Waipu Catchment Water Quality 2007-2011

Technical Report

Ahuroa River at Millbrook Road

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Executive summary

Project

The aim of this report was to identify the extent and likely cause of poor water quality in the Waipu Catchment (particularly nitrogen, phosphorus, clarity and bacteria levels), and recommend options for future management and monitoring. To achieve the aim this research was broken into the following objectives:

Objectives

- Analyse the physical and chemical properties of water samples collected at 10 sites within the Waipu Catchment from the period November 2007 to December 2011 to see if they comply with national water quality guidelines (ANZECC 2000).

- Investigate whether there is a seasonal signature to the data (i.e. is there higher pollution during wet months), and compare annual compliance rates at the different sites through time.

- Identify which streams have the highest concentrations of pollutants and try and relate that to land use management using land use data, resource consent information, and microbial source tracking.

- Recommend options for future monitoring.

Methods

- Water samples were collected by NRC staff and analysed by NRC, Watercare, and Hills Laboratories.

- Twelve water quality indicators were measured to assess water quality. These were total nitrogen, ammoniacal nitrogen, total phosphorus, bacteria, water clarity, suspended sediments, turbidity, dissolved oxygen, pH, water temperature and conductivity. Microbial source tracking was undertaken at the most downstream sites on all four tributaries.

Results

- The Waipu Catchment is heavily impacted and fails to meet the majority of relevant guidelines. The best performing parameter was water clarity, although water turbidity (a similar measure) seemed to contradict this. Total nitrogen (TN), Total phosphorus (TP), and E.coli were all consistently above recommended guidelines. Dissolved oxygen was often below recommended guidelines although there are issues regarding the diurnal fluctuations in DO and the time when sampling takes place (discussed in section 4.5). The percentage compliance with pH often dropped below the 7.2-7.8 range with most samples being slightly acidic. However this is still in the comfortable range of most aquatic organisms. These results are similar to other highly modified catchments in Northland such as the Lower Awanui, Mangere, and Mangonui Rivers.

- Water quality within the Waipu Catchment is influenced by antecedent soil moisture conditions with the wetter months of winter and spring generally having poorer water quality due to increased runoff. Overall water quality at all sample sites was generally poor however the upstream sites were slightly better than downstream sites.

- The best performing tributaries of the Waipu River was the Waiohoihoi and Ahuroa rivers, followed by the Waionehu and Pohuenui rivers. Overall there was little difference between rivers due to the similar land use ratios of small amounts of indigenous/plantation forestry in catchments dominated by intensive pastoral farming. Although there are consents to discharge sewage to land, it is likely the majority of pollutants are related to pastoral farming as supported by microbial source tracking (Section 4.8).

Recommendations

- Undertake a site investigation at 2262 (Waionehu Stream @ McLeans Road) and 1316 (Mill Brook @ Millbridge Road) to identify the source of poor water quality.

- In areas identified as a source of pollution, engage with local landowners to implement "best practice" land management techniques such as farm management plans, riparian buffer zones and fencing.

- Reinstate the monitoring program once the above land management measures have been implemented. Land owners and stakeholders should be made aware that there may be a lag between changes in land management and improvements in water quality as the "best practice" management techniques take time to have an effect.

1 Introduction

Northland has an abundance of rivers and streams, many of which are relatively short with small catchments. The rivers and streams provide habitat for a range of indigenous flora and fauna, as well as being important water supply for rural communities, horticulture and agricultural demands. The rivers and streams also provide important recreational, aesthetic and cultural value to the community.

Pollution can be delivered to rivers and streams directly from industrial discharges, and indirectly during rainfall periods when the rain creates runoff from the land, which then enters the waterways. Because Northland's rivers are comparatively small they have little capacity to dilute the contaminants they receive and are therefore considered sensitive receiving environments. As the majority of Northland's rivers flow into harbours rather than open coastline, poor river quality can also affect the health of the harbours.

A water quality monitoring programme was established for the Waipu Catchment by Northland Regional Council (NRC) in October 1994 to November 1995. The program was initiated to try and ascertain the effects of different land management practises on water quality in the Waipu River and Waipu estuary. Of particular interest were the impacts of dairy farming (dairy effluent discharges and fertiliser application), commercial activities (Sumner's truck wash, Waipu sawmill and log yards), and the impact of the Waipu township (sewage and stormwater). In addition, a number of incidences of dead fish and shellfish were also cause for investigation. A report by NRC (1995) summarises the water quality results over the 1994-1995 sampling period.

The Waipu monitoring program was reinstated in November 2007 and ran to the end of 2011. This purpose of this report is to analyse and present the water quality data, and make recommendations for future monitoring.

1.1 Aim and Objectives

The aim of this report was to identify the extent and likely cause of poor water quality in the Waipu Catchment (particularly nitrogen, phosphorus, clarity and bacteria levels), and recommend options for future management and monitoring. To achieve the aim this research was broken into the following objectives:

I. Analyse the physical and chemical properties of water samples collected at 10 sites within the Waipu Catchment from the period November 2007 to December 2011 to see if they comply with national water quality guidelines (ANZECC 2000).
II. Investigate whether there is a seasonal signature to the data (i.e. is there higher pollution during wet months), and compare annual compliance rates at the different sites through time.
III. Identify which streams have the highest concentrations of pollutants and try and relate that to land use management using land use data, resource consent information, and microbial source tracking.
IV. Recommend options for future monitoring.

2 Catchment description

The Waipu Catchment is approximately 229 km^2 and is located to the southeast of Whangarei. The Waipu River receives most of its water from five tributaries – The Ahuroa River (68 km^2), Waihoihoi River (32 km^2), Waionehu Stream (34 km^2), Pohuenui River (60 km^2), and the Mill Brook (18 km^2). These tributaries flow from the Brynderwyn Ranges at the southern end of the catchment. The solid geology of the area comprises Waipapa Group greywacke and Motatu Group siltstones and sandstones. The overlaying alluvium is comprised of mud, sand and gravel, with minor peat formations. River bed and flood plain deposits are up to 60cm thick; very soft and unweathered. The predominant soil type is the moderately well drained Waipu clay. There are also small areas of Waipu peaty silt loam and peaty clay. The major land cover is pastoral farming dominated by dairying on the flat land and dry stock farming on the steeper slopes. The second largest land cover is indigenous forest located on ridge tops and steeper slopes, followed by plantation forestry and scrubland. The urban centres include the townships of Waipu and Braigh (Table 1 and Figure 1). Mean annual rainfall ranges between 1500 mm on the flat land below the Brynderwyn Ranges and 1300 mm at the coast.

Table 1 Land cover type as classified in the Land Cover Database 2

Land cover type (LCDB2)	**Area (km^2)**	**Percentage of catchment area**
Indigenous forest	56.29	24.6
Pine forestry	34.12	14.9
Scrubland	13.71	6.0
Other exotics	1.07	0.5
Grassland	118.45	51.8
Orchard and cropland	0.88	0.4
Estuary and saline vegetation	0.68	0.3
Fresh open water and riparian vegetation	0.93	0.4
Surface mine	0.66	0.3
Urban areas	1.78	0.8
Total catchment area	228.57	100

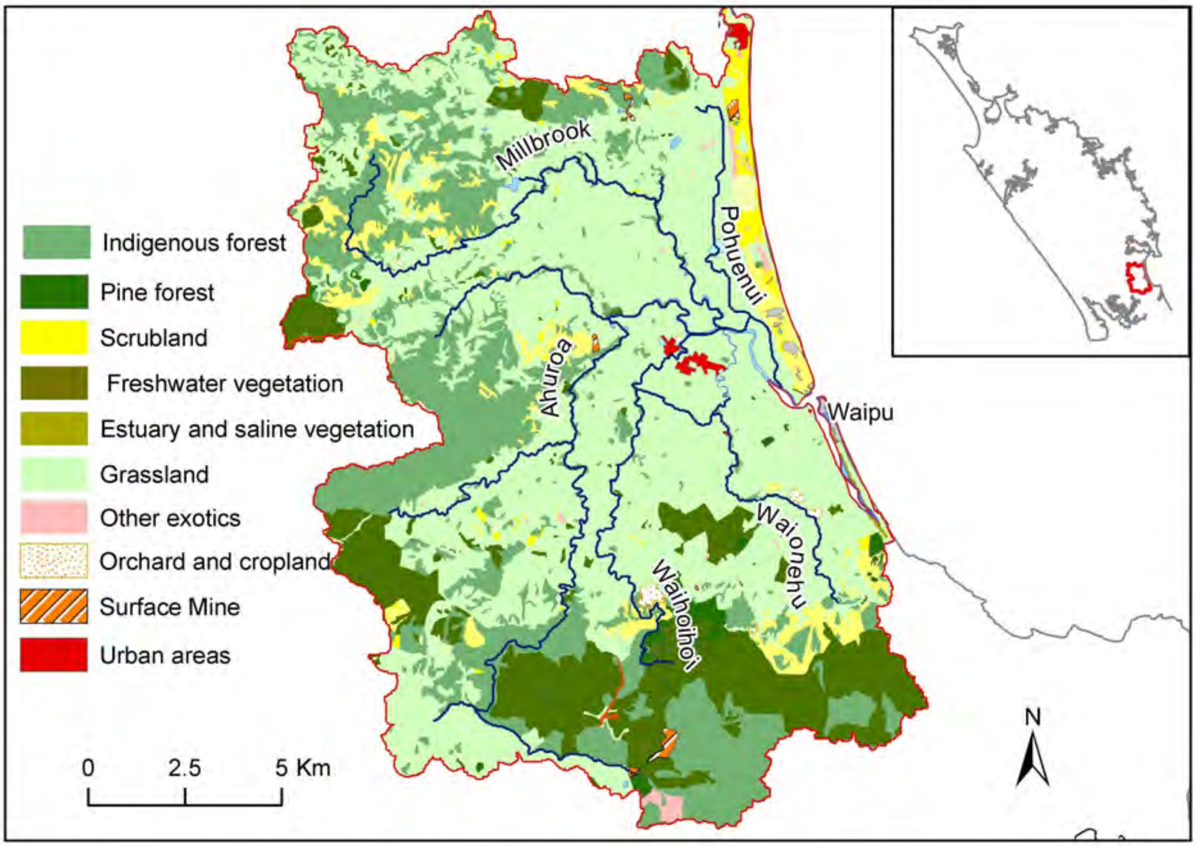


Figure 1 Land cover type as classified in the Land Cover Database 2

2.1 Resource consents

2.1.1 Surface and Groundwater takes

Groundwater in the Waipu Catchment is derived from the Marsden-Ruakaka alluvial and greywacke aquifer. There are 64 groundwater bores with the majority associated with permitted activities (i.e. the daily water abstraction does not exceed 10 m^2 per day and at a rate no greater than 5 litres per second) with the remaining two groundwater takes for irrigation and industrial purposes. In addition, there are nine consented surface water takes.

2.1.2 Discharge consents

There are 29 resource consents to discharge sewage to land within the Waipu catchment (Figure 2). The majority of these are located within the Waipu Township with the remainder situated in the rural areas of the catchment. In addition, there are 21 resource consents to discharge animal waste to water from the consented dairy farms shown in Figure 3.

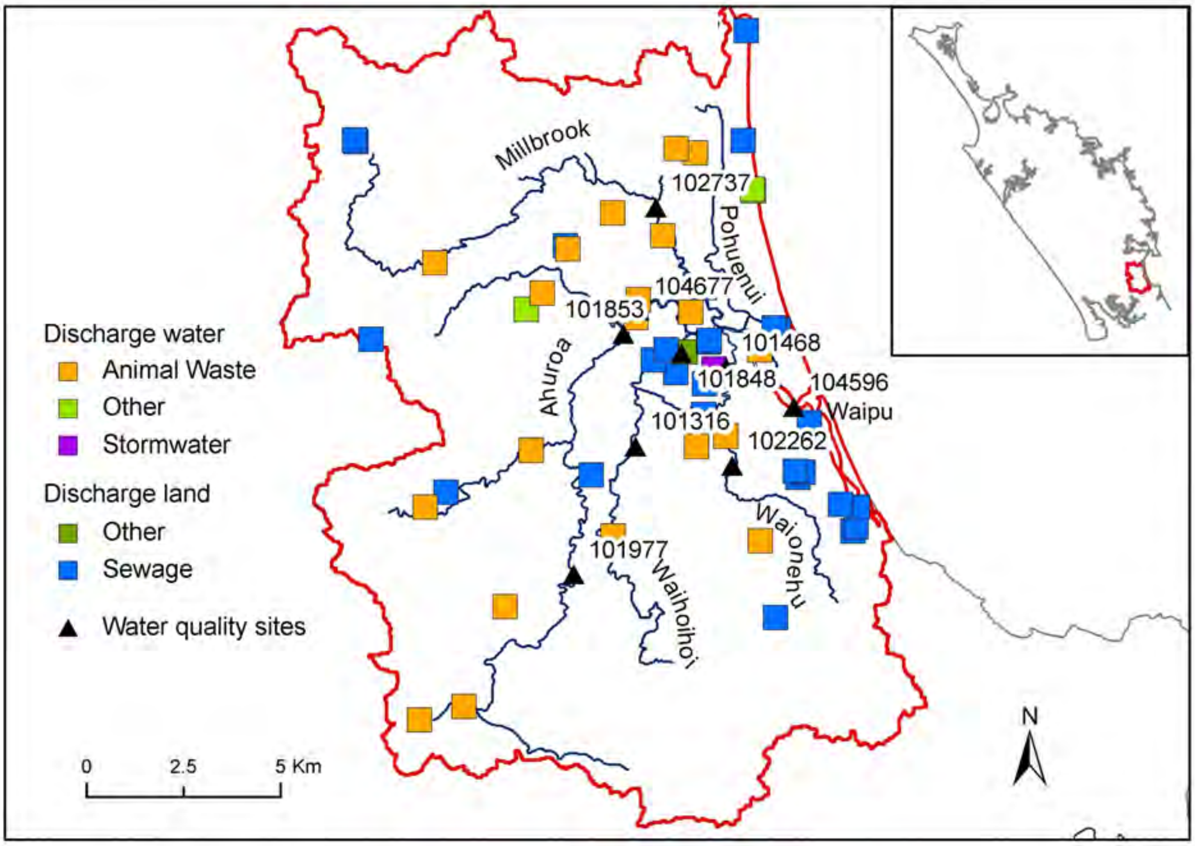


Figure 2 Discharge consents in the Waipu catchment

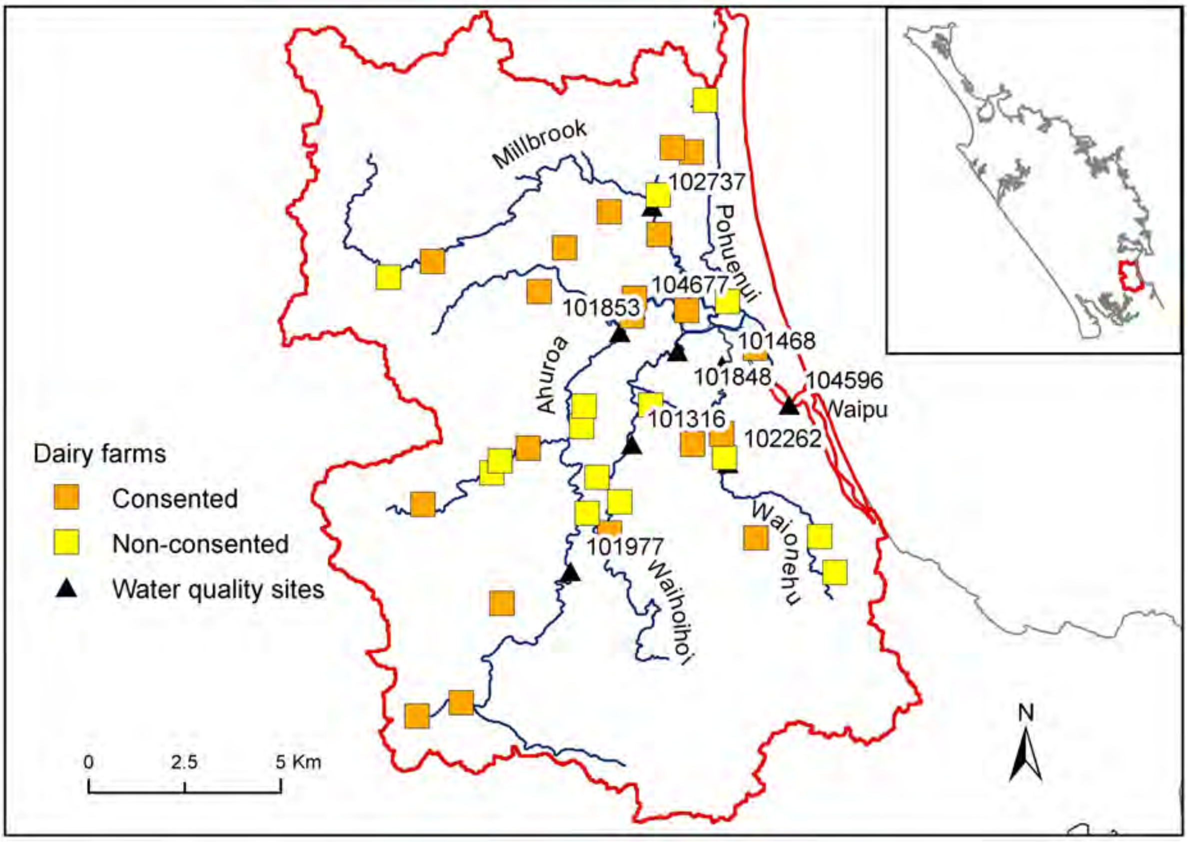


Figure 3 Consented and non-consented discharges from dairy farms in the Waipu catchment

3 Monitoring program and Methods

3.1 Surface water quality sites

The ten sites from the original NRC (1995) monitoring program (1994-95) were selected based on location and accessibility to provide good coverage of the Waipu River and its tributaries. These same sites were used when monitoring resumed in 2007, however in 2008 monitoring was ceased at the most downstream site on the Waipu River (4596) for reasons unknown, but were resumed again in 2011. The other nine monitoring sites are located on the Waipu's main tributaries (Table 2). To aid in quick identification the first two digits (1, 0) of the sample site number will be excluded for the remainder of this report.

Table 2 Surface water quality sites of the Waipu Catchment

Sample site	Site name	Dominant surrounding land use
2262	Waionehu Stream @ McLeans Road	Pasture and some pine/indigenous forest
1468	Waionehu Stream @ Boat jetty	Pasture, sawmill, and Waipu township
1316	Waihoihoi River @ St Marys Road	Pasture and some indigenous forest
1848	Waihoihoi River @ Waipu Reserve	Pasture and Sumner's truck wash
1977	Ahuroa River @ Durham Road	Pasture and small amount of indigenous forest
1853	Ahuroa River @ Millbrook Road bridge	Pasture
3120	Mill Brook @ Millbridge Road	Pasture and small amount of indigenous forest
4677	Ahuroa River Waipu. @ Shoemaker Rd Bridge	Pasture. Confluence of two rivers
2741	Pohuenui R Waipu. @ Connel Rd bridge	Pasture
4596	Waipu River @ Off Hamon Rd	Discharge into estuary water quality

3.2 Sampling programme

Water samples were collected from each site on a monthly basis from November 2007 and analysed for the following parameters:

- Nitrite (NO_2)
- Nitrate (NO_3)
- Ammoniacal nitrogen (NH_4)
- Total Kjeldahl Nitrogen (TKN)
- Total Nitrogen (TN)
- Total Phosphorus (TP)
- *E.coli* concentration
- Turbidity

Onsite measurements of the following parameters are made at the time of sampling:

- Water temperature
- Dissolved oxygen (both mg/L, and % saturation)
- Clarity
- Conductivity
- pH

Observations such as preceding weather conditions and any random events such as livestock or large numbers of waterfowl in stream are also recorded at the time of sampling. All sample and field measurement collection methods follow those documented in the councils Field Monitoring Procedure Manual (NRC, 2010a). All laboratory sample analysis was carried out following the procedures in the 'Standard Methods for the Examination of Water and Wastewater' (APHA, 1998). Where < appeared in raw data set, value was adjusted to half the, value. Where > appeared in the raw data set, the > was removed and the value retained.

The results were compared to the Australian and New Zealand Environmental and Conservation Council (ANZECC) trigger values for the protection of aquatic ecosystems in New Zealand (ANZECC 2000). It is important to note that the trigger values are used to assess the risk of adverse effects on the ecosystem and when results are outside trigger values further investigation is required to determine whether there are adverse effects on the environment and to what extent. The trigger values for lowland rivers are shown in table 3.

Table 3 Trigger values for NZ lowland rivers (ANZECC 2000)

Parameter	Trigger value for lowland rivers
Dissolved oxygen (% saturation)	98-105
Water clarity (m)	> 0.6
Turbidity (NTU)	< 5.6
Dissolved reactive phosphorus (mg/L)	< 0.033
Nitrate, nitrite nitrogen (mg/L)	< 0.444
Ammoniacal nitrogen (mg/L)	< 0.021
Total nitrogen (mg/L)	< 0.614
pH	7.2 - 7.8

As the ANZECC guidelines don't have trigger values for E.coli, the levels of E.coli are compared to the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE and MoH 2003), to determine whether the water is safe for recreational use. Many of the rivers within Northland are used for recreational purposes. The guideline is less than 550 E.coli/100mL of sample. While ANZECC (2000) guidelines do not directly mention E.coli trigger levels, section 9.3.3.2 states that: "Drinking water for livestock should contain less than 100 thermotolerant coliforms/100 mL (median value)."

3.3 Microbial source tracking

In addition to the environmental parameters measured above, a program of microbial source tracking was initiated in late 2011 to try and identify the source of bacterial contamination in the water. The two scientific techniques used were fluorescent whitening agents (FWA's) and polymerase chain reaction (PCR) markers. Fluorescent whitening agents are common ingredients of washing powders and only one is used in New Zealand. In most households, the effluent from toilets is mixed with grey water from washing machines and therefore FWAs are usually linked to human faecal contamination in both septic and community wastewater systems.

Polymerase chain reaction (PCR) markers show the difference between closely related bacteria using DNA sequencing. In some cases, this bacterium is highly host specific (i.e. only associated with the faecal material of one animal or animal group). Therefore the type of animal that the bacteria came from can sometimes be identified. PCR markers for the following host groups have been developed – human, ducks (wildfowl), ruminants (includes sheep, cattle, deer, and goats), possums and pigs, as well as a general indicator of faecal contamination.

4 Results and discussion

4.1 Total Nitrogen

Nitrogen is needed by aquatic plants for growth and occurs naturally in water bodies. Man-made sources of nitrogen include fertiliser runoff, urine from farm animals, and treated wastewater discharges. If nitrogen enters rivers it can result in pollution which can lead to extensive algal growths, which then impact on the aquatic ecosystem. The recommended guideline value for the protection of aquatic ecosystems is that the total nitrogen concentration should remain below 0.614mg/L (ANZECC 2000).

Nitrogen in the rivers and streams of the Waipu catchment was measured in the form of: Nitrate (NO_3^-), Nitrite (NO_2^-), and Total Kjeldahl Nitrogen (TKN) which consists of organic nitrogen, ammonia (NH_3) and ammonium (NH_4^+). The following results are presented using Total Nitrogen (TN) which is the sum of nitrate, nitrite, organic nitrogen and ammonia (all expressed as N). Note that for laboratory analysis purposes, Total Kjeldahl Nitrogen (TKN) is a test performed that is made up of both organic nitrogen and ammonia. Although there are no ANZECC guidelines for TKN, there is for ammonical nitrate (NH_4) with results in the appendix.

All sites had greater than 33% compliance with ANZECC guidelines for total nitrogen (TN) over the period of November 2007 through to May 2011 (Table 4).

Table 4 Median TN concentration, range and percent compliance with ANZECC guidelines for river sampling sites

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITE no.	2262	1468	1316	1848	1977	1853	3120	4677	2741	4596
Samp. sz	46	46	45	46	41	46	46	45	46	14
med	0.65	0.87	0.41	0.59	0.46	0.69	0.73	0.76	0.79	0.6
max	3.77	3.55	8.49	9.86	1.93	9.39	7.31	8.4	6.22	5.1
min	0.18	0.105	0.16	0.29	0.13	0.26	0.21	0.21	0.32	0.27
Within g-lines	21	15	32	24	24	20	20	18	15	7
% comp-liance	46	33	71	52	59	43	43	40	33	50

The Ahuroa River is sampled from three locations. The headwater site 1977 at Durnham Road Bridge had a rate of compliance of 59% which decreased downstream at site 1853 at Millbrook Bridge (43%) and 4677 at Shoemaker Road Bridge (40%). The Millbrook River 3120 at Millbrook Bridge (43%) discharges into the Ahuroa between sites 2262 and 4677 and thus contributes to the slightly higher TN levels downstream. Site 1316 at St Marys Road had the highest rate of compliance (71%) on the Waiohoihoi River but this fell to 52% by the time it flowed through site 1848 at Waipu Reserve. A similar trend occurred on the Waionehu River with compliance ratings at 2262 McLeans

Road Bridge (46%) falling to 33% at site 1468 at Cove Road boat jetty. The Pohuenui River has a similarly low compliance rate with 33% recorded at site 2741 Connels Road Bridge. The final site at Waipu Estuary (4596) is downstream from all tributaries and had a compliance rate of 50%.

Since 2008 annual mean TN concentration has remained relatively stable at all sites (Figure 5) with compliance rates decreasing in 2011 after small improvements the previous years (Figure 4). There appears to be a marked improvement in mean TN concentration and compliance during 2009-10 which can mostly be explained by the drought Northland experienced during November 2009 to May 2010. Subsequently, at least half of the samples for 2010 were taken during drought conditions. With less rainfall runoff during the drought fewer nutrients would have been delivered to the rivers and streams. Additionally, algal growth within the streams would have taken up a lot of the available nitrogen. Both effects would have contributed to the lower nitrogen concentration observed in 2010. Similar improvements in TN concentration were observed right across Northland (NRC 2010b), however data from 2011 is showing concentrations are increasing again at many sites. Overall TN compliance is low and ongoing catchment management is required to improve water quality.

There are 29 resource consents to discharge sewage to land within the Waipu catchment. The majority of these are located within the Waipu Township with the remainder situated in the rural areas of the catchment. Perhaps more significant are the 21 resource consents to discharge animal waste to water within the catchment. It is possible these discharges in combination with stock access to streams and fertiliser runoff are contributing significant volumes of nitrogen to the stream network hence the low rate of compliance (Table 4).

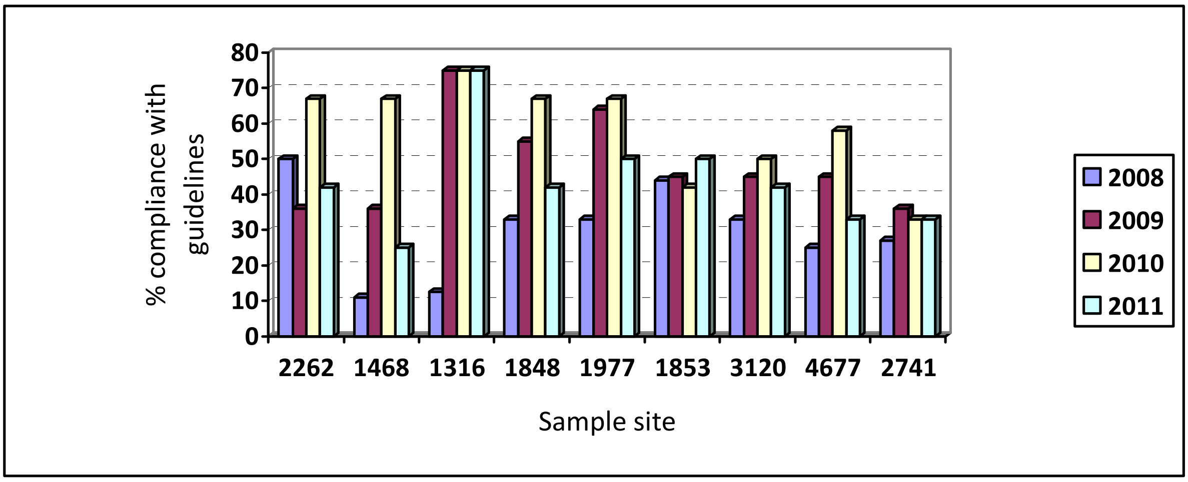


Figure 4 Annual TN % compliance with ANZECC Guidelines for all surface water sampling sites

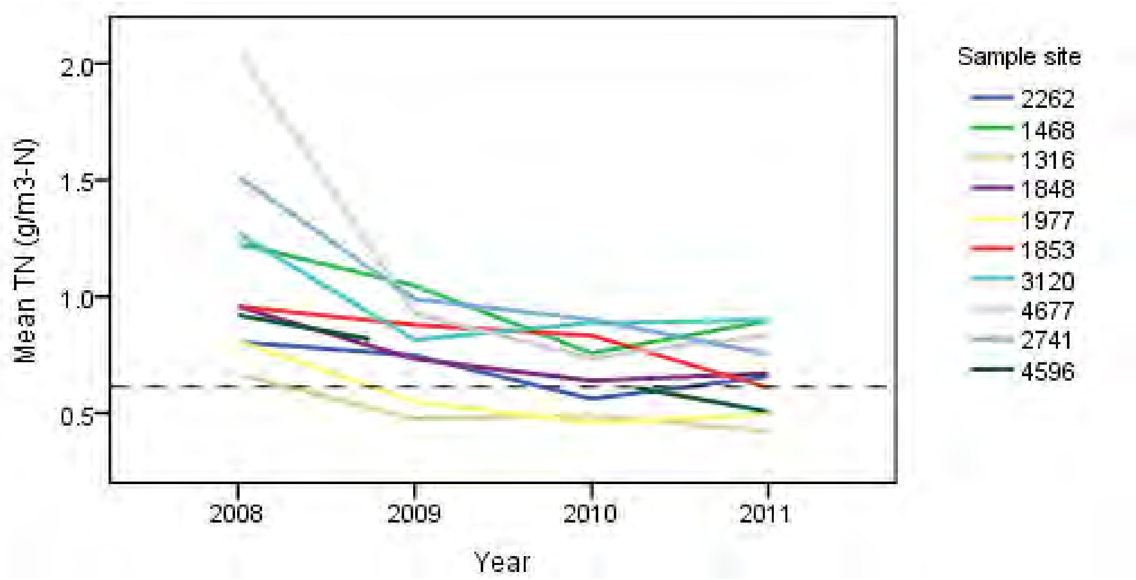


Figure 5 Annual mean TN concentration at the sample sites with ANZECC guideline (black dashed line).

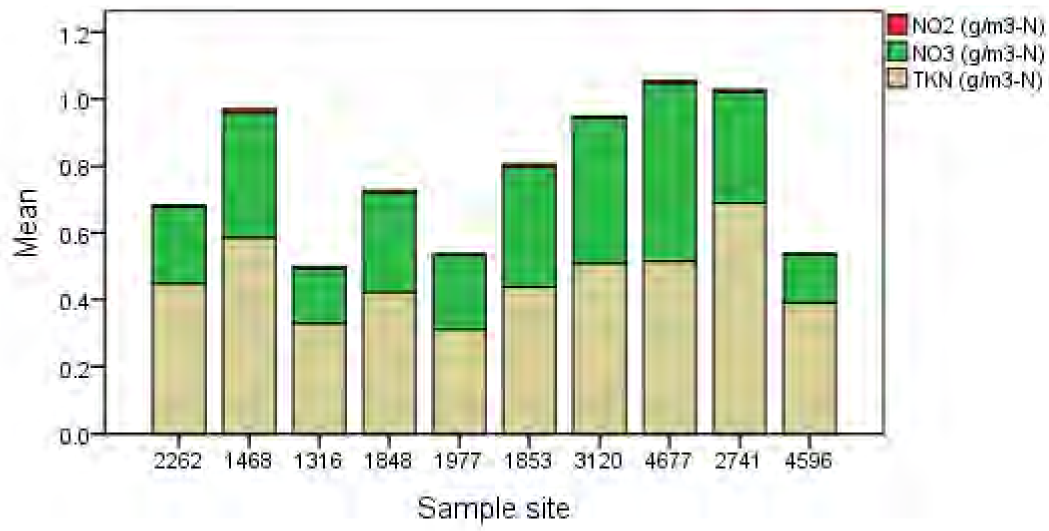
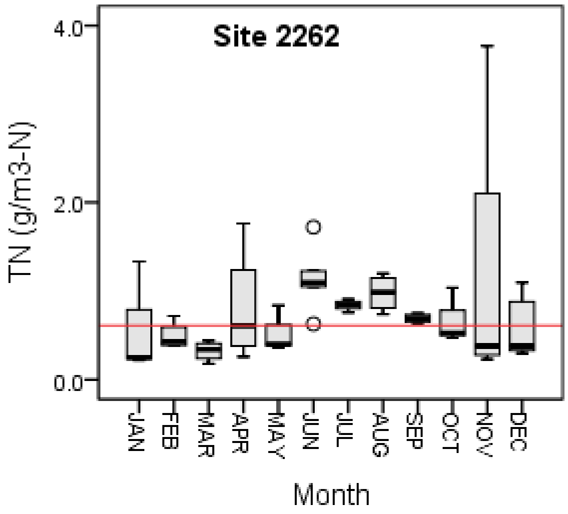
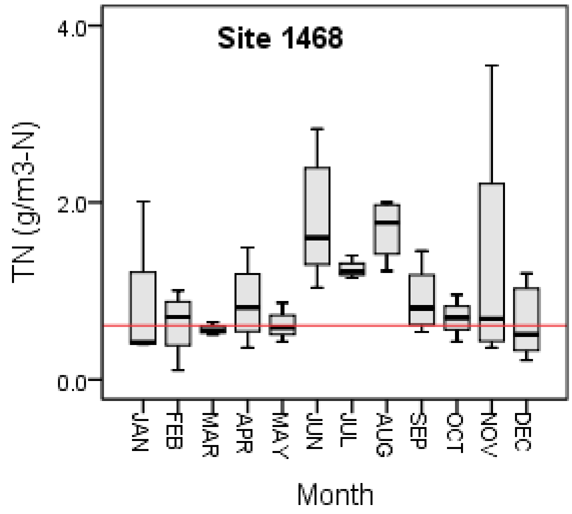
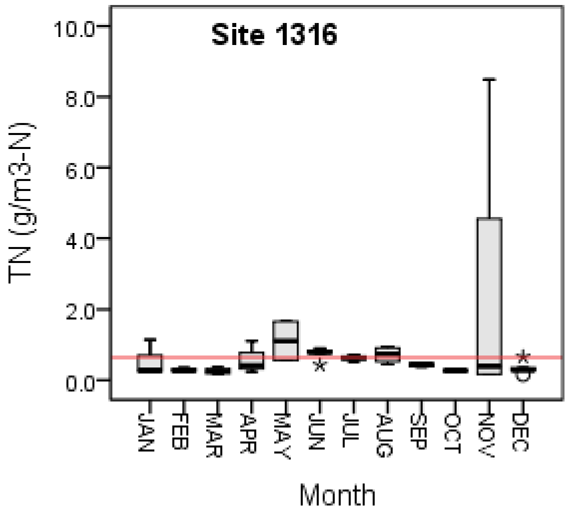


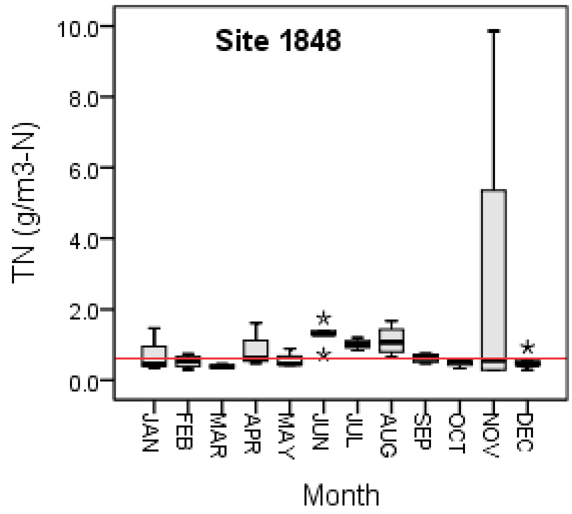
Figure 6 Mean relative contributions of different nitrogen species at each river sampling site

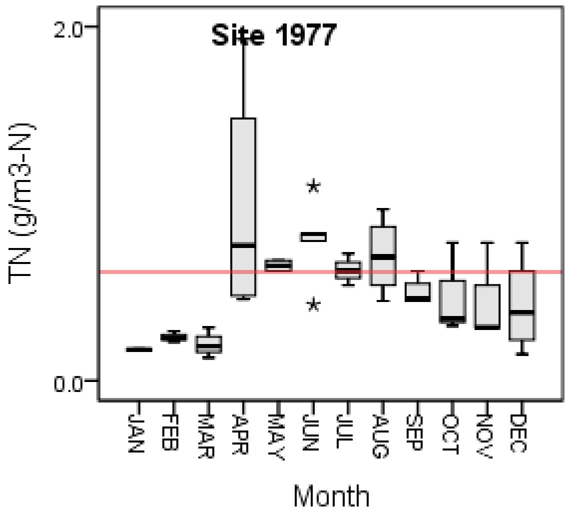
The following box plots show the seasonal variation in TN for each of the study sites. TN concentrations are generally higher in June, July and August, and lowest in January, February, and March (Figure 7). On the 20th November 2007 there was a large peak in TN concentration at all sites which cannot be accounted for by rainfall or environmental incident reports. Therefore the cause of the peak TN levels is unknown. The red lines represent the ANZECC guidelines value.

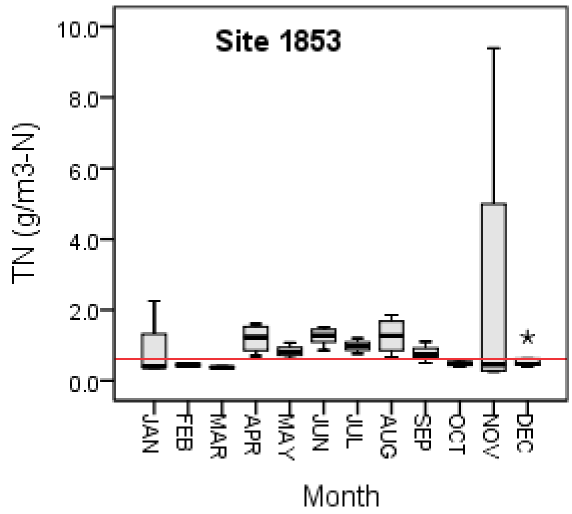

Site 2262
TN (g/m3-N)
4.0
2.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1468
TN (g/m3-N)
4.0
2.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1316
TN (g/m3-N)
10.0
8.0
6.0
4.0
2.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1848
TN (g/m3-N)
10.0
8.0
6.0
4.0
2.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1977
TN (g/m3-N)
2.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1853
TN (g/m3-N)
10.0
8.0
6.0
4.0
2.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month

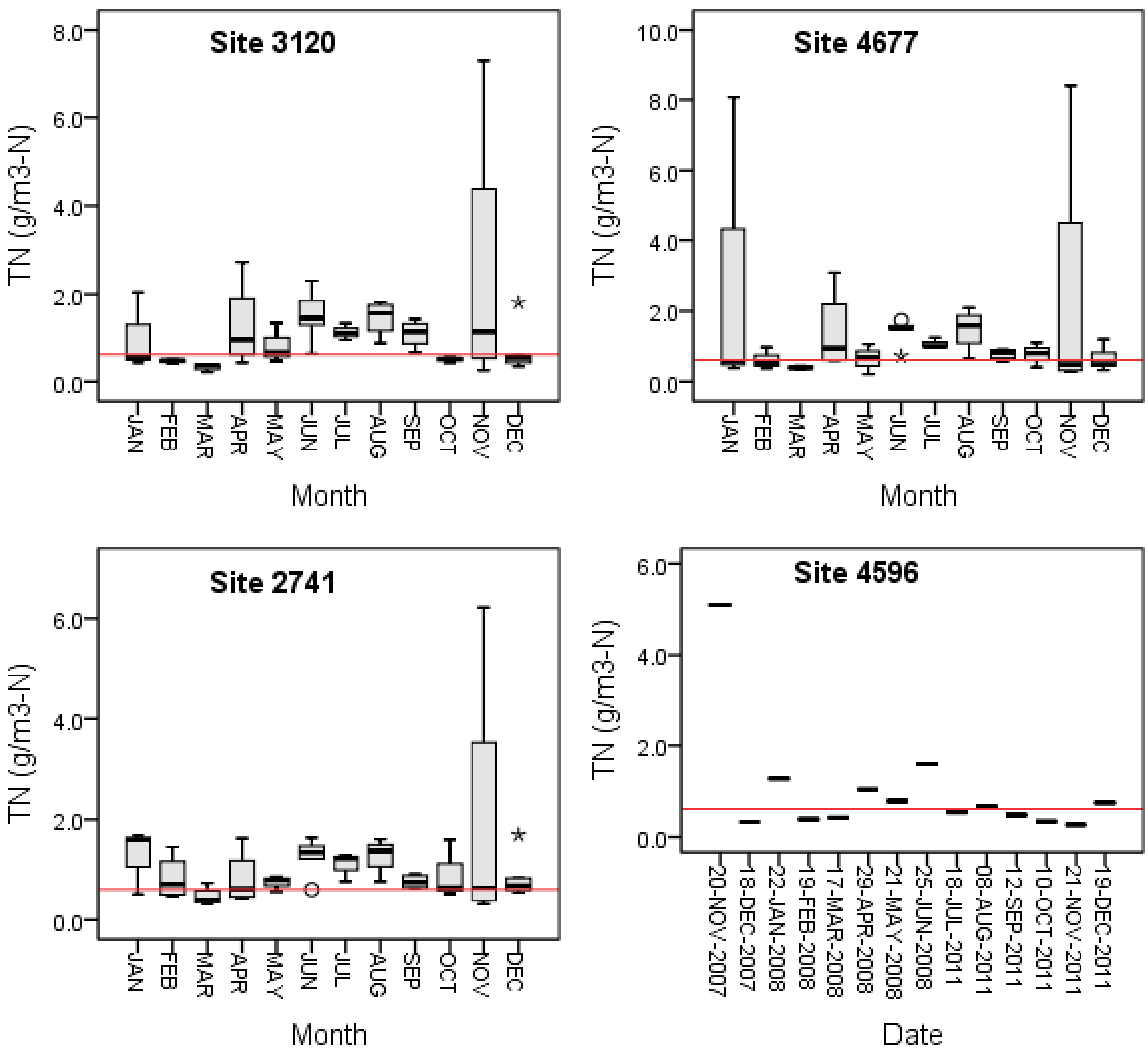


Figure 7 Seasonal box plot of TN concentration (g/m3-N) for all sample sites. The red lines represent the guideline value.

4.2 Total Phosphorus

Like nitrogen, phosphorus is required by plants and algae for growth and occurs naturally in water bodies. Man-made sources include fertiliser runoff, wastewater discharges and runoff after land clearance. If phosphorus enters waterways it can result in pollution which can lead to extensive algal growth which can impact the aquatic ecosystem. The recommended guideline for protection of aquatic ecosystems is that total phosphorus should remain below 0.033mg/L (ANZECC 2000).

The Ahuroa River is sampled from three locations. The headwater site 1977 at Durnham Road Bridge had a rate of compliance of 37% which decreased downstream at site 1853 at Millbrook Bridge (0%) and 4677 at Shoemaker Road Bridge (4%). The Millbrook River 3120 at Millbrook Bridge (0%) discharges into the Ahuroa between sites 2262 and 4677 and thus contributes to the concentrated TP levels downstream. On the Waiohoihoi River site 1316 at St Marys Road had a compliance rate of 24% which fell to 2% by the time it flowed through site 1848 at Waipu Reserve. Similarly poor results occurred on the Waionehu River with compliance ratings at 2262 McLeans Road Bridge (2%)

falling to 0% at site 1468 at Cove Road boat jetty. The Pohuenui River has a very poor compliance rate with 2% recorded at site 2741 Connels Road Bridge. The most downstream site at Waipu Estuary (4596) had the highest rate of compliance with 43% which can be explained by dilution due to more water (Table 5).

Overall, the streams within the Waipu catchment all had very poor rates of compliance with guidelines. A similar trend to TN was observed with headwater sites having slightly greater compliance than downstream sites. The poor TP compliance rate is partly due to Northland's phosphorus rich sandstone and mudstone catchment geology which provides a high background level of phosphorus to streams naturally. Only two of Northland's monitored rivers (Waipapa River and Waipapa Stream) had 100% compliance with the total phosphorus guideline in the 2009-2010 financial year (NRC 2011a).

Table 5 Median TP concentration, range and percent compliance with ANZECC guidelines for river sampling sites

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	2262	1468	1316	1848	1977	1853	3120	4677	2741	4596
Samp. sz	46	46	45	46	41	46	46	45	46	14
med	0.68	0.092	0.056	0.067	0.04	0.076	0.09	0.79	0.925	0.034
max	1.45	1.4	0.66	0.79	0.62	0.86	1.03	0.59	0.58	0.20
min	0.03	0.04	0.02	0.03	0.02	0.04	0.04	0.03	0.03	0.02
Within g-lines	1	0	11	1	15	0	0	2	1	6
% comp-liance	2	0	24	2	37	0	0	4	2	43

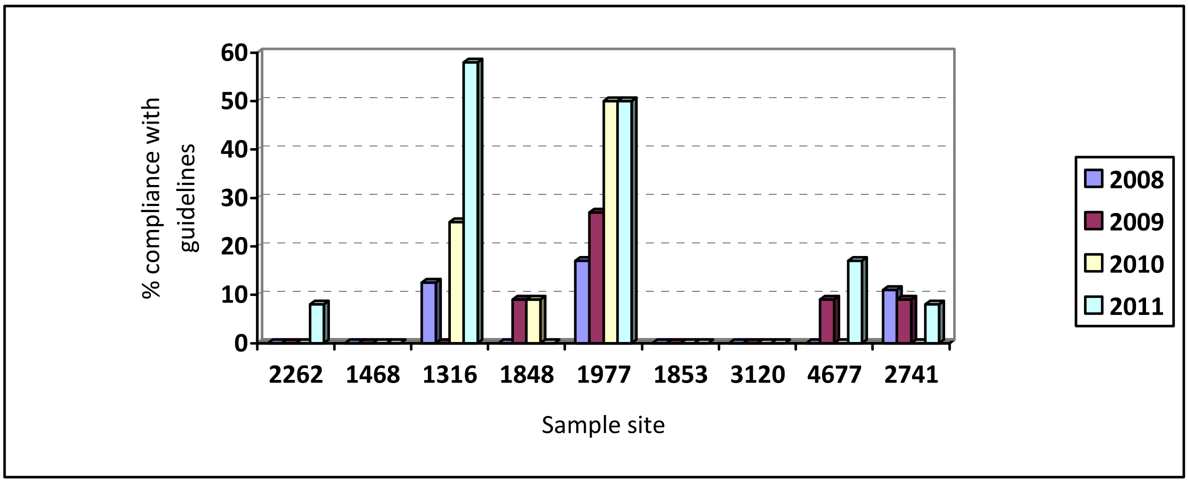


Figure 8 Annual % TP compliance with ANZECC Guidelines for all surface water sampling sites

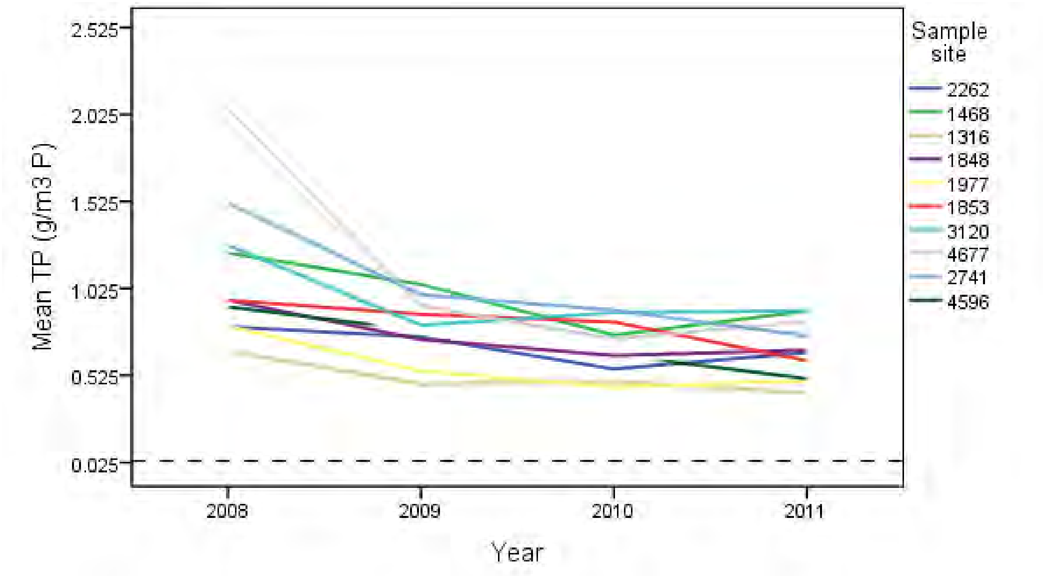
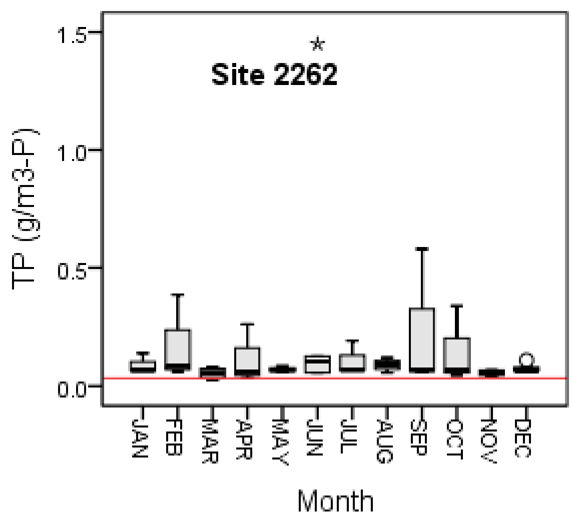
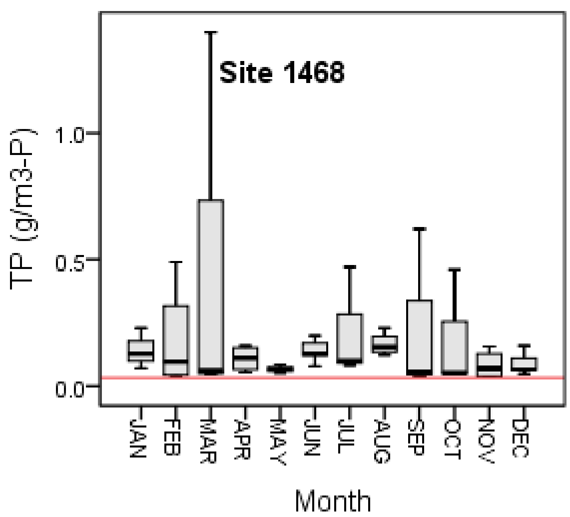
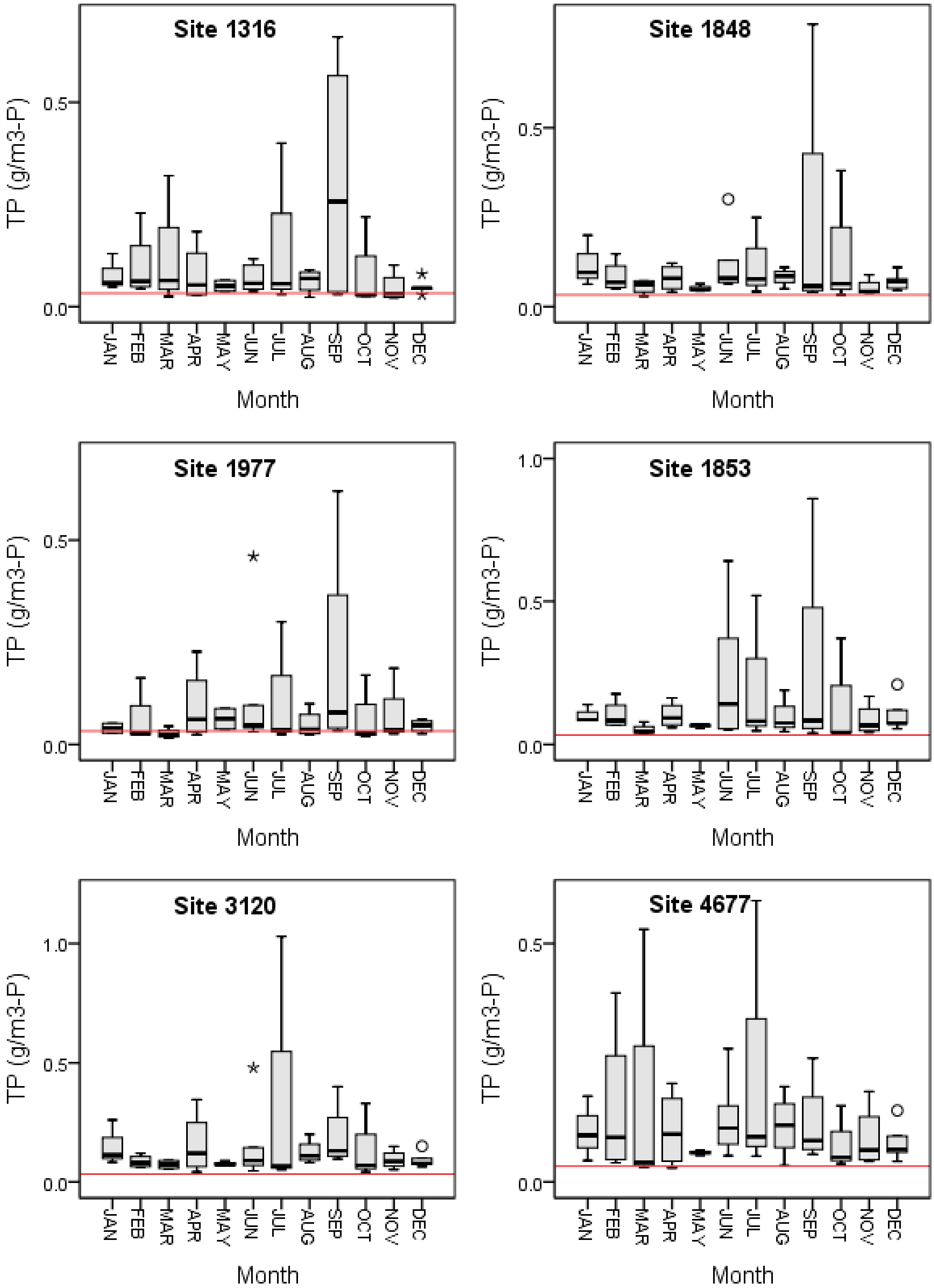


Figure 9 Annual mean TP concentration at all surface water sampling sites with ANZECC guideline (black dashed line).

The following box plots show the seasonal variation in TP for each of the study sites. TP concentrations were generally highest through winter and spring and lowest in summer. Four sites 1468, 1316, 4677, and 4596 showed a large peak in TP on the 24th March 2010. The peak TP level could not be accounted for by rainfall or environmental incident reports and therefore the cause of the peak is unknown.






Site 1316
Site 1848
Site 1977
Site 1853
Site 3120
Site 4677
TP (g/m3-P)
0.0
0.5
1.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Month

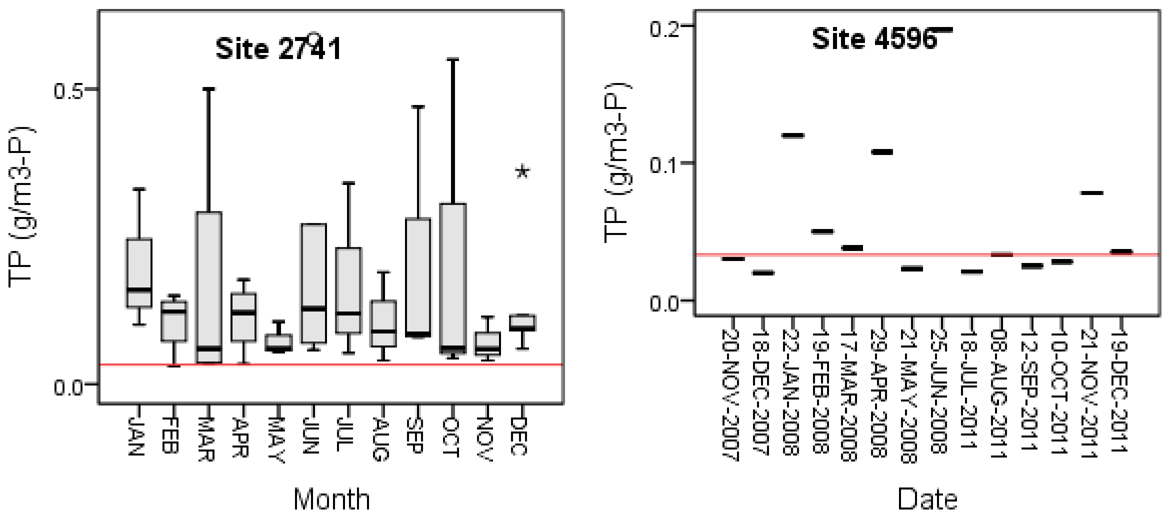


Figure 10 Seasonal box plot of TP concentration (g/m3-P) for all sample sites. The red lines represent the guideline value.

4.3 Bacteria (E.coli)

Low levels of bacteria are present in freshwater bodies as a result of natural processes such as plant decay. However, land-use practices and human activity can increase the levels of bacteria in freshwater bodies. The bacteria Escherichia coli (E. coli) is used to indicate faecal pollution and scientific studies have shown that where E.coli is present, we can assume there are pathogens in the water (MfE 2002). Water that has been contaminated by human or animal faeces may contain a range of disease causing micro-organisms such as viruses, bacteria, and protozoa. These organisms may pose a health hazard when the water is used for recreational activities.

The bathing guideline value for the indicator E.coli is 550/100mL (MfE, MoH 2003). If concentrations of E.coli are greater than this, it may pose health risks for people swimming in the water. While the ANZECC (2000) guidelines do not directly mention E.coli trigger levels, section 9.3.3.2 states that: "Drinking water for livestock should contain less than 100 thermotolerant coliforms/100 mL (median value)."

Table 6 Median bacteria E. coli concentration, range and percent compliance with MfE and MoH (2003) guidelines for recreation at all river sampling sites.

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	2262	1468	1316	1848	1977	1853	3120	4677	2741	4596
Samp. sz	46	46	45	46	41	46	46	45	45	14
med	959	1091	218	717	335	601	848	591	650	98
max	11199	24192	12033	10462	9804	17329	24192	15531	12033	10462
min	145	74	52	96	121	121	85	31	85	5
Within g-lines	13	16	38	19	27	19	14	22	17	10
% comp-liance	28	35	84	41	66	41	30	49	38	71

Table 7 Median bacteria E. coli concentration, range and percent compliance with ANZECC (2000) guidelines for stock drinking water at all river sampling sites.

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	46	46	45	46	41	46	46	45	45	14
med	959	1091	218	717	335	601	848	591	650	98
max	11199	24192	12033	10462	9804	17329	24192	15531	12033	10462
min	145	74	52	96	121	121	85	31	85	5
Within g-lines	0	1	5	1	0	0	1	5	1	7
% comp-liance	0	2	11	2	0	0	2	11	2	50

There were a number of significant peaks in E. coli levels during 2008 (22 Jan, 29 Aug, 3 Sep) and 2009 (25 Aug, 23 Sep). In all but two of these occasions the peaks could be attributed to high rainfall resulting in greater runoff from surrounding land. No recorded environmental incidents could be connected with the remaining two peaks (29 Apr 08, 3 Sep 08). However, August and September (Spring) is the calving period with greter stock numbers and increased rainfall often results in greater farm runoff.

The best performing sites were those situated upstream (1977, 1316) with E. coli levels increasing downstream. Of note are sites 3120 on the Milbrook and 2262 on the Waionehu which have the lowest recreational compliance rates of 30% and 28% respectively (Table 6). Overall, all sites annual compliance rates have improved since 2008 although some sites have decreased again in 2011 (Figure 11 and 13). It is likely that changes in E. coli levels are a result of the drought in 2009-10. With lower rainfall runoff less effluent would have entered the rivers in addition to lower stocking rates due to poor pasture growth. E. coli levels were also regularly above safe drinking water guidelines for stock which is of particular concern to farmers (Table 7; Figure 13). Within the catchment there are a number of consents to discharge sewage and stock effluent to both land and water. The results of Microbial Source Tracking (MST) identified ruminants (stock) as the primary source of elevated bacteria levels in all four tributaries (see Section 4.8).

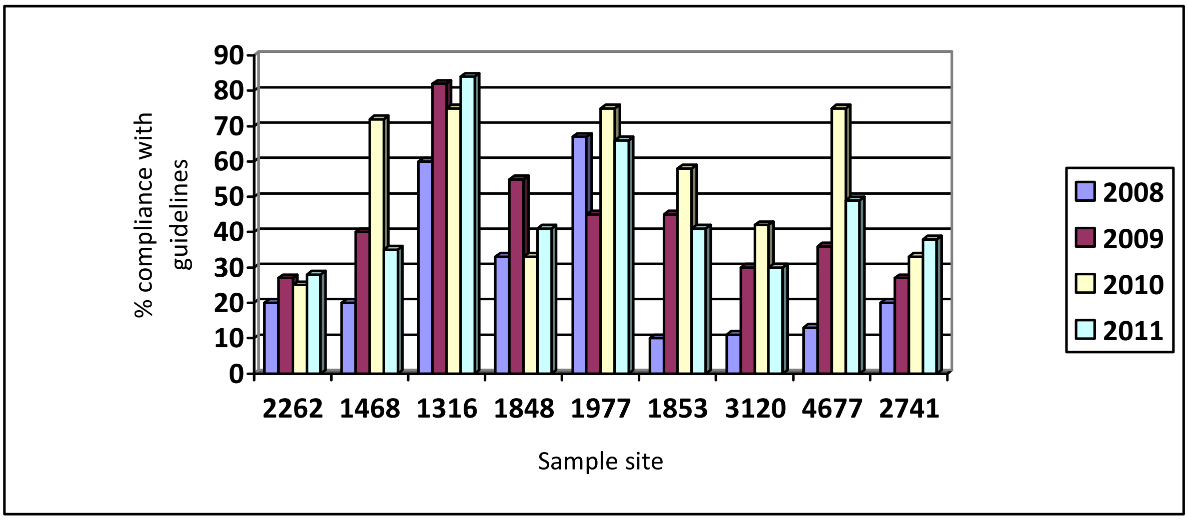


Figure 11 Annual E. coli % compliance with recreational water quality guidelines for all sites.

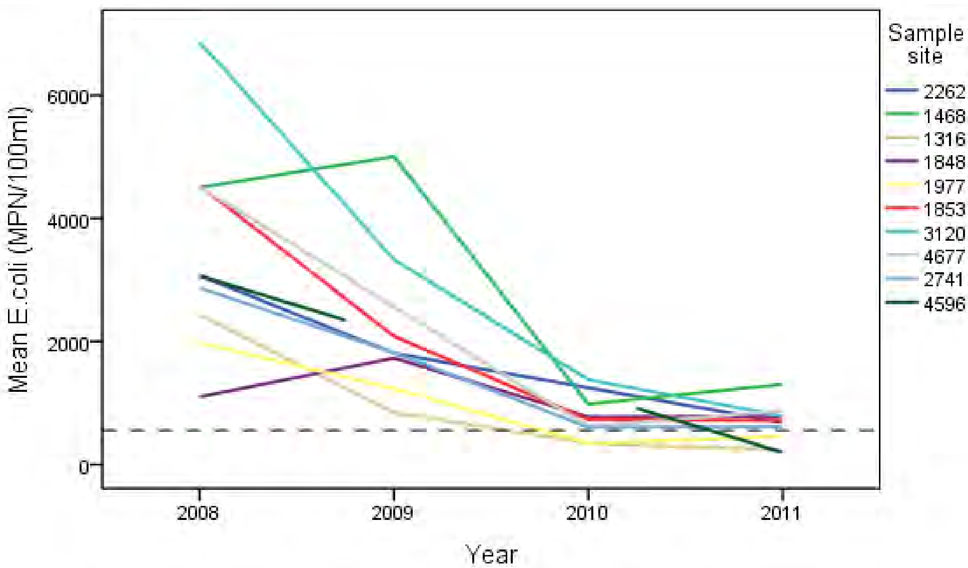
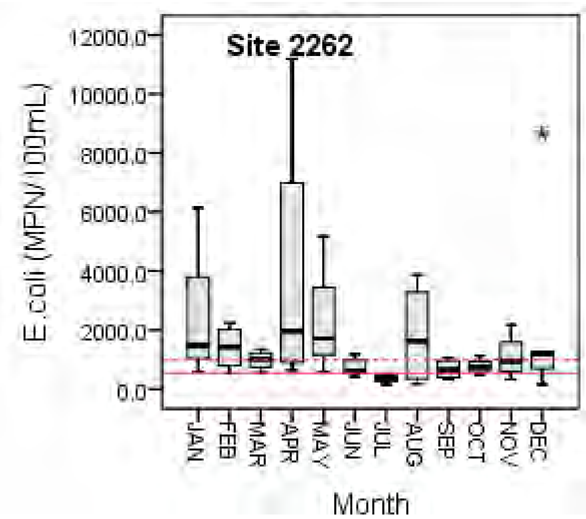
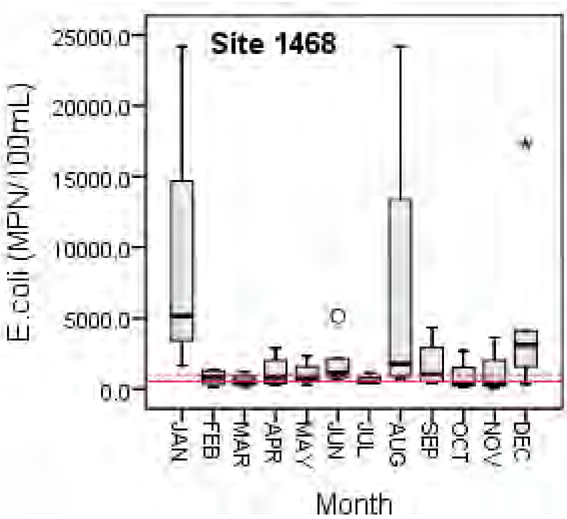
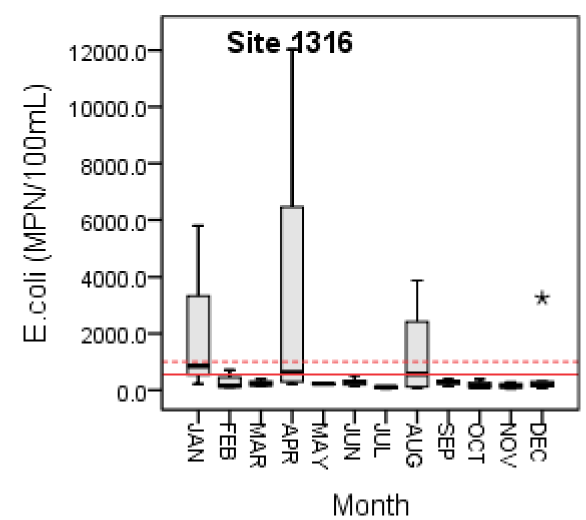
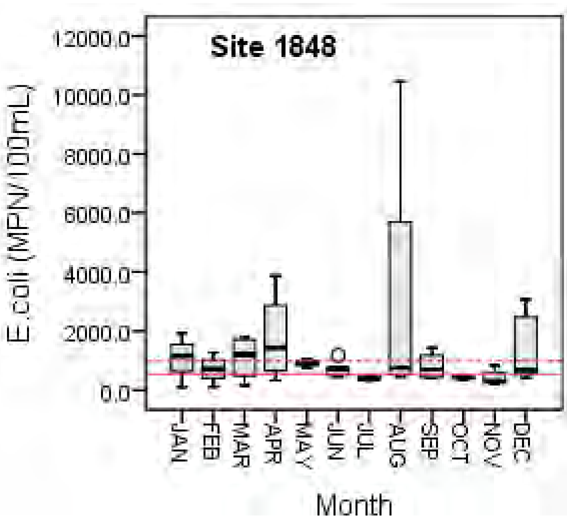


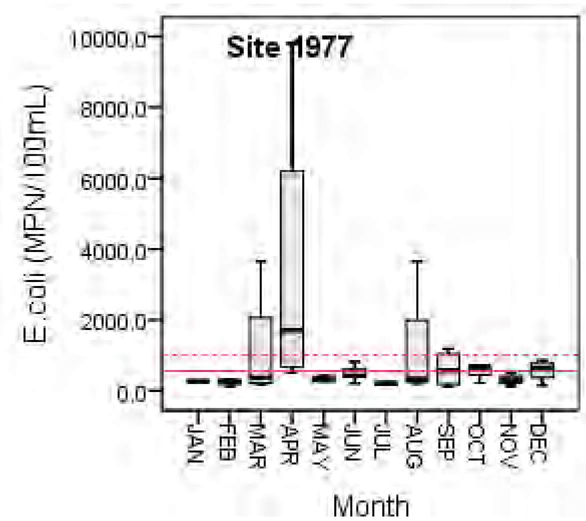
Figure 12 Annual Mean E.coli concentration at all surface water sampling sites with recreational water quality guideline (Black dashed line).

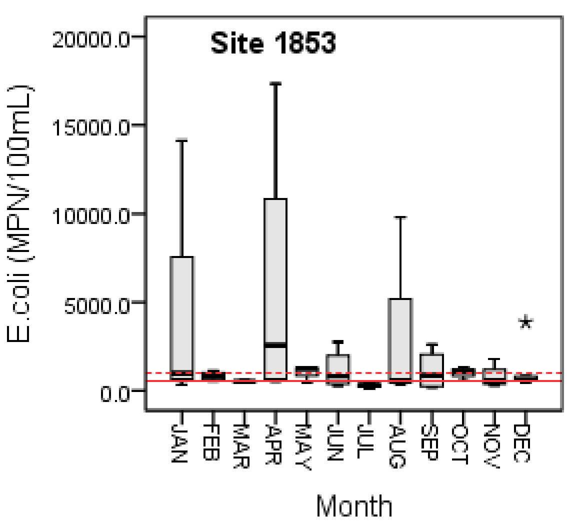

Site 2262
E.coli (MPN/100mL)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1468
E.coli (MPN/100mL)
25000.0
20000.0
15000.0
10000.0
5000.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1316
E.coli (MPN/100mL)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1848
E.coli (MPN/100mL)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1977
E.coli (MPN/100mL)
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1853
E.coli (MPN/100mL)
20000.0
15000.0
10000.0
5000.0
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month

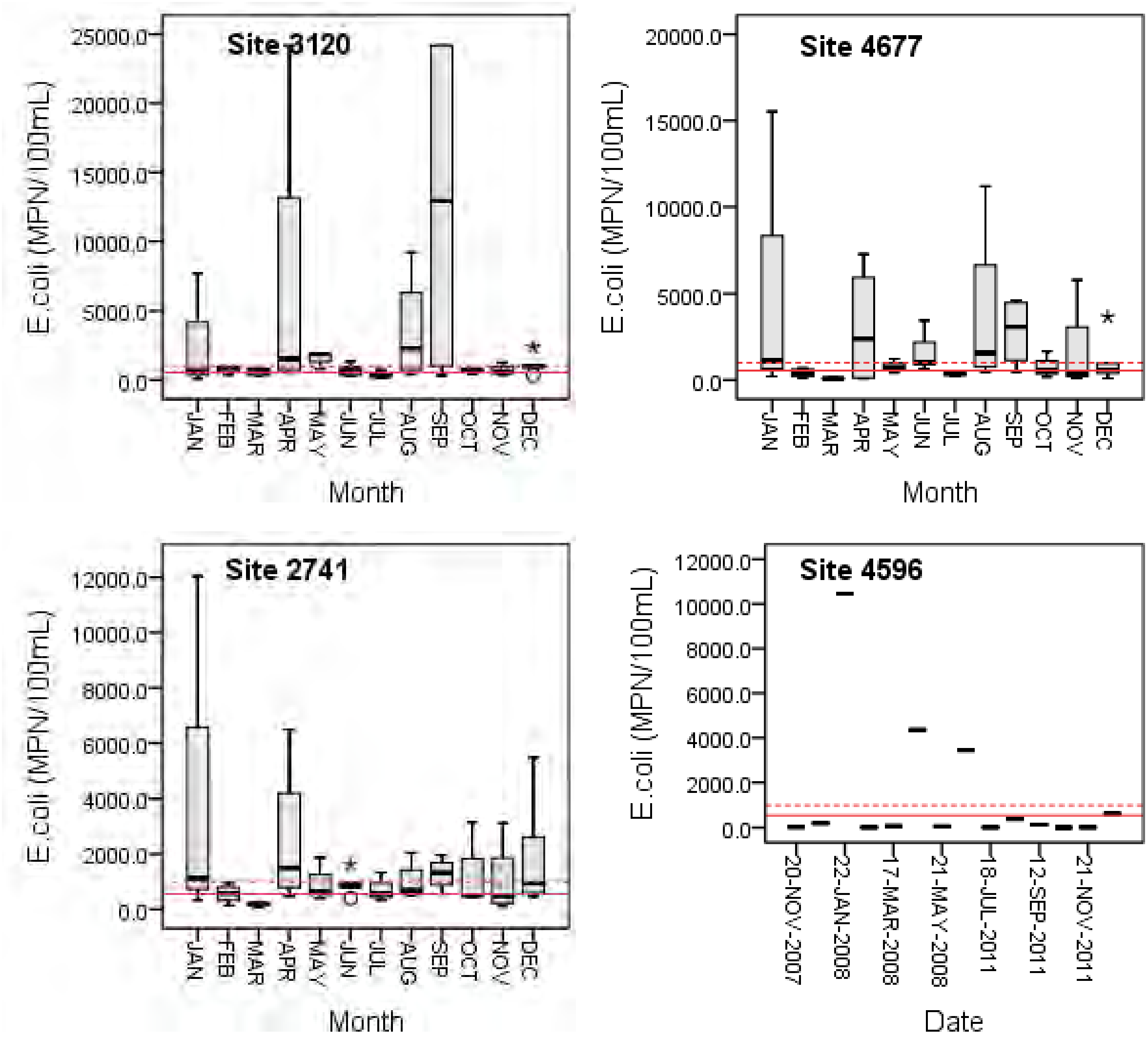


Figure 13 Seasonal box plot of E. coli concentration (MPN/100mL) for all sample sites. The red lines represent the recreational guideline (unbroken), and stock drink water guideline (dashed).

4.4 Water clarity, suspended sediments and turbidity

Water clarity measures how clear the water is. Poor water clarity compromises the river's suitability for swimming and can also impact on river ecosystems by reducing visibility for predators, e.g. wading birds or fish, and by reducing the light available for aquatic plants. Poor water clarity usually indicates that there are high amounts of sediment in the water. Sediments range in size from fine clays, silt and sand particles up to gravels. In a water quality context the fine clays and silts are of greatest concern. These sediments settle to the stream bed and can smother important habitat or irritate the gills of invertebrates and fish. Sediment in the water column is usually referred to as suspended sediment (SS), and measured as a concentration in mg/L.

Sediment may also carry other pollutants into water bodies. Nutrients and toxic chemicals such as heavy metals can attach to sediment and get carried into surface waters where they can settle with the sediment, or detach and become soluble in the water column. Rain washes silt and other soil particles off all surfaces, but particularly those where the vegetative cover has been disturbed. Consequently, soil erosion, and activities such as earthworks, vegetation clearance, and cultivation can result in sediment movement into surface water, particularly after heavy rainfall. Stock trampling in the bed of a stream or trampling the margins and banks can release large amounts of sediment into the water.

A water quality measure that is related to SS is turbidity. This quantifies the degree to which light travelling through water is scattered by the suspended particles present - the greater the amount of suspended material, the greater the light scattering and the higher the turbidity. The light-scattering particles can be both organic (e.g. algae and other plant or animal debris) or inorganic (e.g. fine silts or clays).

The water clarity guideline for ecosystem protection is that visibility should be greater than 0.6 meters (ANZECC 2000). The turbidity guideline value for ecosystem protection is that turbidity should be less than 5.6 NTU (ANZECC 2000). The results for suspended sediments can be found in the appendix although no ANZECC guideline exists for comparison.

Table 8 Median water clarity, range (in metres) and percent compliance with ANZECC guidelines for river sampling sites.

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	45	42	39	45	40	42	45	42	45	14
med	0.73	0.77	1.05	0.78	1.09	0.70	0.64	0.65	0.62	1.12
max	1.8	1.87	1.73	1.29	3.0	1.31	1.4	1.35	1.10	3.04
min	0.33	0.28	0.34	0.19	0.26	0.00	0.27	0.25	0.20	0.28
Within g-lines	32	28	35	34	35	28	27	25	23	11
% compliance	71	67	90	76	88	67	60	60	51	79

Table 9 Median water turbidity, range and percent compliance with ANZECC guidelines for river sampling sites.

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	43	43	42	43	38	43	43	42	43	11
med	13.7	15.2	8.35	10.2	8.9	13.0	17.0	13.9	14.9	7.0
max	65.0	90.0	54.0	57.0	129.0	95.0	158.0	90.0	89.0	44.0
min	5.7	3.6	3.8	4.4	2.3	6.2	5.5	4.4	5.9	2.7
Within g-lines	0	2	6	2	12	0	1	3	0	5
% compliance	0	5	14	5	32	0	2	7	0	45

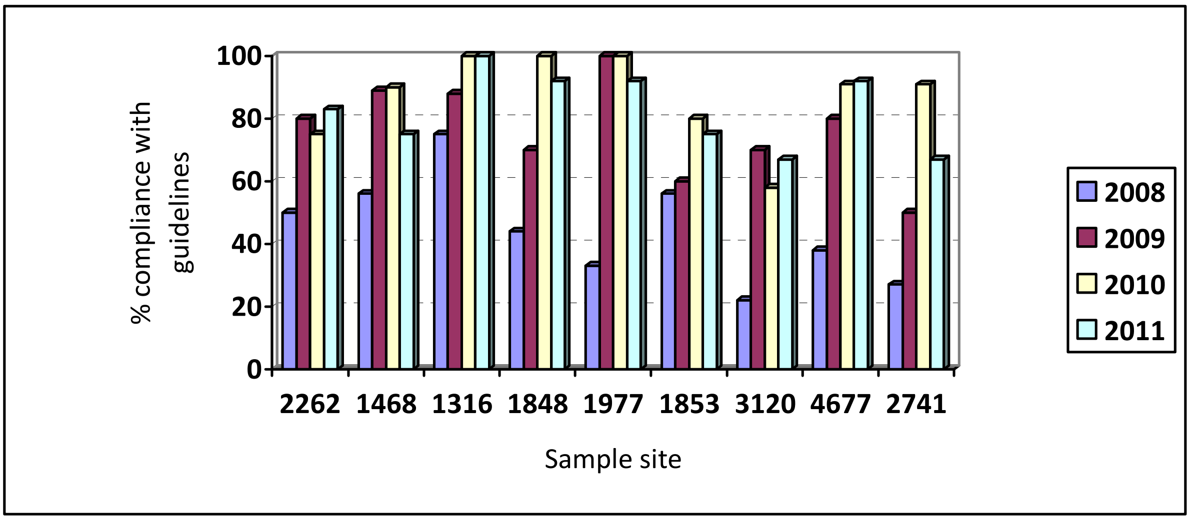


Figure 14 Annual clarity concentration % compliance with ANZECC Guidelines for all surface water sampling sites.

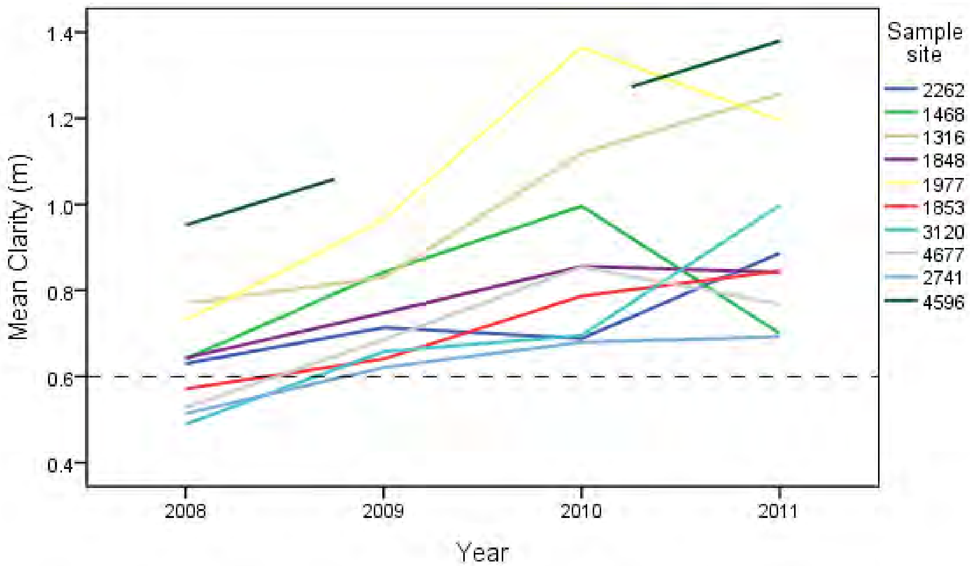
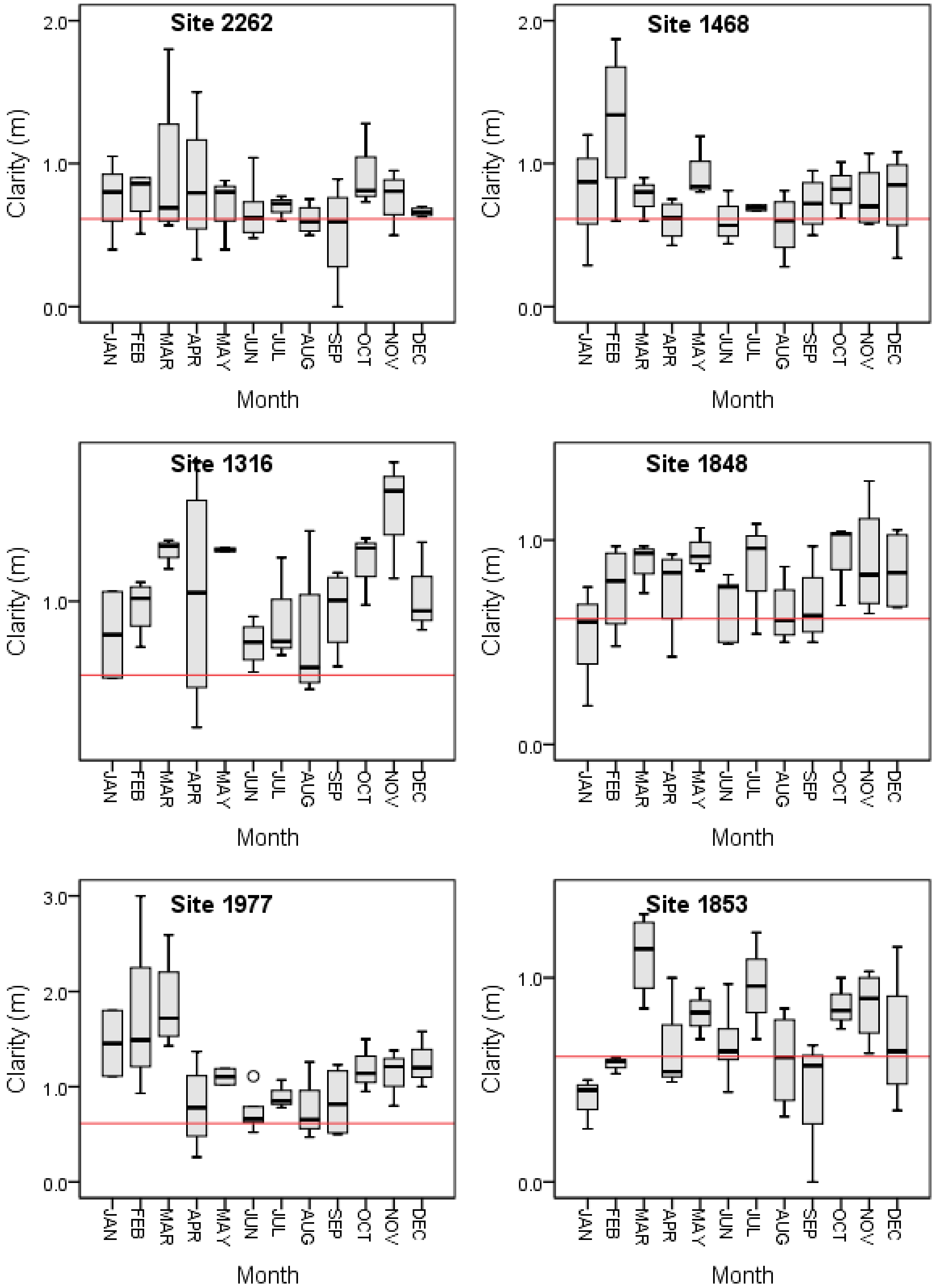


Figure 15 Annual mean clarity at all surface water sampling sites with ANZECC guideline (black dashed line).

Water clarity was the best performing water quality indicator in the Waipu Catchment with the lowest rate of compliance 51% on the Pohuenui River (site 2741) and highest compliance rate 90% on the Waiohoihoi River (site 1316). However, this result is in contrast with turbidity levels which have a lower compliance rate of 0% at three tributaries (2262, 1853, 2741). The highest rate after the Waipu River (45%) is the most upstream sites on the Ahuroa (1977) and Waiohoihoi (1316) at 32% and 14% respectively. This result supports personal observations in the field of high sediment loads, and for this reason turbidity seems a better indicator than clarity when assessing water quality in the Waipu Catchment.


Site 2262
Site 1468
Site 1316
Site 1848
Site 1977
Site 1853
Clarity (m)
Month
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
0.0
1.0
2.0
3.0

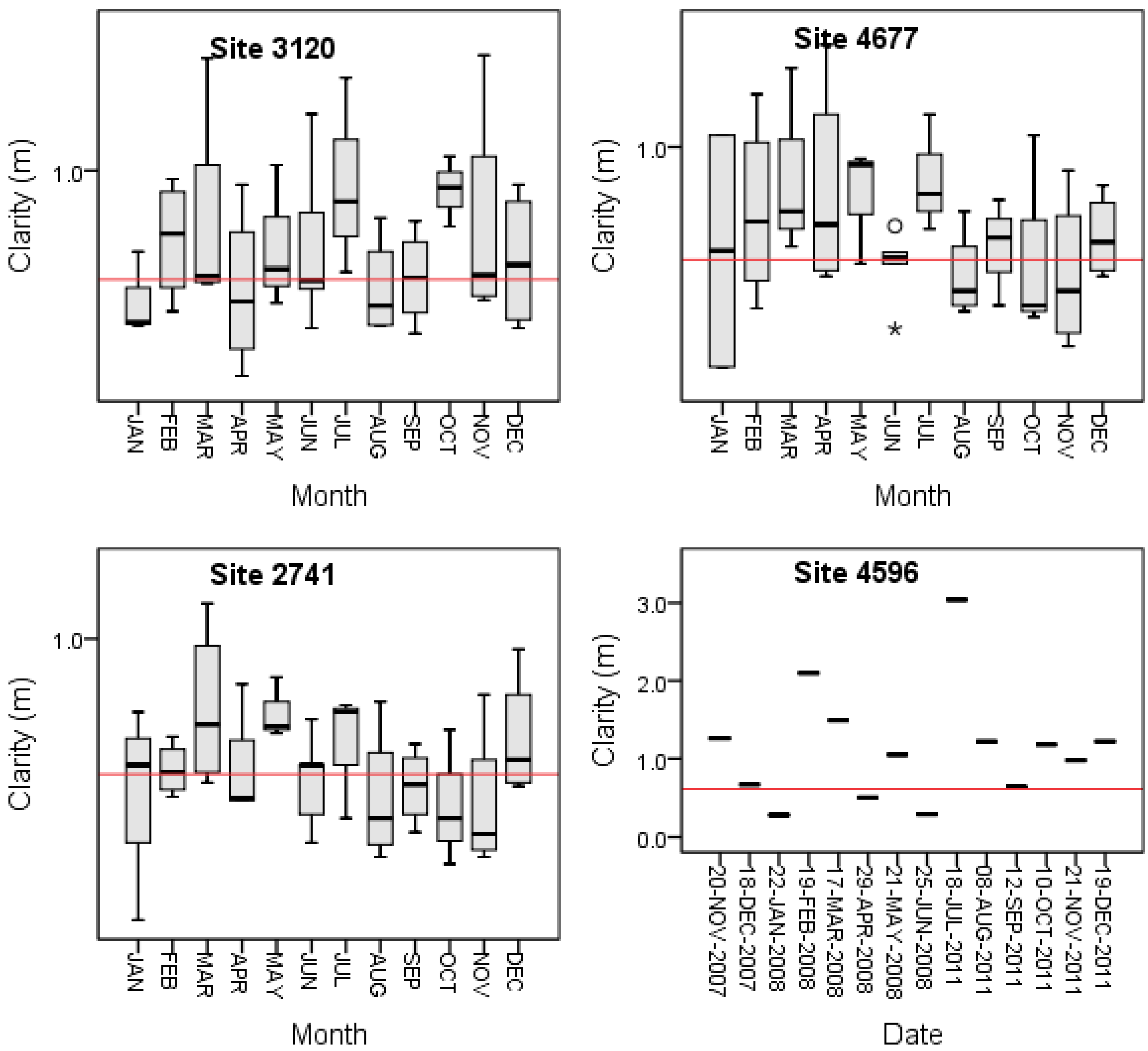


Figure 16 Seasonal box plot of water clarity (m) for all sample sites. The red lines represent the guideline value.

4.5 Dissolved Oxygen

Dissolved oxygen (DO) measures the amount of oxygen that is dissolved in water. Oxygen saturation is important in rivers and streams to sustain animals living in water. Insufficient oxygen in the water can suppress aerobic organisms such as fish. Deoxygenation increases the population of anaerobic organisms such as plants and some bacteria, resulting in fish kills and other adverse effects. In addition, when pollution such as sewage or rotting vegetation is present, bacteria breaks down the organic matter using oxygen in the process. Conversely, too much oxygen in the water (super-saturation) can also be detrimental to aquatic biota which in extreme cases can cause symptoms such as gas bubble disease in fish. Super-saturation oxygen conditions during the day are usually followed by low oxygen (anoxic) levels at night. Oxygen in water has a natural diurnal pattern that is driven by plant photosynthesis and respiration. Photosynthesis is driven by sunlight and produces free oxygen during the production phase (day), which increases DO during the day. During the respiration phase (night) of photosynthesis, algal, microbial, and plant respiration consumes free oxygen, which causes a decrease in DO and releases carbon dioxide during the night. Because visits to surface-water quality stations typically take place between 8 am and 2 pm, these variations generally are not observed unless continuous monitoring takes place. To avoid the detrimental effects of either too much or too little DO the ANZECC Guidelines have an upper and lower limit of 105% and 98%.

Table 10 Median dissolved oxygen, range (%) and percent compliance with ANZECC guidelines for river sampling sites

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	46	46	45	46	41	46	46	45	46	14
med	80.05	80.5	90.2	79.6	95.7	87.5	84.8	88.0	87.6	95.4
max	140.1	135.5	144.2	136.2	156.3	145.2	146.2	155.8	162.7	121.7
min	52.9	56.6	60.7	53.7	64.1	58.9	60.6	65.5	60.6	78.8
Within g-lines	0	0	0	1	12	3	1	1	0	5
% comp-liance	0	0	0	2	29	7	2	2	0	36

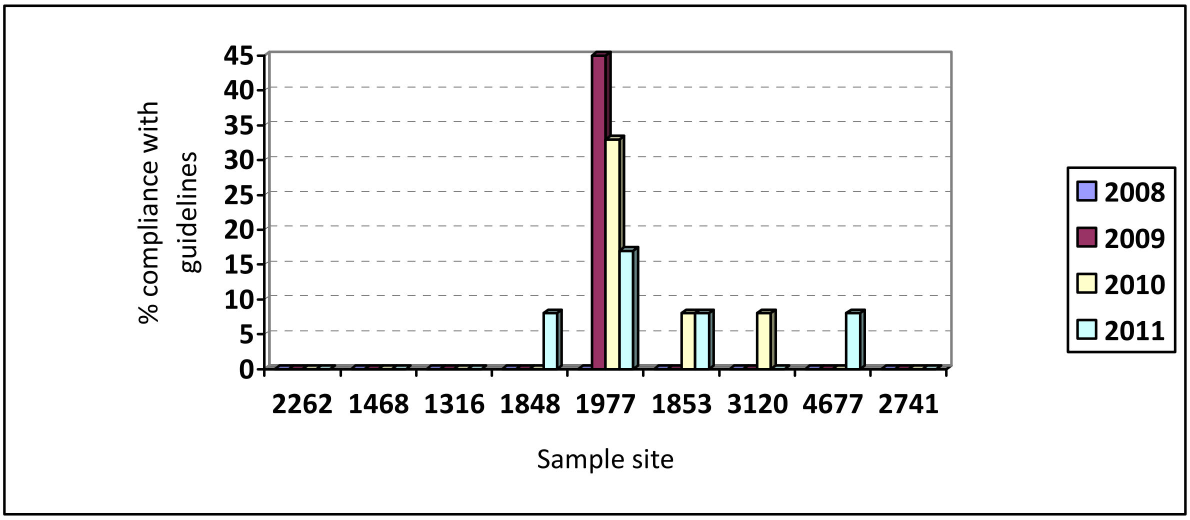


Figure 17 Annual DO concentration % compliance with ANZECC Guidelines for all surface water sampling sites

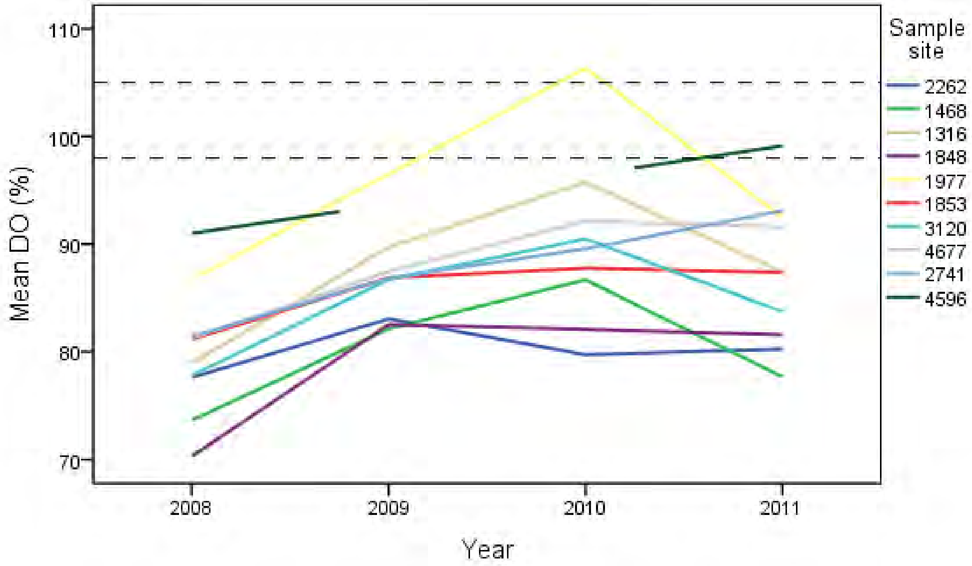
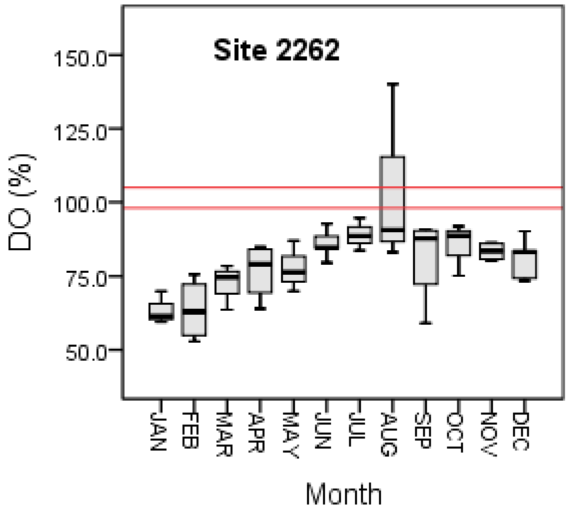
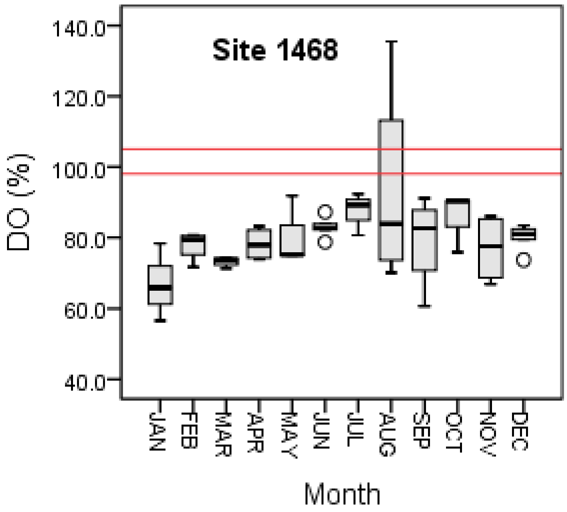


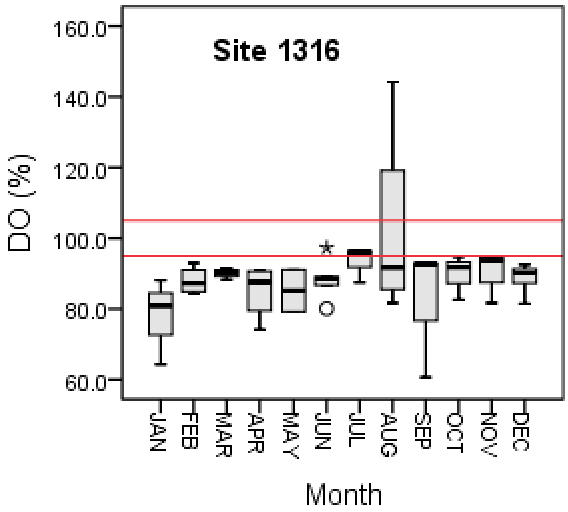
Figure 18 Annual mean dissolved oxygen concentration at all surface water sampling sites with ANZECC guidelines (black dashed line).

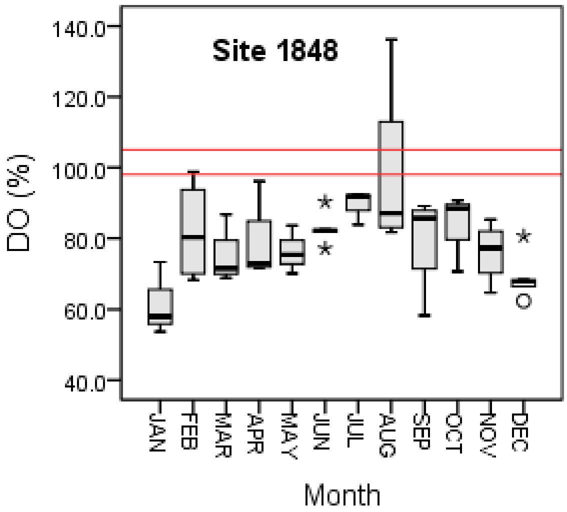
The Waipu Catchment has a very poor rate of compliance for DO levels. However, the results and their interpretation are complicated by a number of interacting factors. These include when the sample was taken with the majority collected in the morning when the cycle of photosynthesis has only just begun. This would skew the results lower overall. Other variables which effect DO levels are the amount of shade and temperature of the stream. This can influence plant growth with warmer temperatures increasing DO through more plant growth and thus photosynthesis, or conversely decrease DO due to the decomposition of organic matter. Another important factor is the amount of flow within a stream with greater flow generating higher DO through increased aeration and turbulence. This could explain the seasonal variation in DO levels observed at the sample sites. In general there are higher values in winter which correlates with increased flow and thus aeration of the water column.

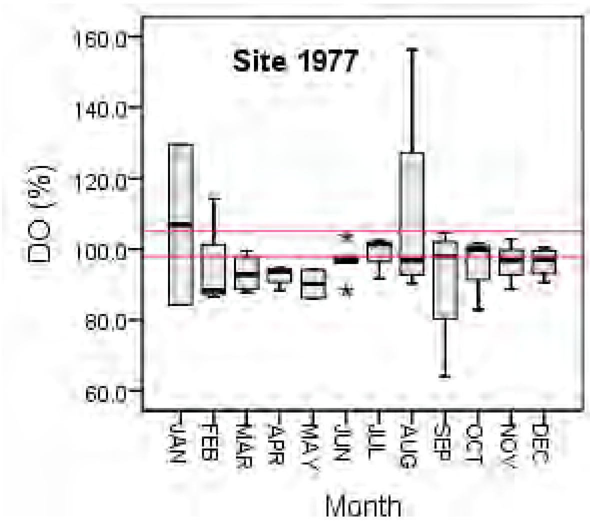
To determine diurnal patterns in DO requires continuous data which is not available for this catchment. However, dataloggers were deployed at two sites on the Mangahahuru Stream just north of Whangarei. The results from this study (NRC 2006) showed a clear diurnal cycle in DO with peaks between 3 and 4pm and lows between 6 and 7 pm. But more importantly it showed the differences between the two sites. The less impacted and shaded site had a smaller range with DO fluctuating by about 10% throughout the cycle, while the more impacted site had a much greater range of about 75%. This was most likely a result of large mats of oxygen weed at the impacted site, which produced copious amounts of oxygen during production (day time) phase of photosynthesis but consumes oxygen during the respiration (night time) phase of photosynthesis. Like the Mangahahuru Stream, the Waipu Catchment also has areas containing oxygen weed. This is of concern as extremes in dissolved oxygen levels as low as 52% saturation have been occurring in the early morning at some sites within the Waipu Catchment.

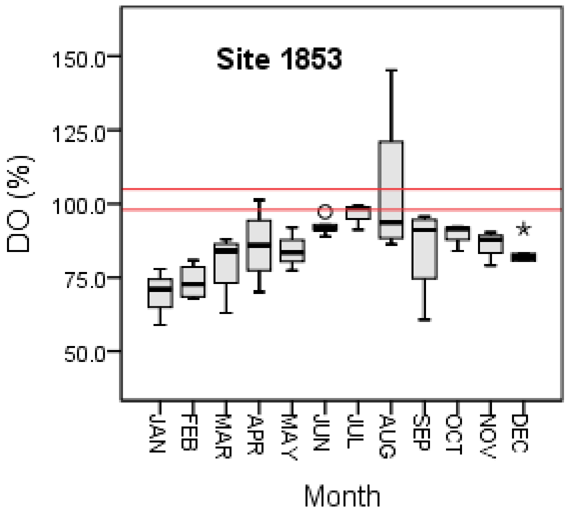

Site 2262
DO (%)
150.0
125.0
100.0
75.0
50.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1468
DO (%)
140.0
120.0
100.0
80.0
60.0
40.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1316
DO (%)
160.0
140.0
120.0
100.0
80.0
60.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1848
DO (%)
140.0
120.0
100.0
80.0
60.0
40.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1977
DO (%)
160.0
140.0
120.0
100.0
80.0
60.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


Site 1853
DO (%)
150.0
125.0
100.0
75.0
50.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month

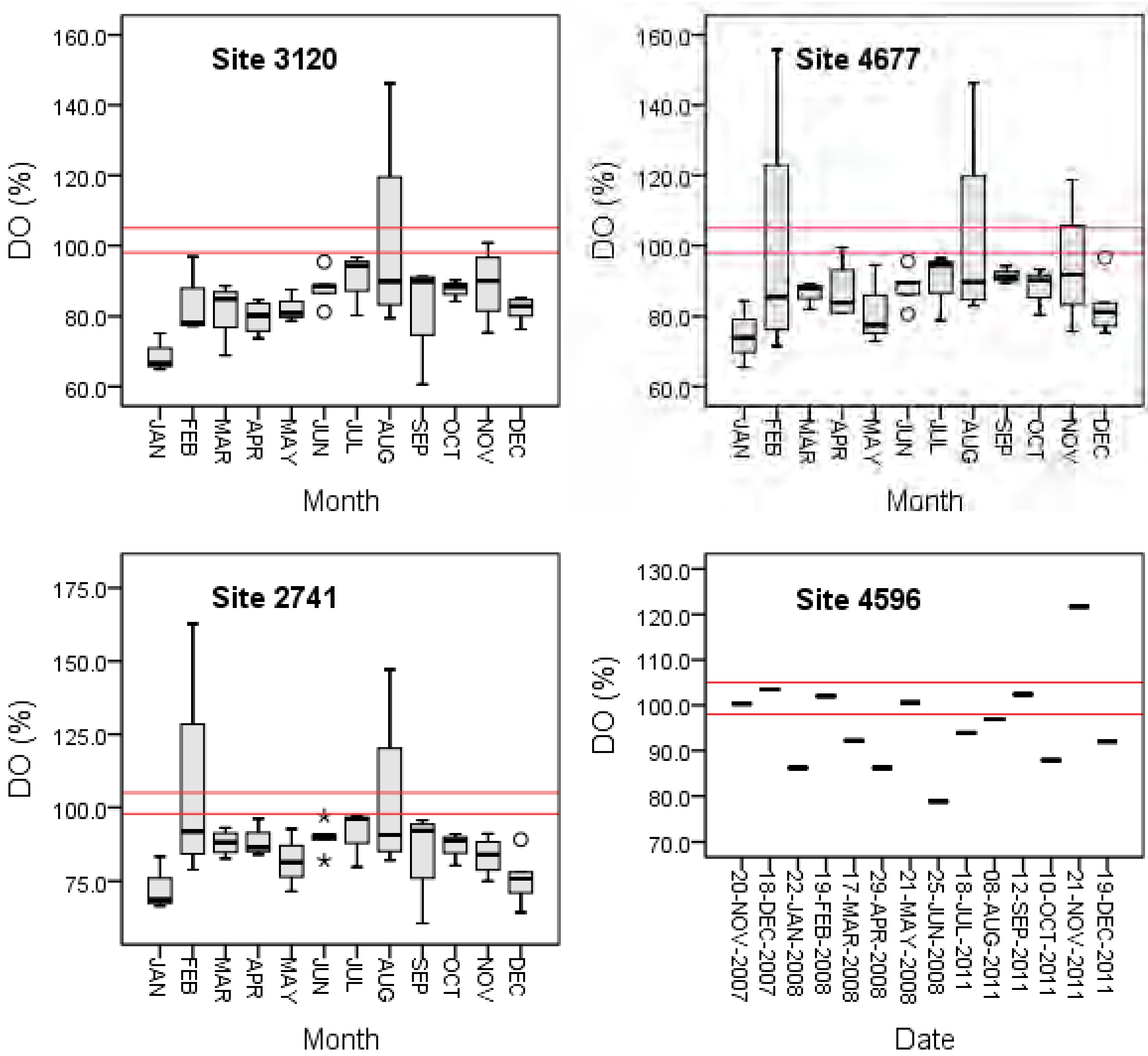


Figure 19 Seasonal box plot of dissolved oxygen concentration (%) for all sample sites. The red lines represent the guideline value.

4.6 pH

The acidity or alkinity of water is measured using the pH scale. The measurement uses the numbers 0 to 14 to indicate the degree of acidity or alkalinity of water. Organisms in Northland streams are generally comfortable living with pH between 6.5 and 9. Beyond that they will move away or die. On the scale, 0 is very strong acid, and 14 is very strong alkaline. Pure water is neutral, scoring 7 which is the middle of the pH scale. Vinegar has a pH level of 3, and lemon juice has a pH of 2. They are both acidic. The recommended guideline for lowland streams is that pH should range between 7.2 and 7.8 (ANZECC 2000). In general the pH of Waipu tributaries is slightly acid while the Waipu River is slightly alkaline. All pH readings apart from the outlier for site 1977 are within the comfortable range for Northlands freshwater organisms.

Table 11 **Median pH, range (%) and percent compliance with ANZECC guidelines for river sampling sites**

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	46	50	45	46	41	46	46	45	46	14
med	7.1	7.2	7.1	7.0	7.3	7.1	6.9	7.3	7.4	8.0
max	7.9	7.8	7.9	7.8	8.4	7.7	7.7	7.9	8.1	8.6
min	6.4	6.4	6.4	6.4	3.8	6.4	6.3	6.5	6.8	7.0
Within g-lines	11	26	11	14	24	18	3	22	30	3
% comp-liance	24	52	24	30	59	39	7	48	65	21

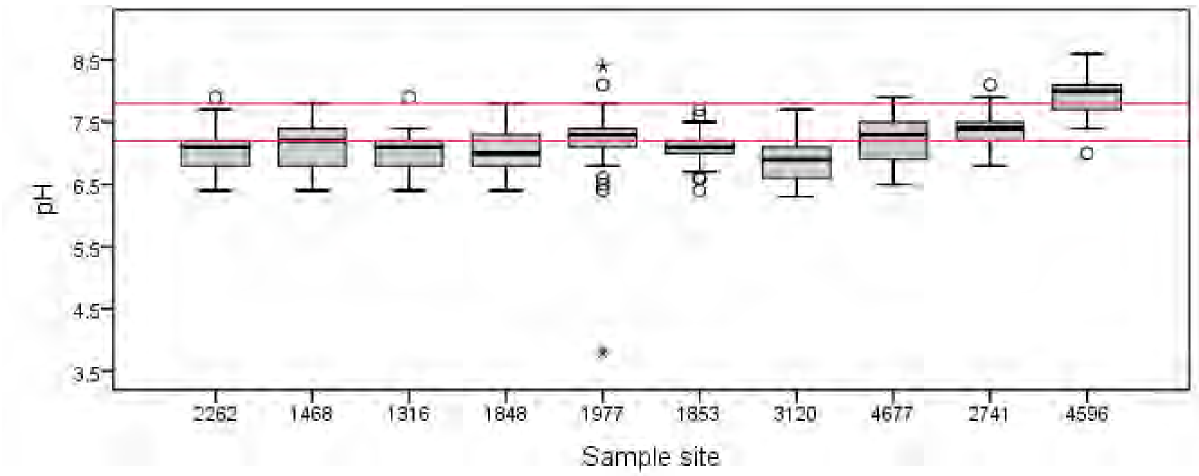


Figure 20 pH of all river sample sites. The red lines represent the guideline.

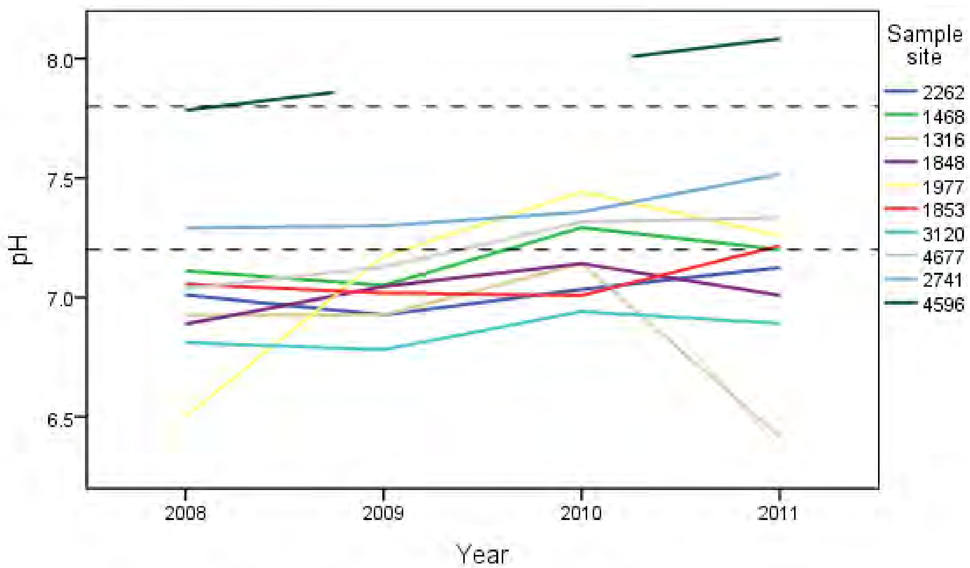


Figure 21 Annual mean pH at all surface water sampling sites with guidelines (Dashed black line).

4.7 Water temperature and Conductivity

Water temperature is controlled by several factors such as channel shading and riparian vegetation, seasonal and annual climates, daily temperatures and sunlight hours, stream flow, river depth and width. Shallow slow moving exposed steams tend to have much higher temperatures than deeper, shaded fast moving streams. The temperature of water is not only important for recreation, it affects both the surface appearance of rivers and more importantly, the aquatic life they support.

The conductivity of water is a measure of its ability to conduct electricity. In many cases, conductivity is linked directly to the total dissolved solids. High quality distilled water has a conductivity of about 0.0055 mS/m, typical drinking water in the range of 5-50 mS/m, while sea water about 5000 mS/m. Subsequently, conductivity is commonly used as a general indicator of water pollution (e.g. high TN, TP and turbidity, and low water clarity).

There are no guidelines for either water temperature or conductivity. Results have therefore been compared to results for other monitoring programs around Northland and throughout New Zealand.

Table 12 Median, maximum and minimum (°C) water temperature for river sampling sites

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	46	52	45	46	41	46	46	45	46	14
med	15.4	17.5	15.0	16.7	15.0	16.2	15.4	17.8	17.9	18.5
max	22.3	24.9	21.4	24.7	24.5	23.0	24.9	26.2	28.0	22.4
min	9.5	10.4	9.1	9.5	9.0	9.5	10.2	10.0	10.3	11.6

Water temperature amongst the sampling sites conforms with the other general trends with the cooler medians (15°C) associated with the better performing headwater sites (1316, 1977). In contrast, the remaining downstream sites have slightly higher temperatures with medians ranging betweeen 15.4 - 18.5°C (Table 12). The headwater sites have greater shading than the downstream sites which would explain the slight changes in temperature. Both the median water temperatures and range are comparable to other lowland rivers in Northland (NRC 2010) and elsewhere in New Zealand (TRC 2009; ORC 2007). All sites display a pattern of seasonal variation with water temperature higher during summer monthes when air temperature is higher, and rainfall and streamflow generally lower, and lowest in winter when air temperature is lower and rainfall and streamflow are higher as seen in Figure 24.

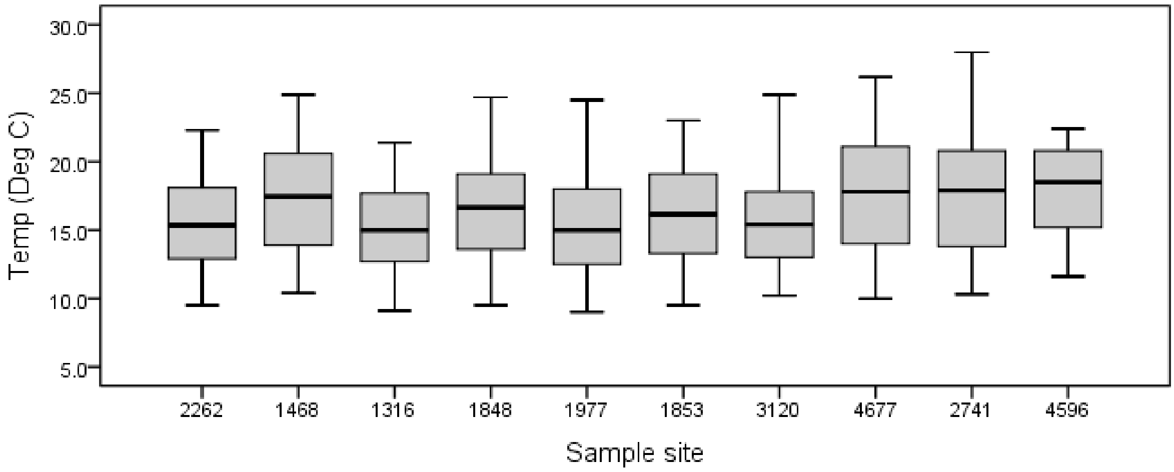


Figure 22 Median water temperature and range of values for all sampling sites.

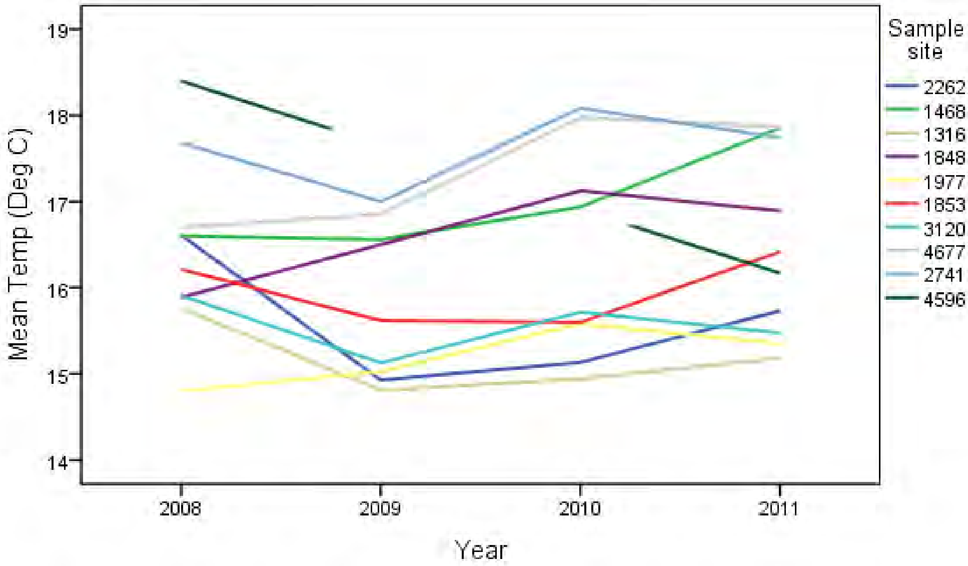


Figure 23 Annual mean water temperature at all surface water sampling sites.

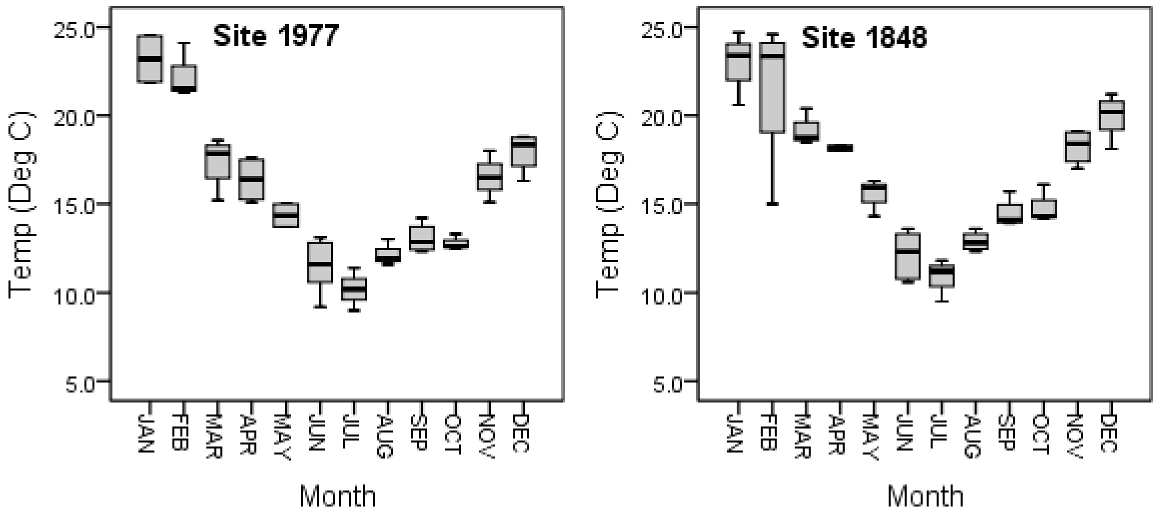


Figure 24 Seasonal box plot of water temperature on the Ahuroa River from sample sites 1977 and 1848.

Table 13 Median, maximum and minimum electrical conductivity for river sampling sites

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	46	47	45	46	41	46	46	45	46	14
med	17.5	698.4	14.0	292.7	14.8	15.95	15.1	332.6	337.0	3197.0
max	20.0	4396.1	18.7	2570.9	17.4	998.3	181.4	3471.5	3263.7	5090.2
min	9.8	3.0	8.6	3.1	11.4	10.8	4.7	15.9	18.6	174.0

Table 13 displays the median , minimum and maximum electrical conductivity at the sampling sites. Of the 10 sites sampled, 6 are brackish (1468, 1848, 1853, 4677, 2741, 4596) and thus have high conductivity values due to the influence of salt water. Median conductivity values at the remaining four sites (2262, 1316, 1977, 3120), range from 14.0 to 17.5 mS/m which falls within the typical drinking water range of 5-50 mS/m.

4.8 Microbial source tracking

Samples were analysed for faecal sterols, FWAs and PCR markers by the Institute of Environmental Science & Research Ltd (ESR). None of the results were consistent with human or wildfowl sources. All 6 samples from each tributary into the Waipu were highly consistent with a ruminant source of sterols, with all three ratios positive (Table 14). PCR samples reported as up to 100% ruminant are consistent with all the general faecal markers having come from a ruminant source. The lower levels reported (10-50%) may be a consequence of the presence of other sources of pollution, or in fact ruminant sources may still account for all the pollution, but this may include aged faecal material where relative levels of the ruminant marker decline more rapidly than the general indicator. The levels detected in these samples are consistent with ruminant dominant sources of pollution – for comparison, if ruminant pollution was a minor contributor, values of 0.1% or 1% would be observed. Although all samples analysed were consistent with ruminant, a total of 3 separate samples from each site would help confirm these results.

Table 14 Results of microbial source tracking.

Date	Site	PCR marker	Sterols
12/09/11	4677 - Ahuroa River @ Shoemaker Rd Bridge	Ruminant (up to 10%)	Ruminant
8/08/11 12/09/11	1468 - Waionehu Stream @ Boat Jetty 1468 - Waionehu Stream @ Boat Jetty	Ruminant (up to 100%) Ruminant (up to 50%)	Ruminant Ruminant
8/08/11 12/09/11	1848 - Waihoihoi River @ Waipu Reserve 1848 - Waihoihoi River @ Waipu Reserve	Ruminant (up to 10%) Ruminant (up to 50%)	Ruminant Ruminant
12/09/11	2741 - Pohenui River @ Connel Rd Bridge	Ruminant (up to 100%)	Ruminant

5 Summary of results

Table 15 summarises the percentage compliance with guidelines for the different environmental parameters at each sample site. Where no guideline is available the median value is listed. The results below show that the Waipu Catchment is heavily impacted and fails to meet the majority of relevant guidelines. The best performing parameter was water clarity, although water turbidity (a similar measure) seemed to contradict this. Total nitrogen (TN), Total phosphorus (TP), and E.coli were all well above recommended guidelines. Dissolved oxygen was often below recommended guidelines although there are issues regarding the diurnal fluctuations in DO and the time when sampling takes place (discussed in section 4.5). The percentage compliance with pH often dropped below the 7.2-7.8 range with most samples being slightly acidic. However this is still in the comfortable range of most aquatic organisms. These results are similar to other highly modified catchments in Northland such as the Lower Awanui, Mangere, and Mangonui Rivers.

Table 15 % compliance with guideline values for NZ lowland rivers over the sampling periods. Note: Where no guideline is available the median value is listed.

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
TN	46	33	71	52	59	43	43	40	33	50
TP	2	0	24	2	37	0	0	4	2	43
E.coli	28	35	84	41	66	41	30	49	38	71
Clarity	71	67	90	76	88	67	60	60	51	79
Turbidity	0	0	0	2	29	7	2	2	0	36
DO %	24	52	24	30	59	39	7	48	65	21
pH	15.4	17.5	15.0	16.7	15.0	16.2	15.4	17.8	17.9	18.5
Temp*	17.5	698.4	14.0	292.7	14.8	15.95	15.1	332.6	337.0	3197.0
COND*	8.5	14.0	5.0	9.0	4.0	8.0	8.0	13.0	14.5	12.5
SS*	2	0	24	2	37	0	0	4	2	43

* Median value

Water quality within the Waipu Catchment is influenced by antecedent soil moisture with the wetter months of winter and spring generally having poorer water quality due to increased runoff. Overall water quality at all sample sites was generally poor however the upstream sites were slightly better than downstream sites. The best performing tributaries of the Waipu River was the Waiohoihoi and Ahuroa rivers, followed by the Waionehu and Pohuenui rivers. Overall there was little difference between rivers due to the similar land use ratios of small amounts of indigenous/plantation forestry in catchments dominated by intensive pastoral farming. Although there are consents to discharge sewage to land, it is likely the majority of pollutants are related to pastoral farming as supported by microbial source tracking (Section 4.8).

This poor compliance with guidelines is consistent with findings at a national level. In 2010 the Ministry for the Environment released a report on national river water quality (Ballantine et al. 2010). This report provided a snapshot of river water quality within New Zealand over the period 2003-2007, with trend analysis from 1998-2007. The report concluded that there were clear differences in water quality based on land-use and topography. Water quality was most impacted in low-elevation source-of flow rivers and pasture and urban environments (Ballantine et al. 2010).

Annual compliance with relevant guidelines across all parameters has improved since 2008 to 2010, although compliance rates fell again in 2011. Although some of the improvements could be attributed to better land management, the majority can be explained by the drought Northland experienced over the period from November 2009 to May 2010. Subsequently, at least half of the samples for 2010 were taken during drought conditions. With less rainfall-runoff during the drought fewer nutrients would have been delivered to the rivers and streams. Similar improvements in water quality were observed right across Northland (NRC 2010b). While increasing compliance with ANZECC guidelines is encouraging, overall compliance is low and ongoing catchment management is required to improve water quality.

6 Recommendations

- Undertake a site investigation at 2262 (Waionehu Stream @ McLeans Road) and 1316 (Mill Brook @ Millbridge Road) to identify the source of poor water quality.

- In areas identified as a source of pollution, engage with local landowners to implement 'best practice' land management techniques such as farm management plans, riparian buffer strips and fencing.

- Reinstate the monitoring program once the above land management measures have been implemented. Land owners and stakeholders should be made aware that there may be a lag between changes in land management and improvements in water quality as the "best practice" management techniques take time to have an effect.

7 References

APHA (1998). Standard methods for the Examination of water and Wastewater, 20th edition. American Public Health Association: 1015 15th Street NW, Washington, DC 2005-2605.

ANZECC (2000). Australian and New Zealand Environment and Conservation Council. Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality management Strategy, Australia and New Zealand Environment and Conservation Council , Canberra.

MfE (2002). Freshwater Microbiology Research Programme: Pathogen Occurrence and Human Health Risk Assessment Analysis. Ministry for the Environment and Ministry of Health, Wellington, New Zealand.

MfE, MoH (2003). Microbial Water Quality Guidelines for marine and Freshwater Recreational Areas. Ministry for the Environment and Ministry of Health, Wellington, New Zealand.

NRC (1995). Waipu Catchment Water Quality Survey 1995. Whangarei, New Zealand: Northland Regional Council.

NRC (2006). Northland River Water Quality Monitoring Network: 2006 State and Trends. Whangarei, New Zealand: Northland Regional Council.

NRC (2010a). Field Monitoring Procedure Manual. Whangarei, New Zealand: Northland Regional Council.

NRC (2010b). Annual Monitoring Report 2009-2010. Whangarei, New Zealand: Northland Regional Council.

NRC (2011a). Northland River water Quality Monitoring Network: State and Trends 2010. Whangarei, New Zealand: Northland Regional Council.

NRC (2011b). Recreational swimming water quality in Northland: Summer 2010-11. Whangarei, New Zealand: Northland Regional Council.

ORC (2007). State of the Environment Report 2007 - Surface Water Quality in Otago. Dunedin, New Zealand: Otago Regional Council.

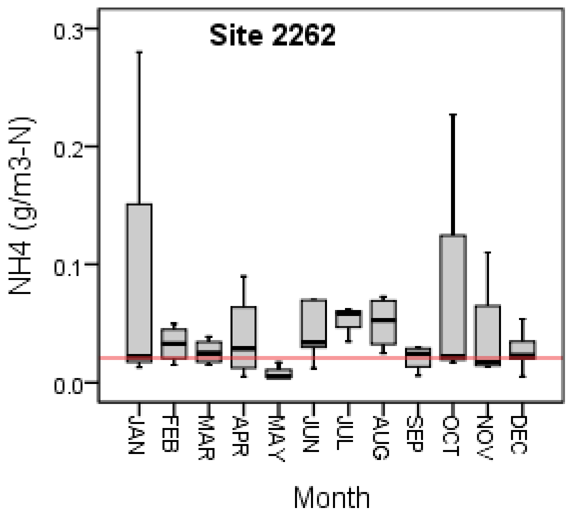
TRC (2009). State of the Environment Report 2009 - Taranaki: Where We Stand. Stratford, New Zealand: Taranaki Regional Council

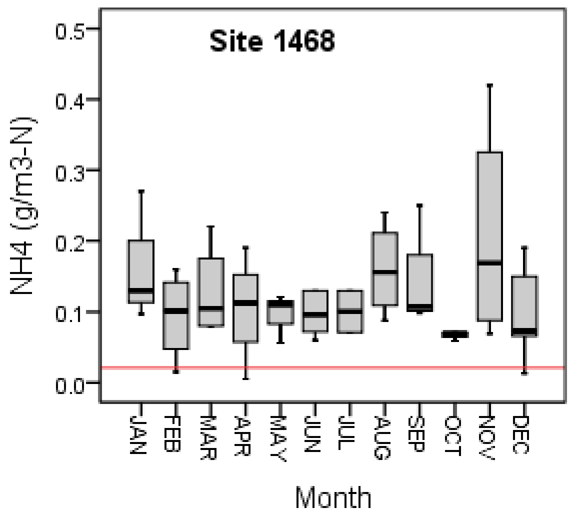
Appendices

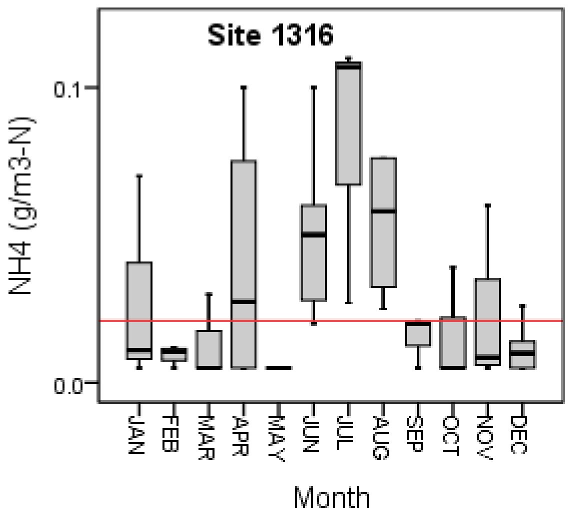
A Ammoniacal Nitrogen

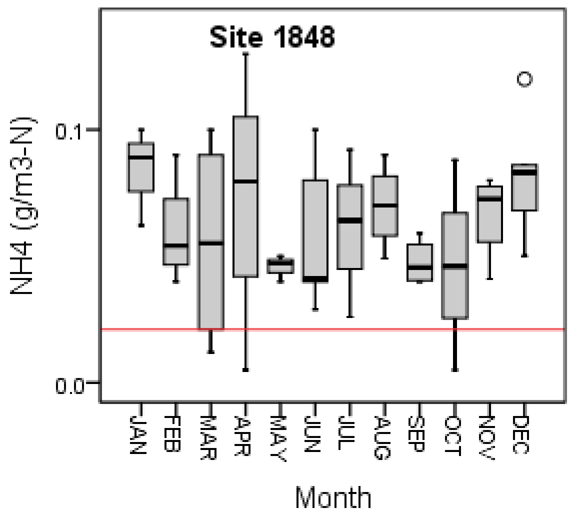
Table 16 Median Ammoniacal Nitrogen (NH4) concentration, range and percent compliance with ANZECC guidelines for river sampling sites. Note ANZECC guideline for NH4 is < 0.021 g/M^3-N.

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	2262	1468	1316	1848	1977	1853	3120	4677	2741	4596
Samp. sz	46	45	45	46	41	46	46	45	46	14
med	0.027	0.11	0.014	0.063	0.013	0.035	0.030	0.050	0.080	0.070
max	0.280	0.420	0.110	0.130	0.060	0.096	0.310	0.180	0.940	0.390
min	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.003
Within g-lines	17	3	26	3	27	8	16	5	2	4
% compliance	37	7	58	7	66	17	35	11	4	29









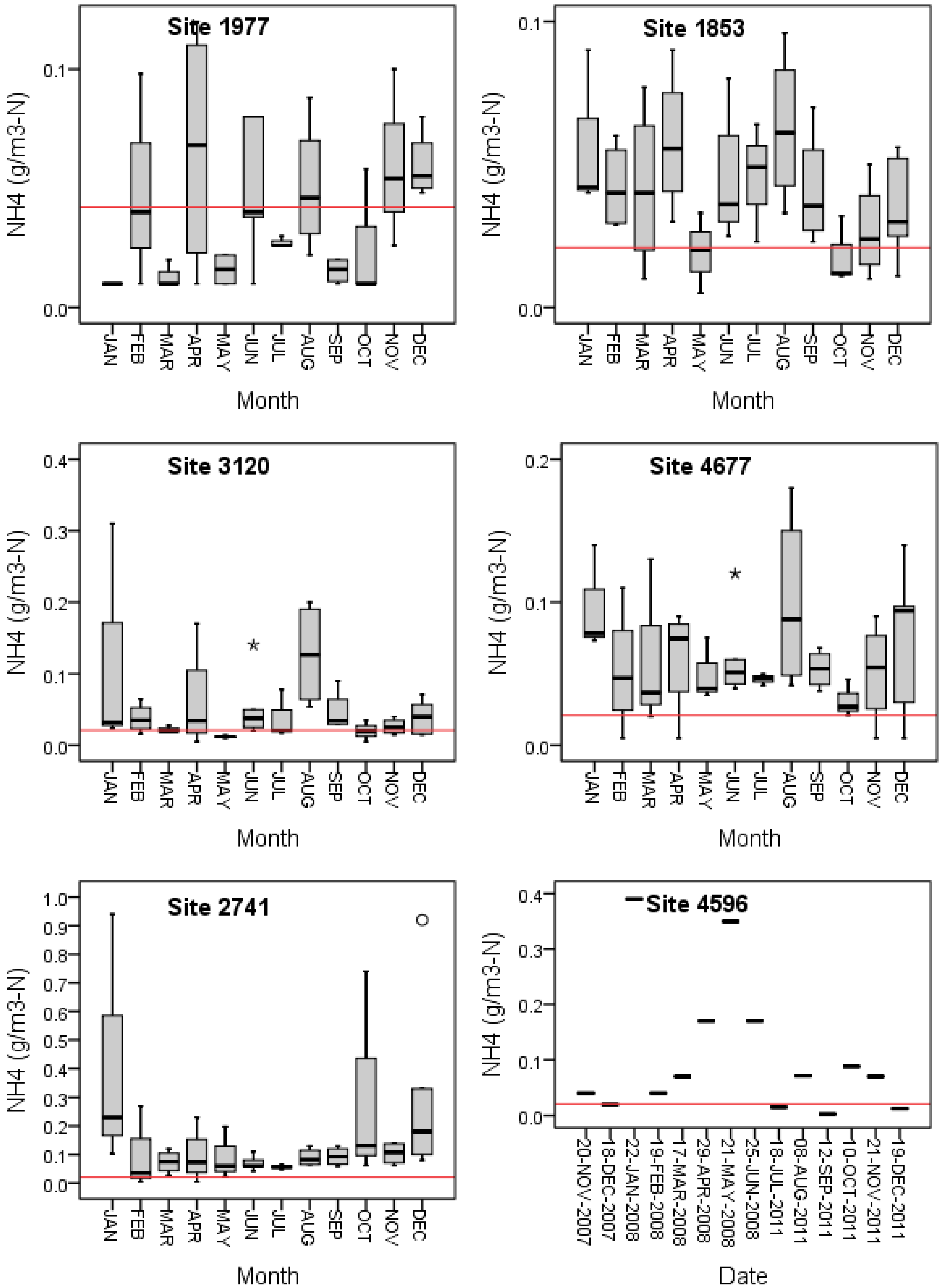
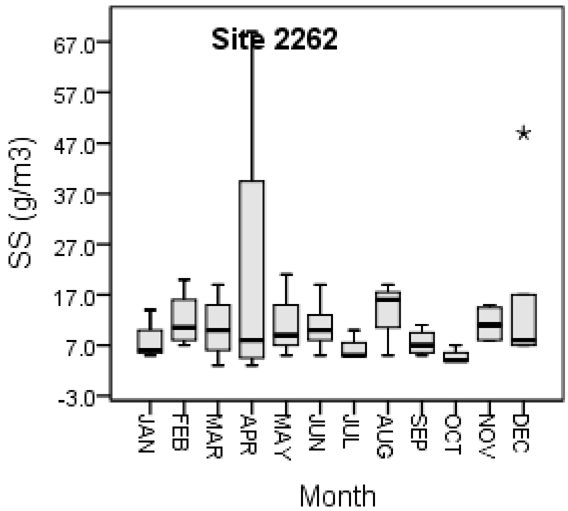


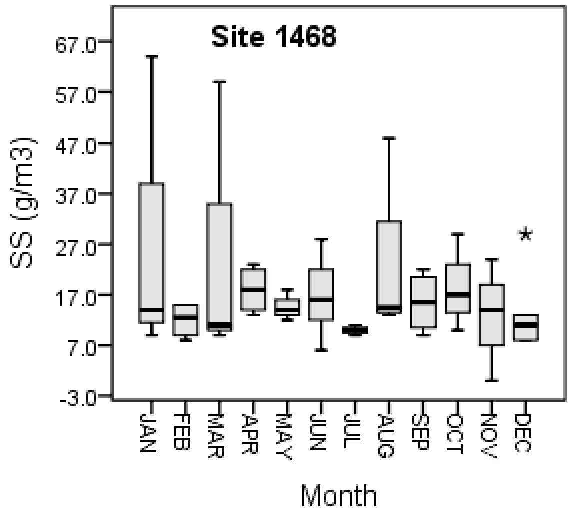
Figure 25 Seasonal box plot of TKN concentration (g/m3-N) for all sample sites. The red line represent the guideline value.

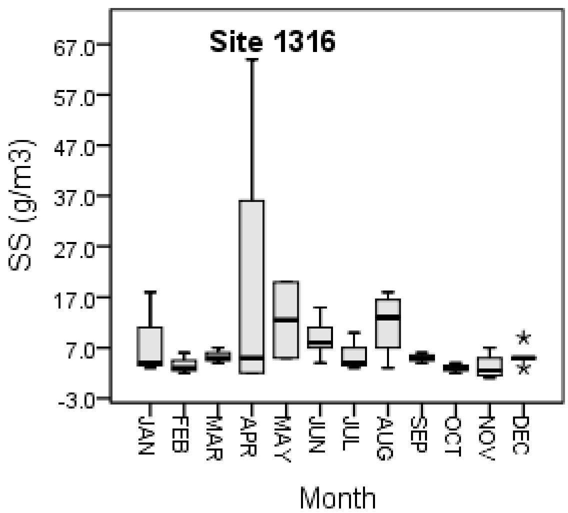
B Suspended Solids

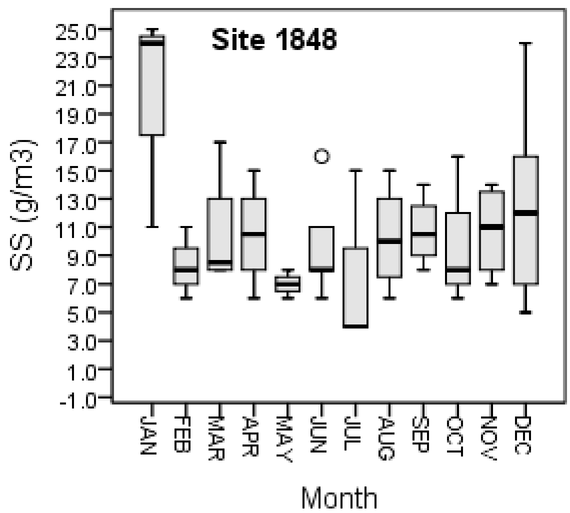
Table 17 Median, maximum and minimum suspended solids for river sampling sites

RIVER	Waionehu		Waiohoihoi		Ahuroa				Pohue-nui	Waipu
SITES	**2262**	**1468**	**1316**	**1848**	**1977**	**1853**	**3120**	**4677**	**2741**	**4596**
Samp. sz	46	45	45	46	41	46	39	45	46	14
med	8.5	14.0	5.0	9.0	4.0	8.0	8.0	13.0	14.5	12.5
max	69	64	64	25	125	71	126	110	89	72
min	3	0	1	4	1	4	1	5	5	6









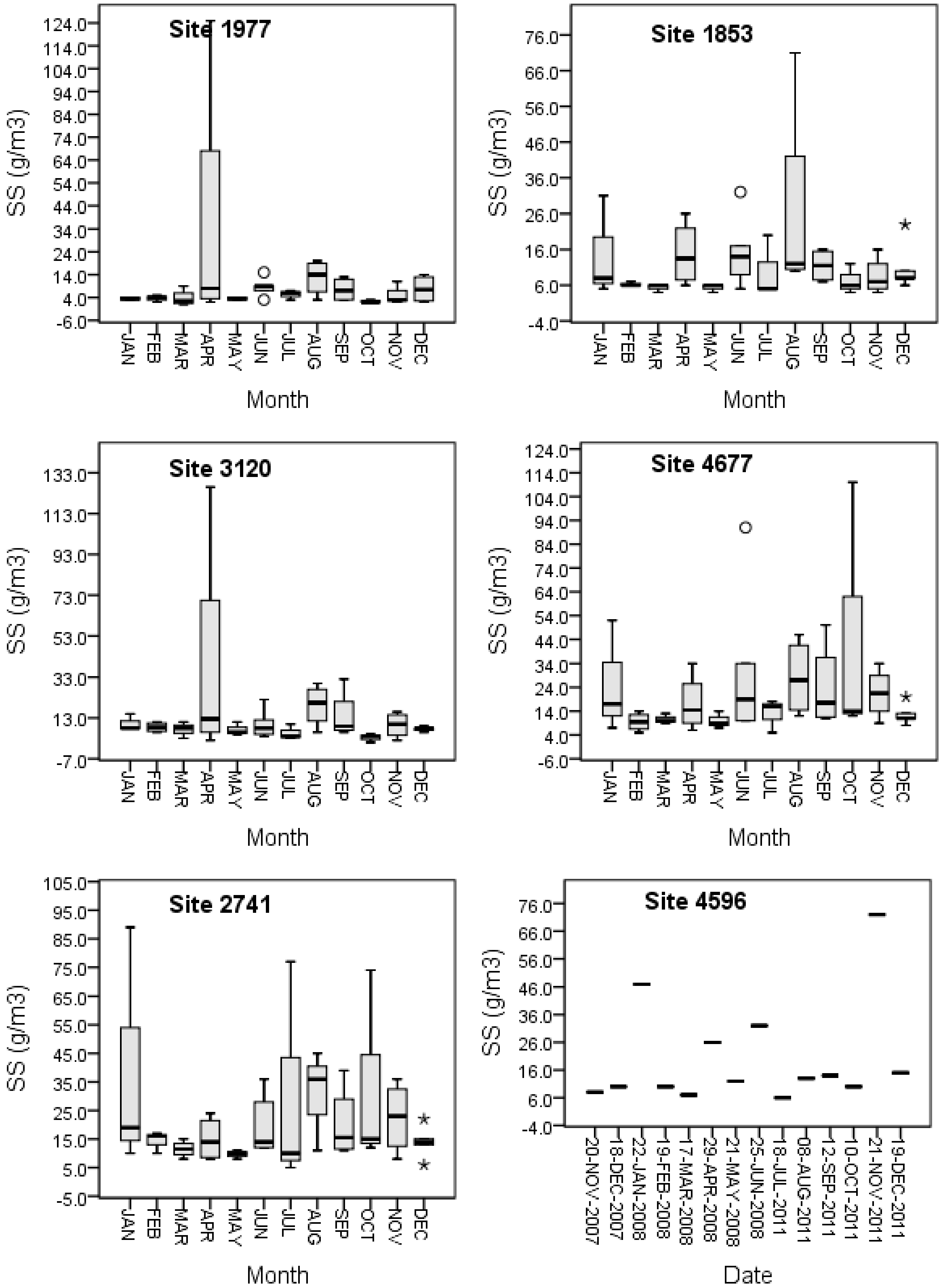


Figure 26 Seasonal box plot of SS (g/m3) for all sample sites.