WATER QUALITY TRENDS AT NRWQN SITES IN NEW ZEALAND FOR 1989-2007

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ABSTRACT

The New Zealand National Rivers Water Quality Network (NRWQN) has been running for 2 decades. The network consists of 44 sites in the North Island and 33 in the South Island (all located near flow recording stations) at which 14 physical and chemical variables are measured monthly. The most recent water quality trend analysis, undertaken by NIWA for the Ministry for the Environment (MfE) in early 2009, covers the 19-year period 1989-2007. Formal trend analysis was carried out on flow-adjusted data using NIWA's Time Trends software. The non-parametric Seasonal Kendall Slope Estimator (SKSE) was used to represent the magnitude and direction of trends in flow-adjusted data. Seven water quality variables were examined, namely temperature, dissolved oxygen, visual clarity, and four forms of the nutrient elements nitrogen and phosphorus.

There were strong overall increasing trends in total phosphorus, dissolved reactive phosphorus, oxidized nitrogen and total nitrogen at the national scale. There was a significant increase in visual clarity (an improving trend) for reasons that are obscure given the *negative* correlation between visual clarity and percent pasture in catchments. The nutrient enrichment trends indicate deteriorating water quality and reflect increasing diffuse pollution, mainly attributable to the expansion and intensification of pastoral agriculture.

KEYWORDS

Water quality; National River Water Quality Network; trend analysis; nutrients; phosphorus; nitrogen; visual clarity

1 INTRODUCTION

The National River Water Quality Network (NRWQN) is New Zealand's most comprehensive freshwater quality monitoring network at the national scale, although increasingly augmented by State of Environment monitoring conducted by Regional Councils. The NRWQN consists of 77 sites on 35 rivers that are fairly evenly distributed over both main islands of New Zealand and drain about one half of the nation's land area (see Smith and McBride (1990) for a description and maps, also Figure 1). The NRWQN sites have been clustered into groups and are coded, based on the locations of the NIWA field stations. The sites are visited monthly by NIWA Environmental Data staff and measurements are made of: *dissolved oxygen* (DO), pH, conductivity, *temperature*, *visual clarity*, turbidity, coloured dissolved organic matter, and different forms of the major nutrients nitrogen (N) and phosphorus (P) (nitrate nitrogen (NO_x-N), total nitrogen (TN), ammoniacal nitrogen, dissolved reactive phosphorus (DRP) and total phosphorus (TP)) — *italicised text* indicates *field* measurements, other measurements are made on water samples freighted by overnight courier to the NIWA-Hamilton laboratory. All NRWQN sites are located at, or close to, hydrometric stations from which flow is estimated for each sampling visit.

The aim of the network is to provide scientifically defensible information on the important physical, chemical, and biological characteristics of a selection of the nation's river waters. The objectives of the network from its inception were to establish a national water quality database to detect trends in water quality and to develop a better understanding of the nature of water resources, so as to assist with their management (Smith & McBride, 1990).

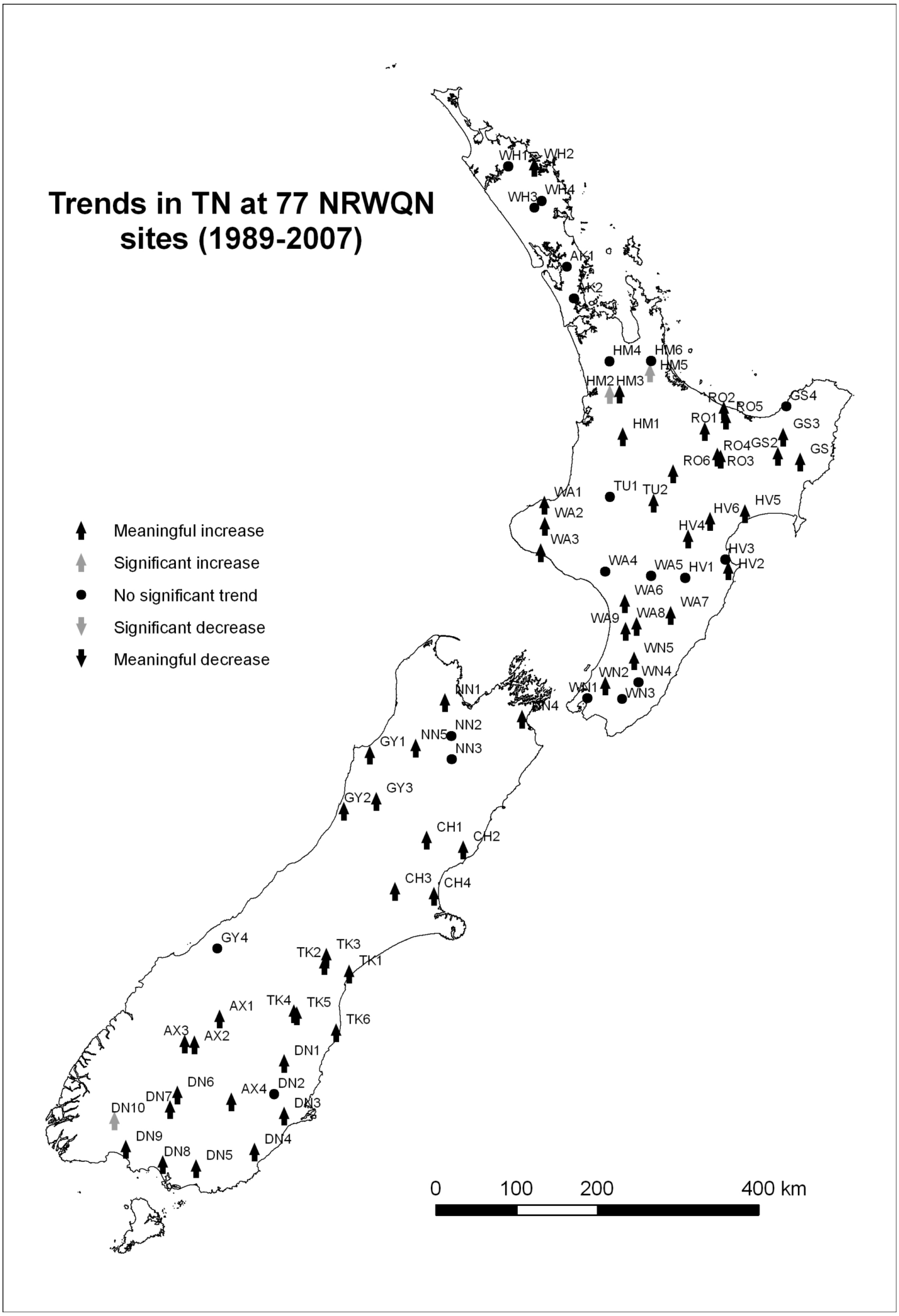

Figure 1 NRWQN sites in New Zealand and trends in TN

Over the past two decades since the NRWQN commenced, several formal trend analyses of the NRWQN data have been conducted (usually at 5-yr intervals), broadly following the approach of Smith et al. (1996). The most recent trend analysis was that of Scarsbrook (2006) for the 15 year period 1989-2003. The Ministry for

Environment (MfE) contracted NIWA to update the formal trend analysis for the 19 year period: 1989-2007 for use in national State of Environment reporting.

This paper presents the findings from formal statistical trend analysis, and aims to address three main areas of assessment, namely to calculate trends over the entire period of record (1989-2007) using suitable software, to categorise trends, and to compare trends with those calculated for 1989-2003 (Scarsbrook, 2006).

2 METHODS

Trend analysis of the NRWQN data was conducted using NIWA-developed **Time Trends** software (http://www.niwa.co.nz/ncwr/tools). Trend analysis was applied to five forms of the nutrient elements nitrogen and phosphorus, plus dissolved oxygen, water temperature and visual clarity. Ammoniacal nitrogen trends are not included due to issues with contamination as discussed in Ballantine and Davies-Colley (2009).

2.1 CALCULATION OF INDIVIDUAL TRENDS

The trend analysis involved firstly, flow adjustment of the data for each variable at each site, followed by trend analysis accounting for any seasonal pattern. Flow adjustment is necessary because most water quality variables are subject to either dilution (decreasing concentration with increasing flow, e.g., conductivity) or land runoff (increasing concentration with increasing flow, e.g., TP). Flow adjustment was performed using LOWESS (LOcally WEighted Scatterplot Smoothing; nested within Time Trends) with a 30% span. This allowed us to detect the overall flow-trend of all the data for each variable at each site. Every data-point in the record was then adjusted depending on the value of flow as outlined by Smith et al. (1996): adjusted value = raw value – smoothed value + median value (where the "smoothed value" is that predicted from the flow using LOWESS).

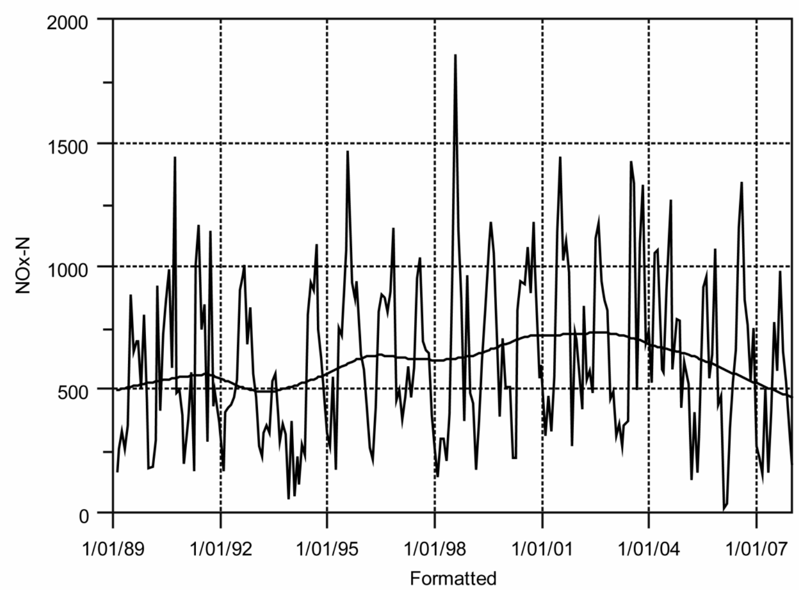

Figure 2 Flow adjusted NO_x-N data for the Manawatu at Opiki Bridge (Site WA9)

The formal trend analysis was applied to the whole 19-yr dataset (1989-2007 inclusive). As in previous work following Smith et al. (1996), the non-parametric Seasonal Kendall Slope Estimator (SKSE) was used to represent the magnitude and direction of trends in flow-adjusted data that were often subject to appreciable seasonality. Values of the SKSE were normalised by dividing through by the raw data median to give the *relative* SKSE (RSKSE), allowing for direct comparison between sites measured as percent change per year. The RSKSE may be thought of as an index of relative rate of change. A positive RSKSE value indicates an overall increasing trend, while a negative RSKSE value indicates an overall decreasing trend. The SKSE calculations were accompanied by a Seasonal Kendall test (performed within **Time Trends**) of the null hypothesis that there is no monotonic trend. If the associated P-value is small (i.e., $P < 0.05$), the null hypothesis can be rejected (i.e., the observed trend, either upwards or downwards, is most unlikely to have arisen by chance). All statistics are reported at the 95% confidence level (i.e., $P < 0.05$).

An example of flow adjusted data is presented in Figure 2. It is interesting to note that the RSKSE value for NO_x-N at this site is positive, and 'meaningful', suggesting that NO_x-N concentrations are increasing, while in reality, concentrations are now decreasing.

2.2 CATEGORISATION OF TRENDS

Scarsbrook (2006) recognised that statistical significance of a trend does not necessarily imply a 'meaningful' trend, i.e., one that is likely to be relevant in a management sense. We have followed Scarsbrook (2006) in denoting a 'meaningful' trend as one for which the RSKSE is statistically significant and has an absolute magnitude > 1% year^{-1}. Trends were accordingly categorised as follows:

i. **no significant change** – the null hypothesis for the Seasonal Kendall test **was not** rejected (i.e., $P > 0.05$);

ii. **significant increase/decrease** – the null hypothesis for the Seasonal Kendall test **was** rejected (i.e., $P < 0.05$). Note that the trend at some sites may be 'significant but not meaningful';

iii. **meaningful increase/decrease** – the null hypothesis for the Seasonal Kendall test was rejected (i.e., $P < 0.05$) **and** the magnitude of the trend (SKSE) was greater than one percent per annum of the raw data median (i.e. the RSKSE value was greater than 1% year^{-1}).

Scarsbrook (2006) recognised that the choice of 1% year^{-1} as the "meaningful" threshold is arbitrary, but we consider it to be a useful benchmark as it represents a rate of change that amounts to 10% decade^{-1} and is meaningful over a human generation (25% over a generation time of 25 years).

2.3 DETERMINATION OF NATIONAL TRENDS

Overall, significant national increasing or decreasing trends in water quality variables were determined using the RSKSE values for each water quality variable and a one-tailed binomial test to assess whether or not there was a statistically significant trend in a particular direction. For example, in the event that there are 45 sites from 77 with a positive RSKSE value, the one-tailed binomial test will determine whether or not there is a statistically significant trend in a positive direction. A P value of less than 0.05 indicates a significant trend in either a positive or negative direction. This test can be used to determine significant positive or negative trends within datasets, and for this study, was based on the total number of positive and negative RSKSE values. The overall median RSKSE value is also a measure of the direction of the national trends. A positive median RSKSE value also indicates an increasing overall trend, while a negative median RSKSE indicates a decreasing overall trend.

2.4 INFLUENCE OF LAND USE ON WATER QUALITY

To assist in interpretation of the trends, we were interested in how land use affects the water quality variables. The proportions of pasture and forest in NRWQN catchments, based on data from the 1997 Land Cover Database, were correlated with the 2007 median water quality values for each site using the non-parametric Spearman rank test. We used the 1997 Land Cover Database for comparison in this analysis because it provided a reference point which was midway through the period being examined. The 1997 database had also been used for the earlier study, therefore its further use in this analysis permitted comparison with the study by Scarsbrook (2006).

3 RESULTS

3.1 INDIVIDUAL TRENDS AND CATEGORIES

The Relative Seasonal Kendall Slope Estimators (RSKSE) for seven water quality variables at 77 NRWQN sites are collated in the full report which is available on the Ministry for Environment website (http://www.mfe.govt.nz/publications/water/water-quality-trends-1989-2007/index.html) along with the site codes, river names and locations. Trends in particular rivers can be obtained from this report. Overall trends for the different variables are considered in turn below.

Trends for baseline and impact sites have been presented separately. 'Baseline' sites are those where there is likely to be little or no effect of diffuse or point source pollution and are therefore expected to account for natural or near- natural effects and trends. 'Impact' sites are downstream of present and possible future areas of agriculture, forestation, industry and urbanization (Smith & McBride, 1990). 'Baseline' sites can be subdivided further to 'true baseline' and 'pseudo baseline', however this distinction is not used in this report as it did not add significantly to the interpretation of the results.

Summary information on the numbers of NRWQN sites in the different trend categories is presented in Table 1. Within these trend categories, the total number of sites (T) has been divided into baseline (B) and impact (I) sites. National trends, determined by use of the binomial test, are also included in Table 1.

Table 1 Summary of water quality trends at NRWQN sites (I=impact, B=baseline, T=total)

National trend	Water quality variable	Upward trend							Downward trend						
		Significant upward trend	Significant but not meaningful			Meaningful			Significant downward trend	Significant but not meaningful			Meaningful		
			I	B	T	I	B	T		I	B	T	I	B	T
Increase[1]	Temperature	13	8	5	13				7	4	3	7			
No significant trend	% DO	17	7	10	17				21	12	9	21			
Significant increase ($P < 0.00013$)	Visual Clarity	26	1	1	2	14	10	24	9				5	4	9
Significant increase ($P = 0.012$)	DRP	22				16	6	22	11		2	2	6	3	9
Significant increase ($P = 0.00003$)	TP	22	2	1	3	11	8	19	9		1	1	6	2	8
Significant increase ($P = 0.019$)	NO_x-N	32	3	1	4	21	7	28	16		1	1	7	8	15
Significant increase ($P < 0.0005$)	TN	57	2	1	3	31	23	54							

[1] Overall increase in temperature was just below the 5% 'significance level' (P=0.057)

3.1.1 TEMPERATURE

There were a number of significant changes observed in water temperature over the 1989-2007 period (Table 1). 'Significant but not meaningful' increases were noted at 13 sites (5 sites in the North Island and 8 sites in the South Island), while 'significant but not meaningful' decreases were noted at 7 sites, 6 of which were in the South Island. The majority of these 'significant but not meaningful' increases and decreases were observed at sites in the South Island.

The median RSKSE value was 0.096% yr^{-1}, suggesting that rivers in New Zealand have warmed slightly (by just under 1% $decade^{-1}$ or about 0.15 degree $decade^{-1}$). At the national scale, the overall trend in temperature just fell below the arbitrary 5% 'significance' level (binomial test; $P = 0.057$), but we can be fairly confident that a warming trend has occurred nationally.

3.1.2 DISSOLVED OXYGEN

There were no 'meaningful' changes in dissolved oxygen percent saturation. There were, however, 'significant but not meaningful' increases at 17 sites, 7 in the North Island and 10 in the South Island. There were 'significant but not meaningful' decreases at 21 sites, of which 17 were in the North Island and 4 were in the South Island (Table 1).

There was no overall significant trend in percent dissolved oxygen at the national scale (median RSKSE = 0.009% yr^{-1}; binomial test: $P = 0.855$).

3.1.3 VISUAL CLARITY

Visual clarity exhibited a number of significant trends at sites throughout New Zealand (Table 1).

'Significant but not meaningful' increases were observed at 2 sites, while 'meaningful' increases were noted at 24 sites, 12 in the North Island and 12 in the South Island. These 'meaningful' improvements in visual clarity were dispersed throughout both islands and were not restricted to any particular region.

While no 'significant but not meaningful' downward trends in visual clarity were observed, 'meaningful' decreases were observed at 9 sites, 6 sites in the North Island, and 3 in the South Island.

At the national level, **there was a significant increasing trend in visual clarity** (binomial test; $P < 0.00013$) which agrees with the findings of Scarsbrook (2006), who also found an overall upward trend in visual clarity. The median RSKSE value was 0.42% yr^{-1}, which also indicates an increase in visual clarity in New Zealand rivers. The increase occurred mainly at 'baseline' sites (Table 2).

3.1.4 DISSOLVED REACTIVE PHOSPHORUS

There were a number of significant changes in DRP across both islands (Table 1).

No 'significant but not meaningful' increases were observed, but 'meaningful' increases were found at 22 sites. There were more 'meaningful' increases in the North Island (16) than the South Island (6). These increases were not confined to any specific geographical area but were distributed throughout both islands. 'Significant but not meaningful' downward trends were observed at 2 sites, while 'meaningful' downward trends were observed at 4 sites in the North Island and 5 sites in the South Island (9 in total). These 'meaningful' decreasing trends in DRP were dispersed throughout both islands, and showed no clear geographical pattern.

At the national level **there was a significant increasing trend in DRP** (binomial test; $P = 0.012$). The median RSKSE value was 0.19% yr^{-1}, which further indicates an upward overall trend in DRP concentrations. The upward trend occurred mainly at 'impact' sites (Figure 3), with little overall trend at 'baseline' sites. Scarsbrook (2006) also found a significant upward trend in DRP (Table 2).

3.1.5 TOTAL PHOSPHORUS

Significant increases and decreases in TP were observed at sites throughout both islands.

'Significant but not meaningful' increases in TP were noted at 3 sites, while 'meaningful' increases were noted at 19 sites. Ten of these 'meaningful' increases were in the North Island, while 9 were in the South Island.

'Significant but not meaningful decreases' in TP were found at 1 site, while there were 'meaningful' decreases at 8 sites. Seven of these 'meaningful' decreases were in the North Island, and 1 was in the South Island.

At the national level there was a **significant increasing trend in TP** (binomial test; $P = 0.00003$). The median RSKSE value was 0.53% yr^{-1}, which also shows that TP concentrations were increasing in New Zealand rivers. Figure 3 shows that TP tended to increase significantly overall at both 'baseline' and 'impact' sites in contrast to DRP, which only increased at 'impact' sites. However, TP was steady, and low, at near-pristine 'baseline' sites, such as the Haast River (GY4).

3.1.6 OXIDISED NITROGEN

"Oxidised nitrogen" refers to nitrogen in the nitrate (NO_3^-) and nitrite (NO_2^-) forms. These are typically analysed together, although nitrate generally dominates in well-oxygenated surface waters.

For the 1989-2007 period, there were significant increases and decreases in NO_x-N throughout both islands (Table 1).

'Significant but not meaningful' increases in NO_x-N were found at 4 sites, while 'meaningful' increases were observed at 28 sites. Of these 'meaningful' increases, 12 were in the North Island and 16 were in the South Island. Increases were not restricted to any particular region but were distributed through all areas of both islands.

'Significant but not meaningful' decreases were noted at 1 site, while 'meaningful' decreases were noted at 15 sites, 8 of which were in the North Island, and 7 of which were in the South Island.

At the national level, there was a **significant increasing trend in NO_x-N** (binomial test; $P = 0.019$). The positive median RSKSE value of 0.49% yr^{-1} also indicates an increase in NO_x-N concentrations. The upward trend in NO_x-N, like that for dissolved P, occurred mainly at 'impact' sites (Figure 3), while there was an overall decreasing trend at 'baseline' sites.

3.1.7 TOTAL NITROGEN

Increases in TN were observed throughout New Zealand (Figure 1). 'Significant but not meaningful' increases were noted at 3 sites while 'meaningful' increases were observed at 54 sites. Of these 'meaningful' increases, 28 were in the North Island and 26 were in the South Island, meaning that a higher proportion of the NRWQN river sites on the South Island were increasing in TN. Otherwise, this tendency towards increasing TN concentrations shows little geographic pattern and is distributed across all areas of both islands.

There were no 'significant' decreases in TN.

At the national scale, there was a **significant increasing trend in TN** (binomial test; $P < 0.0005$). The median RSKSE value was 1.41% yr^{-1}, which also shows that overall, TN concentrations were increasing, and more rapidly than any other variable (TN had the highest median RSKSE value). Figure 3 shows that TN increased significantly overall at both 'baseline' and 'impact' sites in contrast to NO_x-N which only increased at 'impact' sites. However, TN was steady, and low, at near-pristine 'baseline' sites, such as the Haast River (GY4).

3.1.8 SUMMARY OF TREND ANALYSIS

Temperature has increased overall and the rate of increase appears to be accelerating (Figure 3 and Table 2). Dissolved oxygen has remained steady in New Zealand rivers, while visual clarity has increased. Nutrients have increased overall, with TN and TP increasing sharply. Median TN and TP concentrations for 1989-2007 are strongly correlated (Spearman rank = 0.685, highly significant, $P < 0.01$), however RSKSE values for TN and TP are weakly correlated, indicating that increases in TN at individual river sites are not necessarily accompanied by increases in TP (Spearman rank = 0.208, not significant at the 95% level).

Table 2 Comparison of median RSKSE values for 1989-2003 and 1989-2007

	Temp	% DO	Visual Clarity	NO_x-N	TN	DRP	TP
Median RSKSE 1989-2003	0.02	-0.02	0.56	0.47	0.98	0.72	0.44
Median RSKSE 1989-2007	0.096	-0.0009	0.42	0.49	1.41	0.19	0.53
Median RSKSE 1989-2007 Impact sites	0	0	0	0.99	1.41	0.64	0.51
Median RSKSE 1989-2007 Baseline sites	0.12	-0.01	0.51	-0.22	1.38	0	0.57

RSKSE values for each water quality variable have been plotted for 'baseline' and 'impact' sites (Figure 3). The differences between percent dissolved oxygen and temperature for 'baseline' and 'impact' sites are very small. For clarity, there is a positive trend for the 'baseline' sites while for the 'impact' sites there is little change. This is an unexpected finding but may reflect a real improvement at 'baseline' sites (perhaps due to improved soil erosion controls). The lack of change at 'impact' sites may reflect a 'balance' between improving conditions due to soil erosion controls being negated by increasing pressures with pastoral expansion and intensification.

NO_x-N concentrations show a slight downward trend for 'baseline' sites but an upward trend for 'impact' sites, which is consistent with expectations in view of increasing nitrogen fertilizer use and expansion and intensification of pastoral agriculture. DRP concentrations are trending downwards slightly for 'baseline' sites, while for 'impact' sites they are increasing. Again this seems consistent with known trends of pastoral expansion and intensification. Changes in TP and TN concentrations do not vary significantly between 'baseline' and 'impact' sites: both categories of site are increasing in TP, and particularly TN, at similar rates overall. The increase at 'baseline' sites is at first surprising, but may reflect the generally lower concentrations at such sites, in that they are more susceptible to increases, possibly due to increased stocking or fertilizer use. Total nutrients are increasing at both 'baseline' and 'impact' sites, in contrast to dissolved nutrients which are only increasing overall at 'impact' sites.

Our trend assessment (1989-2007) is generally consistent with that of Scarsbrook (2006) for the period 1989-2003 (Table 2). While no overall changes in trend direction have occurred, there are however differences in the magnitude of trends for individual variables. Temperature increased at a greater rate over the longer time frame (suggesting a recent acceleration in the increasing trend) while visual clarity and dissolved oxygen show decreased rates of change compared to those detected by Scarsbrook (2006). NO_x-N and TN concentrations increased at a slightly greater rate for 1989-2007 than for the period 1989-2003. TP increased slightly faster for 1989-2007 than for the 1989-2003 period, while DRP concentrations show a weaker upwards trend over the longer time frame. In comparison with the findings of Scarsbrook (2006), trends in NO_x-N, TN, TP and temperature have strengthened, while those for DRP, dissolved oxygen and visual clarity have weakened.

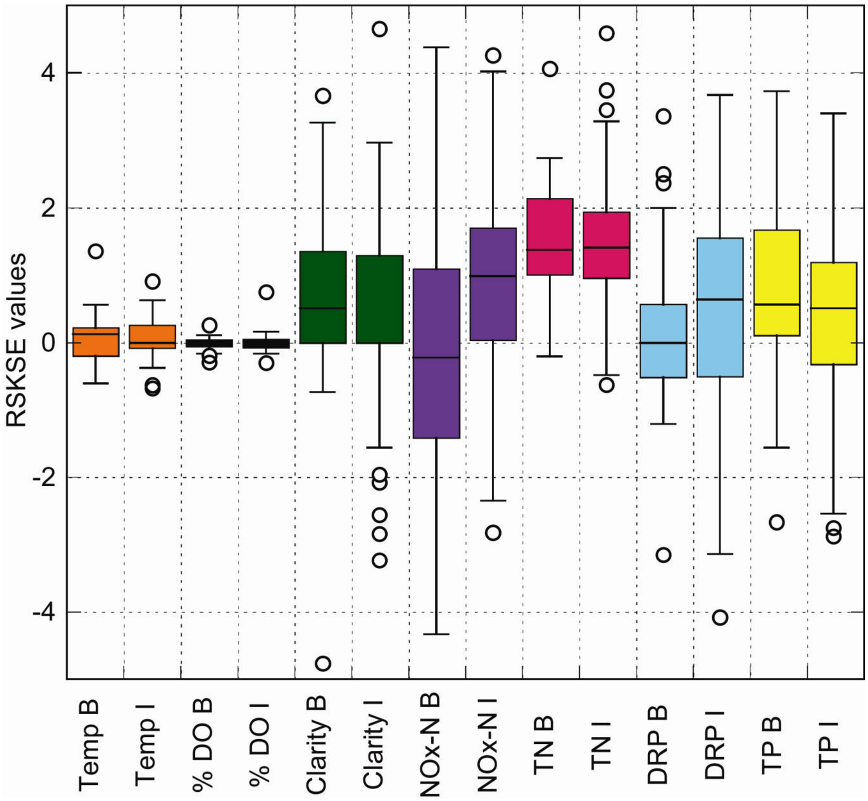

Figure 3 RSKSE values for water quality variables divided into baseline (B left) and impact (I right) sites. These box plots were generated by KaleidaGraph. The box covers the interquartile range, i.e., 50% of the data with the median value displayed as a line. Whiskers mark the values within the data set that fall within a distance of 1.5 x IQR (interquartile range) from the box. Any values outside of this range (outliers) are displayed as circles. (Three high and three low outliers are beyond the scale of this graph and are omitted.)

3.2 LINKS BETWEEN LAND USE AND WATER QUALITY

The effect of pastoral land use on water quality was examined by correlating current water quality state (median water quality values in 2007) with percentage pastoral land and forest cover (Table 3).

*Table 3 Spearman rank correlations for water quality variables (annual median for 2007) and flow adjusted % pastoral land cover. ** = highly significant (P<0.01) *= significant (P<0.05)*

Variable	Median water quality 2007 and % pastoral land cover	Median water quality 2007 and %forest land cover
Temperature	0.496 **	0.151
Dissolved Oxygen %	-0.176	0.2
Visual Clarity	-0.555 **	0.329 **
Oxidised Nitrogen (NO_X-N)	0.665 **	-0.141
Total Nitrogen (TN)	0.79 **	-0.262 *
Dissolved Reactive Phosphorus (DRP)	0.597 **	0.105
Total Phosphorus (TP)	0.699 **	-0.179

With the exception of dissolved oxygen, all the water quality variables had highly significant relationships with the percentage pastoral land cover in their catchments (Table 3). Relationships were mainly positive indicating that as the percentage pastoral land cover increased, concentrations of water quality constituents also increased. Temperature also increased with pastoral land use, probably reflecting solar heating of water in channels through pasture, which are mostly without shade, versus characteristically cooler water draining from shaded forested land. However, visual clarity was *inversely* related to pastoral land cover, plausibly because as pastoral land cover increases, light-attenuating fine sediment tends to be increasingly mobilised. The intensification of pastoral agriculture is a likely contributor to the higher occurrence of nuisance periphyton levels at 'impact' sites, as periphyton cover in New Zealand rivers is also strongly correlated with percentage pasture cover in catchments (Quinn & Raaphorst, 2009).

In contrast, there were few significant relationships between water quality variables and forest cover, with significant relationships only with TN and visual clarity. TN was inversely related to forest cover, i.e., concentrations decrease as forest cover increases, while visual clarity increased as forest cover increased.

4 DISCUSSION

Our trend analysis of NRWQN data over the nineteen year period from 1989-2007 has shown similar trends to those identified by Scarsbrook (2006) for the fifteen years 1989-2003. There have been few noteworthy trends in dissolved oxygen. However, a small upwards trend in river temperature (amounting to about +0.15°C decade^{-1}, and just bordering on 'significant' at the 5% level) is plausibly consistent with global warming.

Over the past two decades there has been a strong shift in importance of point source pollution relative to diffuse pollution, with pastoral agriculture dominating diffuse sources affecting our rivers. Enrichment by the nutrients N and P has continued which may be attributed mainly to expansion and intensification of pastoral land use. The overall upwards trend in DRP has weakened somewhat, but remains strongly upwards at 'impact' sites. The upwards trends in TN, NO_X-N and TP have strengthened overall, and TP and TN are strongly increasing at *both* 'baseline' and 'impact' sites (but not at certain near-pristine sites). We speculate that a reason for these nutrient enrichment patterns is that there may have been an increase in livestock intensity and fertilization over the past 2 decades at 'baseline' sites in extensive agriculture.

The overall trend of increasing visual clarity (which equates with improving water quality), as reported by Scarsbrook (2006) for 1989-2003, has weakened appreciably over the 1989-2007 period. Scarsbrook (2006) attributed this trend to improvements in waste treatment, meaning reduced inputs from point sources. Visual clarity is negatively correlated with % pastoral land in catchments, and Scarsbrook (2006) speculated that a decline in visual clarity might ensue if pastoral expansion and intensification continued. Possibly we are now seeing just such a slowing or reversal of the previous pattern of improving visual clarity because of pastoral expansion and intensification. The improving visibility at 'baseline' sites but not 'impact sites' is consistent with this interpretation.

At some of the NRWQN sites, recent changes in the direction of trends have not yet been recognised in the RSKSE value. For example, at sites WA8 and WA9, trends for TN and NO_x-N for the period 1989-2007 show meaningful increases, although concentrations are now decreasing (Ballantine & Davies-Colley, 2009).

5 CONCLUSIONS

Trend analysis indicates that nutrient concentrations have increased over the past 2 decades due to the expansion and intensification of pastoral agriculture. In particular, there is a strong increasing trend in TN across the country. There are, however, some encouraging recent trends which suggest a slowing of nutrient enrichment or even an improvement in water quality.

There has been a shift in the importance of point source pollution relative to diffuse source, as was first identified explicitly by Vant (2001), such that diffuse source pollution (mainly from livestock farming) is now over-whelmingly dominant in New Zealand. Nutrients tend to be positively, and visual clarity inversely, significantly correlated with percentage pastoral land cover in catchments, indicating a deterioration in water quality with increased pastoral land cover.

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