State and Trends in the National River Water Quality Network (1989–2005)

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Executive Summary

This report assesses the current state and recent trends in river water quality at the national scale. The National River Water Quality Network (NRWQN) is the source of all data.

The NRWQN includes 77 sites distributed nationally at which river flow is measured continuously and at which 14 physical/chemical parameters are measured monthly. All laboratory analyses are carried out at NIWA's Water Quality Laboratory in Hamilton. Data from January 1989 through until December 2005 were used.

An assessment of current state, using data from the 2005 calendar year, indicates strong associations between nutrient concentrations and percent pastoral land cover at the national scale. Median concentrations of all nutrient species and levels of the faecal indicator bacteria *E. coli* are positively correlated with extent of pastoral land cover.

Summaries of changes in annual state over time (1989–2005) highlight significant increasing trends of oxidised nitrogen (NO_x-N) in those rivers that already have high levels of this nutrient. This result implies that our most enriched rivers have deteriorated over the last 17 years, probably as a result of land-use intensification. Levels of dissolved reactive P show a somewhat different pattern. While there is a significant increasing trend for dissolved reactive P concentrations at the 80th percentile, there is not a similar trend in the 95th percentile. Dissolved reactive P concentrations at the 95th percentile actually show a non-linear response over time, with concentrations in our most enriched rivers peaking in the late 1990s and showing a decreasing trend since.

Detailed trend analysis for the period 1989–2003 highlights national-scale trends of decreasing concentrations of ammoniacal nitrogen and biochemical oxygen demand. Both of these patterns are consistent with improvements in our management of point source discharges to waterways. At the same time, increasing trends are observed in rivers around the country with respect to dissolved and total phosphorus and total nitrogen. There are positive correlations between trend magnitude and the extent of pastoral land cover in the catchment.

The picture of water quality in New Zealand rivers that emerges from the analyses and summaries presented in this report is consistent with a continuing shift in relative importance from point source to non-point source pollution as key anthropogenic pressures on surface waters. Resource management is shifting towards a greater emphasis on control of non-point source pollution associated with intensive agriculture. Information gained from the NRWQN supports this shift in emphasis.

1 Introduction

The purpose of this report is to summarise water quality patterns in a selection of rivers around New Zealand and, in doing so, provide an assessment of the current state and recent trends in river water quality at the national scale. This information will be used by the Ministry for the Environment to highlight water quality issues in New Zealand and to assist in reporting on the state of the environment to the New Zealand public and international organisations (eg, OECD). Much of the information in this report will be made available through the Ministry's website.

All data used in this report was sourced from the National River Water Quality Network (NRWQN), a component of NIWA's "Nationally Significant Database: Water Resource and Climate" Programme, which is funded through the Foundation for Research, Science & Technology. Much of the work presented in this report stems from research currently being written up for scientific publication (Scarsbrook et al in prep.).

The report is divided into five subsections:

1. a brief description of the NRWQN
2. a summary of current water quality state (2005 data)
3. a summary of moving annual state (1989–2005)
4. presentation of results from detailed trend analyses carried out for the period 1989–2003
5. a discussion of results in relation to water quality management in New Zealand.

2 The National River Water Quality Network

The New Zealand National River Water Quality Network (NRWQN) commenced operation at the beginning of 1989, following an agreed design (Smith et al 1989; Smith and McBride 1990). The network design nominated two objectives: (i) to detect significant trends in water quality, and (ii) develop better understandings of the nature of the water resources and hence to better assist their management.

The Network includes 77 sites (Figure 1.1) distributed throughout the North Island (44 sites) and South Island (33 sites) at which river flow is measured continuously and 14 physical/ chemical parameters are measured monthly.

According to criteria given by Smith and McBride (1990), sites were selected to reflect both baseline conditions (32 upstream sites) and impact conditions (45 downstream sites). Where possible, sites were selected to have median flow >1 m^3/s. Field work is carried out by NIWA's 14 regional hydrometric field teams; the first two letters of each site descriptor (see Figure 1.1) being taken from the location of the field party, eg, RO for a Rotorua party's site, GY for a Greymouth site. (There were originally 15 teams – GS is now amalgamated with HV.) Laboratory analyses are performed at NIWA's Hamilton laboratory.

At an individual site, sampling on each occasion is generally at the same time of day to remove the variance-inflation attributable to diurnal variability. Flow is measured or estimated on each sampling occasion. Other field measurements include dissolved oxygen (measured as percentage of saturation; % DO), temperature, and visual clarity (measured by horizontal black disc visibility). In the laboratory pH, conductivity, biochemical oxygen demand (five-day test with no inhibition for nitrification; hereafter BOD_5), oxidized-N (ie, NO_x-N = NO_2-N + NO_3-N), ammoniacal-N (ie, NH_4-N = NH_4^+-N + NH_3-N), total N (TN), dissolved reactive P (DRP) and total P (TP) are measured. Analytical methods remained the same over the study period (January 1989–December 2005). See Smith and McBride (1990) for further details. Measurement of levels of *E. coli*, a faecal indicator bacteria, began in 2005.

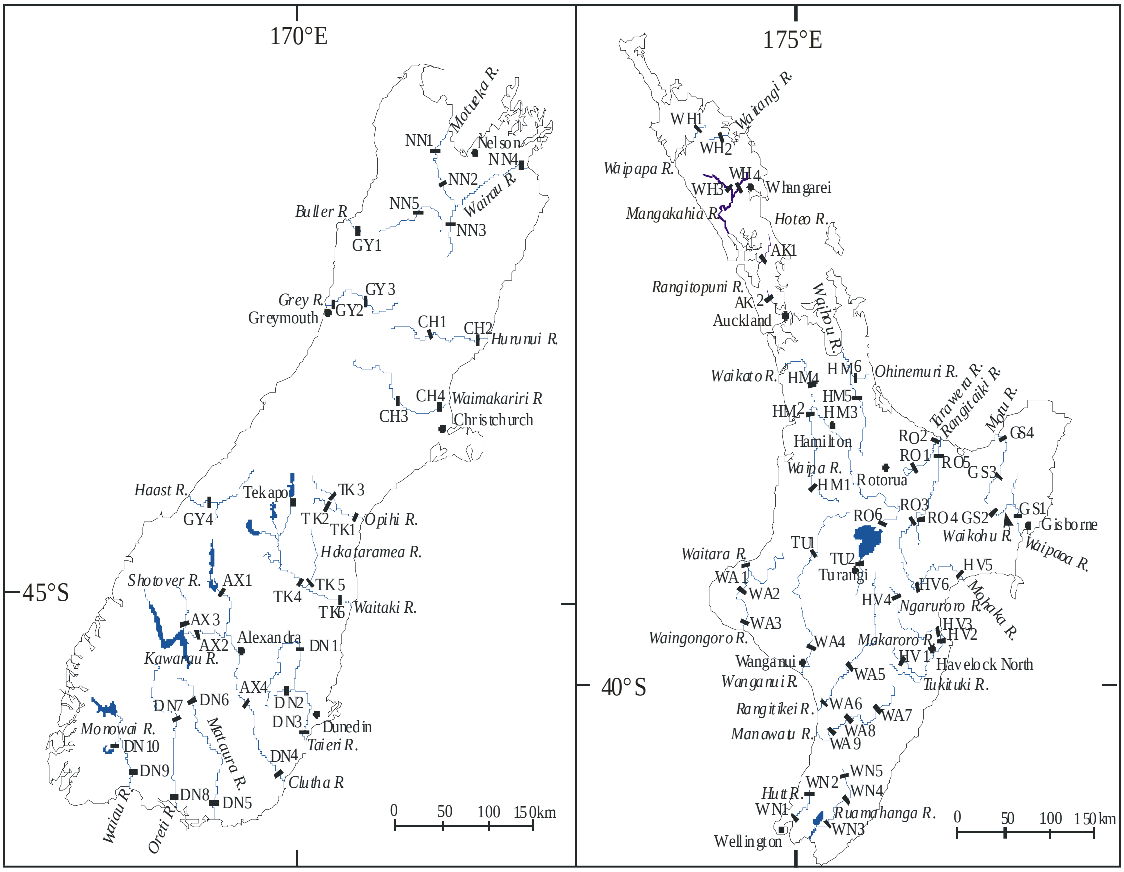


Figure 1.1: Location of 77 NRWQN sites in New Zealand

3 Water Quality State (2005)

Median values for 2005 at each site were calculated based on monthly raw data (January–December) for all parameters.

In the series of figures below, current water quality state is illustrated by overlaying site medians onto maps of New Zealand with the background coloured according to the land cover level of the River Environment Classification (REC; Snelder and Biggs, 2002). Land cover is expressed in three classes: pastoral land cover in green, natural land cover (ie, indigenous forest, unimproved tussock, scrub and bare mountain) in brown, and exotic forest in grey.

To simplify the maps, the site medians have been separated into six groups corresponding to the following percentile bands: <5th percentile, 5–20th, 20–50th, 50–80th, 80–95th and >95th percentile.

In the figure for flow, varying bubble sizes are used to represent the different percentile groups. For all other parameters the percentiles are indicated by a change in colour, with blue representing relatively good water quality and red representing relatively poor water quality.

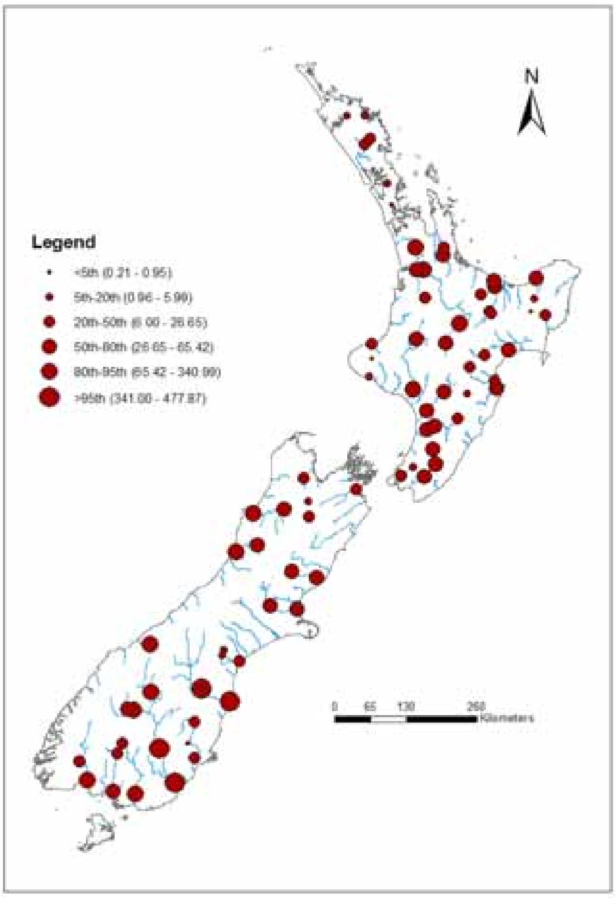


Figure 3.1: River flow ($m^3 s^{-1}$) (2005 medians expressed as percentile bands)

River flows are shown overlain on a network of our larger rivers (Strahler order 6 and higher). The Waitaki and Clutha are our largest rivers. Across all 77 sites the median flow in 2005 was 26.7 $m^3 s^{-1}$.

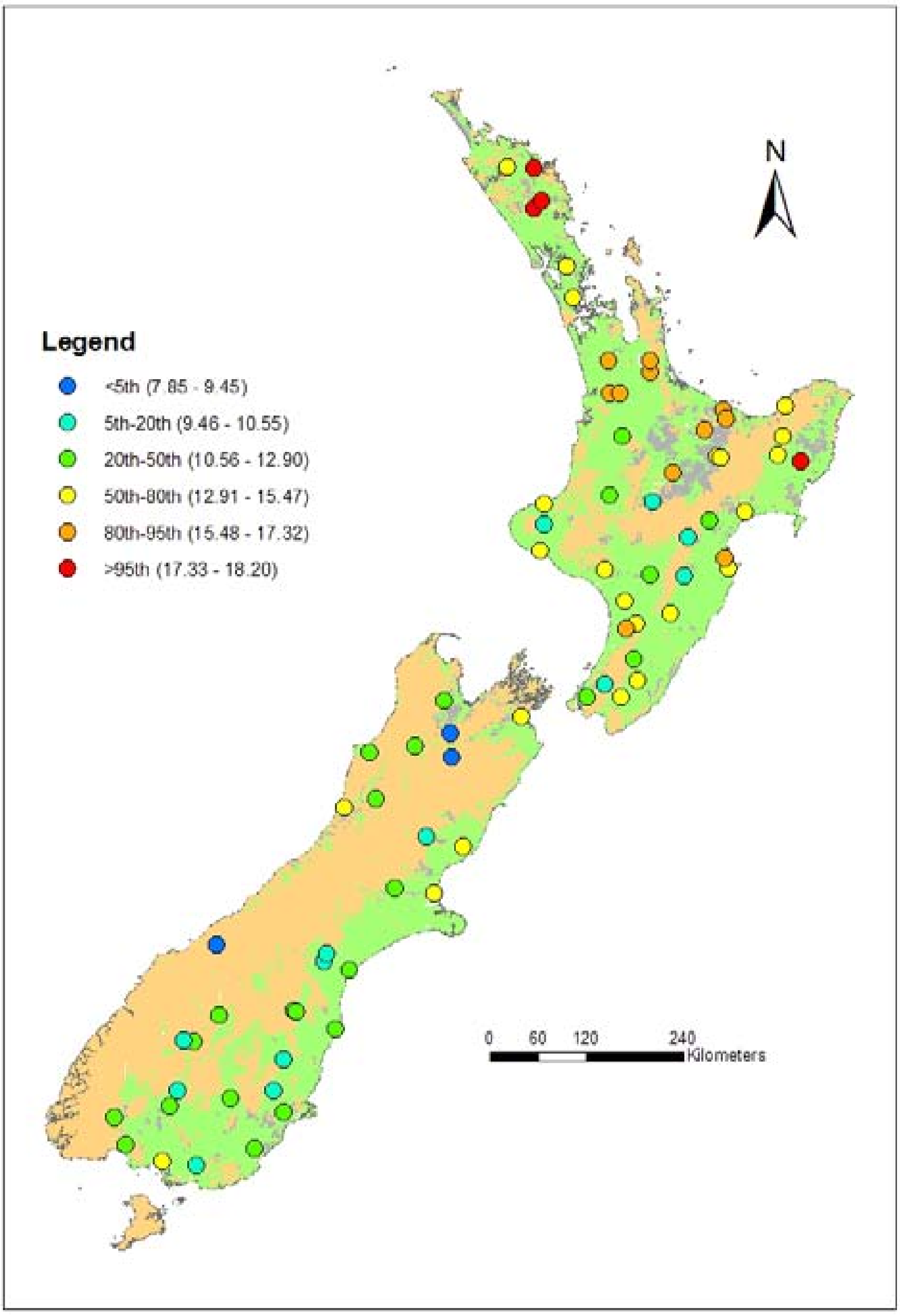


Figure 3.2: Temperature (^{o}C) (2005 medians expressed as percentile bands)

Not surprisingly there are strong latitudinal and altitudinal gradients in water temperature patterns across the country. Sites in Northland (Waitangi and Mangakahia rivers) and Gisborne (Waipaoa) had the highest water temperatures. The coolest rivers were the Motueka, Wairau and Haast. National median river temperature was 12.9ºC.

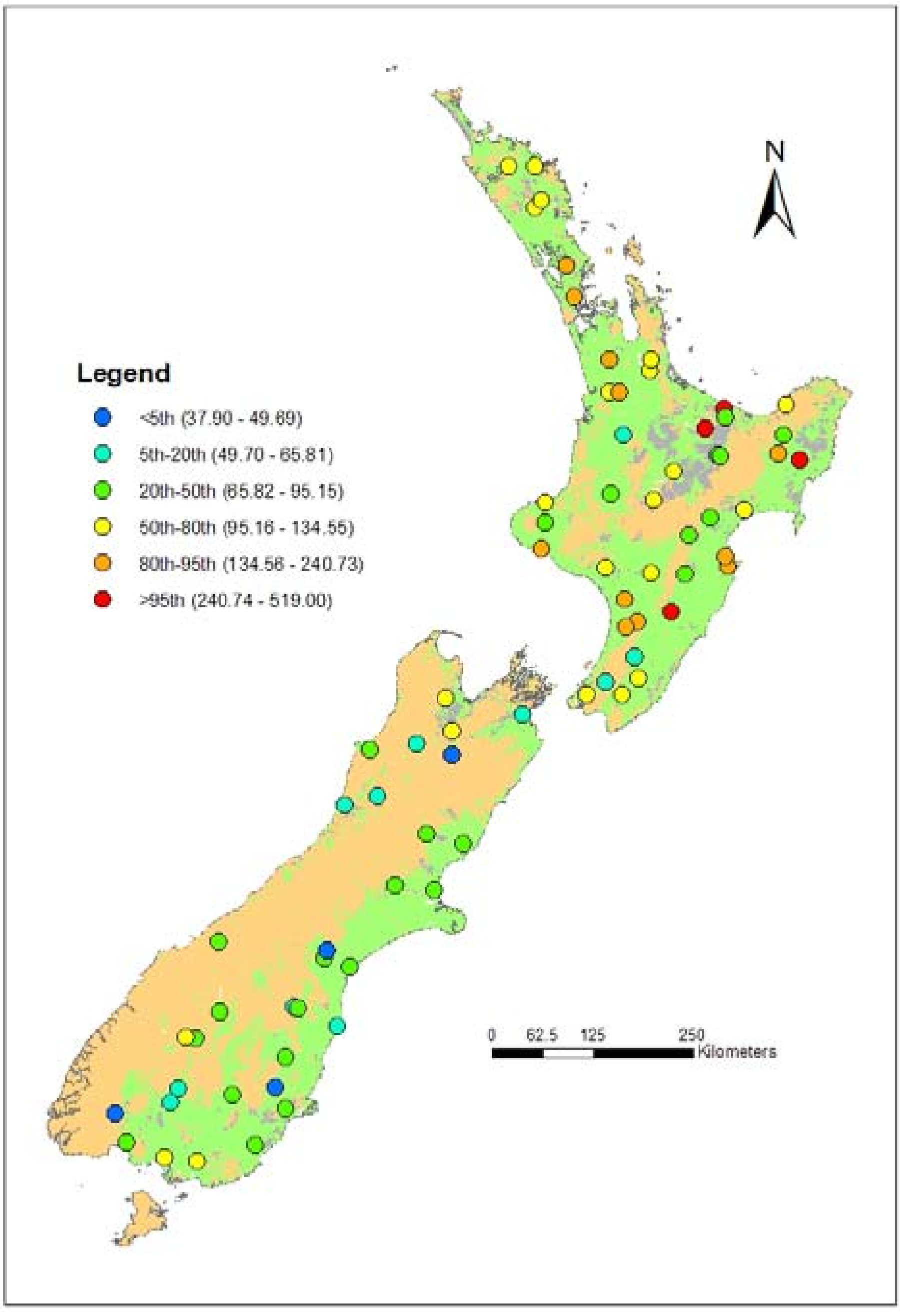


Figure 3.3: Conductivity (µS cm^{-1}) (2005 medians expressed as percentile bands)

There is a strong North Island versus South Island difference in conductivity, probably reflecting the marked geological differences between the North and South Islands. National median for conductivity was 95 µS cm^{-1}.

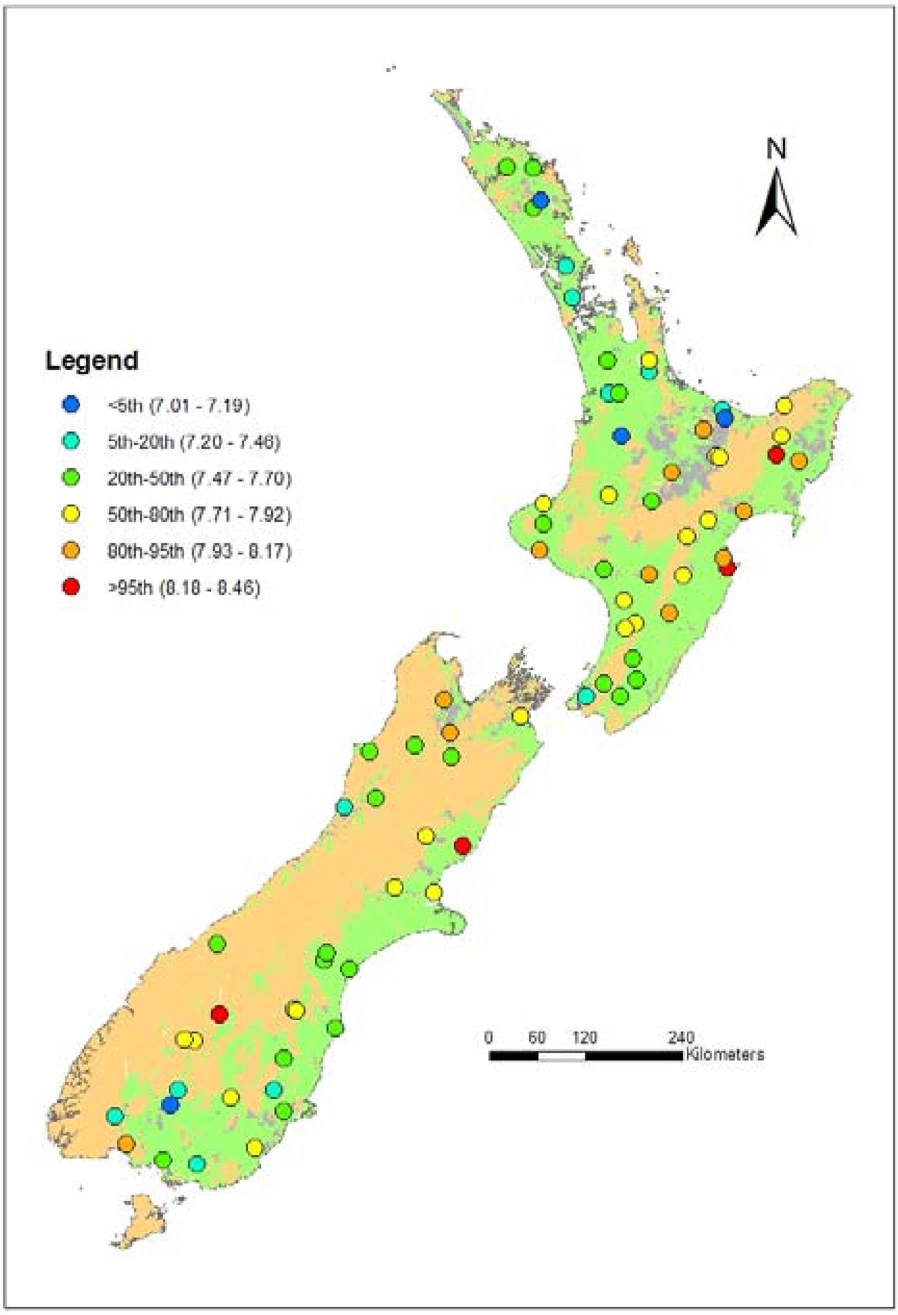


Figure 3.4: pH (2005 medians expressed as percentile bands)

Median pH was highest in the Clutha River at Luggate, the lower Hurunui and Ngaruroro rivers, and the Waikohu River (Gisborne). Median pH was lowest in the upper Oreti River, upper Waipa River and lower Rangitaiki. The national median was 7.7 and no rivers had median pH < 7.0 in 2005.

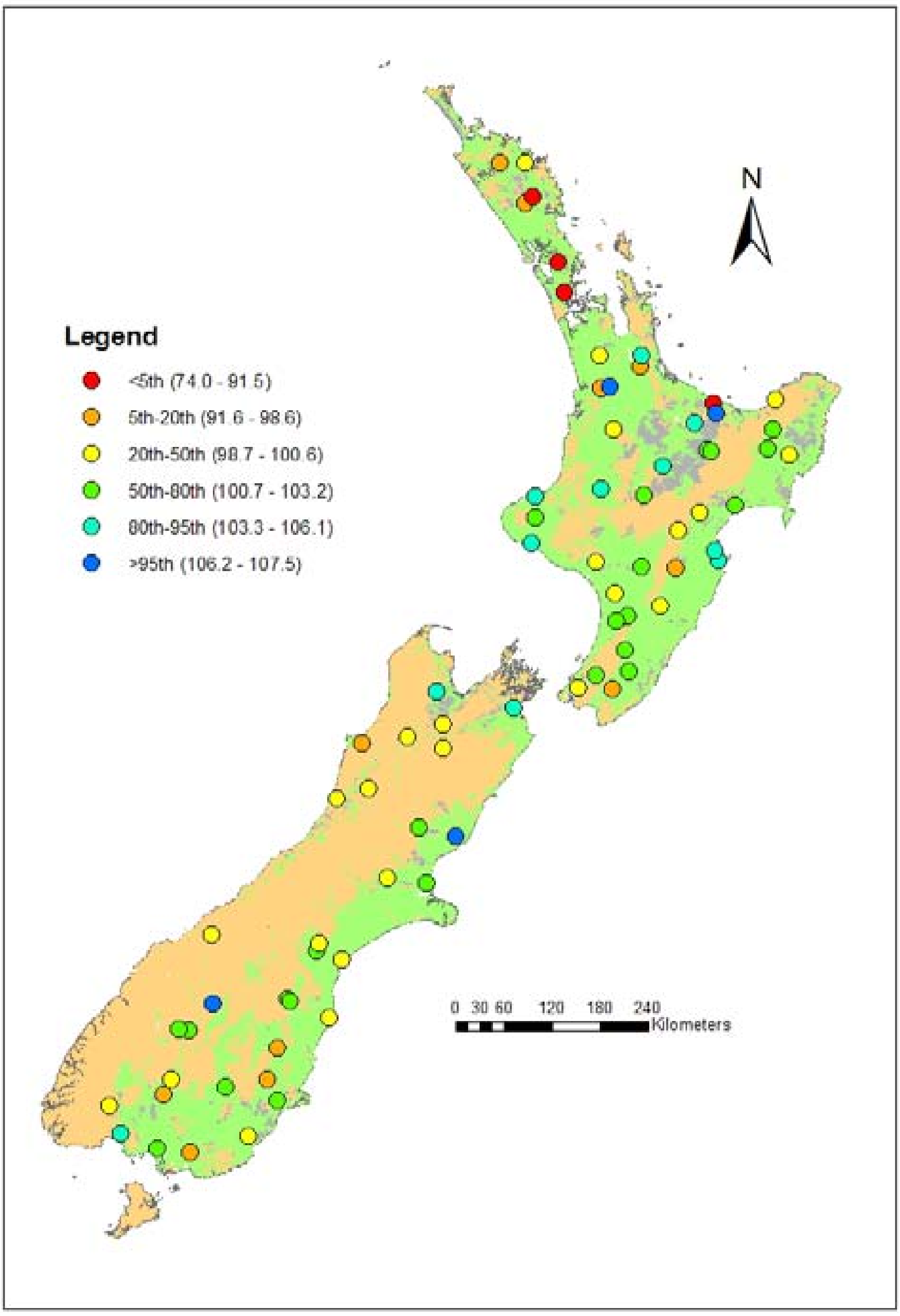


Figure 3.5: **Location of 77 NRWQN sites in New Zealand**

Most rivers around New Zealand are well oxygenated (national median = 101%). However, sites in Northland and Auckland, and the lower Tarawera River had the lowest levels of dissolved oxygen. It is worth noting that monthly measurements of dissolved oxygen provide a relatively poor representation of conditions as there are strong diurnal cycles in DO in many rivers.

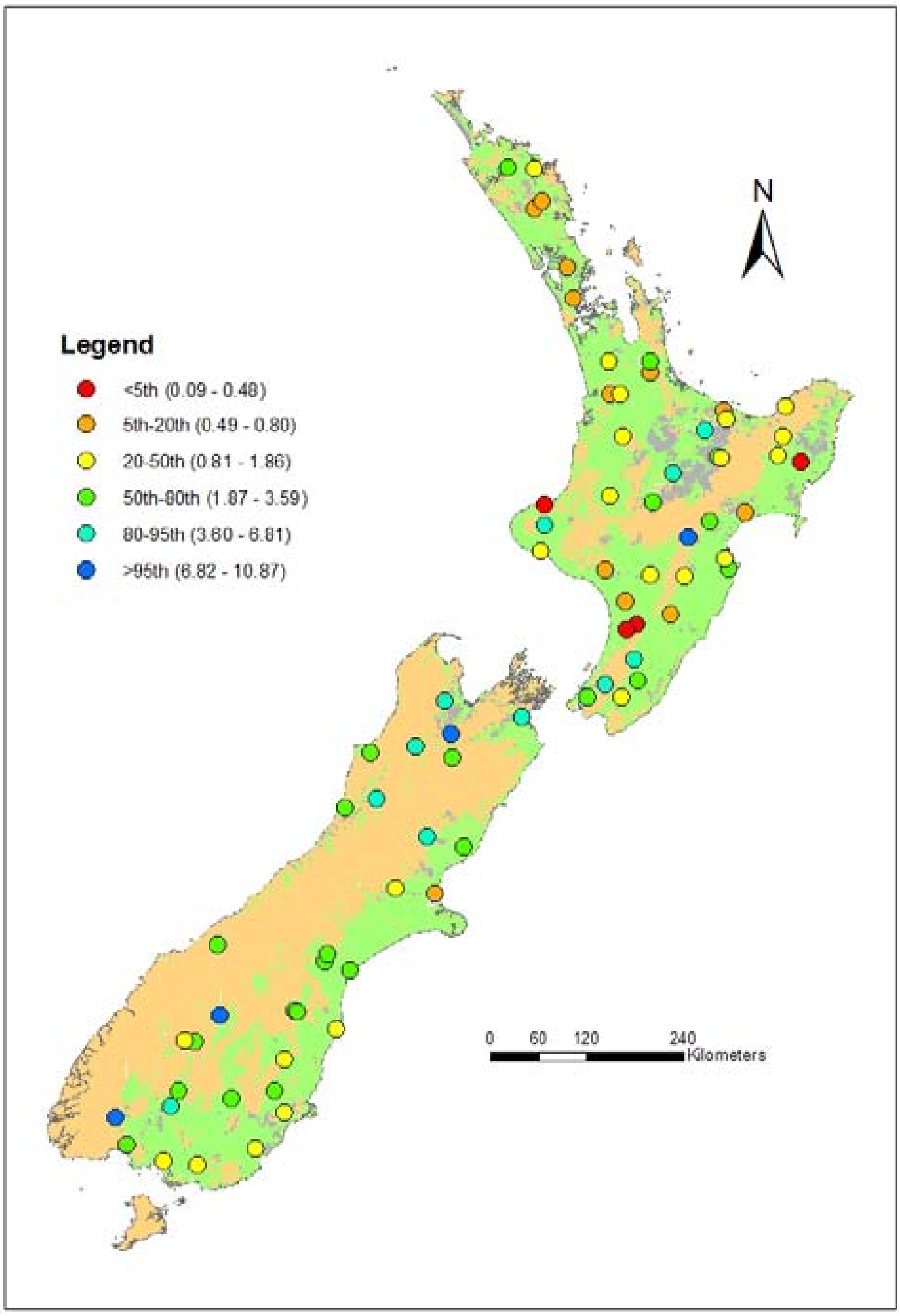


Figure 3.6: Visual clarity (m) (2005 medians expressed as percentile bands)

In 2005, the national median visual clarity was 2.85 m. Highest clarity sites included lake outlet sites (eg, Monowai River, Clutha at Luggate) and headwater sites (eg, upper Motueka and Ngaruroro rivers). The lower Manawatu, Waitara and Waipaoa rivers had the lowest annual median water clarity for 2005.

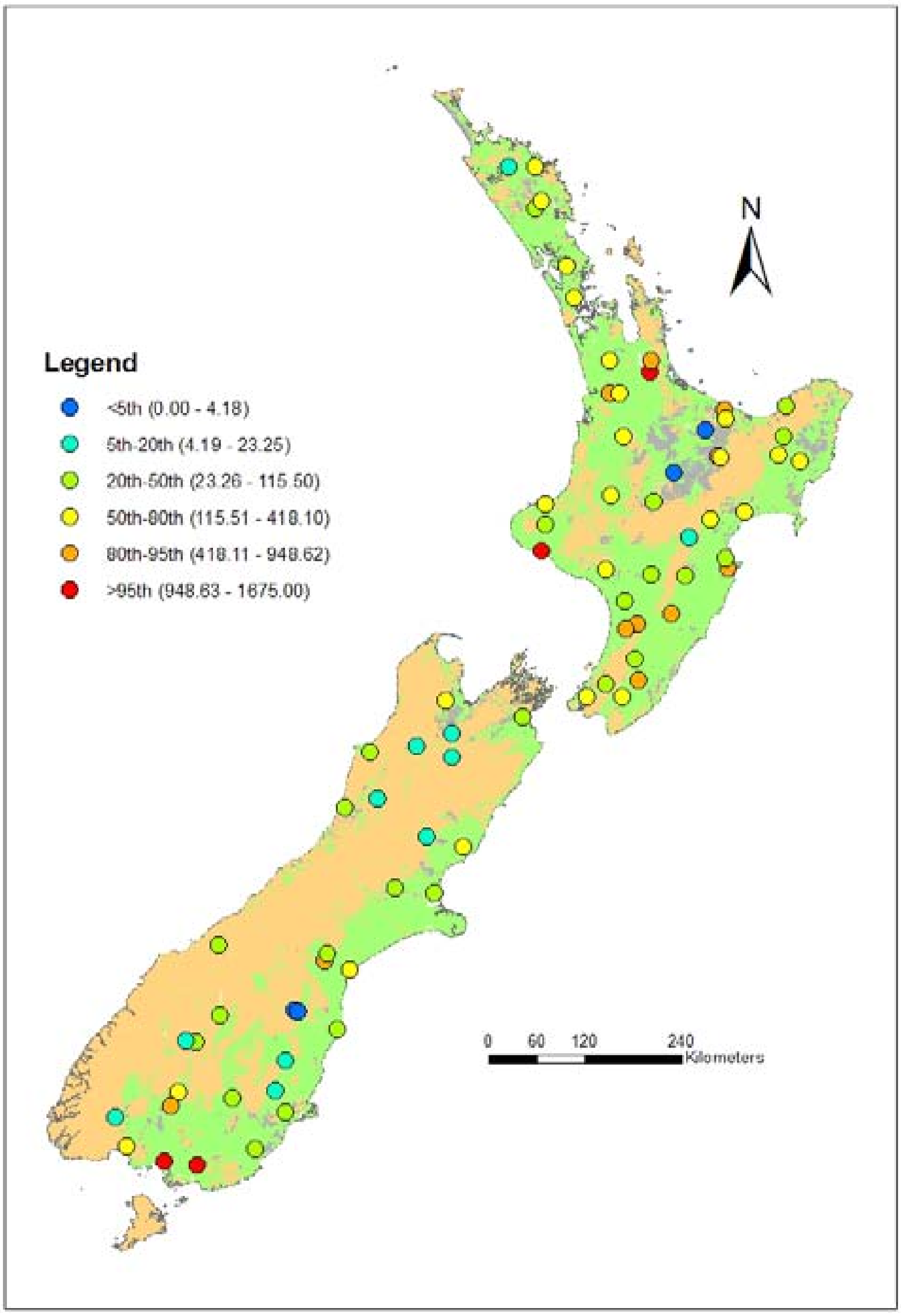


Figure 3.7: NO_X-N (mg m^{-3}) (2005 medians expressed as percentile bands)

Rivers in Southland (Mataura, Oreti), Taranaki (Waingongoro) and Waikato (Waihou) regions had the highest median NO_x-N concentrations in 2005. In contrast, sites draining lakes (eg, Tarawera River below Lake Tarawera, Waitaki below Waitaki hydrolakes, Waikato below Lake Taupo) had very low NO_x-N concentrations. The national median was 115.5 mg m^{-3}.

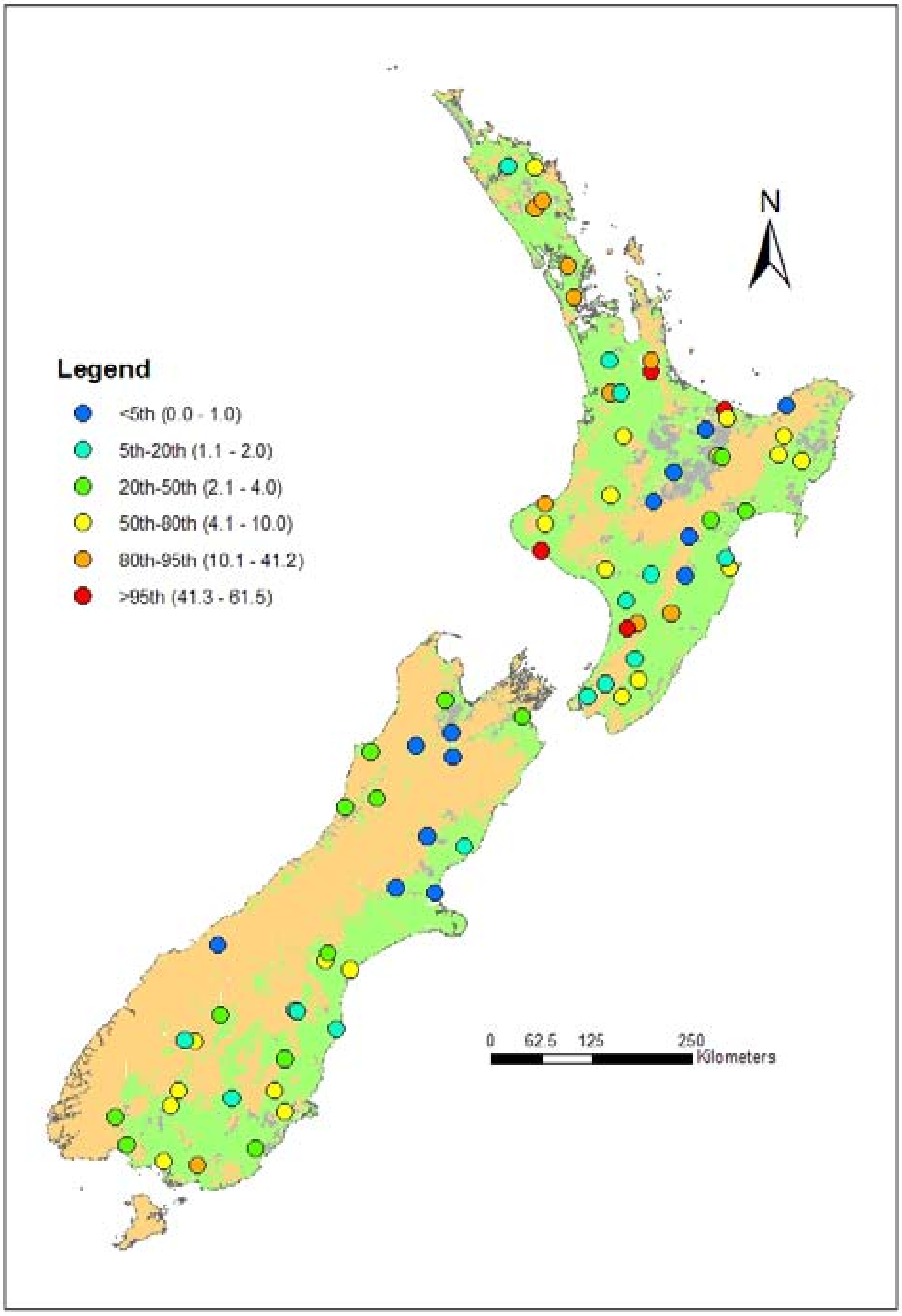


Figure 3.8: NH_4-N (mg m^{-3}) (2005 medians expressed as percentile bands)

NH_4-N concentrations were low in most rivers (2005 national median = 4 mg m^{-3}). Exceptions were sites on the lower reaches of Waingongoro, Manawatu, Waihou and Tarawera rivers.

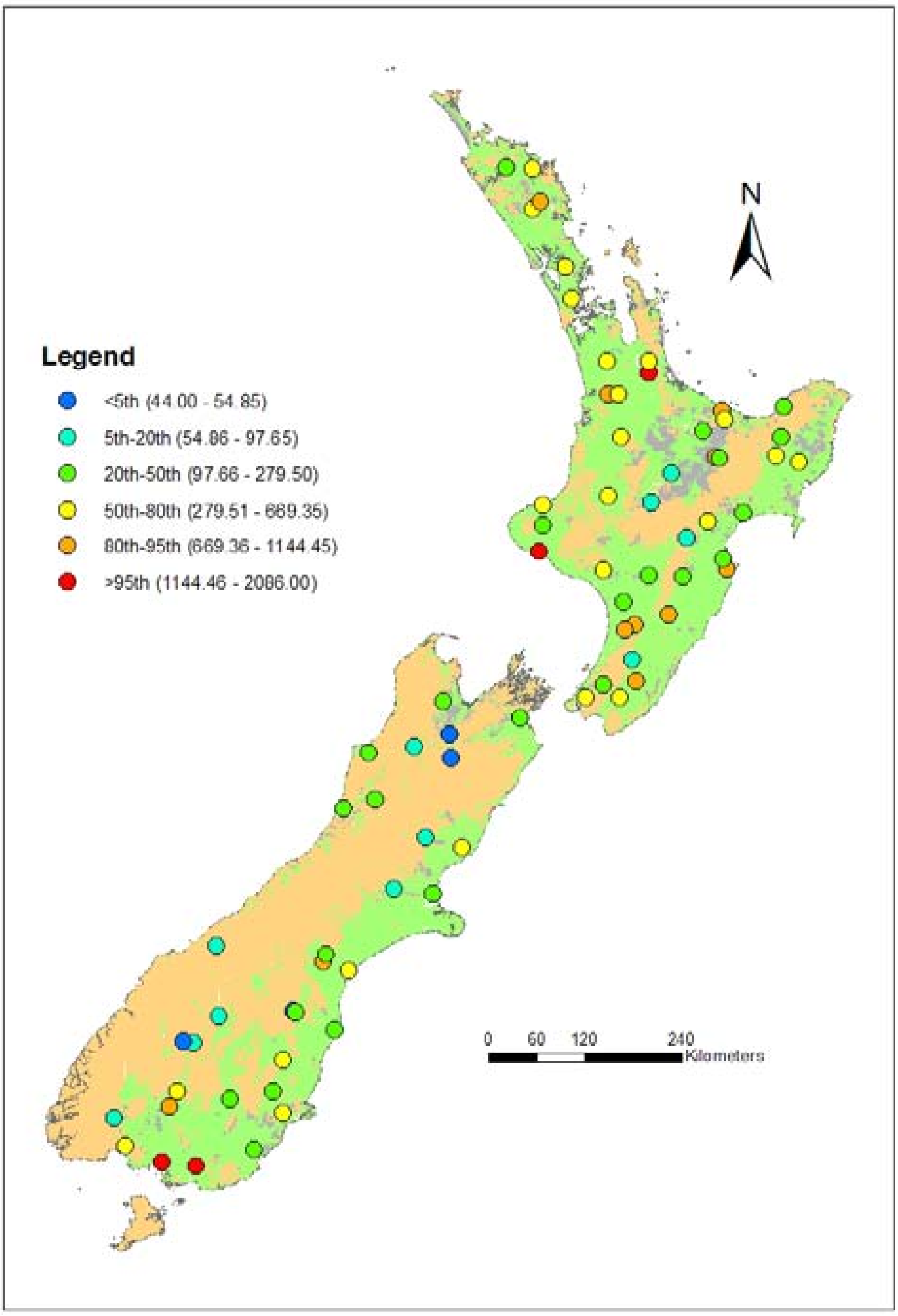


Figure 3.9: TN (mg m^{-3}) (2005 medians expressed as percentile bands)

Spatial patterns for TN were similar to those for NO_x-N. National median concentration of TN were 279.5 mg m^{-3} in 2005. Sites in the South Island high country (eg, upper Wairau and Motueka rivers) tended to have the lowest concentrations.

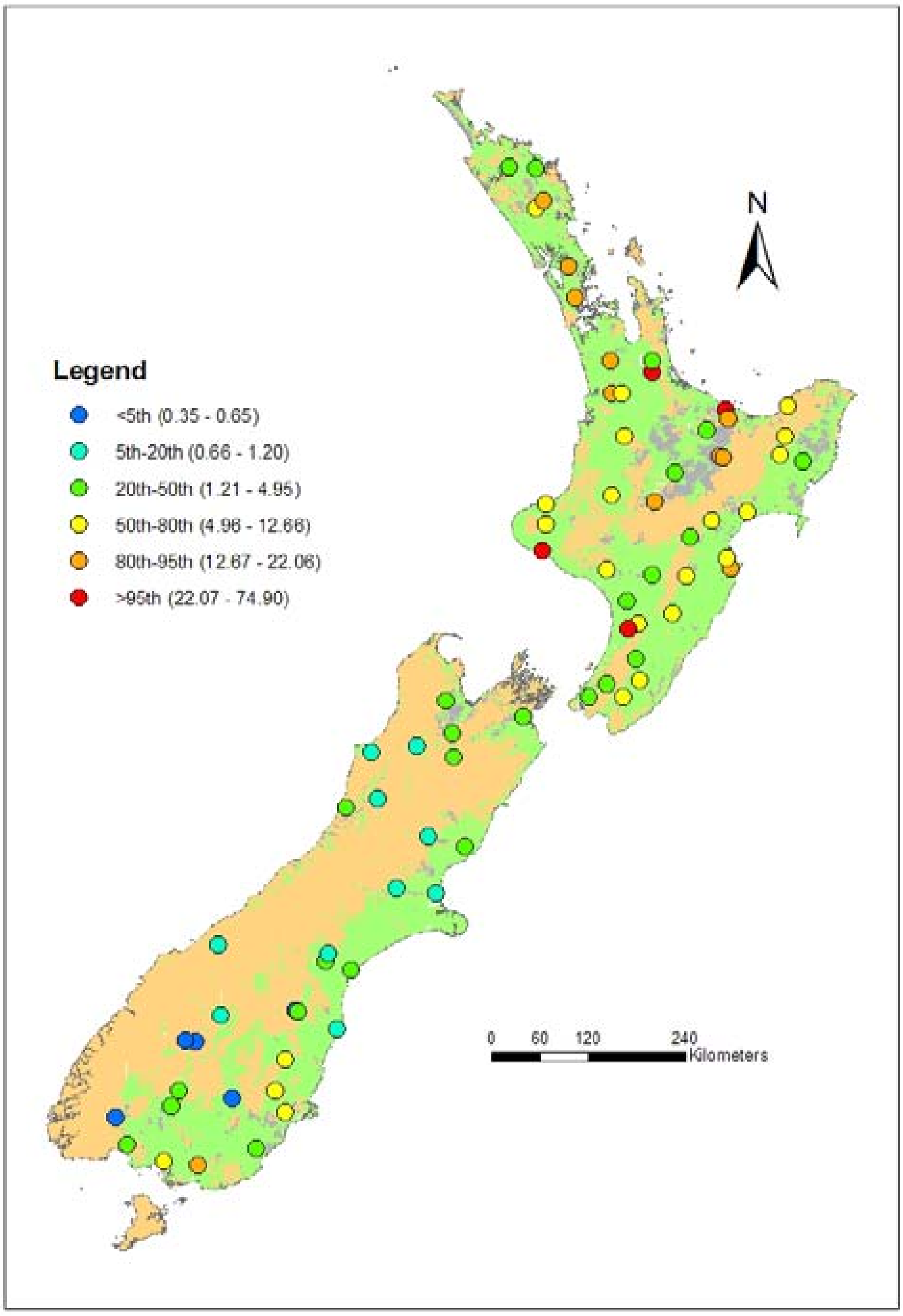


Figure 3.10: DRP (mg m^{-3}) (2005 medians expressed as percentile bands)

DRP concentrations tended to be higher at North Island sites than South Island sites, probably reflecting differences in geology (cf. conductivity results). Highest DRP concentrations were observed in the lower Manawatu, Waingongoro, Tarawera and Waihou rivers (where NH_4-N levels were also high). National median concentration in 2005 was 4.95 mg m^{-3}.

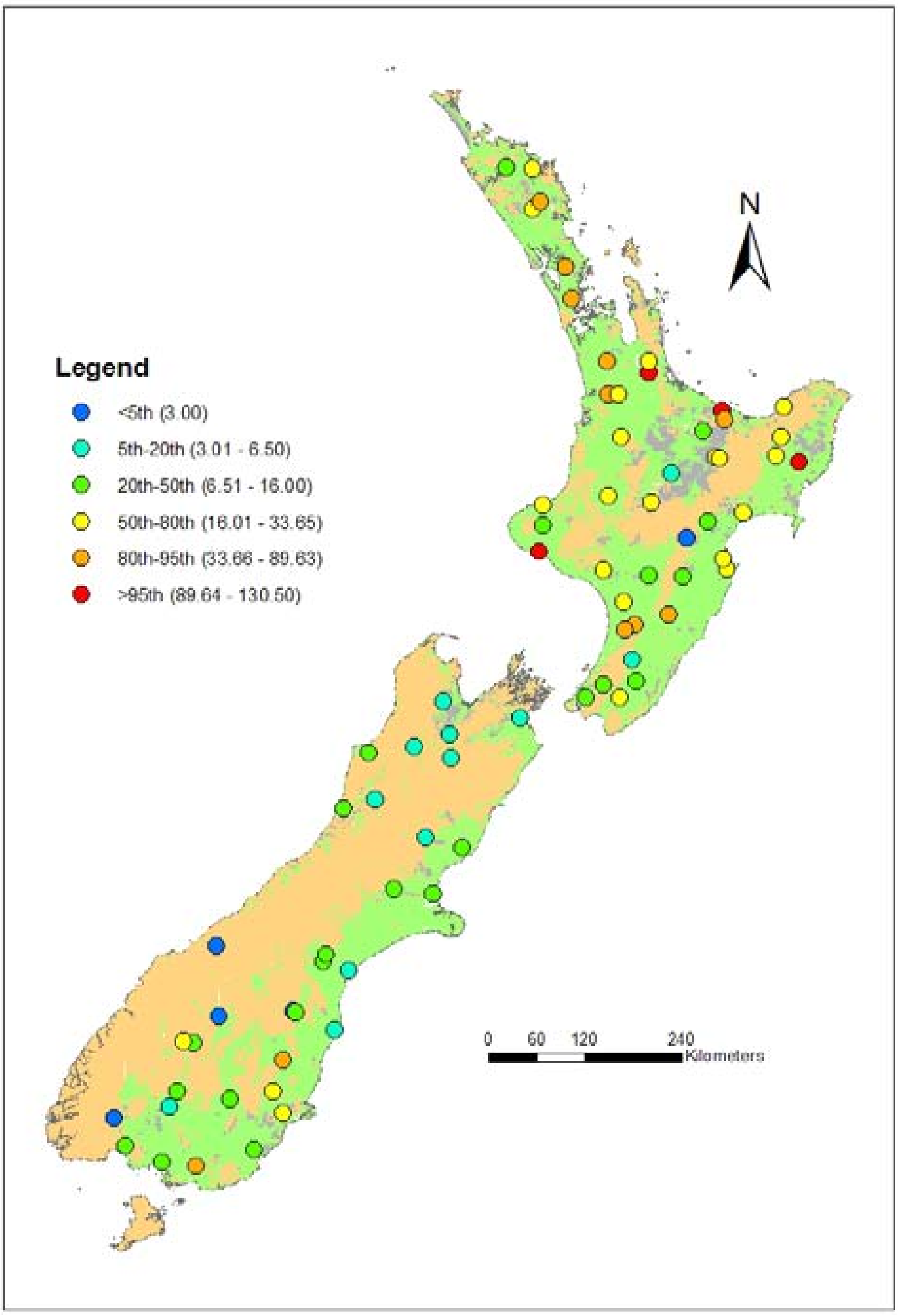


Figure 3.11: TP (mg m^{-3}) (2005 medians expressed as percentile bands)

TP concentrations show a similar pattern to those for DRP although the Waipaoa River joins the group of rivers with highest concentrations in 2005. This probably reflects the high sediment load carried by the Waipaoa River (cf. clarity map above). National median concentration for TP in 2005 was 16 mg m^{-3}.

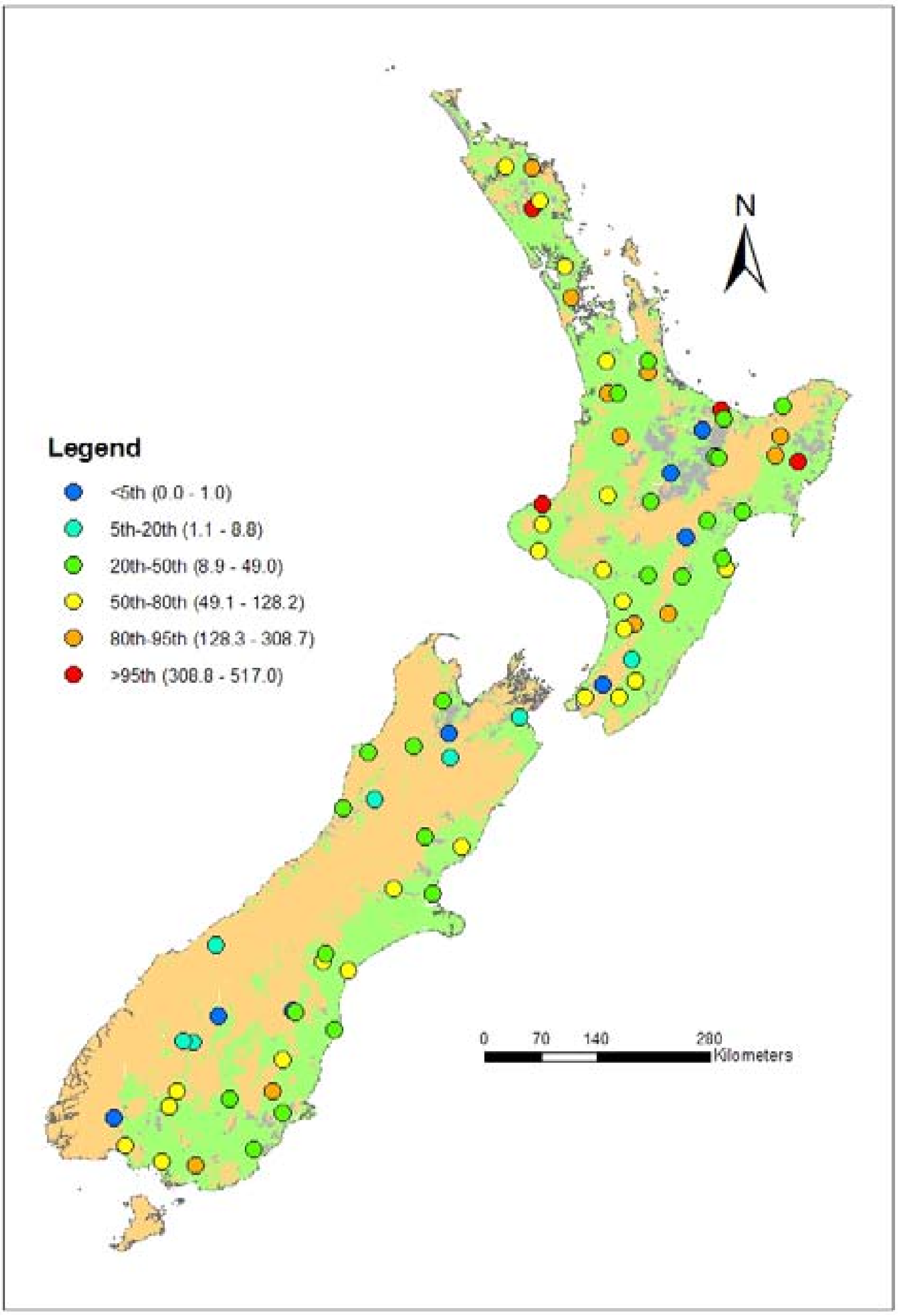


Figure 3.12: ***E. coli*** **(MPN 100 ml^{-1}) (005 medians expressed as percentile bands)**

2005 was the first year for analysis of *E. coli* from NRWQN samples. Levels of *E. coli* tend to be higher in the North Island and especially in low elevation areas. North Island Central Plateau and South Island high-country sites had the lowest levels of *E. coli*. National median for 2005 was 49 MPN 100 ml^{-1}.

Site median values for all parameters (2005 data only) were correlated with percent pastoral land cover in the catchment above each monitoring site. Land-cover data was based on flow-weighted percentage contributing area from LCBD (1997 version; see www.mfe.govt.nz).

Some of the river sites (eg, lower Waingongoro, Manawatu and Mataura rivers) have significant point source discharges upstream. This may introduce a source of error to correlations based solely on percent pastoral land use in the catchment, although rivers with major point sources are likely to have highly developed catchments.

There were significant correlations between percent pastoral land cover and median values for all but three of the parameters summarised above (Table 3.1). The strongest correlations ($r_S > 0.70$) were for the three nitrogen species, total phosphorus and *E. coli* (Table 1.1). Flow, pH and % DO were not significantly correlated with pastoral land cover.

Table 3.1: Correlations for water quality parameters (annual median for 2005) versus percent pastoral land cover

Parameter	% pastoral land cover
Flow	-0.21
Temperature	0.50***
Conductivity	0.55***
pH	-0.19
Dissolved oxygen	-0.17
Visual clarity	-0.60***
Oxidised nitrogen	0.71***
Ammoniacal nitrogen	0.77***
Total nitrogen	0.84***
Dissolved reactive phosphorus	0.67***
Total phosphorus	0.74***
E. coli	0.79***

Note: '***' = very highly significant (*P* <0.001) and relate to the annual median for 2005.

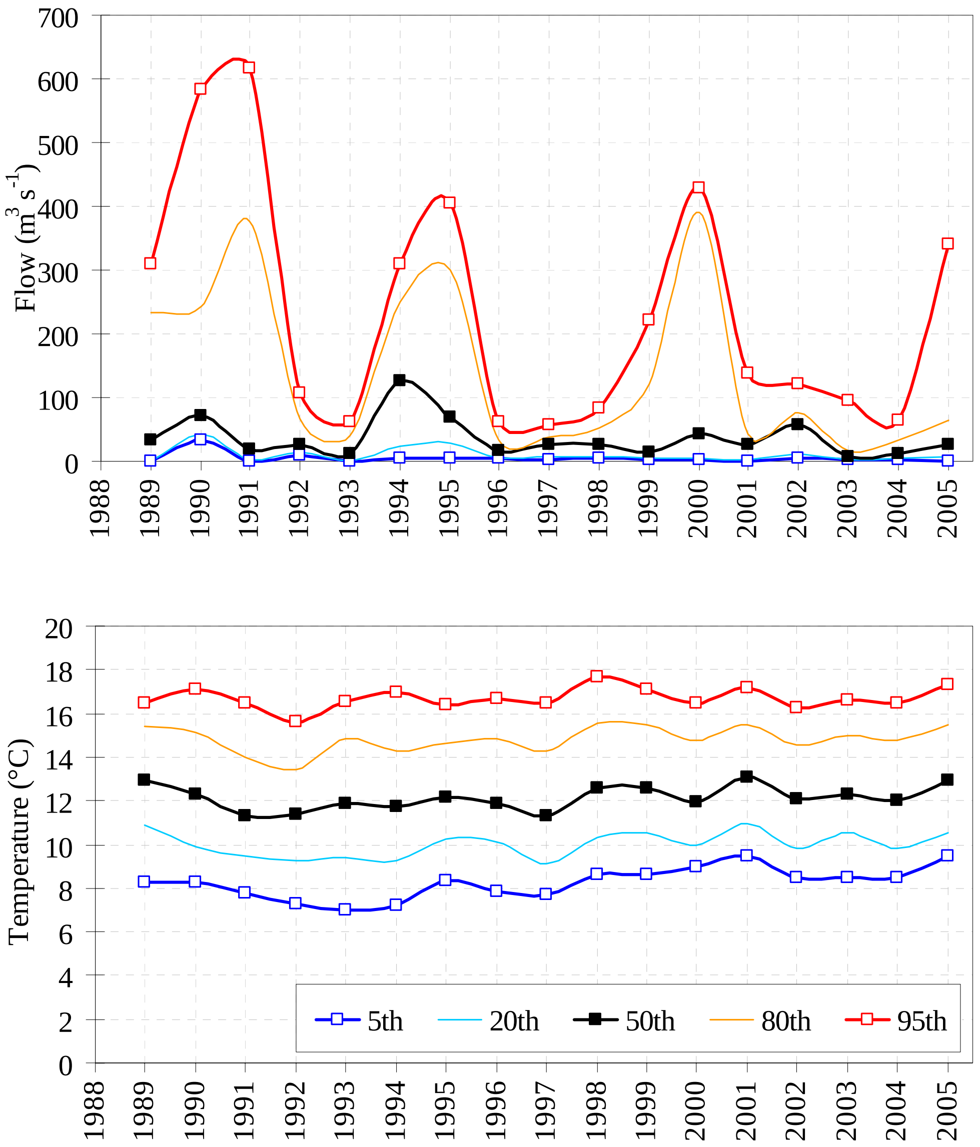
4 Changes in Water Quality State (1989–2005)

A single snapshot of water quality state, such as that provided for 2005 here, can provide a wealth of useful information on areas where water quality is particularly good or bad. However, it does not tell us whether water quality is getting better or worse over time. In addition, because it does not incorporate information about inter-annual variability, a single year's data may provide a limited national-scale picture. In the figures below, water quality patterns over time have been summarised at the national scale. This is a relatively descriptive way to highlight changes in water quality over the 17-year period of the NRWQN's operation.

Annual median values were calculated using monthly data for 12 water quality parameters at each of the 77 NRWQN sites from 1989 to 2005. These annual site medians were then used to calculate the annual 5th, 20th, 50th, 80th and 95th percentile values across the NRWQN sites. The 50th percentile gives us a picture of what is happening in a national "average" river in terms of annual median water quality data. The 20th and 80th percentiles are included because management decisions often follow the 80:20 rule. The 5th and 95th percentiles tell us about state and changes over time in our "best" and "worst" rivers.

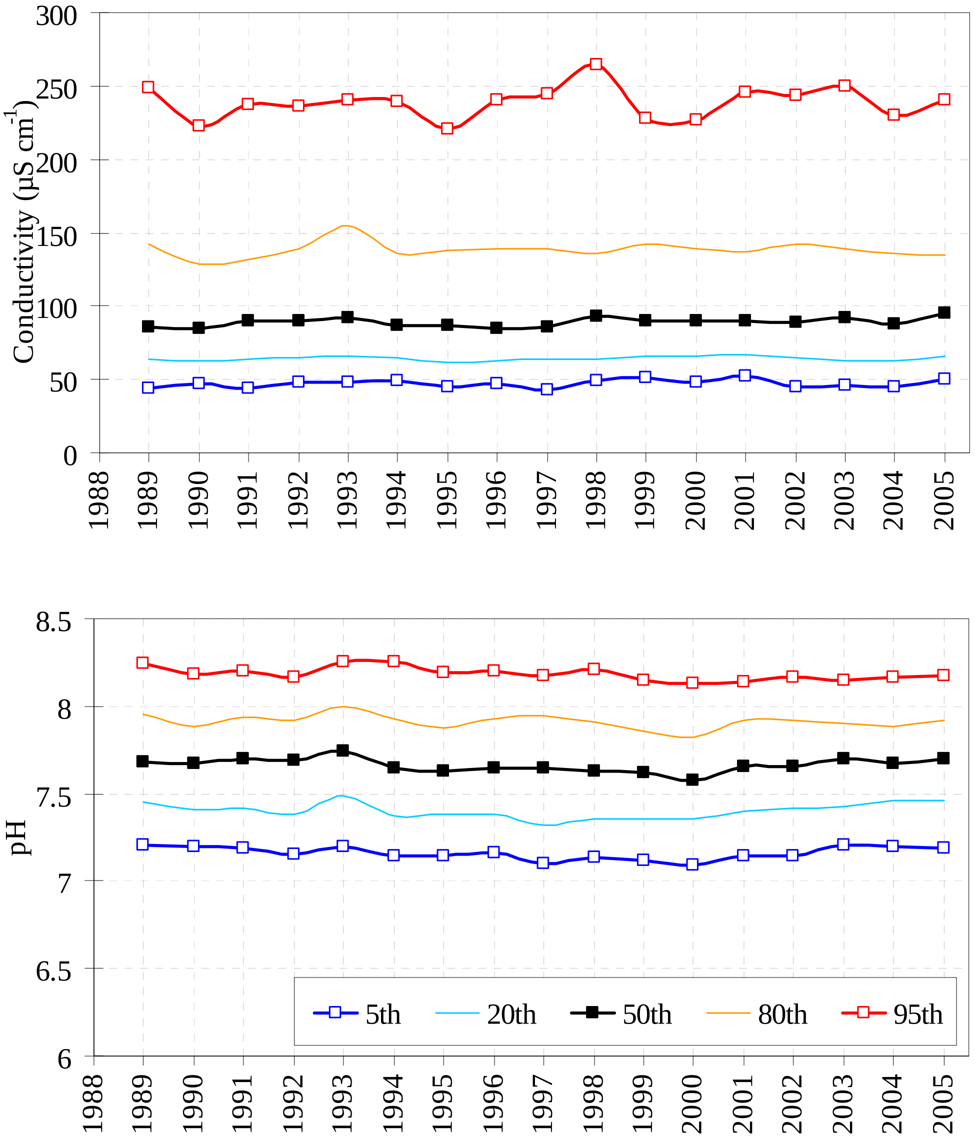
These summaries of moving annual state can be quickly and easily updated each year and could be used to provide early warning of emerging issues for water resource management. It is likely that more formal trend analyses (see Section 5) will occur less frequently (eg, every five years), so the summaries below provide a relatively quick and simple check on changes in water quality on a year-to-year basis. Note that it is possible the descriptive trends presented below may produce different results from a more formal site-by-site trend analysis (see Section 5). This could occur as a result of differing time periods being analysed, the presence of strong seasonal trends that might be obscured when reporting annual medians over time, or the influence of changing flows during the period (formal trend analysis is carried out on flow-adjusted data).

Note that the figure for flow is indicative only, as it involves spot measurements of flow on monthly occasions. More detailed analyses of continuous flow records are likely to produce a more useful summary of changes in flow over time.



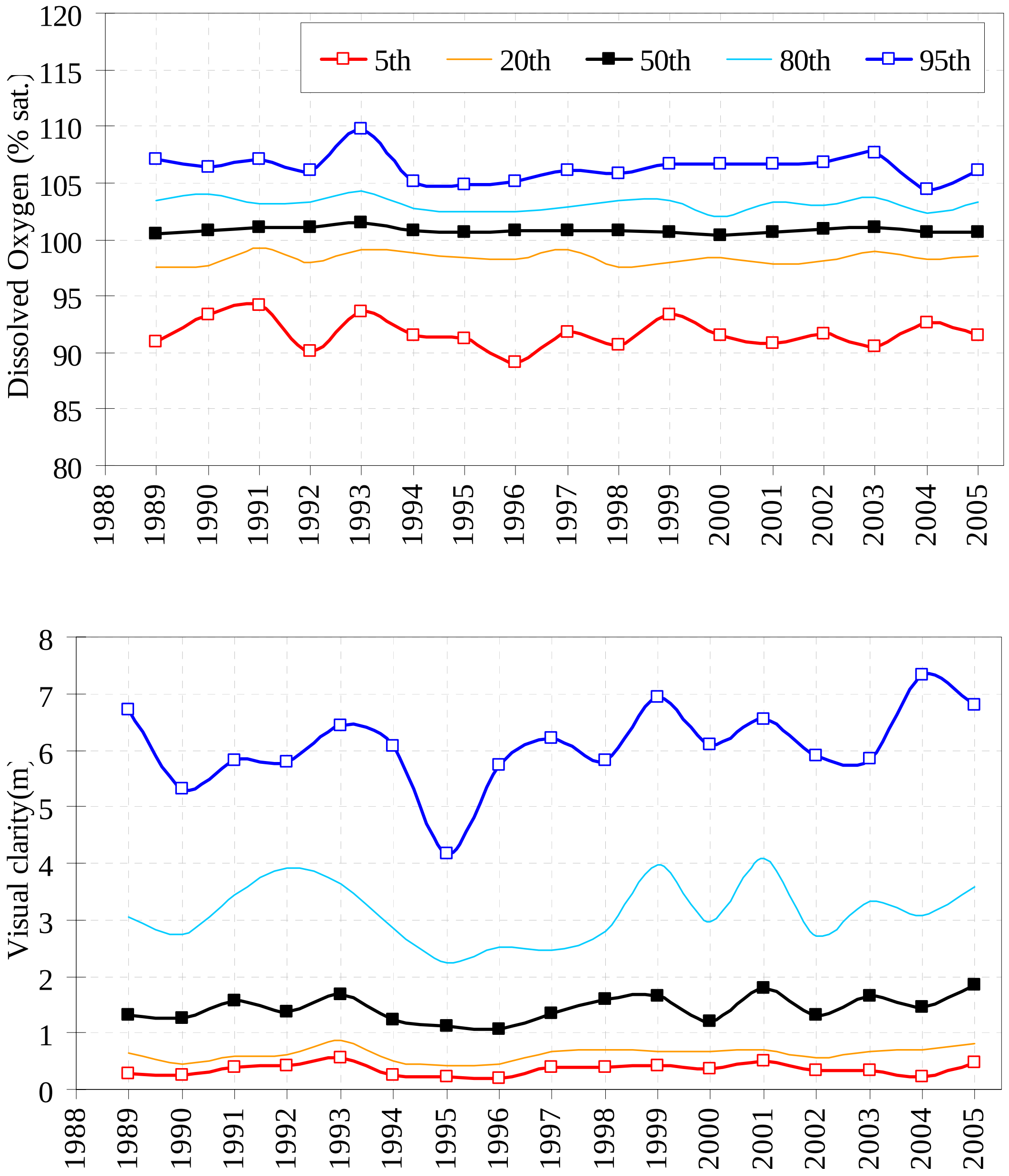
Note: Lines, from bottom to top, correspond to values of the 5th, 20th, 50th, 80th and 95th percentiles for each year (n of sites = 77).

Figure 4.1: **Summary data for flow and temperature from the NRWQN over a 17-year period (1989–2005)**



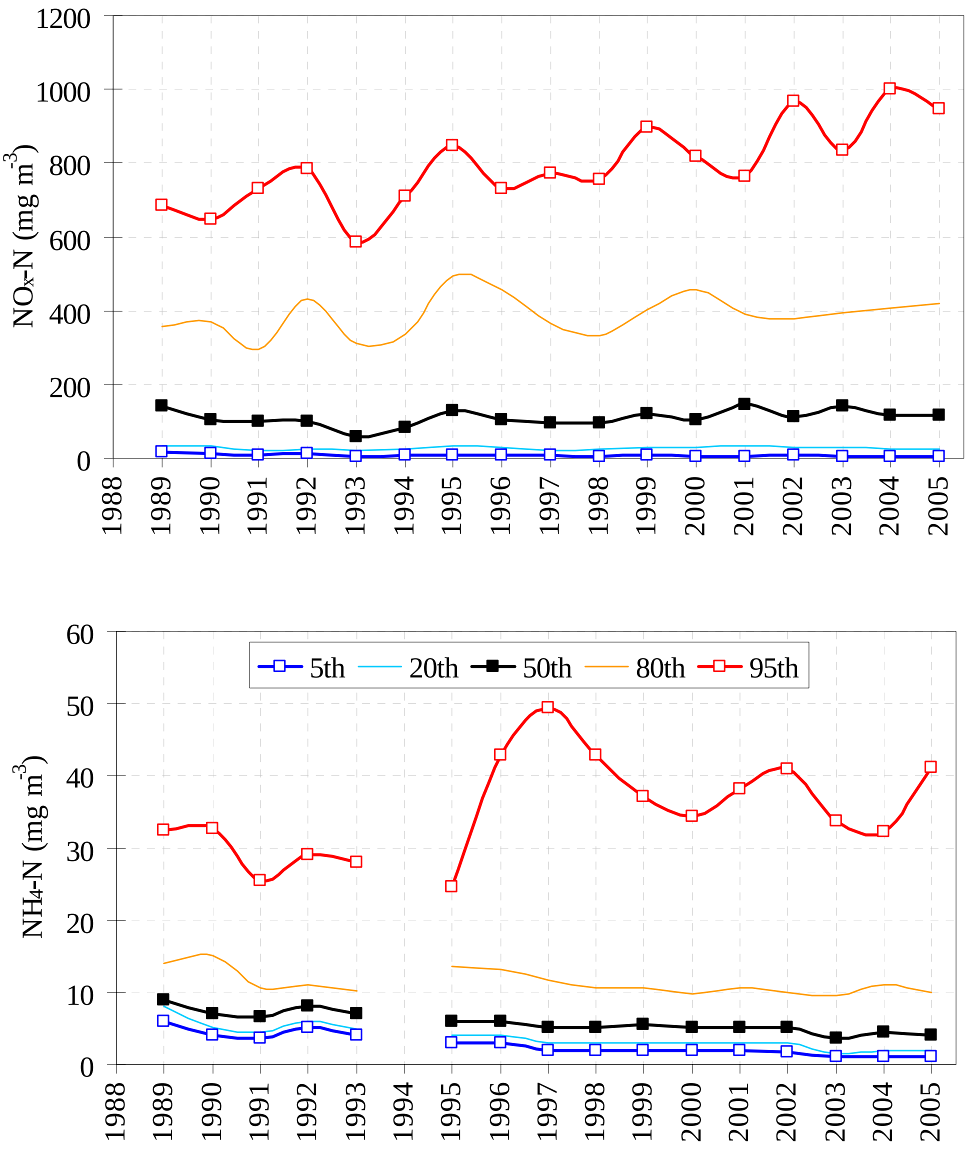
Note: Lines, from bottom to top, correspond to values of the 5th, 20th, 50th, 80th and 95th percentiles for each year (n of sites = 77).

Figure 4.2: Summary data for conductivity and pH from the NRWQN over a 17-year period (1989–2005)



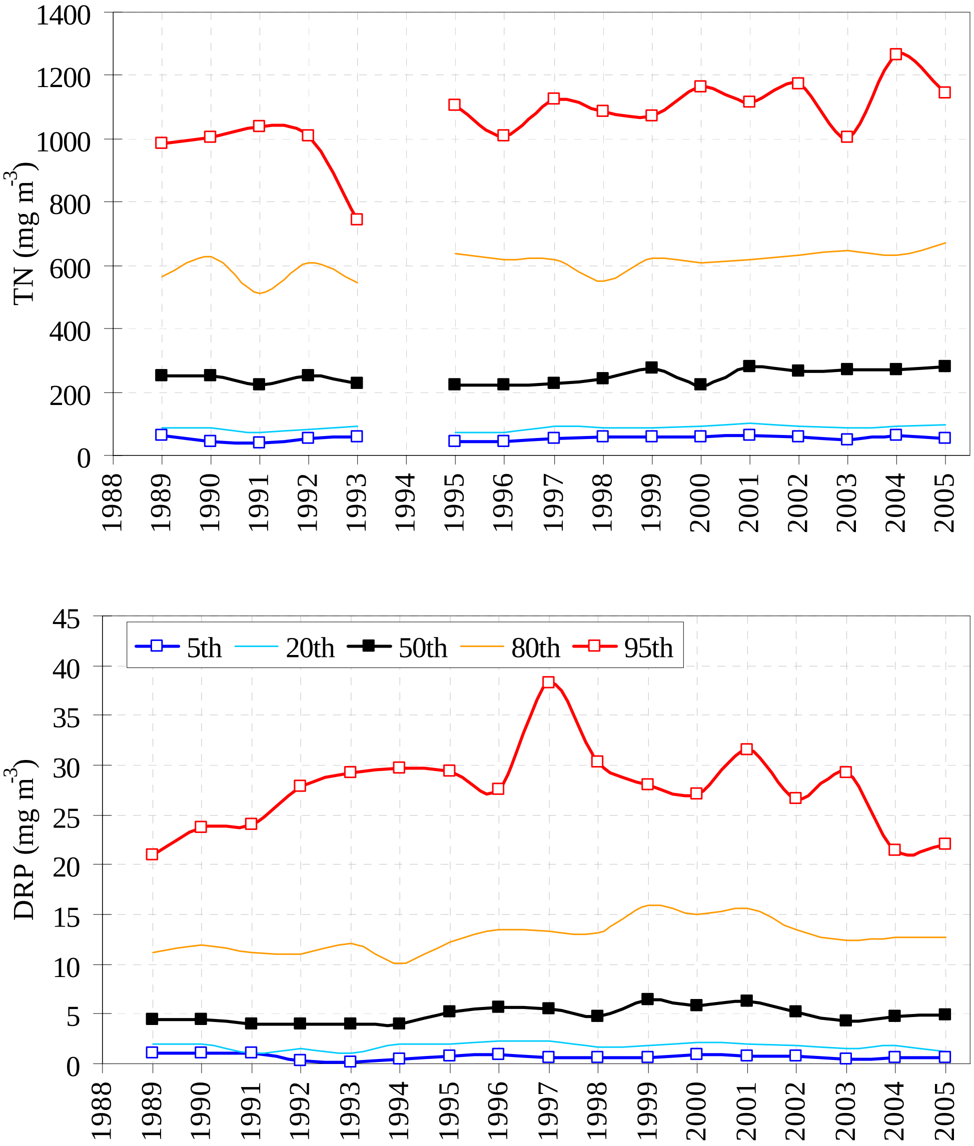
Note: Lines, from bottom to top, correspond to values of the 5th, 20th, 50th, 80th and 95th percentiles for each year (n of sites = 77).

Figure 4.3: Summary data for dissolved oxygen and visual clarity from the NRWQN over a 17-year period (1989–2005)



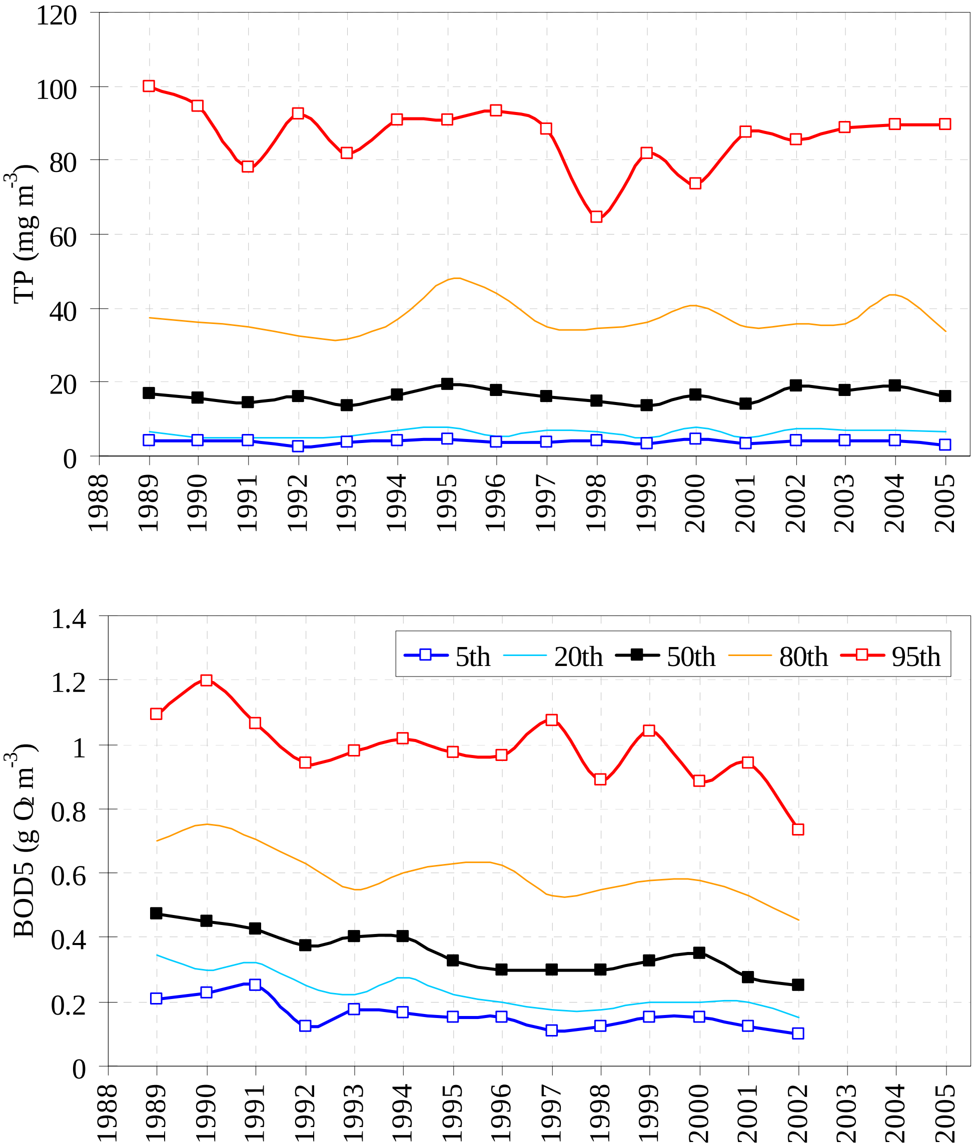
Note: Lines, from bottom to top, correspond to values of the 5th, 20th, 50th, 80th and 95th percentiles for each year (n of sites = 77).

Figure 4.4: **Summary data for oxidised-N and ammoniacal-N from the NRWQN over a 17-year period (1989–2005)**



Note: Lines, from bottom to top, correspond to values of the 5th, 20th, 50th, 80th and 95th percentiles for each year (n of sites = 77).

Figure 4.5: Summary data for total N and dissolved reactive P from the NRWQN over a 17-year period (1989–2005)



Note: Lines, from bottom to top, correspond to values of the 5th, 20th, 50th, 80th and 95th percentiles for each year (n of sites = 77).

Figure 4.6: Summary data for total P and biological oxygen demand from the NRWQN over a 17-year period (1989–2005)

4.1 Trends over time

The data shown in the series of figures in the previous pages were analysed for trends over time using a Spearman Rank Correlation test. Significant trends are in bold. ‘*’ = significant ($P < 0.05$); ‘**’ = highly significant ($P < 0.01$); ‘***’ = very highly significant ($P < 0.001$).

Table 4.1: Spearman rank correlation coefficients for trends over time (1989–2005) based on annual summary data from 77 NRWQN sites

	N (years)	5th	20th	50th	80th	95th
Flow	17	-0.047	-0.061	-0.350	-0.434	-0.260
Temperature	17	**0.701****	0.321	0.333	0.302	0.277
Conductivity	17	0.301	0.213	0.483	-0.010	0.223
pH	17	-0.270	0.059	-0.114	-0.370	**-0.637****
Dissolved oxygen	17	-0.088	0.112	-0.254	-0.269	-0.110
Visual clarity	17	0.127	**0.488***	0.395	0.132	0.436
Oxidised nitrogen	17	**-0.810*****	-0.100	0.373	0.390	**0.797*****
Ammoniacal nitrogen	16	**-0.963*****	**-0.948*****	**-0.939*****	**-0.611***	0.435
Total nitrogen	16	0.394	**0.738****	**0.585***	**0.597***	**0.708****
Dissolved reactive phosphorous	17	-0.256	-0.074	0.475	**0.635****	0.047
Total phosphorous	17	-0.104	0.397	0.235	0.007	-0.368
Biochemical oxygen demand	14	**-0.748****	**-0.886*****	**-0.881*****	**-0.818*****	**-0.704****

4.2 Key results

- Our coolest rivers (5th percentile water temperature) have shown a warming trend between 1989 and 2005. A regression line fitted to the data indicates a change of 1.6°C over 17 years. These rivers are unlikely to be strongly influenced by human activity (see map of 2005 temperature medians in Section 3.2).
- Rivers with naturally high pH (95th percentile) have shown a negative trend (ie, rivers have become slightly less alkaline). The reason for this trend is unclear at present.
- Clarity values tended to show weak positive correlations with time with a significant improving trend for the 20th percentile.
- There has been a steady increase in concentrations of NO_x-N in rivers where this important plant nutrient was already high (ie, 95th percentile). A regression line fitted to this data indicates a slope equivalent to 17.9 mg m^{-3} yr^{-1}. This suggests that rivers identified in Section 3.7 as having high NO_x-N concentrations (eg, Mataura, Oreti, Waingongoro and Waihou) may have become more enriched over the 1989–2005 period, although trends analysis for individual sites over that period would be needed to confirm this. In contrast, rivers with very low levels of nitrate have shown a decreasing trend during 1989–2005 (ie, nitrate levels are declining). These 5th percentile rivers are less likely to be influenced by human activity and changes may be associated with climate variability.

- Levels of ammoniacal nitrogen have shown strong downward trends in most of our rivers, but rivers with high NH_4-N concentrations (ie, 95th percentile) have not shown this decreasing trend. Results in Section 3.8 indicate that sites on the lower reaches of Waingongoro, Manawatu, Waihou and Tarawera rivers are those with the highest NH_4-N concentrations and formal trend analysis at these sites should confirm whether deterioration with respect to ammoniacal nitrogen levels is occurring.

- All except the least enriched rivers show an increasing trend in concentrations of total nitrogen. This is somewhat surprising given the strong decreasing trends in NH_4-N and inconsistency in directions and strength of trends in NO_x-N (ie, increasing concentrations in 95th percentile and decreasing concentrations in 5th percentile rivers), although it is supported by results from formal trend analysis for the 1989–2003 period (Section 5.8) which shows a national-scale increasing trend in TN concentrations.

- DRP shows an increasing trend for the 80th percentile but this is not very strong. TP showed no statistically significant trends. There is a strong non-linear pattern in DRP concentrations for 95th percentile values over time. A second order polynomial fitted to the data produces an R^2 value of 0.63. This suggests that DRP concentrations in our most enriched rivers peaked in the late 1990s and has subsequently trended downwards so that concentrations in 2005 are similar to those observed in 1989.

- There has been a consistent decreasing trend in BOD_5 in all rivers across the country. BOD_5 is now only analysed in samples from three sites (Rangitopuni, and lower Tarawera and Manawatu rivers).

5 River Water Quality Trends (1989–2003)

Monthly water quality data from 77 sites was analysed for trends in individual parameters using Seasonal Kendall tests on flow-adjusted data. Detailed trend analysis of the NRWQN dataset is carried out every five years with the period 1989-2003 constituting the 15-year analysis. Trend analysis was carried out using S-ESTREND (Slack et al, 2003), a software package developed by USGS as an add-on to S-Plus 6.1. Flow adjustment used LOWESS smoothing with a 30 percent span. The Seasonal Kendall Slope Estimator (SKSE) was used to represent the magnitude and direction of trends in flow-adjusted data. Values of the SKSE were relativised by dividing through by the raw data median (RSKSE), allowing for direct comparison between sites.

The statistical significance of trends at the national scale was determined using a binomial test of the hypothesis that the true proportion of upward (or downward) slopes was half. If this hypothesis was rejected ($P < 0.05$), a national trend for the period was inferred. This analysis used slope values from all sites rather than just sites that returned a statistically significant Seasonal Kendall test.

The NRWQN dataset is sizeable. For any one parameter at a site the number of samples (N) can be as high as 180. As with most statistical analyses, the null hypothesis may be rejected more often when sample size is large, even when differences or changes are small (and especially when variability is low). In some cases, a small change may be assigned statistical significance but have little meaning in an ecological or management sense. Therefore, we need to protect against making inferences where the magnitude of trends is very small. To address this we have sought to identify a “meaningful” trend that is likely to be relevant in a management sense. In the figures below, we have summarised results of trend analysis in the following terms:

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

ii. significant increase/decrease – the null hypothesis for the Seasonal Kendall test **was** rejected (ie, $P < 0.05$)

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

Note that the choice of one percent to infer a meaningful increase/decrease is purely arbitrary. It may be possible to develop more rigorous indicators of actual versus statistical significance, but that is outside the scope of the current report.

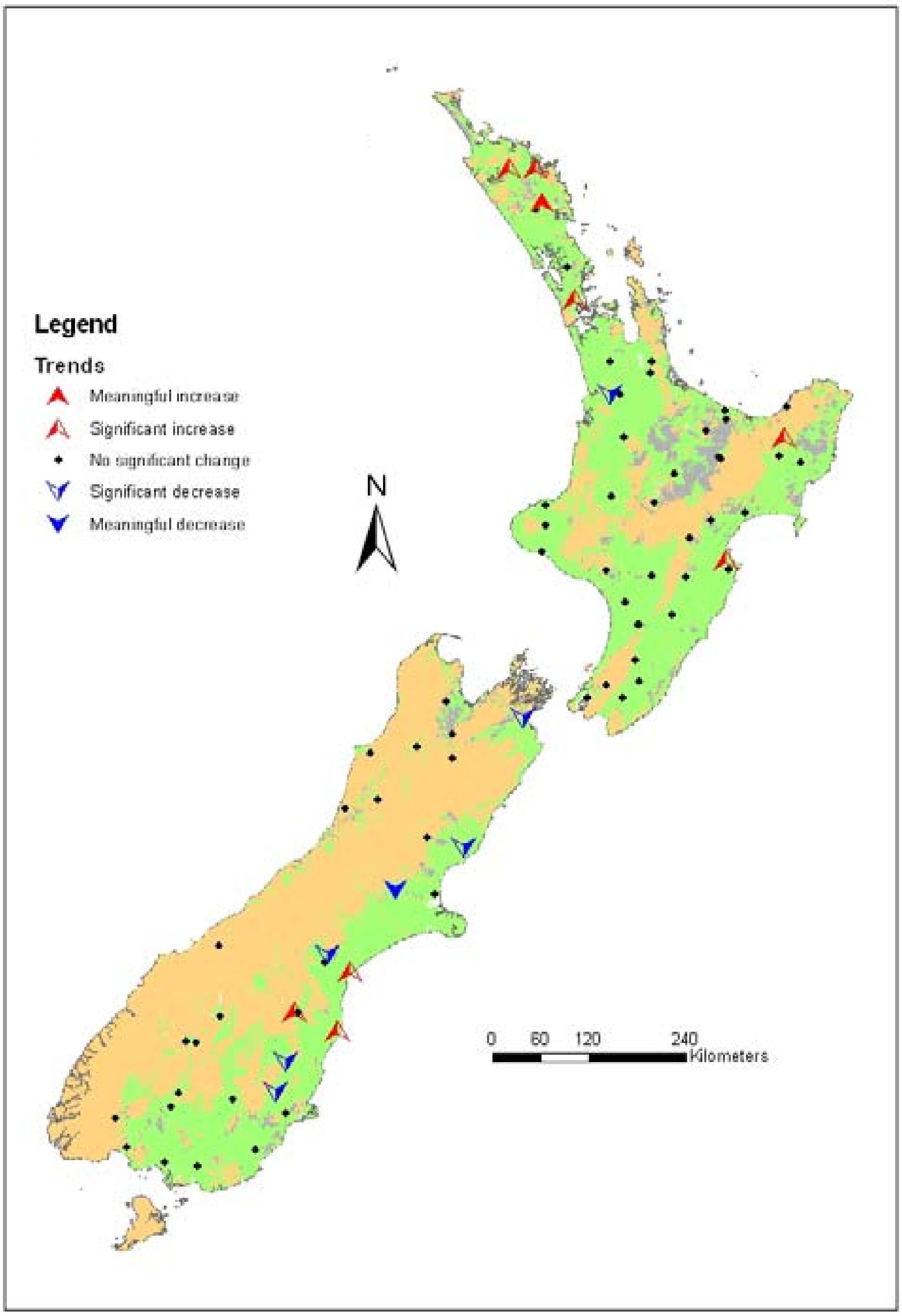


Figure 5.1: Trends in temperature (1989–2003)

There were few meaningful trends in water temperature over the 1989–2003 period, and significant increasing and decreasing trends occurred at only nine and six sites respectively. At the national scale there was no significant trend in temperature (binomial test; P = 0.181). The median RSKSE for temperature was 0.02% year^{-1}.

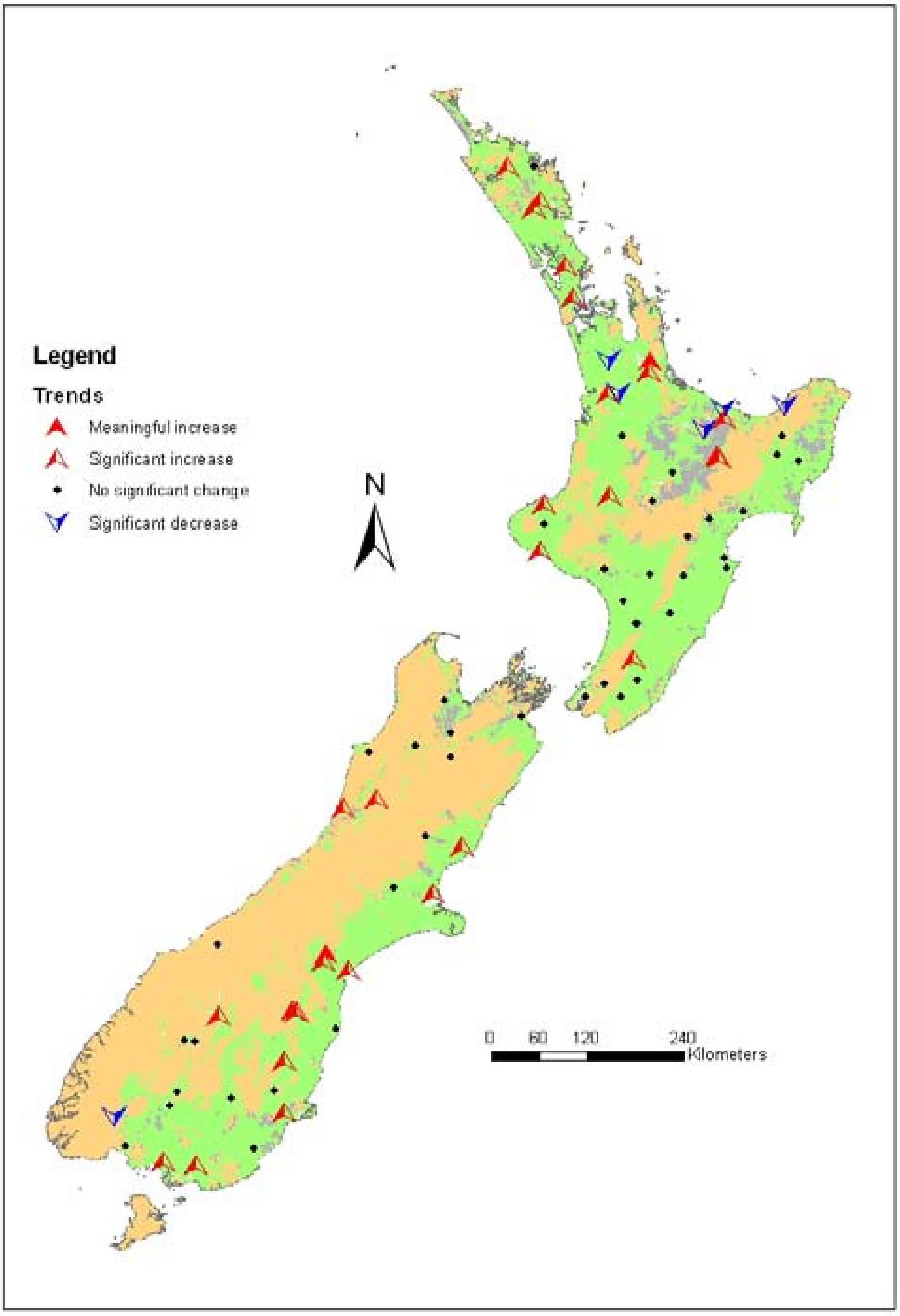


Figure 5.2: Trends in conductivity (1989–2003)

There were significant increasing trends in conductivity around the country, with Ohinemuri (HM6) and Hakataramea (TK5) rivers showing meaningful increasing trends. There was a significant increasing national trend in conductivity over the period 1989–2003 (binomial test; $P < 0.001$), although the median RSKSE was only 0.15% year^{-1}. This suggests that the changes are relatively minor and the cause is not known at this time.

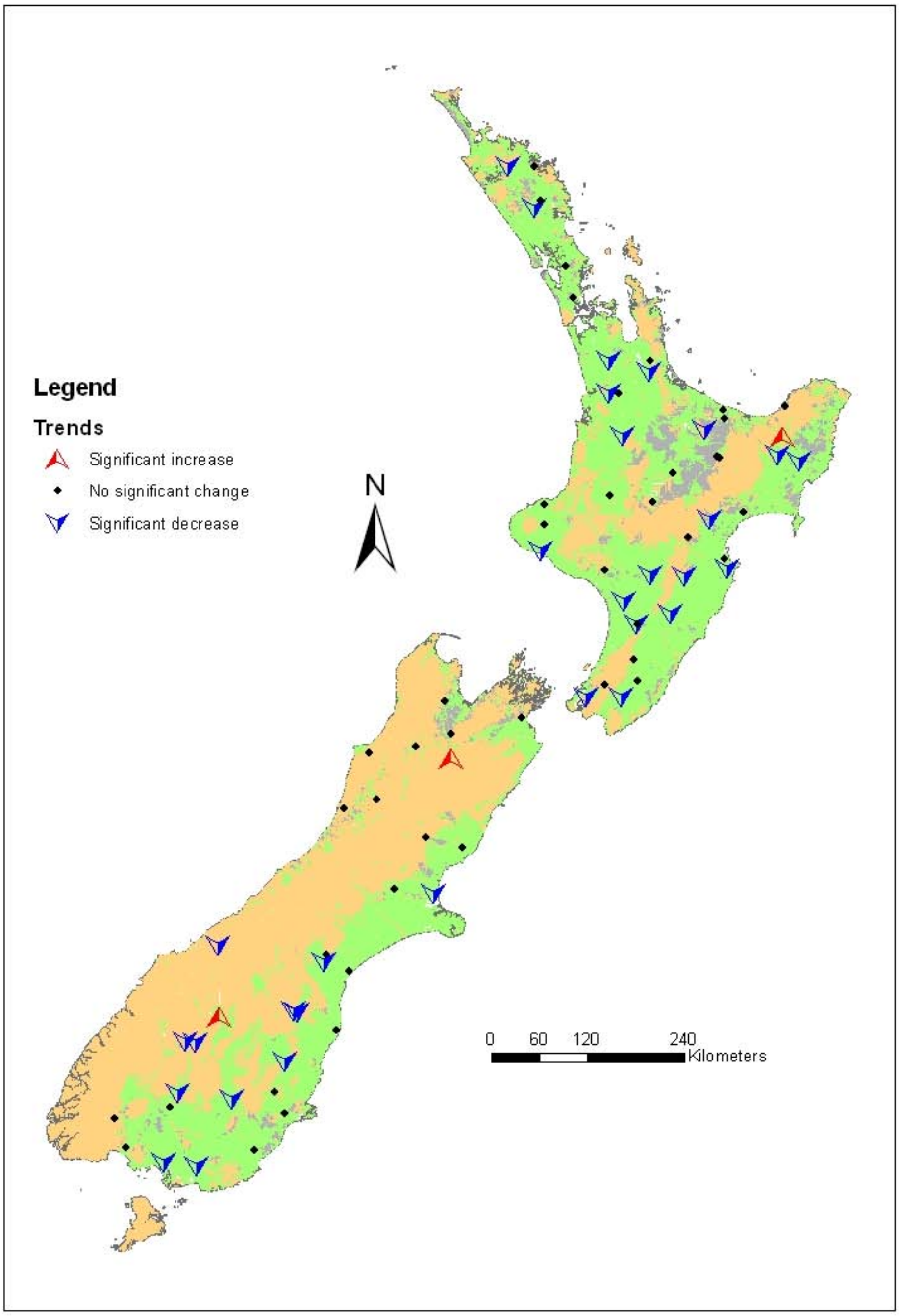


Figure 5.3: Trends in pH (1989–2003)

There were no meaningful increases or decreases in pH over the period 1989–2003, but there were a large number of statistically significant decreases. At the national scale, there was a significant decreasing trend in pH ($P < 0.001$) but the magnitude of this change was very low (median RSKSE = -0.04% year^{-1}).

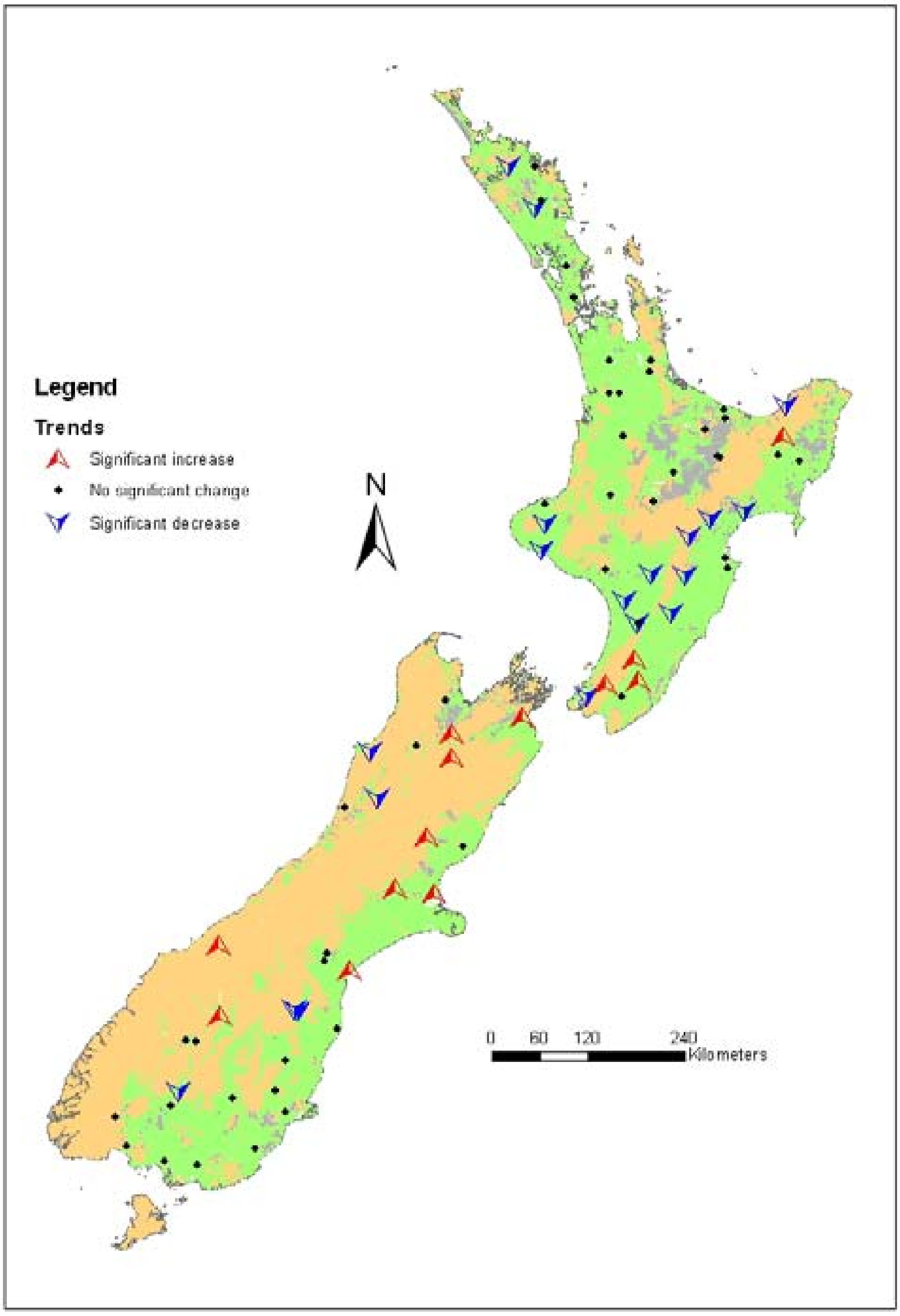


Figure 5.4: Trends in % DO (1989–2003)

Increasing and decreasing trends in dissolved oxygen were observed throughout the country but no trends were large enough to be defined as meaningful. There was no significant trend in % DO at the national scale ($P = 0.127$) and the median RSKSE was only -0.02% year^{-1}.

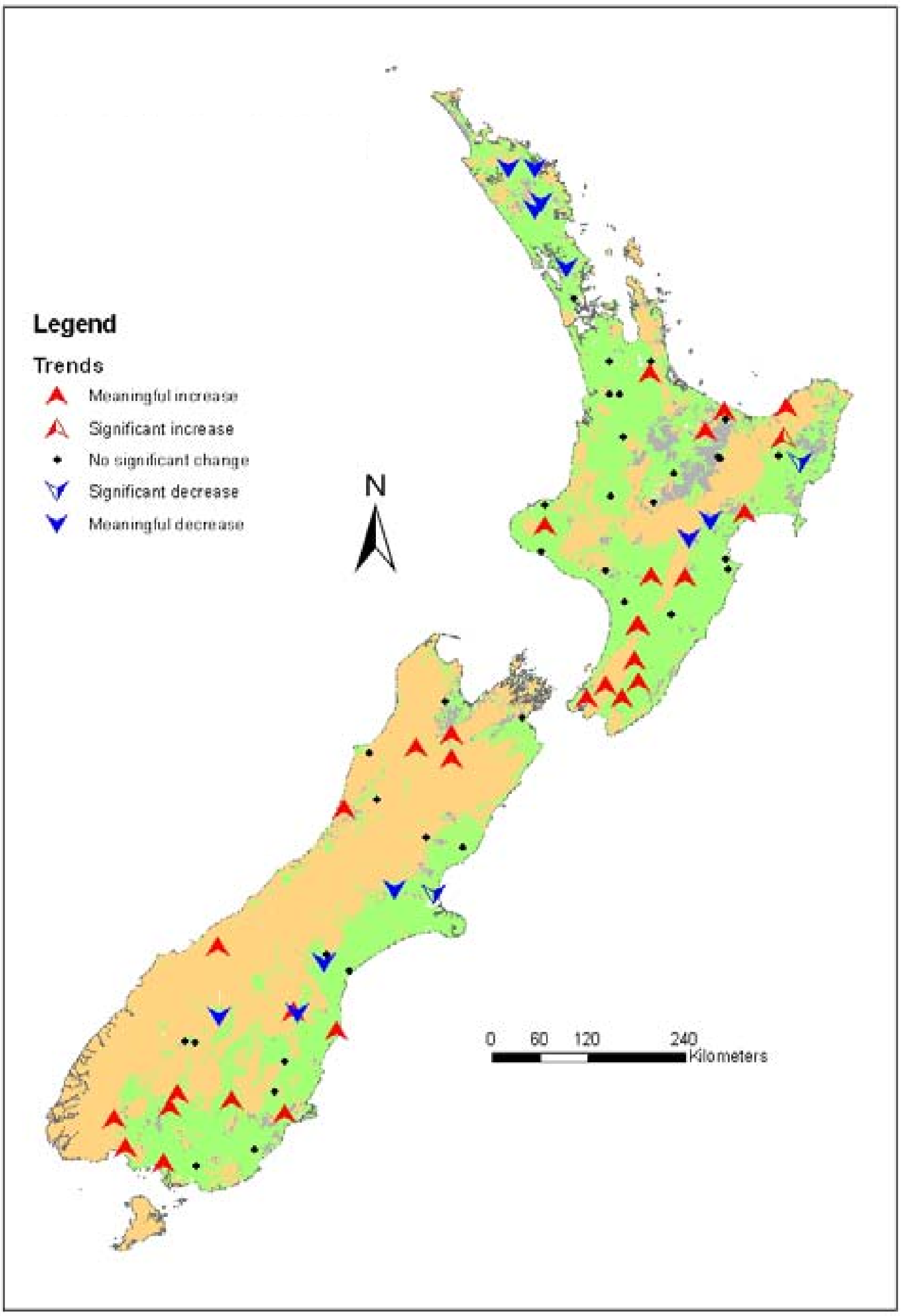


Figure 5.5: Trends in visual clarity (1989–2003)

A large number of meaningful trends in water clarity were seen at sites throughout New Zealand. Decreasing clarity was observed at northern sites whereas increasing clarity was a feature of central and southern sites. Overall, there was a significant national trend of improving water clarity during 1989–2003. Median RSKSE was 0.56% year^{-1}.

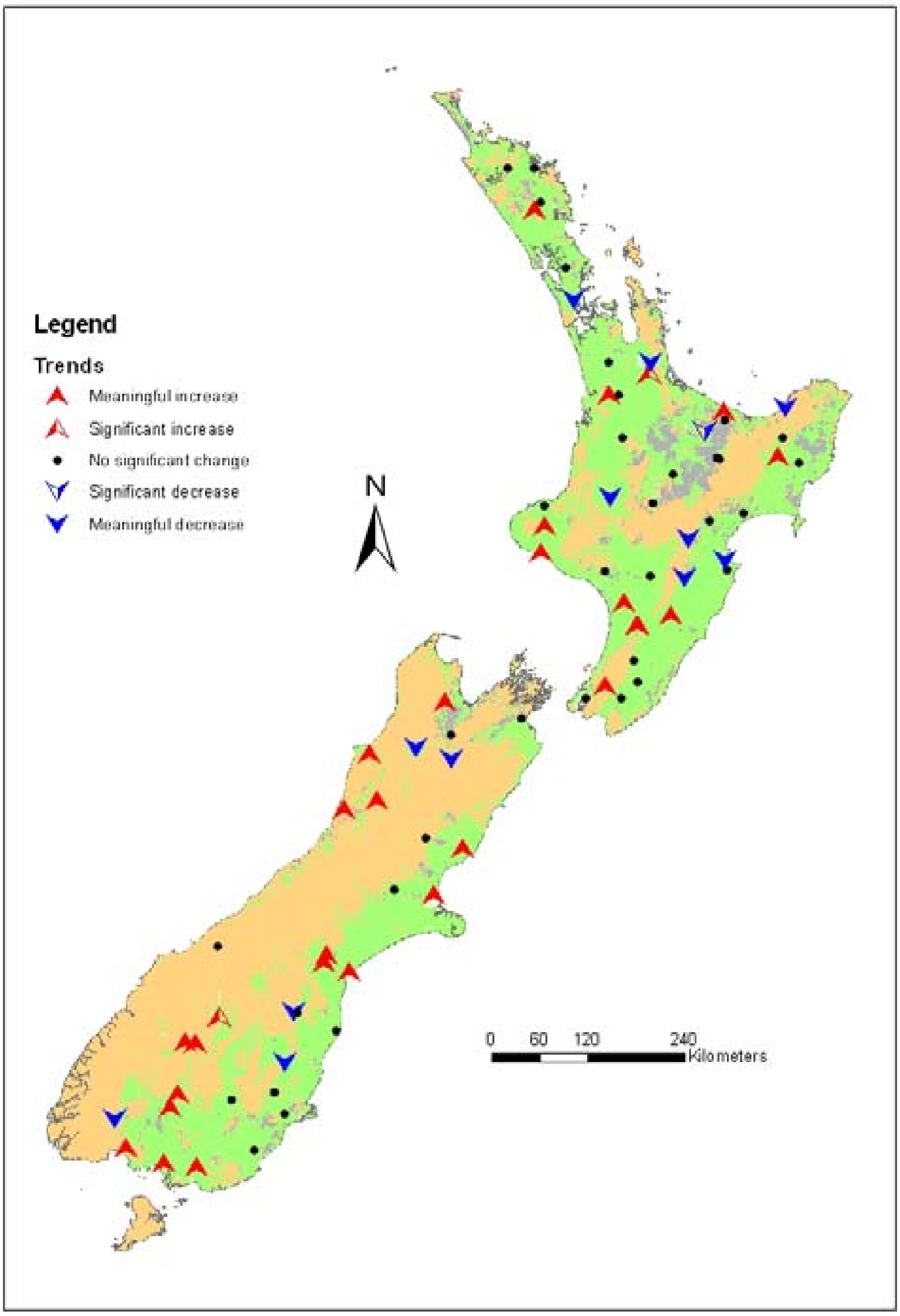


Figure 5.6: Trends in NO_x-N (1989–2003)

Meaningful increases in NO_x-N were observed at 26 sites during 1989–2003 whereas meaningful decreases were seen at 12 sites. However, at the national scale there was no statistically significant difference in the ratio of positive:negative slopes ($P = 0.055$). Median RSKSE was 0.47% year^{-1}.

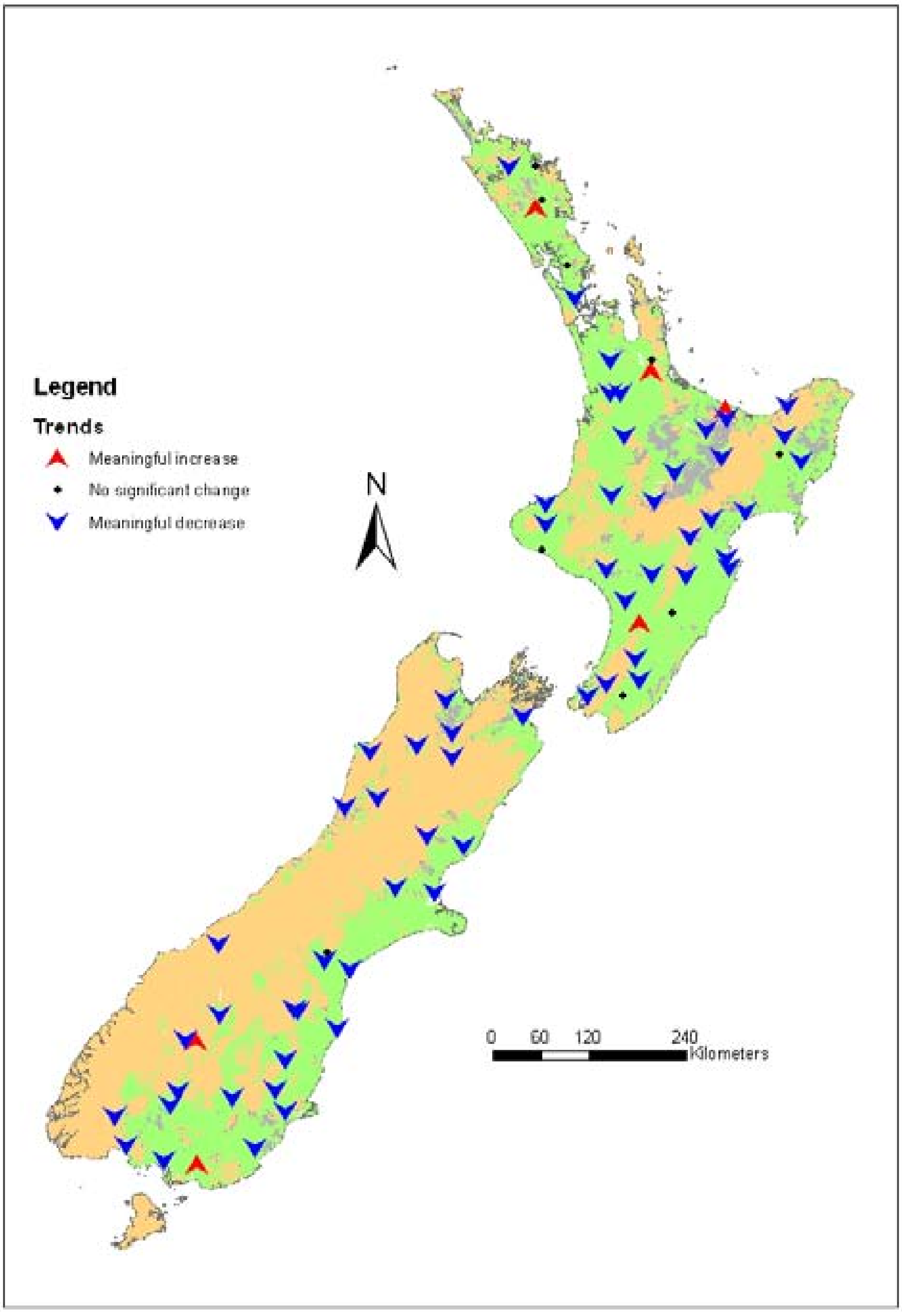


Figure 5.7: Trends in NH_4-N (1989–2003)

Most sites showed meaningful decreases in NH_4-N during 1989–2003. The lower Mataura, Manawatu, Tarawera, Waihou and upper reaches of Mangakahia and Kawarau rivers all showed meaningful increases. Overall, ammoniacal nitrogen showed a significant decreasing trend at the national scale during 1989–2003 ($P < 0.001$). Median RSKSE was -4.4% year^{-1}.

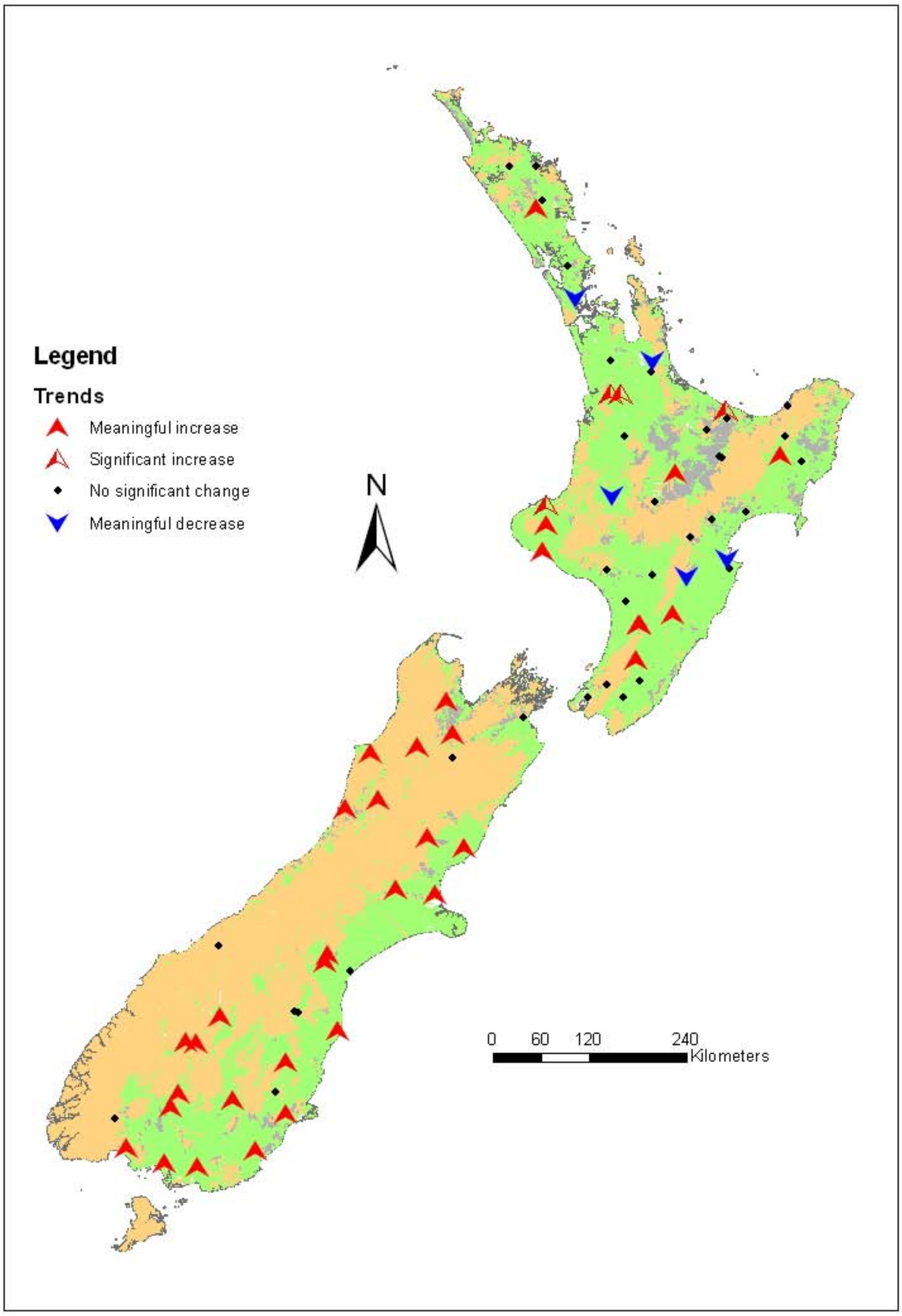


Figure 5.8: Trends in TN (1989–2003)

There was a strong increasing trend in total nitrogen at the national scale during 1989–2003 ($P < 0.001$). This is consistent with results of moving median trends (Section 4). Median RSKSE was 0.98% year^{-1}. Increasing trends in TN were particularly evident in the South Island where 25 of 33 sites showed meaningful increases.

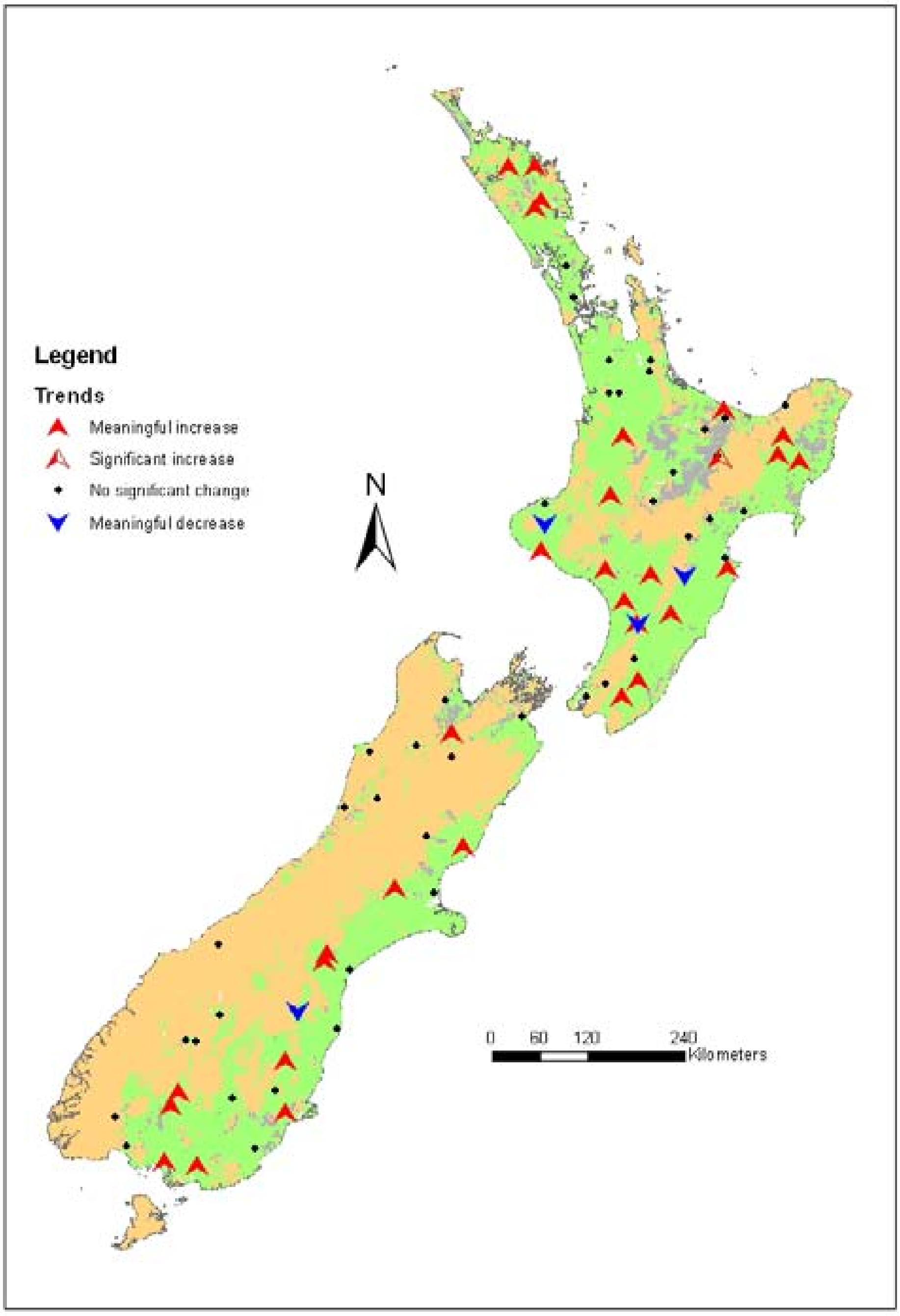


Figure 5.9: Trends in DRP (1989–2003)

Meaningful increases in DRP tended to be observed in the lower reaches of rivers. Overall, there was a strong national trend of increasing DRP concentrations during 1989–2003 ($P < 0.001$). Median RSKSE was 0.72% year^{-1}. This result contrasts with the relatively weak trends observed in moving medians (Section 4). One explanation is that DRP may have decreased in 2004–05, and this could be tested using formal trend analysis.

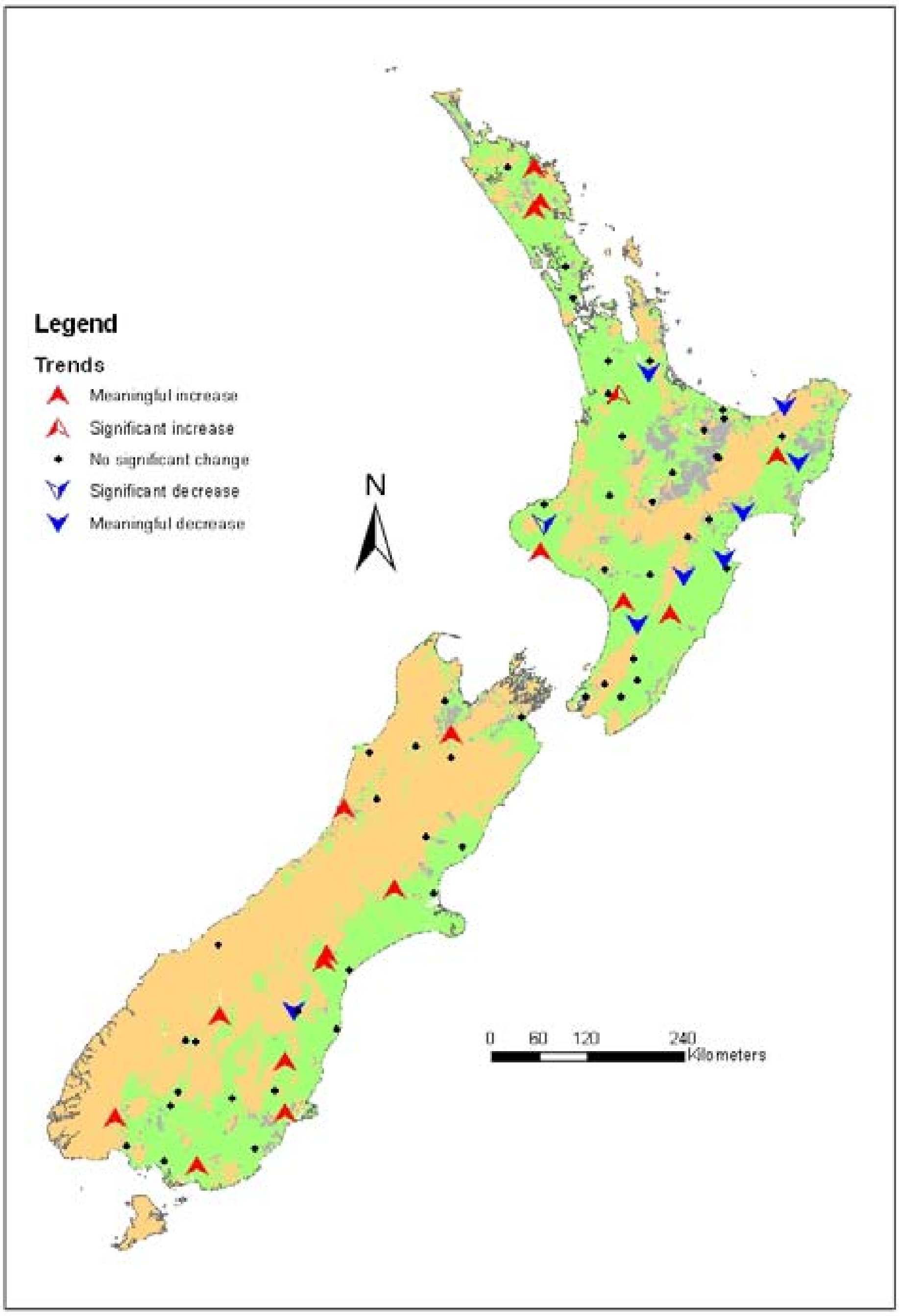


Figure 5.10: Trends in TP (1989–2003)

Meaningful increases and decreases in TP were observed at sites throughout New Zealand. Increases tended to be concentrated in the South Island and decreases in the North Island. Overall, there was a significant national trend of increasing TP concentrations during 1989–2003 (P = 0.001). Median RSKSE was 0.44% year^{-1}.

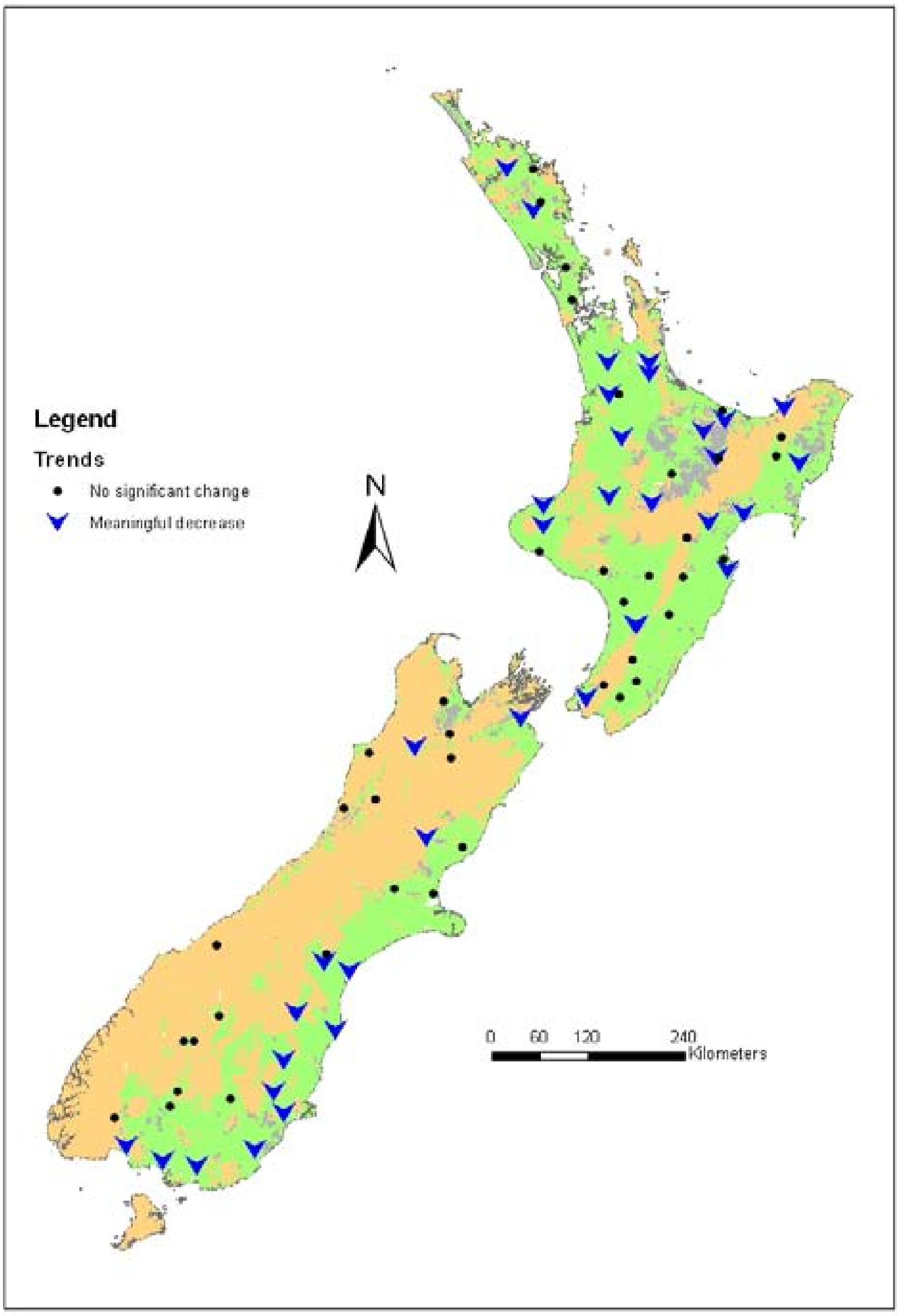


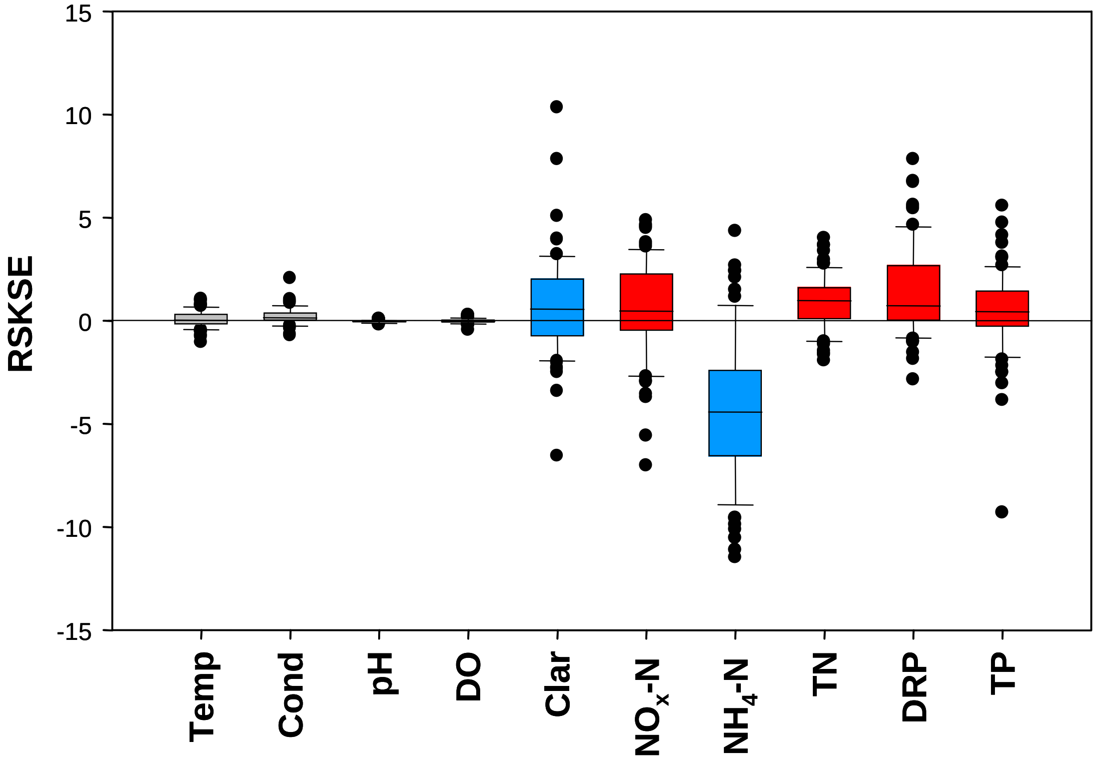
Figure 5.11: Trends in BOD_5

BOD_5 showed consistent strong decreasing trends. Indeed, all sites showed negative values for RSKSE and, as a result, there was a very strong national-scale decreasing trend ($P < 0.001$). The median RSKSE was -2.14% $year^{-1}$. Note: BOD_5 analyses were suspended for 74 of the 77 sites in July 2002. Rangitopuni (AK2), and lower Tarawera (RO2) and Manawatu (WA9) rivers continue to be sampled monthly for BOD_5.

5.1 Summary

Data shown in the maps in the previous pages were summarised in a box plot (Figure 5.12) to show the relative levels of change observed in different parameters and highlight parameters where national-scale trends were observed.

National-scale trends were detected for pH and conductivity but the magnitude of these changes across all sites was small (Figure 5.12). This suggests the changes may not be a significant concern for water resource managers, although it should be noted that pH is measured on a log-scale, so even relatively small changes could have significant ecological effects. In contrast, the national trends observed in TN, DRP and TP involve some sizeable increases (ie, > 5% year^{-1} at some sites; Figure 5.12). Such changes may signal marked deteriorations in water quality over relatively short periods and, as such, justify the attention of water resource managers. Changes in NO_x-N were also large at some sites although there was no statistically significant aggregate national trend for this parameter.



Note: Data covers period 1989–2003. Boxes in red are of concern (ie, indicate deteriorating water quality) whereas boxes in blue indicate improving water quality.

Figure 5.12: Summary of Relative Seasonal Kendall Slope Estimator (RSKSE) values (n = 77) for 10 water quality parameters

5.2 Links between trends and land use

Correlations between land use and trend magnitude were calculated using both the SKSE and RSKSE values. It was felt that reporting the RSKSE alone might hide some important associations. For example, sites with high median NO_x-N concentrations may have large SKSE values but, when divided by large median values, the reported trend magnitude might be very small.

With respect to SKSE values, highly and very highly significant positive correlations were observed for conductivity, NO_x-N, TN, DRP and TP (Table 5.1). Significant positive correlations were also found between the magnitude of RSKSE values for DRP and NH_4-N and percent pastoral land cover in the contributing catchment. Weaker positive correlations for RSKSE were observed for conductivity and NO_x-N. Dissolved oxygen and pH trends were weakly and negatively correlated with pastoral land cover for both RSKSE and SKSE values.

In Table 3.1, associations between percent pastoral land cover and current water quality state (2005) were reported. Table 5.1 reports on associations between percent pastoral land cover and the magnitude of change over time (1989–2003). Despite the differences in time periods, the information in these tables provides an indicator of changing pressures on river ecosystems. For example, high DRP concentrations are associated with sites draining highly developed catchments, and for the period 1989–2003 the magnitude of increases in DRP was strongly associated with percent pastoral land cover in the catchment. What this tells us is that streams draining highly developed catchments are coming under increasing pressure. While it is not possible to associate cause and effect with the data reported here, the patterns observed would be consistent with the increasing use of fertilisers associated with land-use intensification.

Table 5.1: Correlations for associations between percent pastoral land cover and values of SKSE and RSKSE at 77 NRWQN sites

Parameter	SKSE	RSKSE
Temperature	0.19	0.20
Conductivity	0.47***	0.40***
pH	-0.28*	-0.28*
Dissolved oxygen	-0.27*	-0.27*
Visual clarity	-0.26*	-0.11
Oxidised nitrogen	0.30**	0.23*
Ammoniacal nitrogen	0.29*	0.68***
Total nitrogen	0.35**	-0.01
Dissolved reactive phosphorus	0.59***	0.48***
Total phosphorus	0.31**	0.18

Note: ‘*’ = significant ($P < 0.05$); ‘**’ = highly significant ($P < 0.01$); ‘***’ = very highly significant ($P < 0.001$).

6 Discussion

The picture of water quality in New Zealand rivers that has emerged from the analyses and summaries presented here is consistent with a shift in relative importance of point source vs. non-point source pollution as key anthropogenic pressures on surface waters.

The summary of 2005 data (Section 3) indicates strong associations between nutrient concentrations and percent pastoral land cover at the national scale. Median concentrations of all nutrient species and levels of the faecal indicator bacteria *E. coli* were positively correlated with extent of pastoral land cover. 2005 is the first year of *E. coli* analyses in the NRWQN and it is encouraging to see its usefulness as a national-scale indicator of water quality correlated with pastoral land use. It should be noted again that percent pastoral land cover in the catchment does not allow a clear cause-effect relationship to be inferred between water quality patterns and non-point source pollution because several of the NRWQN sites are downstream of significant point sources (eg, Waingongoro River), and this has not be factored into the analysis.

In Section 4, summaries of annual state over time (1989–2005) highlighted a number of patterns of significance to resource managers. For example, concentrations of NO_x-N in rivers with naturally low concentrations (ie, 5th percentile rivers) showed a significant decreasing trend with time, whereas rivers with very high levels of NO_x-N showed a significant increasing trend over time. Given the strong association of NO_x-N concentrations with pastoral land cover it is reasonable to conclude that rivers draining large areas of pastoral land have deteriorated significantly over the last 17 years with respect to NO_x-N concentrations. Levels of DRP showed a somewhat different pattern. While there was a significant increasing trend for DRP concentrations at the 80th percentile, there was not a similar trend in the 95th percentile. DRP concentrations at the 95th percentile actually show a non-linear response over time with concentrations in our most enriched rivers peaking in the late 1990s and showing a decreasing trend since.

Other patterns worthy of note are the increasing temperature trend in our coolest rivers, and the reducing pH trend at the 95th percentile. Both of these trends could be associated with climate change but the level of analysis carried out so far is insufficient to allow more than speculation at this stage. Increasing levels of atmospheric CO_2 could lead to reductions in pH in waters as a result of increasing dissolution of CO_2 to form carbonic acid.

Detailed trend analysis for the 1989-2003 period confirmed some of the patterns identified from the higher-level analysis in Section 4 (eg, increases in TN) but also produced some inconsistencies. For example, the moving median trends in Section 4 showed relatively weak increasing trends for DRP over the 1989–2005 period whereas the formal trend analysis in Section 5 identified a national-scale trend of increasing DRP concentrations over the 1989–2003 period. This inconsistency probably reflects the differing time periods used for analysis and highlights a major issue with interpreting trend analysis results. Interpretations should always be restricted to the period of record as it is dangerous and inappropriate to extrapolate trend results beyond the period of record.

The strong decreasing trends in concentrations of ammoniacal nitrogen and biochemical oxygen demand observed over the 1989–2003 period are consistent with water quality improvements that would be expected from reductions in point source pollution. Increases in visual clarity may also reflect improvements in point source management, although improvements in farming and forestry practices could be drivers of improving water clarity. However, median clarity was negatively correlated with percent pastoral land cover, so it is seems more likely that clarity improvements are associated with improved point source management. In contrast, increasing trends in NO_x-N, total nitrogen and dissolved phosphorus are consistent with increases in non-point source delivery of contaminants to waterways.

Overall, the results derived from state and trend analyses of data from the NRWQN over the last 17 years paint a picture highlighting the good, the bad and the ugly of river water quality in New Zealand.

Improvements in levels of BOD, ammoniacal nitrogen and visual clarity are very positive signs and should be highlighted as success stories where clear cause-effect relationships between removal or improved management of point source pollution and improved water quality can be established.

The decreasing trends in pH and increases in conductivity are difficult to interpret and are of relatively low magnitude. However, the pH result in particular highlights the potential for climate change to have significant consequences for water quality and aquatic ecosystems. Further research is needed to identify what effects future changes in pH and temperature might have on our rivers.

The least positive results from these analyses are the increasing trends in total nitrogen and phosphorus and the significant increases in NO_x-N observed in our most enriched rivers. The challenge for resource managers and industry over the next decade or more is to control non-point source contamination of our waterways.

7 References

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