monitoring trends showed no significant impacts on MCI scores or turbidity, clarity or suspended solids measurements at the nearest downstream site (at Eltham Road).

An additional nine sites, to the thirteen referenced above, showed temporal trends in MCI scores (all improvements) which were not as strong ($p < 0.05$ without FDR analysis). At one of these sites (Mangawhero Stream near the Waingongoro River confluence), the LOWESS-smoothed MCI range was 8 units and therefore probably not ecologically significant. Brief comments relating to the remaining sites are as follows:

Huatoki Stream at Hadley Drive and near the mouth (sites HTK000350 and HTK000745)

Improved farming practices and wastes disposal management in the catchment between the outskirts of New Plymouth and the seepage source of this stream (below the National Park) may have contributed to the positive trend in MCI scores at all three sites along the Huatoki Stream. Both sites have consistently shown a grading of 'fair' stream health through the ten-year period.

Waiwhakaiho River at Constance Street (site WKH000920) and near Lake Rotomanu (WKH000950)

Both of these sites in the lower reaches of the river (in New Plymouth) showed improvements particularly over the last five years coincident with an increase in the summer residual flows required to be released by Taranaki Generation Ltd's Mangorei HEP scheme. Both sites have improved from 'poor / fair' to 'fair / good' gradings of river 'health' over the ten-year period.

Kaupokonui River at Glenn Road (site KPK000880)

A similar temporal trend (although weaker statistically) to the improvement shown at the site upstream of the Fonterra (lactose) factory, was found at this site some 10 km downstream of the factory. Reasons for the trend are presented in section 2.4 earlier in the report. River 'health' has more consistently remained 'fair' in recent years.

Waiau Stream at Inland North Road (site WAI000110)

Due to the relatively short monitoring period to date this trend is not analysed further at this stage for this site in the mid-reaches of a small, entirely farmed catchment. Stream 'health' has remained in the 'fair' grading throughout the monitoring period.

Mangati Stream at Te Rima Place, Bell Block (site MGT000520)

Improved control and treatment of industrial point source discharges have coincided with this temporal trend of increased MCI scores, particularly over the most recent three-year period. Stream 'health' has moved from a grading of 'very poor' to 'poor' over the latter two-thirds of the monitoring period.

Waiaua River at SH45 (site WAA000447)

A gradual improvement has been coincidental with recovery from extensive headwater erosion events (which subsequently caused severe sedimentation in the lower and mid reaches of the river). This recovery has been more apparent in the last three years, probably as substrate stability has become more established.

3. Conclusions

Temporal changes in stream 'health' as reflected in biological communities may occur for a variety of reasons. They may result from physical disturbances, flow regulation, changing land use (including stocking rates, fertilizer application), variability in wastes assimilation, physicochemical water quality, biotic interactions, and / or combinations of these and other factors. Management initiatives such as increased surveillance of point source discharges, requirements for upgrading / improving wastewater treatment standards, riparian retirement, fencing and planting of stream margins may all contribute to temporal changes in stream macroinvertebrate communities. These changes therefore result from factors occurring in the catchment; some distance upstream from the site where monitoring has been undertaken, rather than in the immediate vicinity of that site. This is particularly the case with riparian planting which initially involves fencing, but requires planting and subsequent growth providing shading over some distance of the main stream / river and tributaries before impacting significantly downstream. Similarly, the cumulative impacts of point source dairy treatment ponds systems' discharges in ringplain rivers and streams are more pronounced in the mid and lower reaches of these catchments. Therefore, improved management and surveillance monitoring of these systems, have the potential to impact significantly on temporal trends of aspects of surface water quality including those illustrated by the freshwater biological communities.

A combination of all, or some, of these factors spread over the catchment upstream of a monitoring site may therefore have subtle, long-term influences on the site's biological communities and be responsible for a resultant temporal trend rather than any single obvious incident or factor specific to the site or in its immediate vicinity.

It should be emphasised that during the 1995-2005 period, TRC water management initiatives have included increased surveillance monitoring and improvements in standards of point-source discharges, particularly dairy farm systems, and ensured a rapid and effective response to pollution incidents (spillages etc). Land management initiatives (and the Fonterra Dairying and Clean Streams Accord) have instigated and intensified the extent of ringplain fencing and planting of surface waters throughout the region. However, not until riparian planting provides effective shading and covers significant proportions of mainstream and / or tributary catchments, will impacts on downstream biological communities become significant. Thus, the longer-term SEM programmes (eg 20 years or more) should be more likely to discern trends attributable to riparian initiatives.

Some specific activities or reasons have been promulgated to account for the positive significant temporal trends statistically analysed at up to nine sites (of 60) monitored by the SEM macroinvertebrate programme from 1995 to 2005. Two other sites have also shown strong temporal trends of improvement but for these sites the programme has only been operative for five years. All sites have also shown significant ecological improvement in terms of LOWESS trended MCI scores and in most cases grading of stream / river 'health' (using TRC-modified Start (1985) bandings) has shown a one to two grade improvement in MCI categories.

However, it is appropriate to place in perspective the stream / river 'health' (as assessed from MCI bands) for all sixty sites trended (Stark and Fowles, 2006) as it

existed at the commencement (1995) and end (2005) of the SEM period. This is summarized in Table 2.

Table 2 'Health' assessments for all sites (TRC-modified MCI bands) at the start and end of the 1995 to 2005 SEM programme

Band		Excellent	Very good	Good	Fair	Poor	Very poor
Location	Date	(%)	(%)	(%)	(%)	(%)	(%)
Upper reaches (12 sites)	1995	0	83	17	0	0	0
	2005	8	67	25	0	0	0
Mid reaches (22 sites)	1995	0	9	32	50	9	0
	2005	0	5	63	23	9	0
Lower reaches (26 sites)	1995	0	0	12	53	31	4
	2005	0	0	31	46	23	0
Overall (60 sites)	1995	0	20	20	41	17	2
	2005	2	15	42	28	13	0

[NB: Percentages of all sites monitored in each category ( ) and in total]

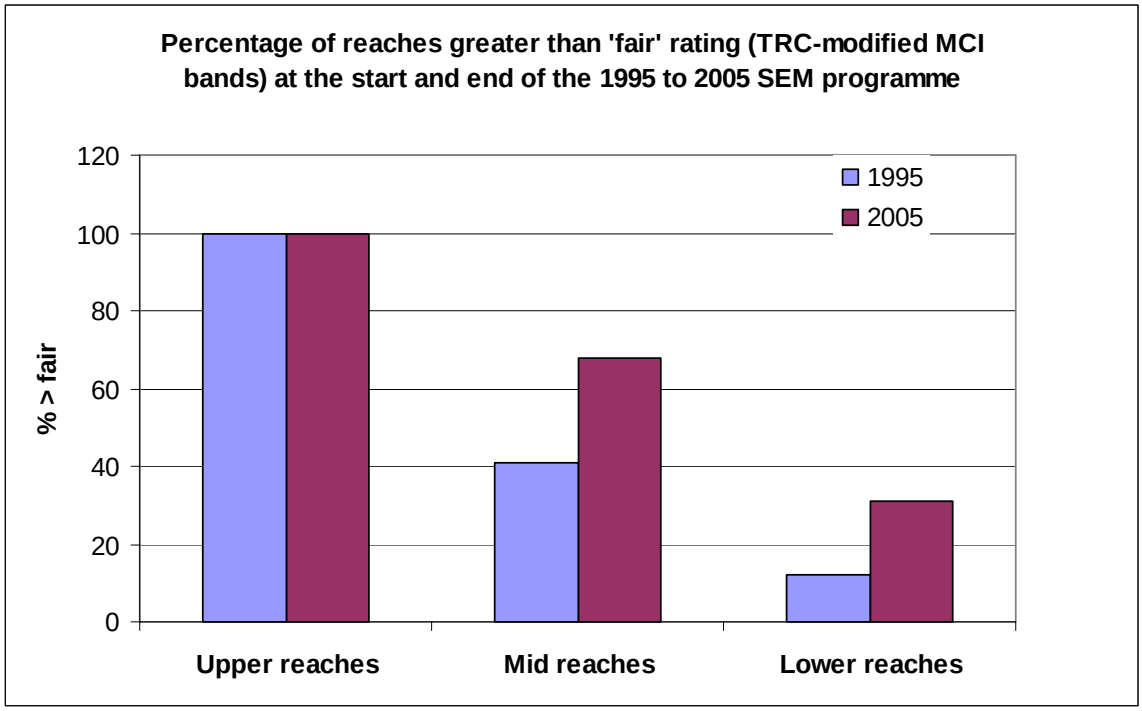

Figure 2 Percentage of reaches greater than 'fair' rating (TRC-modified MCI bands) at the start and end of the 1995 to 2005 SEM programme

Overall, there was a general improvement in stream / river 'health' (based on MCI bands). This occurred principally at sites in the middle and lower reaches of catchments where in general only 41% and 12% of sites respectively were graded better than 'fair' in 1995, but by 2005 these percentages had increased to 68% and 31% respectively.

It should be noted that an 'excellent' grading (MCI > 140 units) of stream / river 'health' is seldom achieved, and generally limited to ('reference') sites in the upper reaches of pristine (usually National Park-sourced) surface waters. It should not be anticipated that sites located further downstream (in mid and lower reaches) may trend upwards into, or close to, such a grade. There are likely to be limits to such improvements (in terms of the maximum MCI likely to be achieved) which are determined by physical habitat (eg substrate composition, non-point source runoff, channel width etc) and biotic factors, many of which have cumulative impacts increasing with channel distance below the source of the stream or river. There is no guarantee that any observed trend will continue into the future. Therefore any positive temporal trends will plateau at some point in time (with the likelihood of an improvement of one or two grades at most at sites in the mid or lower reaches of streams / rivers).

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