Effects of sampling frequency on water quality trend analysis in Hawke's Bay rivers (1996-2005)

NIWA Client Report: HAM2007-042
April 2007

NIWA Project: ELF06201/HAB3

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Mike Scarsbrook
Graham McBride

Prepared for

Hawke's Bay Regional Council

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National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

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Reviewed by:

Judi Hewitt

Approved for release by:

Graham McBride

Formatting checked

A. Bartley

1. Introduction

As part of on-going reviews of the structure of their State of the Environment monitoring networks, Hawke's Bay Regional Council contracted NIWA Ltd, through MoRST's Envirolink Fund, to undertake an investigation of the influence of sampling frequency on ability to detect trends in water quality data. Essentially, a comparison of monthly versus quarterly sampling frequencies was required to determine what effect sampling frequency has on the ability of Regional Council staff to detect trends in water quality that may either signal deterioration in waterways, or reflect improvements associated with changes in management practices.

In this report we summarise trend analyses carried out for the period 1996-2005 using monthly data from six Hawke's Bay river sites monitored as part of NIWA's National River Water Quality Network (NRWQN; Smith & McBride 1990). Comparisons are made of trends at monthly and quarterly sampling frequencies. In addition, we compare trends in the upper Mohaka River with those from a regional reference sites to determine whether observed trends might be anthropogenic or associated with natural variability.

2. Methods

A sub-set of NRWQN water quality parameters were chosen for analysis – visual clarity (m), turbidity (NTU), nitrate/nitrite nitrogen (NO_x-N; mg/m3), ammoniacal nitrogen (NH_4-N; mg/m^3), total nitrogen (TN; mg/m^3), dissolved reactive phosphorus (DRP; mg/m^3) and total phosphorus (TP; mg/m^3). Flow and temperature data were also analysed to provide an indication of changes in climate over the period of water quality analysis. Data for six Hawkes Bay river sites was sourced from the National River Water Quality Network. The sites were:

- HV1 MAKARORO AT BURNT BR U22:928488 (Baseline)
- HV2 TUKITUKI AT RED BRIDGE V22:466581 (Impact)
- HV3 NGARURORO AT CHESTERHOPE V21:425715 (Impact)
- HV4 NGARURORO AT KURIPAPANGO U20:969974 (Baseline)
- HV5 MOHAKA AT RAUPUNGA W19:672285 (Impact)
- HV6 MOHAKA AT GLENFALLS V20:240188 (Baseline?)

The time period for trend analysis was January 1996 until December 2005 (i.e., last 10 years of available data).

We used the Seasonal Kendall test for all trend analysis. The Seasonal Kendall test is the most commonly used method for the analysis of temporal trends in New Zealand water quality data (Smith et al. 1996; Stansfield 2001; Scarsbrook et al. 2003).

Trend analysis software was S-ESTREND (Shertz et al. 1991) implemented in S-PLUS 6.1 (Slack et al. 2003). We inferred a significant water quality trend, where a Seasonal Kendall test applied to the time series data from a particular site was statistically significant ($\alpha = 0.05$).

Both raw and flow-adjusted data were analysed for trends. Flow adjustment utilized LOWESS smoothing (30% span). Flow adjustment is required, because many of the water quality variables being assessed are strongly influenced by discharge (e.g., visual clarity is negatively correlated with flow) and monitoring occurs at all flow stages. For further details see Helsel & Hirsch (2002).

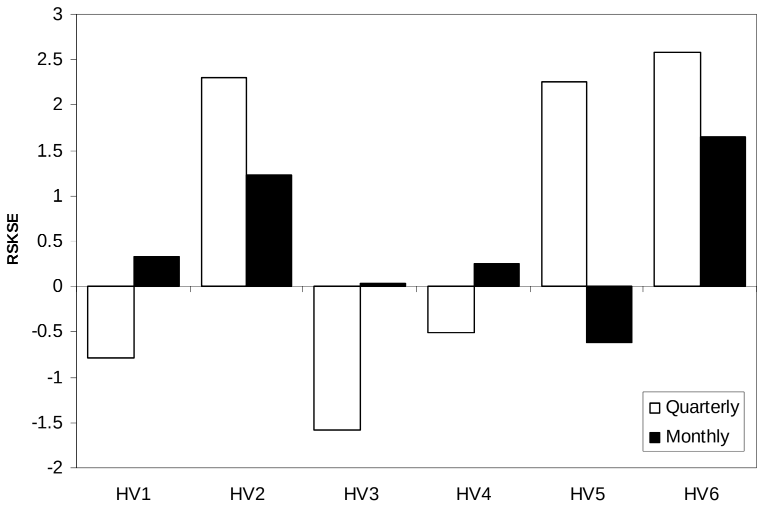
Trend analysis produced values of the Seasonal Kendall Slope Estimator (SKSE), which were then relativised (i.e., expressed as the % of raw data median; RSKSE) to allow comparisons between sites.

3. Results

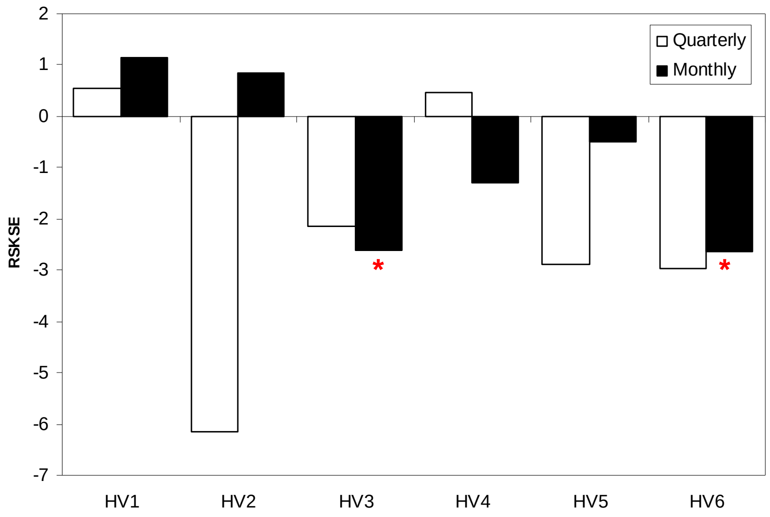
3.1 Flow-adjusted data

In general, there were many fewer significant trends observed for quarterly data than for monthly data (Figs 1 & 2). For monthly, flow-adjusted data, significant trends were observed for 14 out of 42 site/parameter combinations, whereas quarterly sampling produced 5 significant trends. However, both quarterly and monthly sampling picked up significant increasing trends for NO_x-N and TN at HV5 and HV6. TN showed significant trends at sites on the Ngaruroro, and Mohaka rivers, but not on the Tukituki (Fig. 1E). Quarterly sampled failed to detect improving trends in turbidity (HV3 & HV6; Fig 1B), ammoniacal nitrogen (HV2, HV3 & HV4; Fig. 1D) and DRP (HV6, Fig. 1F), and deteriorating trends in TN (HV4; Fig 1E) and TP (HV2 & HV5; Fig. 1G).

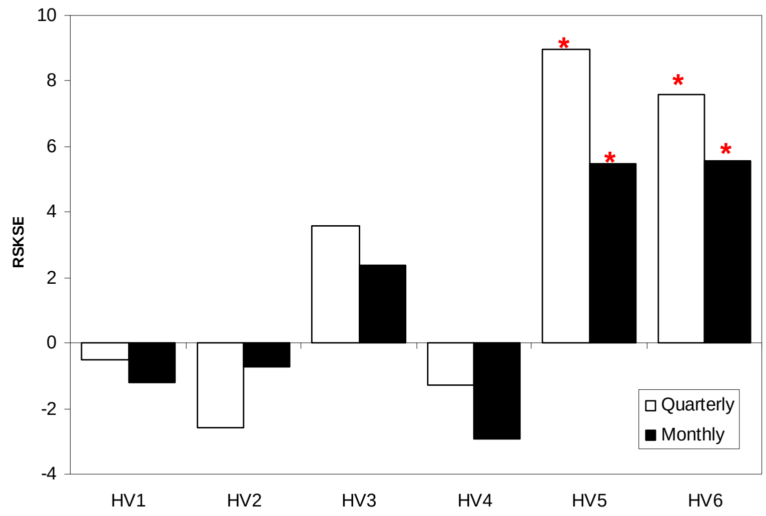
A) Clarity



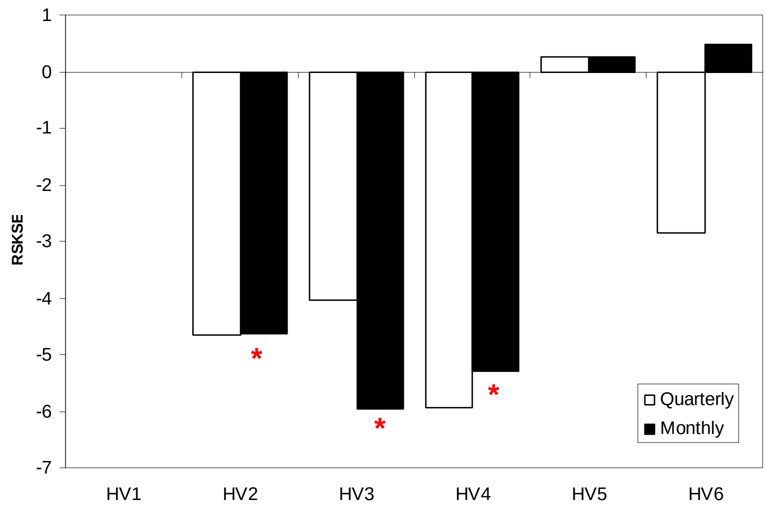
B) TURB



C) NO3-N



D) NH4-N



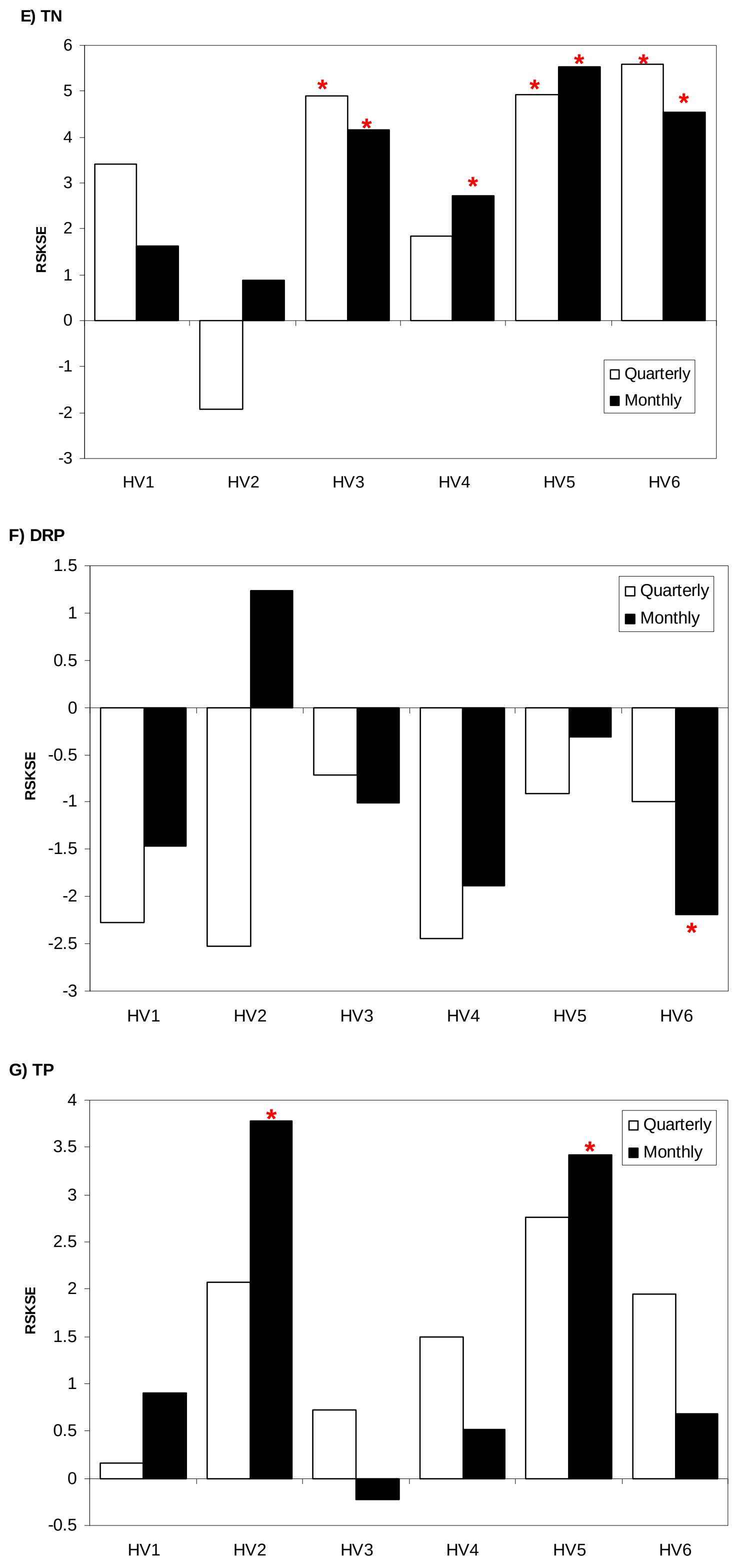
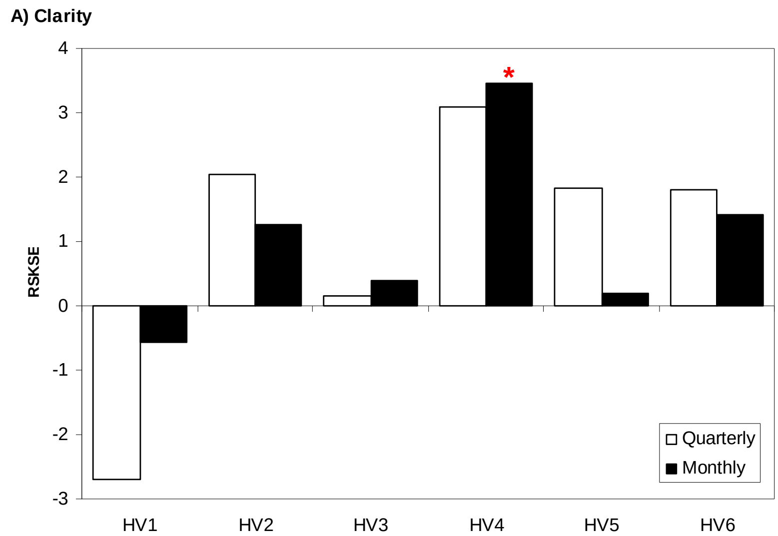
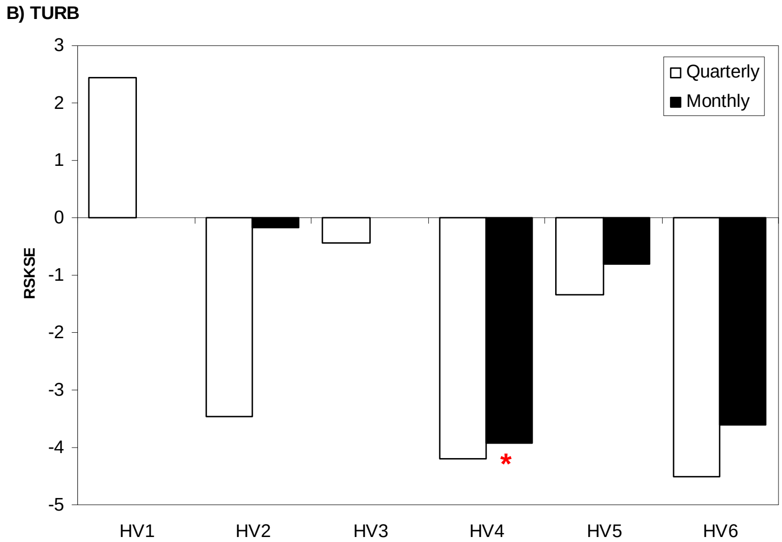


Figure 1: **A-G.** Plots of Seasonal Kendall Slope Estimator (expressed as % of raw data median) for flow-adjusted data from 6 Hawkes Bay river sites analysed at monthly and quarterly time steps. Red asterisk denotes a statistically significant Seasonal Kendall test statistic (*P*<0.05) at a particular site.

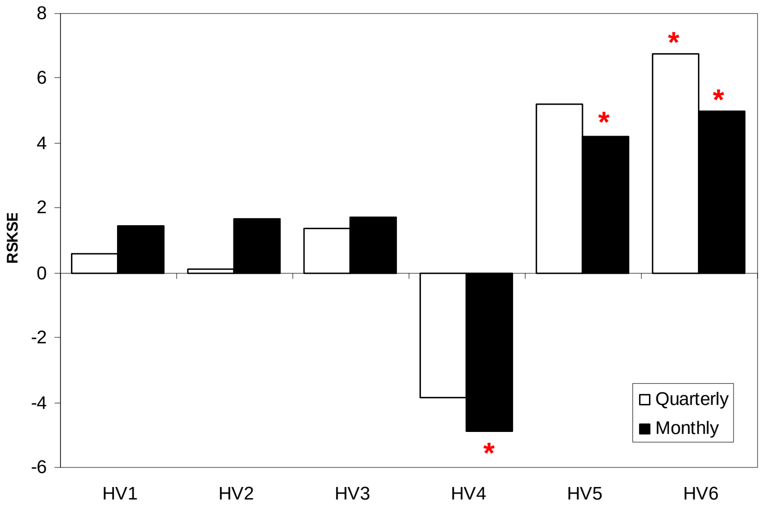
3.2 Raw data

For monthly, raw data, significant trends were observed for 13 out of 42 site/parameter combinations, whereas quarterly sampling produced 4 significant trends (Fig. 2). Only 10 of the 19 significant trends for flow-adjusted data were matched by corresponding trends in raw data. Most of the matches (7 of 10) occurred with NO_x-N and TN, with sites on the Mohaka showing similar trends for both raw and flow-adjusted data for these variables.

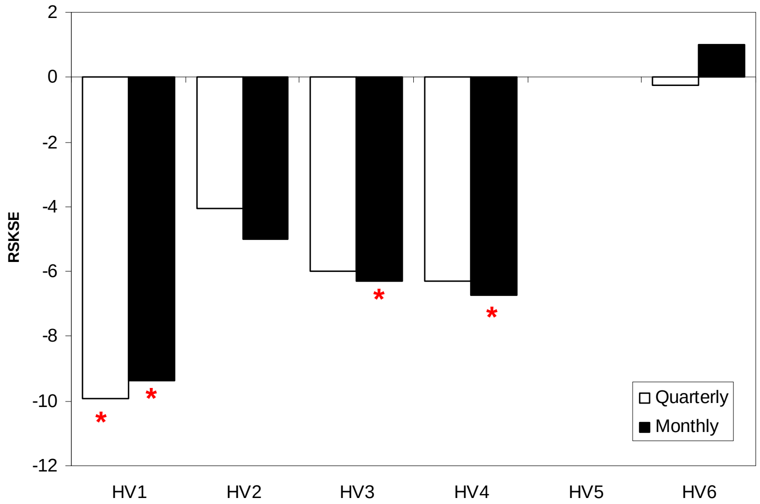




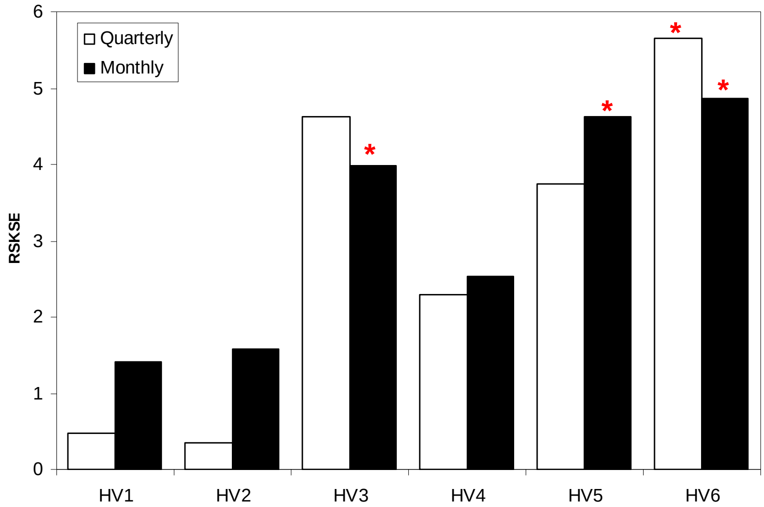
C) NO3-N

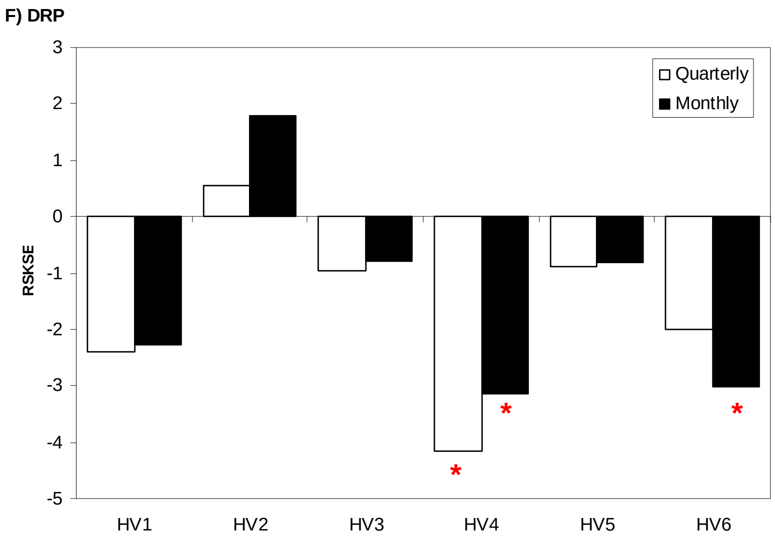


D) NH4-N



E) TN





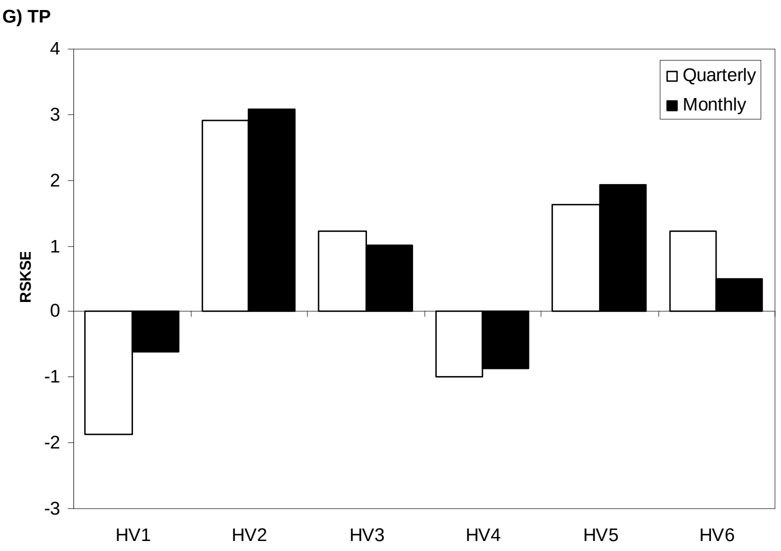


Figure 2: **A-G.** Plots of Seasonal Kendall Slope Estimator (expressed as % of raw data median) for raw data from 6 Hawkes Bay river sites analysed at monthly and quarterly time steps. Red asterisk denotes a statistically significant Seasonal Kendall test statistic (*P*<0.05) at a particular site.

3.3 Climate data

There were no significant trends in flow (Fig. 3A), and only one significant trend in raw values for temperature (Fig 3B; HV3), which suggests that potential effects of climate on the water quality trends may have been minor (Fig. 3). Note that when the temperature data was flow-adjusted there were no statistically significant trends.

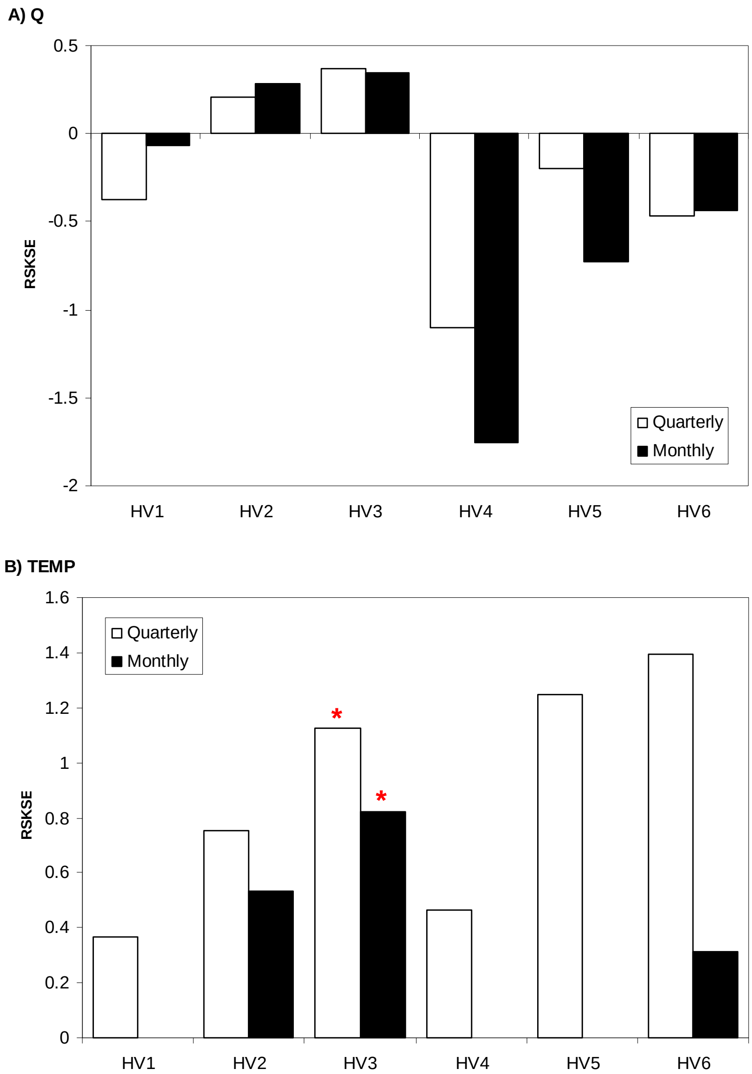


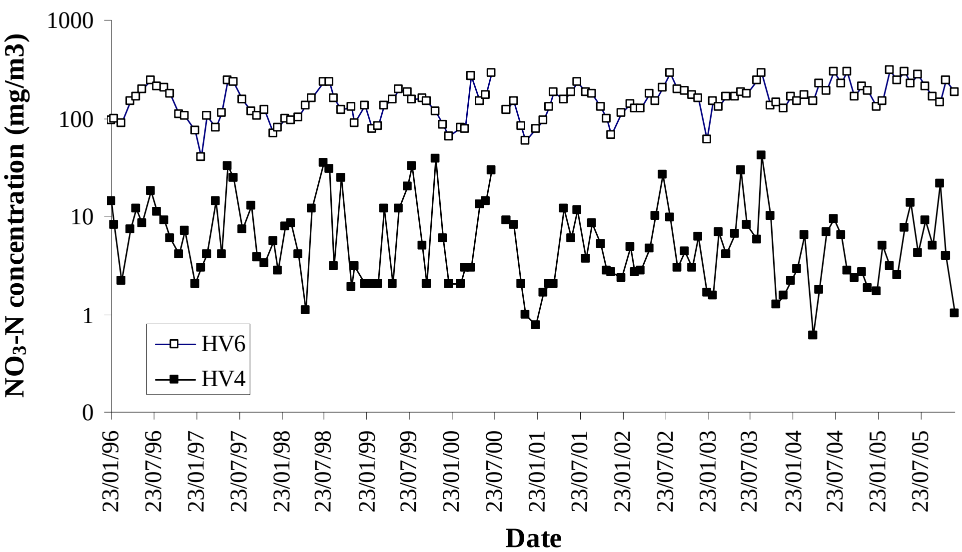
Figure 3: **A-B.** Plots of Seasonal Kendall Slope Estimator (expressed as % of raw data median) for raw data from 6 Hawkes Bay river sites analysed at monthly and quarterly time steps. Red asterisk denotes a statistically significant Seasonal Kendall test statistic (P<0.05) at a particular site.

3.4 NO_3-N trends in upper Mohaka River

The strong increasing trend in NO_x-N concentrations observed in the upper Mohaka catchment is a cause for concern (Figs 1C & 4A). When the NRWQN was set up in 1989, HV6 (Mohaka @ Glenfalls) was considered a “baseline” site (i.e., mainly bush catchment but some pasture development). Hawke’s Bay Regional Council staff now consider this site to be an “impact” site (Brett Stansfield, pers. comm.)

Determining the factors that might be driving trends can be very difficult. Trends may simply result from natural climate variability (e.g., Scarsbrook et al. 2003), or they may be associated with human land use practices (e.g., Scarsbrook 2006). However, by comparing trends over time at a potential impact site and a reference site we assume that the effects of natural variability will be factored out. With this in mind we calculated the difference in NO_x-N concentrations between HV6 (our potential impact site) and HV4 (a regional reference site). A Seasonal Kendall test of the difference (Fig. 4B) showed a significant increasing trend (SKSE = 7.79; $P < 0.001$) for monthly data and quarterly data (SKSE = 10.23; $P < 0.001$).

A)



B)

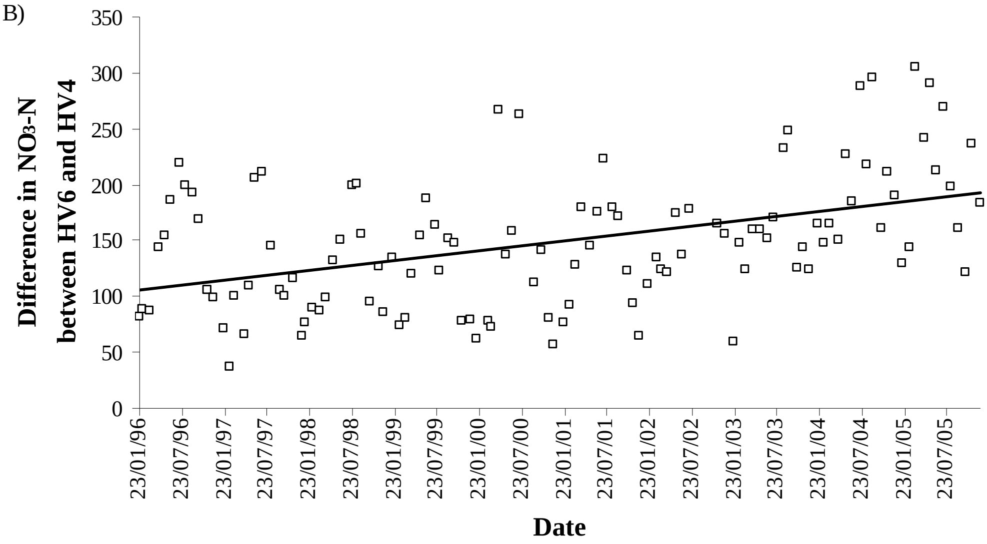


Figure 4: Time series plots for NO_3-N concentrations at A) HV6 and HV4 (note $\log_{10}$ scale), and B) the differences between the two sites.

3.5 Detecting trends over different time periods

Using flow-adjusted NO_x-N and TN data for HV6 we also compared the ability of monthly vs quarterly sampling to detect trends across different time periods. In particular, we were interested to see how soon an emerging trend became statistically significant. For the full 10-year period, monthly and quarterly sampling both showed significant trends for NO_x-N and TN at HV6 (see Figs. 1C & E and 5A-B). However, the significance of trends detected in either NO_x-N and TN was lost more quickly for quarterly sampling than monthly (Fig. 5A-B). For monthly data, significant trends in both NO_x-N and TN were observed in a seven year time period (1996-2002), but eight years was required to see a significant trend for quarterly data.

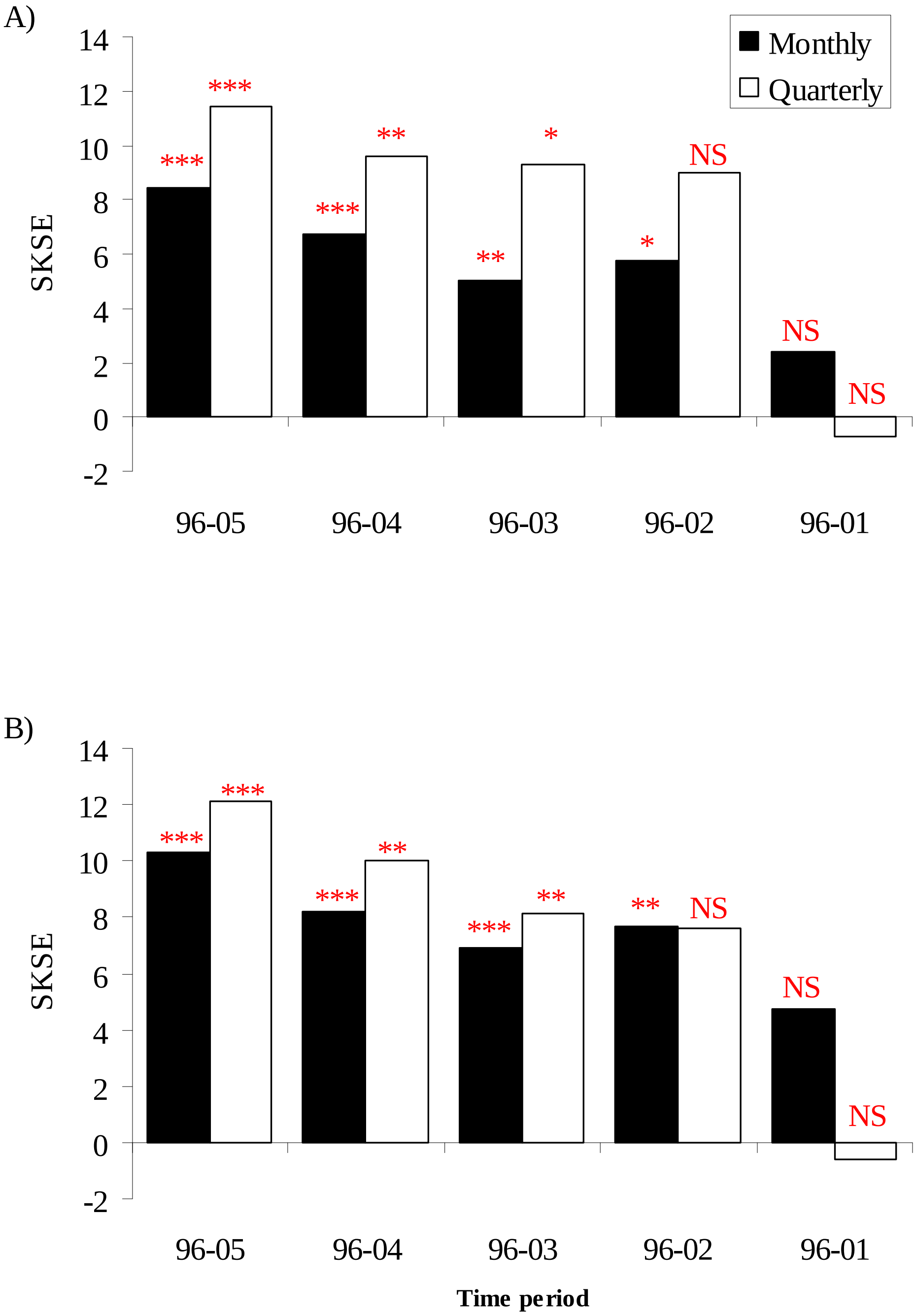


Figure 5: Seasonal Kendall slope estimator (SKSE) for different time periods at HV6. A) NO_3-N; B) TN. "***" *P* < 0.001; "**" *P* < 0.01; "*" *P* < 0.05; "NS" *P* > 0.05.

4. Discussion & recommendations

Reductions in sampling frequency within state of the environment monitoring networks can provide direct economic benefits, but this comes at a cost to data quality, and the ability to detect the patterns the monitoring was set up for.

Our results show that changing from a monthly to a quarterly sampling frequency greatly reduces the number of significant trends observed over a given time period. Stansfield (2001) found similar results for Greater Wellington Regional Council datasets. The implications of this are an increased risk of Type II errors (i.e., failing to detect a trend that may have management significance), and the potential for a State of the Environment report to misrepresent water quality trends in the region. Reporting on the effectiveness of policies implemented through the Regional Plan may also be compromised.

We also found that changing from monthly to quarterly sampling frequency may increase the response time of Council to particular issues of concern. For example, increasing levels of nitrogen in the headwaters of the Mohaka over the last 10 years are of concern since the trends do not appear to be associated with natural variability. Monthly sampling provides a reduction in the time taken to detect the emerging trend, and hence reduces potential response time.

5. References

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