Freshwater Periphyton Monitoring Programme (Periphyton monitoring in relation to amenity values) State of Environment Monitoring Report 2014-2016

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Executive summary

Section 35 of the Resource Management Act requires local authorities to undertake monitoring of the region's environment, including land, air, and fresh and marine water quality. The Taranaki Regional Council began monitoring for nuisance periphyton in the 2002-2003 monitoring year. This report summarises the results of the State of the Environment periphyton programme for the monitoring period 2014/2016.

Periphyton is a mixture of algae and cyanobacteria that naturally occurs in rivers and streams. It plays a fundamental role in stream ecosystem functioning by utilising sunlight via photosynthesis and providing a food source for invertebrates which in turn provide food for other organisms such as fish and birds. Nuisance periphyton in the form of prolific thick mats, pervasive long filaments or cyanobacteria can cause a range of issues such as streams becoming un-inviting for recreational users, anglers having difficulty fishing, streams closures due to cyanobacteria toxins and adverse impacts on stream ecology.

This freshwater periphyton programme has been designed to monitor for the presence and biomass of 'nuisance' algae in Taranaki streams and rivers at levels which may affect the instream values of these streams i.e., aesthetic values (contact recreation and landscape values), biodiversity values, and those values linked to Maori culture and tradition.

Twenty-one sites are surveyed each year in 10 catchments around the Taranaki Region. Sites were chosen to be representative of different catchment types such as high conservation, agriculture, riparian and major abstraction. Most rivers or streams had one upper (mostly un-impacted) site, and one or two lower sites (with various degrees of land use impact).

The Hangatahua (Stony) River and Maketawa Stream were selected for their high conservation values. The Manganui, Patea and Waiwhakaiho Rivers, and the Mangaehu River were chosen as examples of waterways with large catchments and /or multiple human impacts. The Waingongoro River was included in the programme as a river under intensive usage and the Waiongana Stream as a stream from which there is a major water abstraction. The Punehu Stream was included as a stream within a primarily agricultural catchment and the Kapoaiaia Stream as a western Taranaki stream targeted for riparian planting initiatives.

Periphyton surveys were scheduled for two times per year, spring (15 September to 31 December) and summer (1 January to 15 April). Sampling was always carried out after an extended period of low flow of at least 10 days since a fresh of 3x median base flow (i.e. after sufficient time for excessive growths to establish). At each site, ten random assessments were made across the stream using a periphyton viewer. Types of periphyton cover on the stream bed within each square were estimated visually as percentage coverage on the substrate; types being one of a range e.g. thin, medium and thick films of mats and short and long filaments. The colour of the growth (brown, black, or green) was also recorded. Additionally, during the summer period periphyton samples were collected from ten rocks randomly selected at each site and levels of chlorophyll *a* pigment analysed in a laboratory to determine periphyton biomass.

The New Zealand Periphyton Guidelines, established by the Ministry for the Environment (Biggs, 2000), provide a reference at which point growths of periphyton exceed the recreational guideline. This point is exceeded when at least 30% of the bed is covered by filamentous algae and/or at least 60% of the bed is covered by thick mats of algae. A TRC specific periphyton index score derived from the standard periphyton index score (Biggs et al., 1998) was also calculated from the periphyton cover data and scores converted into one of five grades.

Chlorophyll *a* was used to estimate the amount of live periphyton biomass over two summers. Guidelines for chlorophyll *a* were established by the Ministry for the Environment (Biggs, 2000). The National Objectives Framework (NOF) (MfE, 2014) also uses chlorophyll *a* to assign bands to rivers and streams. There is a Government-imposed requirement to ensure streams and rivers are above the D band (chlorophyll *a* 200 mg/m^2) from 2025 onwards. The Council's long-established chlorophyll *a* sampling protocol differs from that established more recently for the NOF guideline and therefore results cannot be directly translated to NOF bands.

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton for all sites and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

The results for the SEM nuisance periphyton programme during the 2014/2015 monitoring year showed that five sites breached nuisance periphyton guidelines at some time. No sites breached the guideline for thick mats, but 5 out of 21 sites surveyed breached the guidelines for long filaments. For the 2015/2016 monitoring year 4 sites breached nuisance periphyton guidelines. One site breached each of the thick mat and long filament guidelines on one occasion for each, while three other sites breached only the long filament guideline, on one occasion (refer Table 1 for all results). The Mangaehu River at the Raupuha Road site failed the guideline for thick algal mats (the only site to do so on any occasion over the two years under review). Eight sites in total failed for long filamentous algae on at least one occasion out of the four surveys conducted at each site during the two years under review.

Out of 84 site surveys for each of the two periphyton measures- thick mats and long filaments- over the two years (ie 168 surveys in total), 158 surveys (94%) found periphyton levels to be below guideline limits.

All rivers received a rating of at least 'moderate' for the TRC periphyton index score in all individual surveys except for the Waiongana at Devon Rd and the Kapoaiaia River at Wataroa Rd, which each had 'poor' ratings for one survey. One hundred and sixty-eight surveys in total were conducted.

For the TRC Periphyton Index, the median index value for 2014-2016 monitoring showed that 13 sites (62%) recorded a 'very good' rating, 6 sites (29%) recorded a 'good' rating, and two sites (10%) recorded a 'moderate' rating.

No sites had cyanobacteria mats above 50% streambed coverage, that would place a site in the 'Action' category and present a significant health hazard.

Table 1: Summary of SEM periphyton results for 2014-2016 monitoring year

River/Stream	Site	Distance from Nat Park (km)	Median TRC Periphyton Index	Indicative trend		Periphyton cover		Periphyton biomass (chlorophyll *a* mg/m^2)	
				Thick mats	Long filaments	Thick mats	Long filaments	2015	2016
Hangatahua (Stony)	Mangatete Road	7.3	Very good	Decreasing	Decreasing	4/4	4/4	5	4
	SH45	12.5	Very good	Decreasing	Decreasing	4/4	4/4	5	4
Maketawa	Derby Rd	2.3	Very good	Decreasing	Increasing	4/4	4/4	2	1
	Tarata Road	15.5	Very good	Decreasing	Decreasing	4/4	4/4	10	28
Manganui	SH3	8.7	Very good	Decreasing	Decreasing	4/4	4/4	2	1
	Bristol Road	37.9	Good	Increasing	Decreasing	4/4	3/4	219*	10
Patea	Barclay Road	1.9	Very good	Decreasing	Decreasing	4/4	4/4	15	6
	Skinner Road	19.2	Good	Increasing	Decreasing*	4/4	4/4	106	126
Waiwhakaiho	SH3 (Egmont Village)	10.6	Very good	Increasing	Decreasing	4/4	3/4	212*	19
	Constance St, NP	26.6	Good	Increasing	Decreasing	4/4	4/4	70	10
Waingongoro	Opunake Road	7.2	Very good	Decreasing*	Decreasing	4/4	4/4	9	7
	Stuart Road	29.6	Very good	Decreasing	Decreasing	4/4	4/4	196	173
	Ohawe Beach	66.6	Good	Increasing	Decreasing	4/4	3/4	193	140
Punehu	Wiremu Road	4.4	Very good	Increasing	Decreasing	4/4	4/4	3	2
	SH45	20.9	Very good	Decreasing	Decreasing	4/4	4/4	12	8
Kapoaiaia	Wiremu Road	5.7	Very good	Decreasing*	Decreasing*	4/4	4/4	10	2
	Wataroa Road	13.5	Very good	Decreasing	Decreasing	4/4	3/4	790*	132
	Cape Egmont	25.2	Good	Decreasing	Decreasing	4/4	2/4	86	78
Waiongana	SH3a	16.1	Good	Decreasing	Decreasing	4/4	3/4	318*	104
	Devon Road	31.2	Moderate	Increasing	Increasing	4/4	3/4	674*	140
Mangaehu	Raupuha Road	NA	Moderate	Increasing	Decreasing	3/4	3/4	112	246*

* Significant trend at $p<0.05$ after FDR adjustment or breach of NOF standard

Periphyton biomass was in excess of the NOF standard (200 mg/m^2) at five sites for the summer 2015 survey and at one site for the summer 2016 survey, and was in excess of the guideline to protect benthic biodiversity (50 mg/m^2) at eleven sites for the summer 2015 survey and eight sites for the summer 2016 survey.

Periphyton biomass results reflected nuisance periphyton levels and to a lesser extent TRC PI scores. There were six sites with chlorophyll *a* levels in exceedance of the NOF bottom line criterion but for each of the six sites only one of the two surveys was in exceedance. As noted above, these results do not mean that a 'D' NOF classification can be applied to the six sites, as three years of monthly data is required to produce a NOF rating, and the NOF protocol allows sites to have one sample per year (out of 12 surveys if the NOF procedure was used) above the 200 mg/m^2 standard without deeming the site's quality to be in non-compliance.

Long term periphyton trend analysis) revealed that for the majority of sites nuisance periphyton was decreasing but the trends were not statistically significant. Thirteen sites showed decreasing trends (ie reductions in the average extent of periphyton) for thick mats (reductions at two sites were statistically significant after FDR adjustment) and 18 sites showed decreasing trends for long filaments (reductions at two sites were statistically significant after FDR adjustment). The significant trends were at three sites: the upper Kapoaiaia and Waingongoro River sites having decreasing levels of thick algal mats and the upper Kapoaiaia and lower Patea River sites having decreasing levels of long filamentous algae. No sites showed a statistically significant increase in either periphyton measure.

The data used for nuisance periphyton guidelines (thick algal mats and long filaments) overlaps with the periphyton index score but was potentially completely distinct from the periphyton biomass data as rocks viewed for periphyton cover are not necessarily, and probably unlikely, to be the same ones used to collect periphyton biomass. Therefore, even though ten replicates were used, results can potentially differ significantly between the two methods. Furthermore, periphyton coverage examines both live and dead periphyton while periphyton biomass uses chlorophyll *a* which is contained within live material only.

Of the 21 sites used for periphyton monitoring, two rivers with two sites each were selected based on their high conservation values/ water quality and an additional seven sites were selected as upper, mostly unimpacted sites, situated relatively close to the National Park boundary. Of these eleven sites, all of them except for the upper sites in the Waiwhakaiho River and Waiongana Stream contained very low levels of periphyton based on all three measures used in the current SEM programme (nuisance periphyton limits, TRC PI and chlorophyll *a*). The upper sites in the Waiwhakaiho River and Waiongana Stream were the furthest downstream from the National Park boundary (>10 km) of all the upper sites.

All ringplain sites located further than 10 km from the National Park boundary and the Mangaehu River site, except for the two high conservation value waterbodies the Stony River and Maketawa Stream, had moderate to high levels of periphyton for at least one of the four surveys and of those eleven sites, eight had at least one breach of a nuisance periphyton limit and six had a periphyton biomass level above the NOF guideline at some time over the four biomass surveys at each site. Two of the other three sites came extremely close to breaching one of the guidelines (ie a result 2% below long filament guideline or 4-7 mg/m^2 of chlorophyll *a* below NOF standard). This indicates that the majority of sites located a reasonably distance from the National Park boundary or that have a substantial modified catchment above the site can potentially have problems with nuisance periphyton under certain conditions conducive to proliferation.

In keeping with the last reported period (2012/2014) but unlike other earlier reported results, the difference between spring and summer surveys was not significant. Summer surveys usually have considerably higher periphyton levels than spring surveys (e.g. TRC, 2014) but the average TRC PI score was identical for the spring 2014, spring 2015 and summer 2016 surveys, though the summer 2015 had a slightly lower score. Average thick mat levels were either the same or higher for the spring surveys compared with the summer surveys. Average long filament levels were higher for both summer surveys but not by a considerable amount. Breaches in guidelines were similar between surveys though slightly higher for the summer 2015 survey: spring 2014 one breach, summer 2015 four breaches, spring 2015 two breaches and summer 2016 three breaches.

No *Didymosphenia geminate* was found for the monitoring period under review.

Overall, the following conclusions can be made:

1. Generally, the monitored sites almost always complied with nuisance periphyton guidelines, with 99% and 89% of surveys complying with the periphyton guideline for thick mats and long filaments respectively.
2. 'Upstream sites' with little agriculture in their catchment had typically lower levels of periphyton compared with sites located further down the catchment that had nuisance periphyton levels which occasionally breached guideline limits.
3. Due to the number of variables involved (e.g. nutrients, sunlight, temperature, substrate type, time since last fresh or flood, water clarity, level of invertebrate grazing etc) and interaction affects between variables it can be difficult to ascertain the main factors driving periphyton biomass.
4. The cumulative effects of agricultural discharges via point source or diffuse pollution were probably the main cause of algae proliferation in 'downstream' catchment sites.
5. Flood flows can cause a reduction in periphyton growth but the degree of this effect is not consistent within streams or seasons.

From these conclusions, a number of recommendations are made in the report. Monitoring of the streams should continue as previously performed.

In response to the invasion of *Didymosphenia geminate* in the South Island, it is also recommended that samples continue to be taken by the Council at selected sites and sent away for analysis.

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1. Introduction

The Resource Management Act 1991 ("the RMA") established new requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Taranaki Regional Council ("the Council") has established a state of the environment monitoring ('SEM") programme for the region. This programme is outlined in the Council's "State of the Environment Monitoring Procedures Document", which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the Council's Regional Policy Statement for Taranaki (2008) and also the Regional Freshwater Plan for Taranaki (2001).

The SEM programme is made up of a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). For these annual monitoring activities, summary reports are produced following the end of each monitoring year (i.e., after 30 June). Where possible, individual, consent monitoring programmes have been integrated within the SEM programme to save duplication of effort and minimize costs. The purpose of annual SEM reports is to summarise monitoring activity results for the year and provide a brief interpretation of these results.

The SEM Freshwater Nuisance Periphyton programme began in the 2002-2003 monitoring year. Three previous reports have been written, summarising the 2002-2006, 2006-2010 and 2010-2012 survey periods. The reporting period was changed to biennial for the 2010-2012 reporting period and this report continues with the biennial report format, hence this report summarises the results for the 2014-2016 monitoring period. The freshwater nuisance periphyton programme has been designed to monitor the coverage and biomass of algae in Taranaki streams and rivers which may affect the instream values of these streams i.e., aesthetic values (contact recreation and landscape values), biodiversity values and those values linked to Maori culture and tradition.

This report is the second to examine periphyton biomass as estimated by chlorophyll *a* and incorporates two years of data for the reporting period.

Responsibilities under the Resource Management Act

Water management in New Zealand is principally controlled by the RMA. Section 5 of the RMA describes its purpose:

1. The purpose of this Act is to promote the sustainable management of natural and physical resources.

2. In this Act, "sustainable management" means managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their health and safety while –

    a. Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
    b. Safeguarding the life-supporting capacity of air, water, soil and ecosystems; and
    c. Avoiding, remedying or mitigating any adverse effects of activities on the environment.

Under section 30 of the RMA, functions and powers for water management lie with regional councils.

In certain circumstances periphyton can proliferate and become a nuisance and adversely affect water quality for a range of instream values. The RMA provides for waters to be classified in regional plans as an aid to the management of water quality. In recognition of the potential problems created by high-biomass biological growths in streams, the RMA specifies the following standard for waters being managed for aquatic ecosystem purposes, fish spawning, contact recreation, water supply, irrigation and industrial abstraction: "There shall be no undesirable biological growths as a result of any discharge of a contaminant into water" (schedule III).

1.1 Nuisance periphyton

What is periphyton?
Periphyton is the 'slime' and algae found on the beds of streams and rivers (Photo 1). It is essential for the functioning of healthy ecosystems, but when it proliferates it can become a nuisance by degrading swimming and fishing spots and clogging irrigation and water supply intakes. The periphyton community is composed predominantly of algae and cyanobacteria (blue-green algae).

Photo 1 Extensive filamentous algae growth in the Kapoaiaia Stream (KPA000700)

How is it important?
Periphyton is found in all aquatic habitats but is most conspicuous in streams and rivers. Periphyton communities contain the main primary producers of streams and are they major source of food to stream and river foodwebs.

What factors contribute to periphyton growth?
The local factors controlling the biomass and type of periphyton existing at any given point in a stream, and at any given time, are a result of a hierarchy of environmental controllers. Large scale factors include catchment geology and climate (rainfall and temperature). More immediate reach scale factors that influence periphyton growth include:

- Light – the amount of sunlight can regulate periphyton communities; a lack of riparian margins can increase the potential for nuisance growths to occur, particularly in smaller streams where a vegetation canopy would normally provide significant shade to limit periphyton growth. Shading from stream banks and turbid water will also limit light levels.
- Nutrients – nutrient enrichment typically occurs as a result of effluent discharges from stock and town sewerage schemes, agricultural fertilisers, particularly in intensively farmed areas and meatworks where the dilute remains of stock are applied to land or as a point source discharge to waterbodies. A lack of riparian margins can exacerbate diffuse nutrient inputs into waterbodies. Nitrogen and phosphorus are both critical nutrients to periphyton growth. When just one of these two nutrients is limited, it will constrain periphyton proliferation.
- Stream flow regimes – the frequency of flood events are a particularly important controller of periphyton (repeated freshes will limit growth); also the duration of

stable low flows, particularly in summer may allow significant accrual of periphyton biomass.
- Water temperatures may influence the growth rates of periphyton (especially near the mouth of the stream), i.e. warmer temperatures (summer) allow periphyton to grow faster, whereas colder temperatures (winter) may limit growth. Water temperature regulation may be influenced by shading from riparian vegetation, directly in smaller streams or by cooling the water that flows into larger streams.
- Invertebrate grazers reduce periphyton growth by directly feeding on periphyton.
- Substrate type - periphyton generally occurs on hard surfaces such as boulders and cobbles and is less unlikely to form on soft sediment such as silt and sand unless flows are very slow and stable.

The interaction between all these factors must be considered when interpreting periphyton monitoring data. Both the extent and intensity of summer low flows and nutrient concentrations can be strongly influenced by human activity through changes in land use and hydrology, or by meteorological variations year by year.

It is important to note that periphyton is a normal phenomenon and in some streams at certain times of the year thick algal mats and long filamentous algae will naturally occur. For example, long, wide, shallow rivers may have some growths during late summer when temperatures are high and flows are low.

Values affected by nuisance periphyton growth
The waterways of New Zealand are valued for a wide range of reasons, all of which can be affected by the presence of nuisance periphyton.

Problems associated with excess bioaccumulation (nuisance growths) are most prominent during low flows and therefore may only occur at certain times of the year (Biggs, 2000). Common stream related values are listed in Table 1.

Table 1 Instream values affected by nuisance growths of algae (adapted from Biggs 2000)

Instream Value	Problem
Aesthetics	Degradation of scenery, odour problems
Biodiversity	Loss of sensitive invertebrate taxa through habitat alteration, possible reduction in benthic biodiversity
Contact recreation	Impairment of swimming, odour problems, dangerous for wading
Industrial use	Taste and odour problems, clogging intakes
Irrigation	Clogging intakes
Monitoring structures	Fouling of sensory surface, interferes with flow
Potable supply	Taste and odour problems, clogging intakes
Native fish conservation	Impairment of spawning and living habitat
Human and animal health	Toxic blooms of cyanobacteria
Trout habitats/angling	Reduction in fish activity/populations, fouling lines, dangerous for wading
Waste assimilation	Reduces stream flow, reduces ability to absorb ammonia, reduces ability to process organics without excessive DO depletion
Water quality	Increased suspended detritus, interstitial anoxia in stream bed, increased DO and pH fluctuations, increased ammonia toxicity, very high pH
Whitebait fishing	Clogging nets

1.1.1 Periphyton guidelines

New Zealand Periphyton Guidelines (Biggs, 2000) were released in June 2000 by Ministry for the Environment. The guidelines relevant to monitoring conducted in this programme are listed in Table 2.

Table 2 New Zealand periphyton guidelines from (Biggs, 2000)

Instream value	Diatoms/cyanobacteria	Filamentous algae
Aesthetics/recreation (1 November to 30 April)		
Maximum cover of visible streambed	60% > 3mm thick	30% > 2cm long
Maximum chlorophyll *a* (mg/m^2)	n/a	120
Benthic biodiversity		
Monthly mean chlorophyll *a* (mg/m^2)	15	15
Maximum chlorophyll *a* (mg/m^2)	50	50
Trout habitat and angling		
Maximum chlorophyll *a* (mg/m^2)	200	120

Accompanying these guidelines, NIWA published a Stream Periphyton Monitoring Manual (Biggs and Kilroy, 2000) for Ministry for the Environment to assist monitoring agencies in the methods of periphyton monitoring. Several predominant periphyton community groups are specified in the manual and help to interpret what these periphyton communities indicate i.e., oligotrophic (high water quality), mesotrophic (moderately enriched), and enriched streams (Appendix 2 in Biggs and Kilroy, 2000).

1.1.2 Cyanobacteria

Periphyton in the form of benthic cyanobacteria in streams and rivers can affect amenity values by causing health problems to humans, domestic animals and livestock. In 2009, the Ministry for the Environment released an interim guidance document entitled "*New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters*" (MfE and MoH, 2009). These guidelines provide a national alert–level framework for assessing the public health risk from cyanobacteria associated with contact recreation in lakes and rivers.

Table 3 below shows the alert-level framework for benthic cyanobacteria.

Table 3 Alert level framework for benthic cyanobacteria

Alert level[a]	Actions
Surveillance (green mode) Up to 20% coverage of potentially toxigenic cyanobacteria attached to substrate.	• Undertake fortnightly surveys between spring and autumn at representative locations in the water body where known mat proliferations occur and where there is recreational use. • Take scrapings every second survey for microscopic identification, to compare with visual assessments in order to ensure cyanobacteria is being recorded accurately, and to provide an indication of the species present.
Alert (amber mode) 20−50% coverage of potentially toxigenic cyanobacteria attached to substrate.	• Notify the public health unit. • Increase sampling to weekly. • Recommend erecting an information sign that provides the public with information on the appearance of mats and the potential risks. • Consider increasing the number of survey sites to enable risks to recreational users to be more accurately assessed. • If toxigenic cyanobacteria dominate the samples, testing for cyanotoxins is advised. If cyanotoxins are detected in mats or water samples, consult the testing laboratory to determine if levels are hazardous.
Action (red mode) *Situation 1:* Greater than 50% coverage of potentially toxigenic cyanobacteria attached to substrate; or *Situation 2:* up to 50% where potentially toxigenic cyanobacteria are visibly **detaching** from the substrate, accumulating as scums along the river's edge or becoming **exposed** on the river's edge as the river level drops.	• Immediately notify the public health unit. • If potentially toxic taxa are present then consider testing samples for cyanotoxins. • Notify the public of the potential risk to health.

a The alert-level framework is based on an assessment of the percentage of river bed that a cyanobacterial mat covers at each site. However, local knowledge of other factors that indicate an increased risk of toxic cyanobacteria (e.g., human health effects, animal illnesses, prolonged low flows) should be taken into account when assessing a site status and may, in some cases, lead to an elevation of site status (e.g., from surveillance to action), irrespective of mat coverage.

Photo 2 Thick mat of cyanobacteria

1.1.3 Methodology

1.1.3.1 Periphyton surveys

Periphyton surveys were performed twice a year:

- spring (15 September – 31 December) and
- summer (1 January – 15 April).

Prior to the 2010-2012 monitoring periods, surveys were performed three times a year:

- spring (September, October, November, early December)
- summer (late December to early February)
- late summer (late February- April).

At each site ten random assessments were made across the stream using a periphyton viewer (110 cm^2). Periphyton cover on the stream bed within each square was estimated visually as a percentage cover on the substrate, using the categories in Table 4.

Widespread coverage of thick mats or long filaments on the streambed are often seen as nuisance growths, whereas thin films of algae act as an important food source for many of the 'sensitive' stream invertebrates.

Table 4 Periphyton categories used in visual estimates of cover (note for no cover TRC gives a score of 10 while standard method excludes no cover percentage from calculation)

Type	Size		Colour	TRC Periphyton Index Score
None			Clean stones, not slippery	10
Mat/film	Thin	< 0.5 mm	Green	7
			Light brown	10
			Black, dark brown, very dark green	10
	Medium	0.5-3 mm	Green	5
			Light brown	7
			Black, dark brown, very dark green	9
	Thick	> 3 mm	Green	4
			Light brown	4
			Black, dark brown, very dark green	7
Filaments	Short	< 2 cm	Green	5
			Brown/reddish	5
	Long	> 2 cm	Green	1
			Brown/reddish	4
Other			Describe	N/A

Streams were sampled at least 10 days after the last fresh in excess of three times the median flow. This allows some time following a fresh for the periphyton community to recover and reflect actual water quality conditions rather than the effects of the most recent flood though a climax community may take up to six weeks to establish (Biggs, 2000). Floods of a magnitude of three times median flow or greater are considered sufficient to move substrate and scour the bed of the stream, significantly reducing periphyton biomass.

Wherever possible all streams were sampled within a day or two of each other; sites within each individual stream catchment were always sampled on the same day.

1.1.3.2 Periphyton index

Percentage cover data gathered is used to establish a periphyton index score. This index was introduced as part of the Stream Health Monitoring and Assessment Kit (SHMAK) produced by the Ministry for the Environment, and uses a scoring system, where each type of periphyton cover was assigned a score (Table 4). Scores have been assigned according to the conditions in which each category is usually found dominating the cover of stream beds (Biggs, Kilroy and Mulcock, 1998). The lower the score the more eutrophic the conditions.

The periphyton index score (PI) is found using the following equation:

$$PI = \frac{\sum \text{(mean cover by periphyton category x rating of category)}}{\sum \text{(mean cover by all periphyton groups)}}$$

The resultant periphyton index score gives an indication of the periphyton community composition of the stream at that point in time, although it is based on the concept of a typical periphyton community i.e. one that has not been recently scoured away by floods, or proliferated in low flows. This is considered by Biggs *et al* (1998) to be after a period of six weeks since a three times median flood. In the case of Taranaki, it could be argued that sampling after a shorter period (as allowed by the protocols adopted by the Council) means that a community is being sampled that is still affected by a previous flood. However, due to the relatively high flood frequency in Taranaki, it is considered that a 'flood affected' community is relatively typical for this region. The only drawback of this policy is that late summer surveys that are less flood-affected will potentially record a lower PI, all other influences being equal. However, this still reflects what is typical of a Taranaki stream at that time.

The indicator scores are preliminary and are derived from Biggs et al. 1998 and unpublished data of the authors. It was anticipated that the scoring methodology would be updated as new information was collected (Biggs and Kilroy, 2000) but this has not yet occurred. Currently, the index scores give significantly different weightings based on differences in colour which corresponds to different taxonomic groups. For example, light brown thick mats (diatoms) have a score of 4 while dark brown or black thick mats (cyanobacteria) have a score of 7. A streambed completely covered in thick black mats of the toxin producing cyanobacteria *Phormidium*, would produce a periphyton index rating of 'good' even though a river in that condition should be closed for recreational use. Therefore, scores reflect stream health rather than suitability for recreational use or aesthetes.

Biggs *et al* (1998) give the substrate area that is clear of algae a 'zero' score which strongly influences the periphyton index score of some sites in Taranaki, such as some higher up in catchments. For example, one site in the Stony River on 18 February 2003 recorded 96.5% of the bed to be clear of algae, with the remaining 3.5% made up of long (1%) and short (2.5%) filaments. This resulted in a PI score of 3.9, which is considered to be indicative of enriched conditions. When the SHMAK PI is used in flood affected communities it could potentially return a result supposedly indicative of enriched conditions, implying a slimy, algae covered stream, when in fact the reverse is the case. It is precisely for this reason that the SHMAK PI should only be used in climax communities, i.e. when the community has matured and is stable to the point of there being little further change in biomass.

Taking this into account, a 'TRC PI' value has been created, which gives an area clear of algae a score of 10. A drawback of this value is that the steeper, higher energy sites high on the mountain will have an inflated TRC PI score compared to the lower sites due to greater bed turnover during smaller floods. Any site with some substrate clear of algae will record a higher TRC PI than SHMAK PI. However, the TRC PI is useful when describing the degree of undesirable algal growths in a flood-prone stream.

The periphyton index is not an absolute measure like the periphyton guidelines, which are either exceeded or not. In addition, it is not restricted to only long filaments and thick mats, including all types of cover, acknowledging the fact that undesirable growths may be present, even when the guidelines are not exceeded. However, there are some pitfalls to this type of interpretation, as shown by Table 5. It is possible that a site in breach of the recreational and aesthetic guidelines returns a very good PI. Therefore this type of interpretation should not be done in complete isolation from the percentage cover (guideline compliance) data.

Table 5 Range of Periphyton Scores when in exceedance of recreational and aesthetic guidelines

	Diatoms/cyanobacteria 60% > 3mm thick			Filamentous algae 30% > 2cm long		
Assuming remainder of bed is:	Clear of Algae[1]	Thin brown films[1]	Short filaments[1]	Clear of Algae[1]	Thin brown films[1]	Short Filaments[1]
SHMAK PI	4.0[2]-7.0[3]	6.4[2]-8.2[3]	4.0[2]-5.8[3]	1.0[4]-4.0[5]	7.3[4]-8.2[5]	3.1[4]-4.0[5]
TRC PI	6.4[2]-8.2[3]	6.4[2]-8.2[3]	4.0[2]-5.8[3]	7.3[4]-8.2[5]	7.3[4]-8.2[5]	3.1[4]-4.0[5]

[1] Although a mixture of thin films, medium mats and short filaments is much more likely, and would result in a different PI value
[2] 60% Thick green mats
[3] 60% Thick black mats
[4] 30% Long green filaments
[5] 30% Long brown filaments

The lowest possible periphyton score for the SHMAK PI is 0 and for the TRC PI is 1 (100% long green filaments).

In short, while a high TRC PI may still be associated with a breach of the periphyton guidelines, a low TRC PI is almost certainly a reflection of undesirable algal growths. The TRC PI will be used in this report, as it is more reflective of the periphyton community in a flood-prone stream.

Below is a general explanation of the SHMAK periphyton index scores taken from Biggs, Kilroy and Mulcock (1998).

Score: 0 to 1.9
There are mainly long filamentous green algae at the site indicating that there is high to moderate enrichment from phosphorus and/or nitrogen. Such enrichment could be from enriched seepage, a discharge from a treatment pond, or could occur naturally in streams that have a high proportion of mudstone/siltstone or recent volcanic rocks (central North Island) in their catchments.

Score: 2 to 3.9
These communities suggest a moderate level of enrichment from phosphorus and/or nitrogen. Such enrichment could be from enriched seepage, a discharge from a treatment pond, or could occur naturally in streams that have a high proportion of mudstone/siltstone or recent volcanic rocks (central North Island) in their catchments.

Score: 4 to 5.9
These communities suggest slight enrichment from phosphorus and/or nitrogen. Such enrichment could be from enriched seepage, a discharge from a treatment pond, or could occur naturally in streams that have a high proportion of mudstone/siltstone, recent volcanic rocks (central North Island), limestone or marble in their catchments. Clean stones can result from recent abrasion by flood flows or intense grazing by invertebrates/insects that live in the gravels.

Score: 6 to 7.9
These communities are generally composed of species that are able to grow under moderate to low nutrient conditions. These communities also usually grow back first after a flood has removed previous growths, but may be out-grown by filamentous algae if nutrient levels are sufficiently high.

Score: 8 to 10
These communities usually signify low concentrations of nutrients and/or intensive grazing by invertebrates/insects that live among the gravels.

Scores have been broken down further into category rating for descriptive purposes (Table 6).

Table 6 Category ratings for TRC PI scores

Rating	TRC PI score
Very good	8-10
Good	6-7.9
Moderate	4-5.9
Poor	2-3.9
Very poor	1-1.9

1.1.3.3 Periphyton biomass

Chlorophyll *a* gives an indication of the total amount of live biomass in a periphyton sample. Chlorophyll *a* is considered to be the most widely recognised method for estimating periphyton biomass (Kilroy, 2013) and is the method used to estimate periphyton in the National Objectives Framework (NOF) that will create national standards for certain water quality parameters (Snelder et al., 2013).

Periphyton biomass surveys were started in the 2010-2011 monitoring year for the summer 2011 survey at the same 21 sites that periphyton cover was surveyed and was always done in conjunction with periphyton cover surveys. Periphyton biomass surveys were only undertaken during summer (January 1- April 15) as the time and cost involved in collecting and analysing the samples was significantly higher than surveying for periphyton cover. This report examines chlorophyll *a* data for two summers (2014-2016).

The method for collecting periphyton biomass was adapted from Biggs and Kilroy (2000). Ten randomly selected rocks and a known area of periphyton ($0.0196m^2$) was scrapped off each rock. TRC employs a slightly different process to sample the periphyton as suggested by Biggs and Kilroy (2000). A device was constructed that allows periphyton from a fixed area to be sucked up via a tube connected to a pump. This has the advantage that periphyton does not need to be first removed from the surrounding area as it does with the methodology suggested by Biggs and Kilroy (2000). A small change to the methodology occurred between the 2015 and 2016 surveys whereby if strands of particularly long filamentous algae naturally extend beyond the area assessed (sample circle) then in 2015 and previous surveys the strands would be included within the sample while for the 2016 survey strands existing beyond the sample circle would be excluded. This brings the TRC methodology into line with Biggs (2000) and with other regional councils (Summer Green pers. comm). In practice, very few samples would have exhibited a difference in chlorophyll *a* levels between the two methodologies though in a very small number of samples collected between 2011-2015 chlorophyll *a* levels were likely higher than what would have been found using the new methodology and it might have given rise to some large outliers.

The ten periphyton samples were combined to form a single sample for a site and the sample was brought back to a laboratory where chlorophyll *a* was extracted and analysed. Periphyton guidelines for chlorophyll *a* (Biggs, 2000) suggest a range of maximum chlorophyll *a* limits to protect benthic biodiversity, aesthetics and trout habitat/angling depending on whether the algal type is diatoms/cyanobacteria or long filaments (Table 2). In practice, composite samples will likely contain a mixture of both diatoms/cyanobacteria and long filaments. The National Objective Framework (NOF) proposes four bands (Table 7) which are maximum limits based on a monthly monitoring regime undertaken year-round. The minimum record length for grading a site based on periphyton biomass is three years. The bottom line that must be met is 200 mg/m^2 of chlorophyll *a*.

Table 7 National Objective Framework standards for periphyton using chlorophyll a for rivers in the default class (all current monitored sites)

Band	Chlorophyll *a*
	Exceeded no more than 8% of samples
A	0-50
B	>50-120
C	>120-200
National Bottom Line	**200**
D	>200

Photo 3 Device used to extract periphyton for chlorophyll *a* analysis. Periphyton was scrapped off the rock using a stiff paint brush. The tube at the side is used to suck up fine particles of periphyton

Photo 4 Periphyton covered rock with clear area where all the periphyton has been extracted for chlorophyll *a* analysis

1.1.4 Site locations

Twenty-one sites were chosen in ten catchments around the Taranaki Region (Table 8). Sites were chosen to be representative of different catchment types such as high conservation, riparian and major abstraction. Generally, each river/stream has one upper (mostly un-impacted) site and one or two lower sites (with various degrees of potential effects arising from land management activities).

Sites have been chosen within the existing hydrological flow monitoring network where possible, as hydrological information is helpful to the interpretation of results. Details of the catchments monitored are summarised in Figure 1.

Table 8 Summary of nuisance periphyton monitoring sites in the SEM programme

Feature	Sites				
	River/Stream	Location	Site Code	Distance from Nat Park (km)	Altitude (m)
High conservation	Hangatahua (Stony)	Mangatete Road	STY000300	7.3	160
		SH45	STY000400	12.5	70
	Maketawa	Derby Rd	MKW000200	2.3	380
		Tarata Road	MKW000300	15.5	150
Large catchments/ multiple impacts	Manganui	SH3	MGN000195	8.7	330
		Bristol Road	MGN000427	37.9	140
	Patea	Barclay Road	PAT000200	1.9	500
		Skinner Road	PAT000360	19.2	240
	Waiwhakaiho	SH3 (Egmont Village)	WKH000500	10.6	175
		Constance St, NP	WKH000920	26.6	20
Intensive usage	Waingongoro	Opunake Road	WGG000150	7.2	380
		Stuart Road	WGG000665	29.6	180
		Ohawe Beach	WGG000995	66.6	10
Primary agricultural	Punehu	Wiremu Road	PNH000200	4.4	270
		SH45	PNH000900	20.9	20
Riparian	Kapoaiaia	Wiremu Road	KPA000250	5.7	240
		Wataroa Road	KPA000700	13.5	140
		Cape Egmont	KPA000950	25.2	20
Major abstraction	Waiongana	SH3a	WGA000260	16.1	140
		Devon Road	WGA000450	31.2	20
Eastern hill country	Mangaehu	Raupuha Road	MGH000950	NA	120

Periphyton communities in the Kaupokonui River are also monitored monthly as part of the Riparian State of the Environment Monitoring Programme. Results relating to this catchment are summarised in other Council reports (e.g. TRC, 2004) and will not be presented in this report.

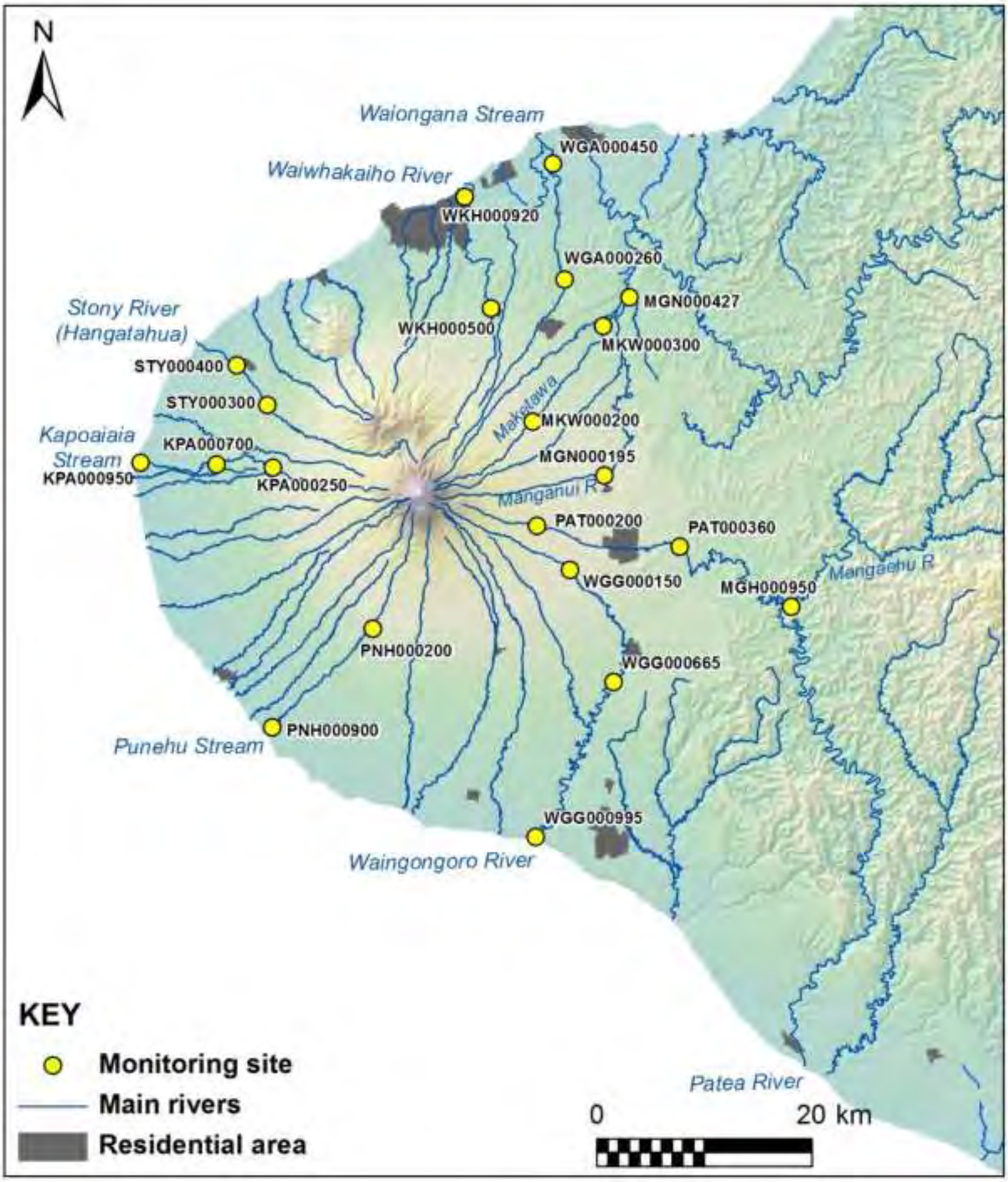


Figure 1 Sampling site locations

2. Results

2.1 Hangatahua (Stony) River

The Hangatahua (Stony) River rises within the National Park boundary, on the north-western side of Mount Taranaki. Upon leaving the National Park, it heads in a north-westerly direction for a distance of approximately 15 kilometres to the coast. The upper reaches of the catchment contain indigenous vegetation, the middle is mixed (including exotic trees and pasture), while the lower area is barren or comprises introduced grasses and weeds.

The Stony River is occasionally affected by significant natural erosion events in the headwaters, which can scour periphyton and limit proliferation and is a major source of sand for the Taranaki region.

Figure 2 Monitoring site locations in relation to consents operating in the Stony River catchment

This river is protected in its natural state by way of a Local Conservation Order. As such there are no abstractions from the river, and no direct discharges. The river has also been designated as one of only two river catchments in the draft Freshwater and Land Management Plan for Taranaki (2015) to be in the Freshwater Management Unit A outstanding freshwater bodies.

The top sampling site (Mangatete Rd, STY000300) is within seven km of the park boundary (as close as feasible for regular access), while the downstream site (STY000400) is just above SH45 (12km downstream of the National Park boundary). This is the final place at which the river is easily accessed before flowing through private land and out to sea.

2.1.1 Flow and nutrient data and survey dates

A hydrological flow recorder was installed in the Stony at Mangatete Road and flow data for this site was available from 2004-2011 but no continuous flow gauging data has been collected since 2011. The nearby Kapoaiaia River at the lighthouse has a telemetered hydrological monitoring station and provides a general indication of the flow history in relation to sampling times in the Stony River catchment (Appendix 1).

Due to frequent fresh and flood events monitoring could not be carried out in the spring of 2014 at both the Mangatete Road and SH45 sites. The summer 2015 survey was conducted on 22 January 2015, 21 days after a fresh in excess of both 3x median flow and 32 days after a fresh in excess of 7x median flow.

The spring 2015 survey was conducted on 3 November 2015 10 days after a very large fresh in excess of both 3x and 7x median flow. The summer 2016 survey was carried out on 3 February 2016 15 days after a fresh in excess of both 3x and 7x median flow.

Nutrient data from the SEM physiochemical programme was collected at site STY000300. The SEM physiochemical programme involves monthly water quality sampling on the second Wednesday of every month. A range of parameters are collected including dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN) and total nitrogen (TN). The site met the guideline for total nitrogen for an upland site but not for dissolved reactive phosphorus (DRP) (ANZECC 2000) (Appendix 2). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels.

2.1.2 Periphyton cover

The Stony River is generally characterised by a low periphyton biomass throughout its catchment.

In the 2014-2015 and 2015-2016 monitoring years no nuisance periphyton was found at either the upper survey site at Mangatete Rd or at the lower survey site at SH45 for the spring and summer surveys (Figure 3 and Figure 4).

The majority of the Stony River catchment runs through national park with only a very limited area in the mid and lower part of catchment in agricultural use. Nutrient inputs into the river would therefore be expected to be very low and the periphyton results for the 2014-2016 monitoring period support this.

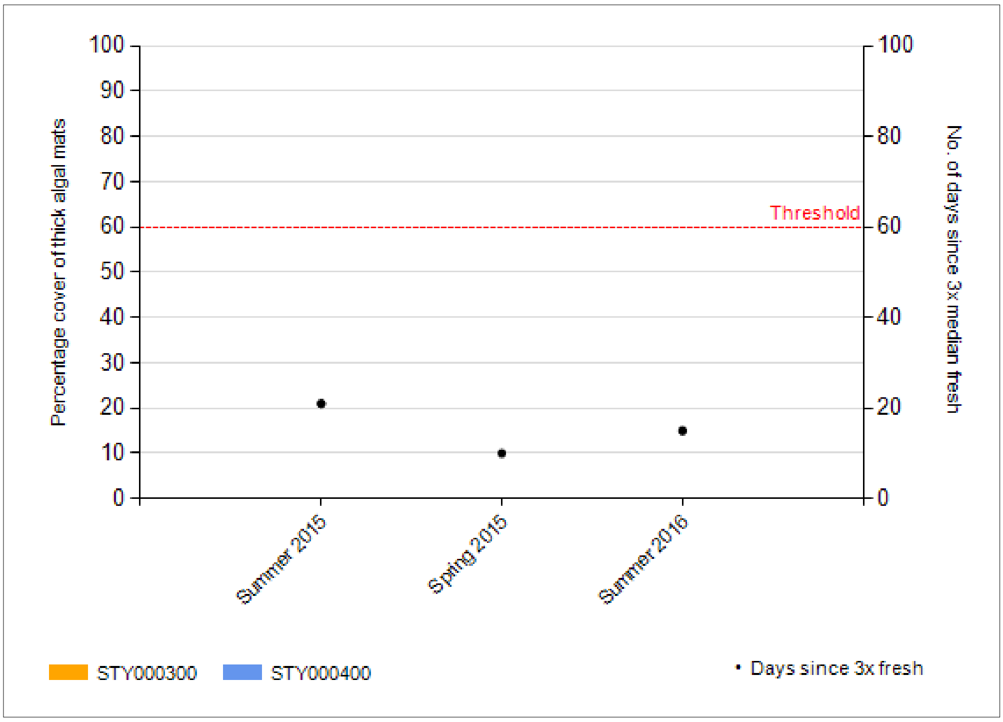


Figure 3 Percentage cover of thick mats of periphyton on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

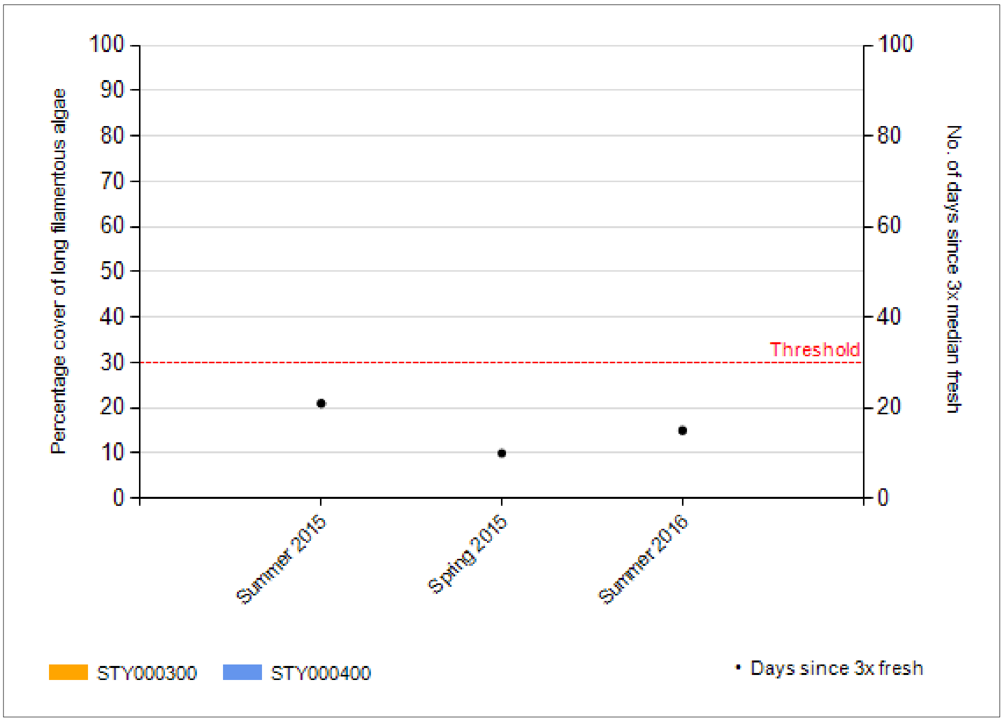


Figure 4 Percentage cover of long filamentous algae on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

Based on historical monitoring data, it appears unlikely that nuisance periphyton growths will develop in this catchment. Further riparian planting in the catchment may improve the already high water quality conditions in this catchment by reducing diffuse agricultural runoff which is generally a significant nutrient source in intensively farmed areas.

2.1.3 Periphyton Index Score

Over the 2014-2016 monitoring period the Stony River had low levels of periphyton with both sites within the monitoring period having a 'very good' TRC periphyton index score. For the 2014-2015 monitoring period there was little change across the upstream site and downstream site; scoring very high scores for summer (Table 9). For the 2015-2016 monitoring period there was a very minor decrease in TRC PI at the downstream but not the upstream site for the spring period. There was no difference in the summer survey with both sites getting maximum scores.

The historical median for the upstream and downstream site indicates that the downstream site generally has a lower TRC PI score than the upstream site, but this difference is only very minor with the downstream site still in the 'very good' category (Table 9).

Table 9 Seasonal periphyton index scores for the Stony River. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
STY000300	9.7	10.0	10.0	10.0	10.0
STY000400	9.9	9.6	10.0	10.0	9.4
Difference	-0.2	0.4	0	0	0.6

2.1.4 Periphyton biomass

The results for the summer of 2015 and 2016 for both sites had extremely low recorded chlorophyll *a* levels (4-5 mg/ m^2) (Figure 5). These values are well within guidelines to protect biodiversity, aesthetic and trout habitat/angling values (Table 2) and NOF guidelines (Snelder et al., 2013). The extremely low chlorophyll *a* levels are congruent with the periphyton cover results and reinforces the findings that the Stony River has outstanding water quality.

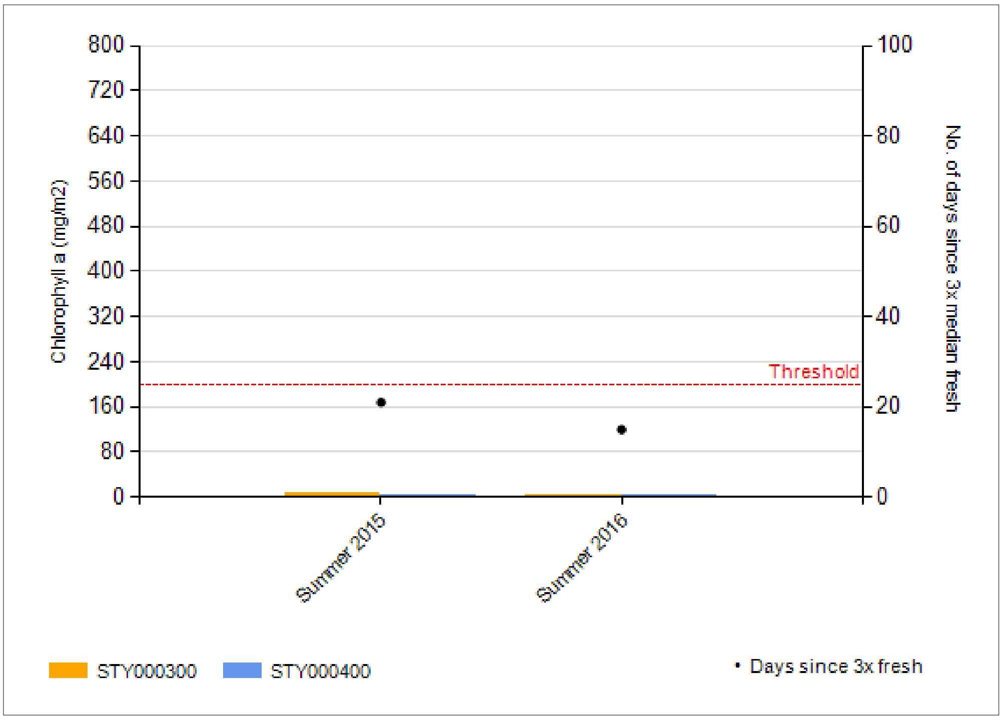


Figure 5 Periphyton biomass (chlorophyll a) on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.1.5 Summary of 2002-2016 (14 year data set)

Over the 14 year period there has been very little periphyton proliferation at both sites monitored in the Stony catchment (Figure 6 and Figure 7). Periphyton has remained consistently low over the past 14 years. There have been occasional spikes but no record ever came close to a breach in periphyton guidelines for mats or filaments at either of the Stony catchment sites.

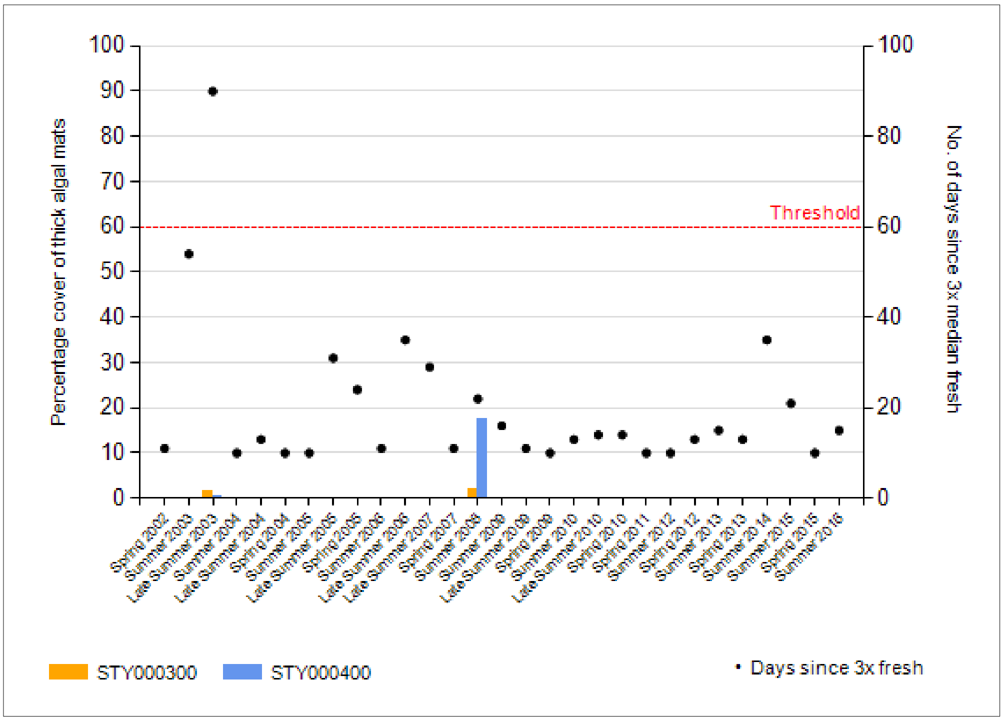


Figure 6 Percentage cover of thick mats of periphyton on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2002-2016 period

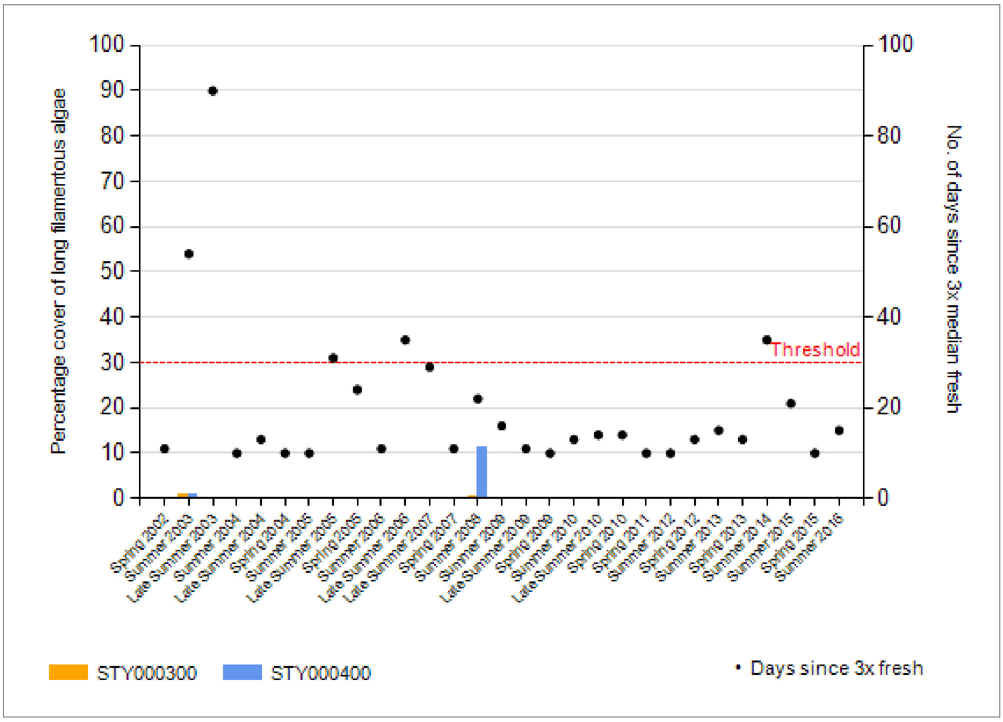
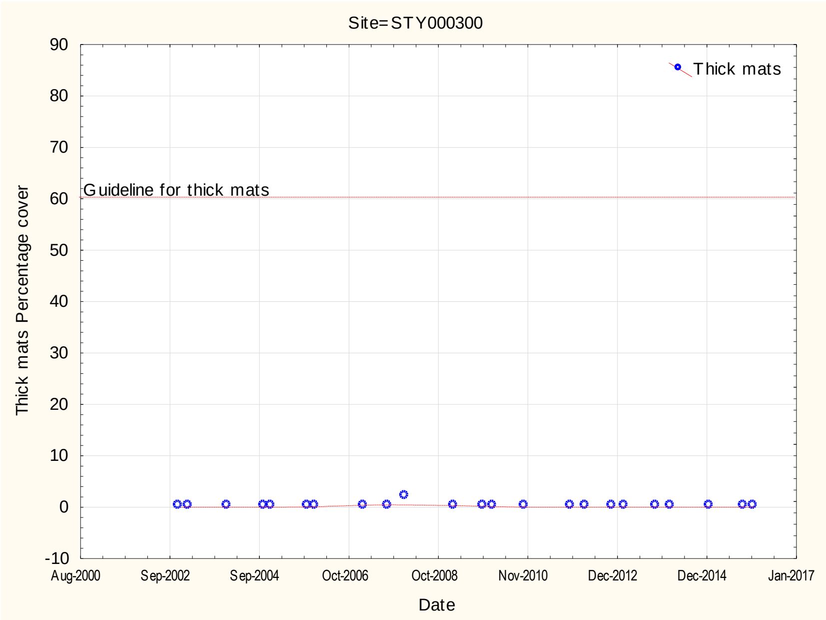


Figure 7 Percentage cover of long filamentous algae on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2002-2016 period

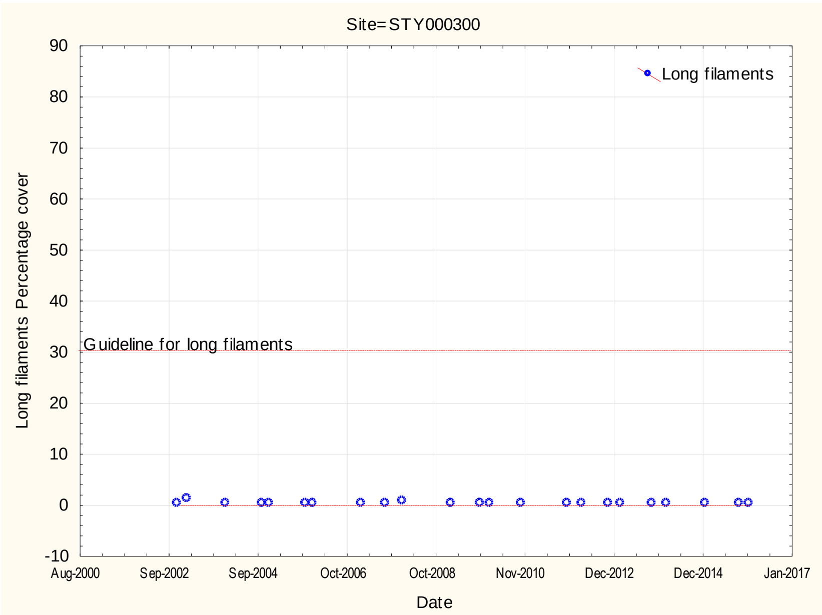
2.1.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Stony River, at Mangatete Road and SH45 over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 8 to Figure 11).



n = 23
Kendal tau = -0.054
p-value = 0.720
FDR p-value = 0.796

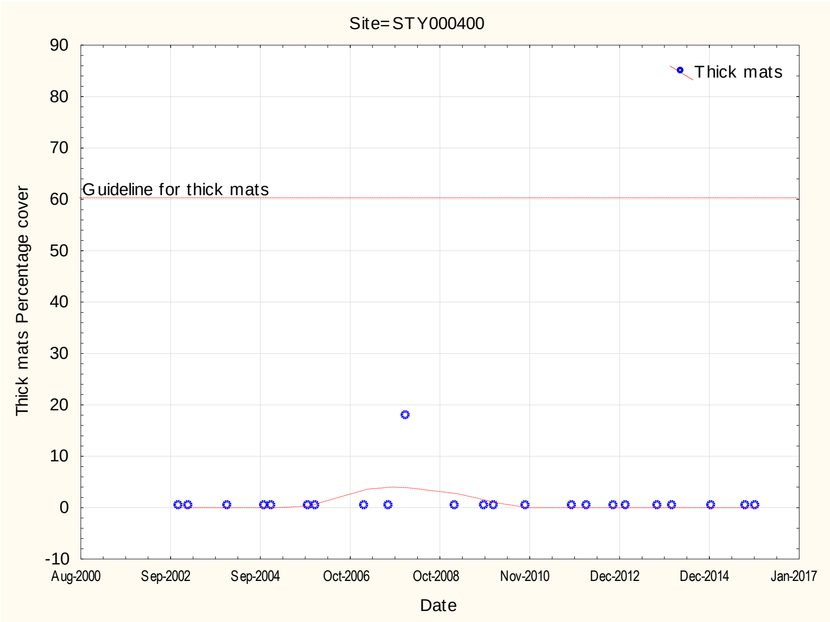
Figure 8 LOWESS trend analysis of percentage cover of thick mats at Stony River, Mangatete Road (STY000300)



n = 23
Kendal tau = -0.240
p-value = 0.109
FDR p-value = 0.273

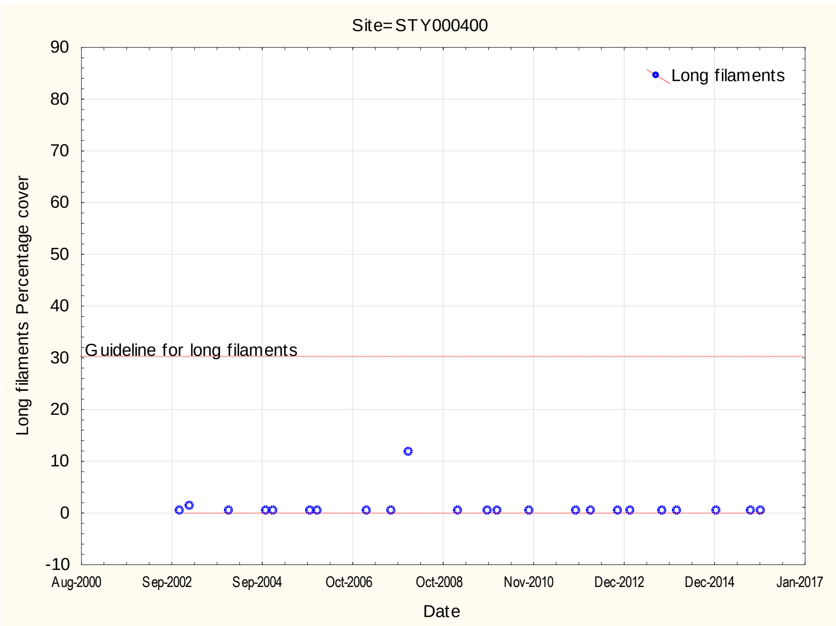
Figure 9 LOWESS trend analysis of percentage cover of long filaments at Stony River, Mangatete Road (STY000300)

At Mangatete Road (STY000300) over the 14 year monitored period there were no significant trends for thick mats (p=0.796) or long filaments (p=0.273) at the 5% level of significance after false discovery rate adjustment.



n = 23
Kendal tau = -0.054
p-value = 0.720
FDR p-value = 0.796

Figure 10 LOWESS trend analysis of percentage cover of thick mats at Stony River, SH45 (STY000400)



n = 23
Kendal tau = -0.221
p-value = 0.141
FDR p-value = 0.281

Figure 11 LOWESS trend analysis of percentage cover of long filaments at Stony River, SH45 (STY000400)

At SH45 (STY000400) over the 14 year monitored period there were no significant trends for thick mats (p=0.796) or long filaments (p=0.281) at the 5% level of significance after false discovery rate adjustment.

2.2 Maketawa Stream

The Maketawa Stream originates in Egmont National Park, flowing approximately 25 kilometres north east before joining the Ngatoro Stream, shortly before this enters the Manganui River. Exotic trees, pasture and mixed vegetation are all present within the catchment.

The Maketawa Stream generally contains good water quality throughout the whole catchment. This stream is subject to headwater erosion events which can lead to poorer water clarity and higher phosphorus values (Appendix 2).

The Maketawa Stream has a catchment with high conservation status and has been designated as one of only two river catchments in the draft Freshwater and Land Management Plan for Taranaki (2015) to be in the Freshwater Management Unit A: outstanding freshwater bodies. Two sites have been located in this catchment to monitor periphyton communities (Figure 12). The top site (MKW000200) is 3.5km from the National Park boundary. Upstream of this site the stream has good riparian cover over most of this length. The bottom site (MKW000300) is in the lower reaches of a developed farmland catchment and is representative of a sub-catchment of the Manganui River and Waitara River catchments.

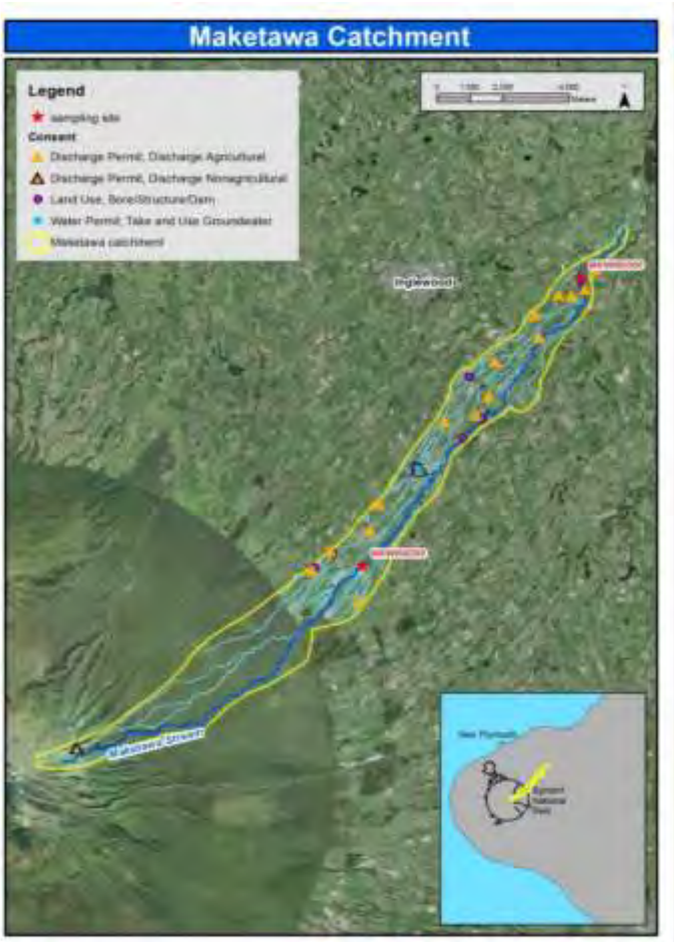


Figure 12 Monitoring site locations in relation to consents operating in the Maketawa Stream catchment Manganui River

2.2.1 Flow and nutrient data and survey dates

No continuous flow data is collected for the Maketawa Stream. The nearby Manganui River at SH3 has a telemetered hydrological monitoring station, and provides a general indication of the flow history in relation to sampling times in the Maketawa Stream catchment (Appendix 1).

The spring 2014 survey was conducted on 3 December 2014 15 days after a fresh in excess of 3x median flow and 16 days after 7x median flow. The summer 2015 survey was carried out on 15 January 2015 14 days after a fresh in excess of both 3x and 7xmedian flow (Appendix 1).

The spring 2015 survey was conducted on 13 October 2015 10 days after a fresh in excess of 3x median flow and 11 days after 7x median flow. The summer 2016 survey was carried out on 12 February 2016 24 days after a fresh in excess of both 3x and 7xmedian flow (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at site MKW000300. The site did not meet the guideline for DRP for a lowland site (ANZECC 2000) (Appendix 2). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels.

2.2.2 Periphyton cover

During the first four years that this programme had been operating (2002-2004), the upper catchment site was monitored at SH3 (MKW000250), after which time the site was moved upstream to Derby Road (MKW000200). This report looks at the Derby Road site and Tarata Road site from 2014-2016.

During the 2014-2015 monitoring period a very low level of nuisance periphyton was detected at the lower site at Tarata Road. In the 2015-2016 monitoring period moderately low levels of nuisance periphyton in the form of thick mats was recorded at the lower site at Tarata Road during the Spring 2015 survey but this was well below the guideline level (Figure 13 and Figure 14).

The thick algal mats consisted of mostly thick black mats (15.5%) which were likely to be the cyanobacteria *Phormidium* but the level found would not trigger the ‘Alert’ level for breaching 20% bed coverage (Figure 14).

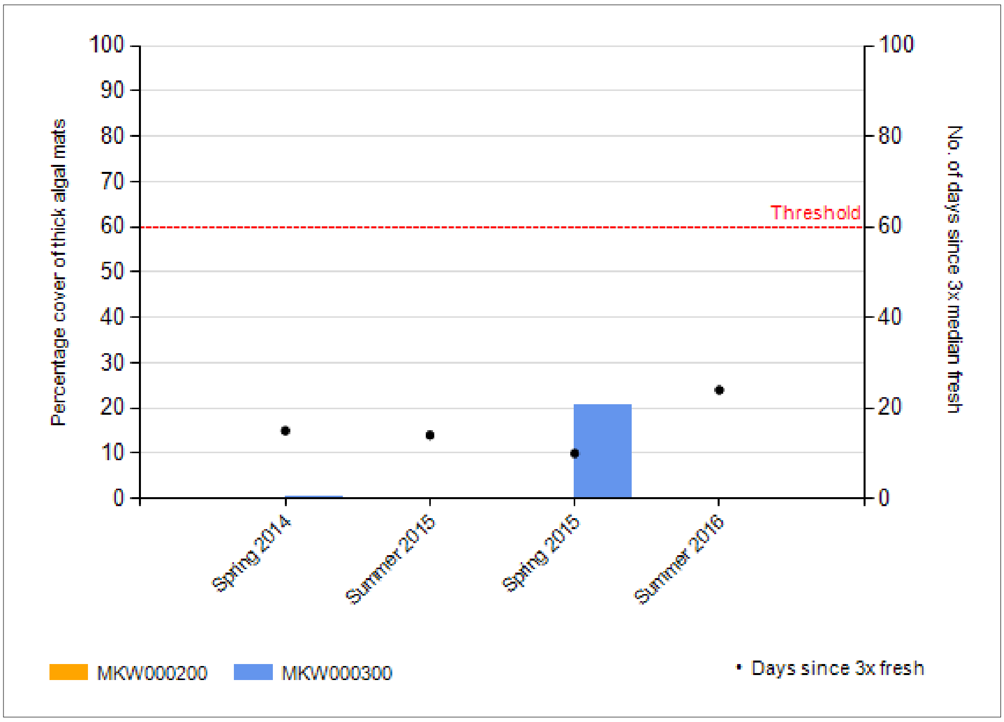


Figure 13 Percentage cover of thick mats of periphyton on the Maketawa streambed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

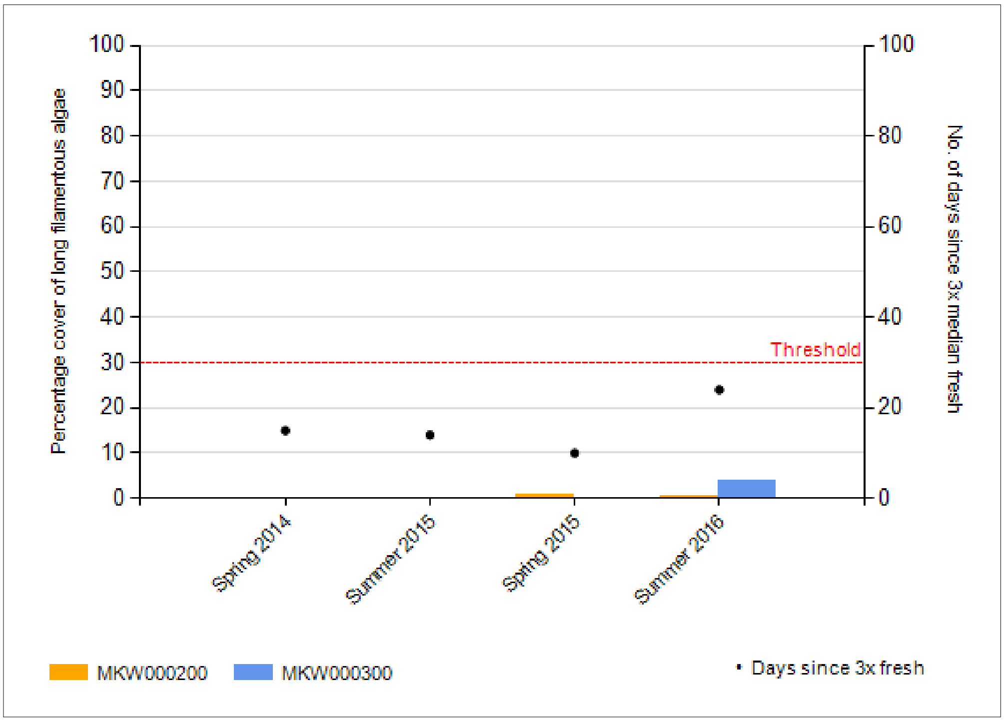


Figure 14 Percentage cover of long filamentous algae on the Maketawa streambed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.2.3 Periphyton Index Score

The Maketawa Stream at the upstream site (MKW000200) and downstream site (MKW000300) had 'very good' TRC PI scores during both spring and summer surveys (Table 10). TRC PI scores were within one unit of historical medians for all surveys. As reflected by both the current monitoring period results and the historical medians, the downstream site (MKW000300) had a consistently lower TRC PI rating. The difference in scores between the two sites was likely a reflection of the increased nutrient inputs from agricultural land between the sites.

The TRC PI scores showed no obvious seasonal variation apart from the Tarata Road site had an improvement in TRC PI during the 2014-2015 monitoring year from spring to summer but showed no improvement in the 2015-2016 monitoring year (Table 10). Historical, TRC PI scores were usually lower during summer than spring which would be expected due to increased periphyton growth/biomass caused by longer sunlight hours, warmer temperatures, and less scouring events over the summer period.

Table 10 Median seasonal periphyton index scores for Maketawa Stream. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
MKW000200	10.0	10.0	9.5	9.8	9.9	9.7
MKW000300	8.1	9.7	8.5	8.5	8.9	8.3
Difference	1.9	0.3	1.0	1.3	1.0	1.4

2.2.4 Periphyton biomass

The results for the 2014- 2016 monitoring period found extremely low levels of chlorophyll *a* (1-2 chlorophyll *a* mg/m^2) at the upstream site and low levels at the downstream site (10-28 chlorophyll *a* mg/m^2) which were well below NOF standards (Figure 15). The results are congruent with TRC PI scores indicating that the Maketawa Stream has only low levels of periphyton but the downstream site has higher levels than the upstream site.

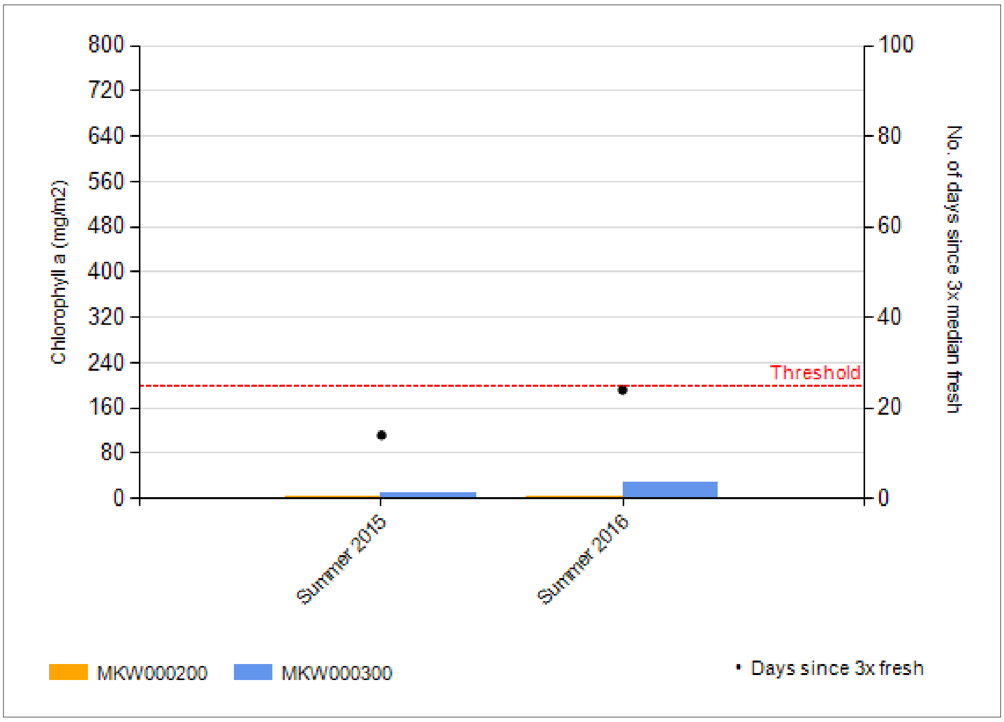


Figure 15 Periphyton biomass (chlorophyll *a*) on the Maketawa riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.2.5 Summary of 2002-2016 (14 year data set)

Thick algal mats have never breached recreational guidelines at the two Maketawa Stream sites surveyed (Figure 16). Where thick algal mats have proliferated it was typically at the downstream site with only one occasion where thick mats at the upstream site have proliferated which was in the spring 2009 survey.

Long filamentous algae has varied dramatically at both sites, with a higher cover present during summer periods during low flows, particularly at the downstream site (Figure 17). This has led to five breaches in the long filamentous guidelines at the downstream site, mostly within the summer seasons but with one event in spring 2005. The breaches usually coincided with longer periods of low flow. The upstream site occasionally recorded some nuisance growths of filamentous algae from 2002-2010 but not to the same extent as the downstream site. There were small proliferations of thick algal mats recorded at the downstream site during spring 2015 but this was well below guideline levels.

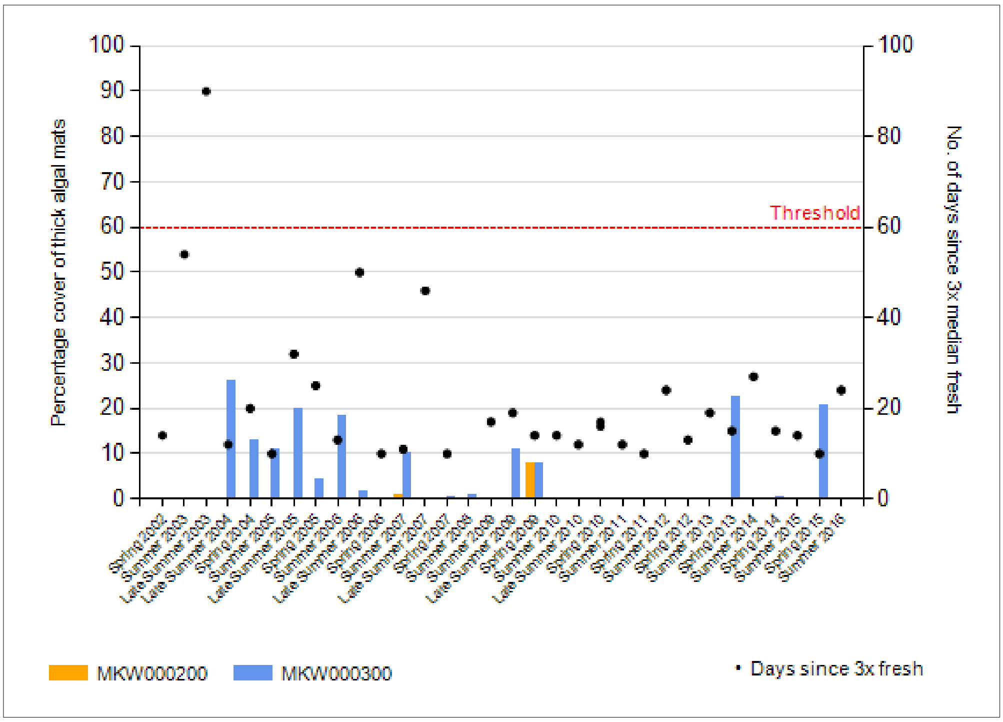


Figure 16 Percentage cover of thick mats of periphyton on the Maketawa streambed in relation to the guidelines for recreational values over the 2002-2016 period

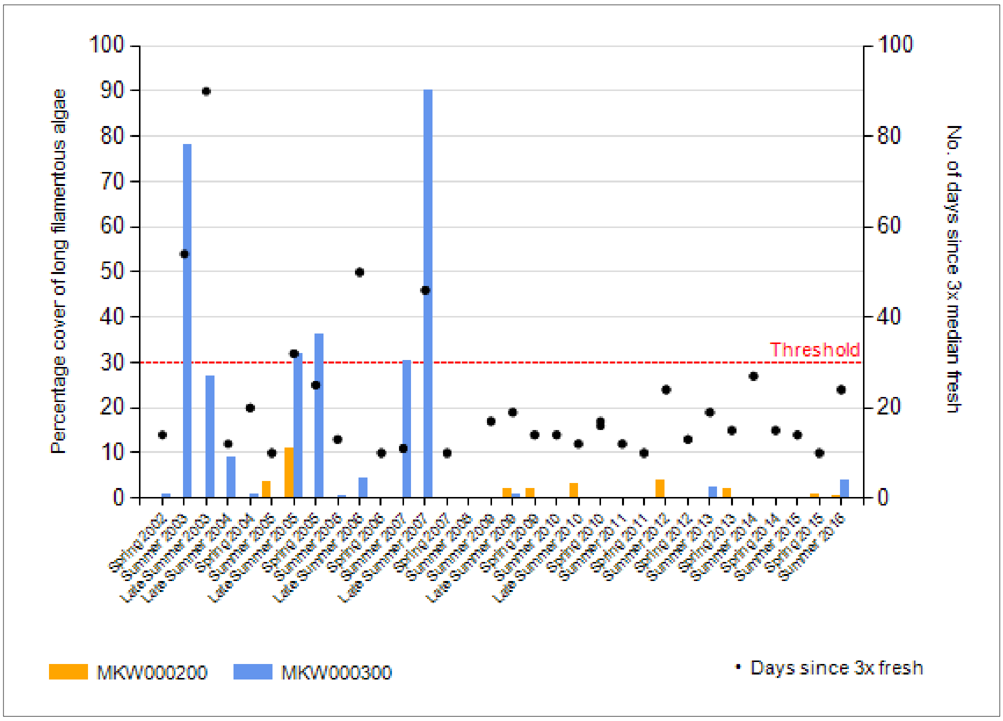
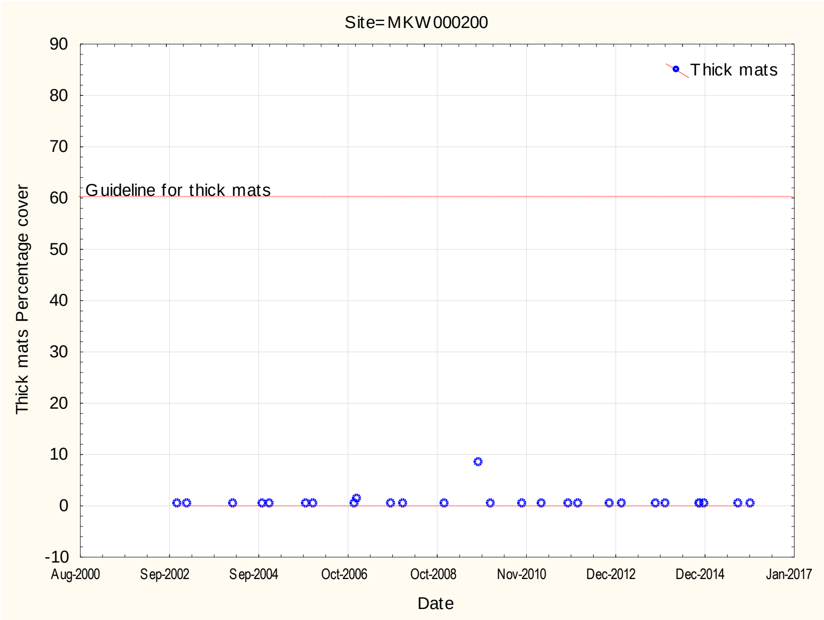


Figure 17 Percentage cover of long filamentous algae on the Maketawa streambed in relation to the guidelines for recreational values over the 2002-2016 period

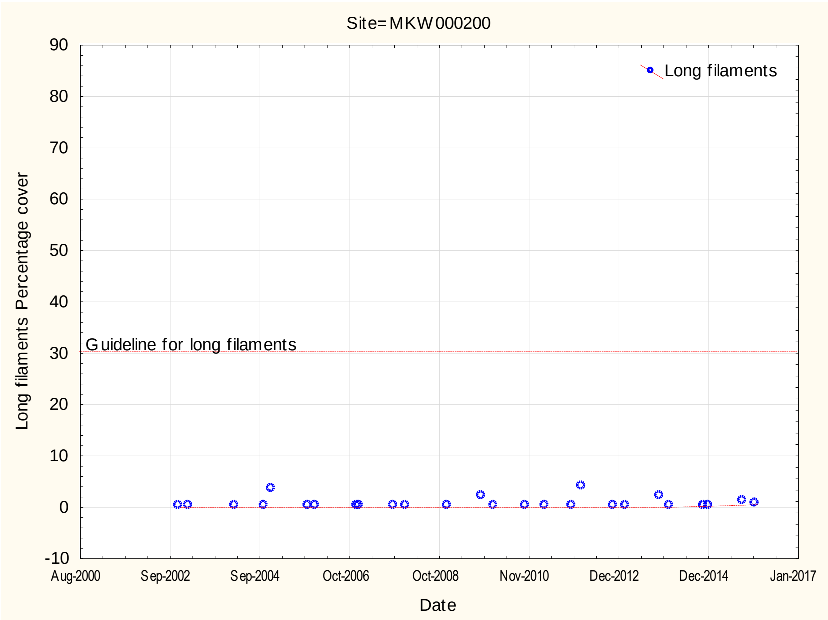
2.2.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Maketawa Stream, at Derby Road and Tarata Road over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 17 to Figure 21).



n = 26
Kendal tau = -0.071
p-value = 0.609
FDR p-value = 0.753

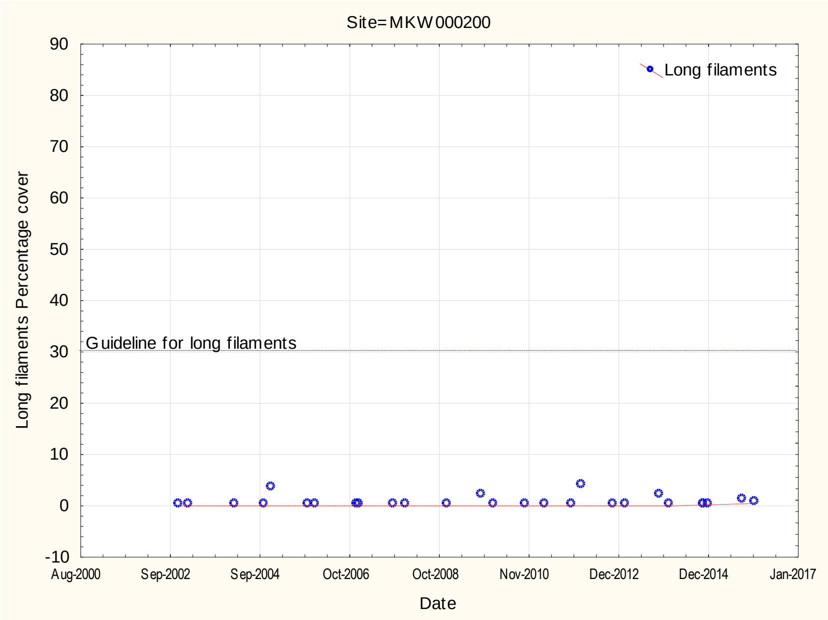
Figure 18 LOWESS trend analysis of percentage cover of thick mats at Maketawa Stream, Derby Road (MKW000200)



n = 26
Kendal tau = 0.211
p-value = 0.131
FDR p-value = 0.281

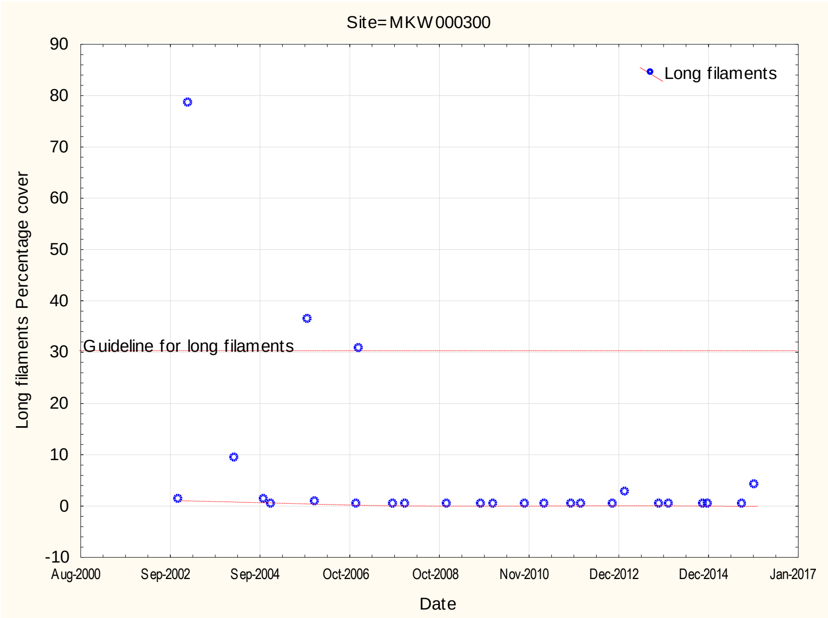
Figure 19 LOWESS trend analysis of percentage cover of long filaments at Maketawa Stream, Derby Road (MKW000200)

At Derby Road (MKW000200) over the 14 year monitored period there were no significant trends for thick mats (p=0.753) or long filaments (p=0.281) at the 5% level of significance after false discovery rate adjustment.



n = 26
Kendal tau = -0.236
p-value = 0.091
FDR p-value = 0.337

Figure 20 LOWESS trend analysis of percentage cover of thick mats at Maketawa Stream, Tarata Road (MKW000300)



n = 26
Kendal tau = -0.364
p-value = 0.009
FDR p-value = 0.061

Figure 21 LOWESS trend analysis of percentage cover of long filaments at Maketawa Stream, Tarata Road (MKW000300)

At Tarata Road (MKW000300) over the 14 year monitored period there was no significant trend for thick mats (p=0.337) or long filaments (p=0.061) at the 5% level of significance after false discovery rate adjustment.

2.3 Manganui River

The Manganui River arises in the National Park and flows approximately 44 kilometres before joining the Waitara River; first heading east, then curving north near Midhirst through agricultural land.

The top site at SH3 (MGN000195) is located approximately 8 km downstream of the National Park boundary (Figure 22). The lower site is located at Bristol Rd (MGN000427), 38 km downstream of the National Park boundary, where the river is draining a largely agricultural catchment. The flow in this river is monitored continuously at both SH3 and at Everett Park (just downstream of the Bristol Road site).

There are two main abstractions from the Manganui River, with a significant consent relating to Trust Power Ltd, located at Tariki Road (downstream of the top site). Under this consent, much of the flow of the river is diverted through the Motukawa hydroelectric power scheme and then to the Waitara River. Therefore, except when the Tariki Rd weir is overtopping, most of the water in the Manganui River at Bristol Road (14 km downstream of this diversion) comes from tributaries such as the Mangamawhete, Waitepuke, Maketawa, and Ngatoro Streams.

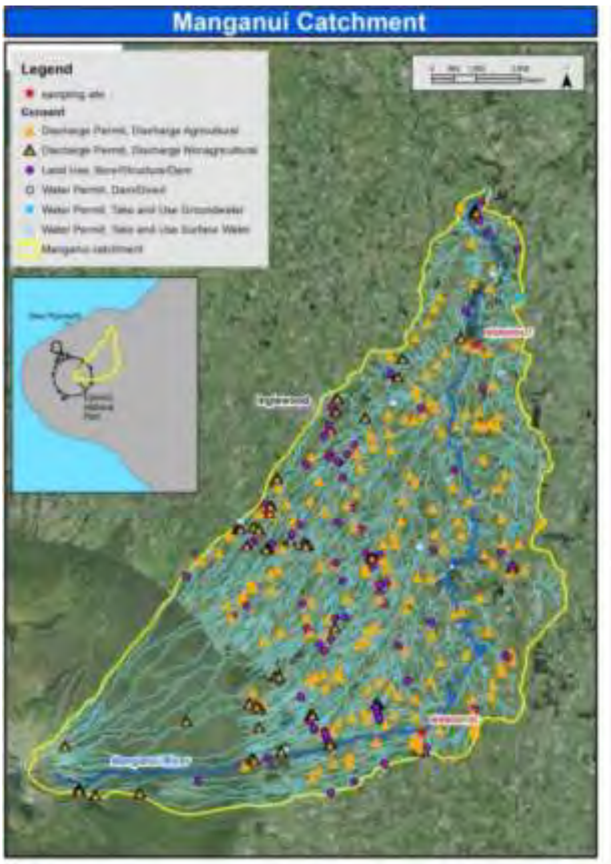


Figure 22 Monitoring site locations in relation to consents operating in the Manganui River catchment

2.3.1 Flow and nutrient data and survey dates

There are two telemetered hydrological monitoring stations on the Manganui River, the upper site is at SH3 Midhurst which coincides with the upper periphyton site and the lower site is at Everett Park which is used for the lower periphyton site at Bristol Road (Appendix 1).

The spring 2014 survey was conducted on 3 December 2014 15 days after a fresh in excess of 3x median flow and 16 days in excess 7x median flow for the SH3 site and 11 days after a fresh in excess of 3x median flow and 30 days in excess 7x median flow for the Bristol Rd site. The summer 2015 survey was carried out on 15 January 2015 14 days after a fresh in excess of 3x and 7x median flows for both sites (Appendix 1).

The spring 2015 survey was conducted on 13 October 2015 10 days after a fresh in excess of both 3x median flow and 11 days after a fresh of 7x median flow for both sites. The summer 2016 survey was carried out on 10 February 2016 22 days after a fresh in excess of 3x median flow and 33 days after a 7x median flow for both sites (Appendix 1).

No nutrient data was collected from the Manganui River for the reported period.

2.3.2 Periphyton cover

The Manganui River was characterised by no nuisance periphyton in the upper catchment at SH3 and moderately low to very high levels of nuisance periphyton at the lower site at Bristol Road (Figure 23 and Figure 24).

In the 2014-2015 monitoring year the downstream site had low levels of periphyton during the spring 2014 survey but levels nearly breached guideline levels for the summer 2015 survey (28% long filaments). In the 2015-2016 monitoring year a highly significant breach of guidelines occurred at the downstream site for long filaments (59%) during the spring 2015 survey. Thick algal mats were also present at moderately low levels (23%) at the time of the survey and in total 82% of the streambed was covered in nuisance periphyton. The summer 2016 survey recorded only low levels of nuisance periphyton well below guideline levels indicating a substantial drop in nuisance periphyton levels from the preceding survey.

The upstream site in the Manganui River was well shaded by riparian vegetation. This shade, in conjunction with low nutrient levels, would limit the growth of periphyton at this site. The Bristol Road site had a much wider bed and was not shaded. The Manganui River runs through a substantial amount of agricultural area and the combination of high sunshine, water temperature (21.9 °C) and nutrient levels has caused significant nuisance periphyton growth at this site. Of the four surveys, the high spring 2015 survey was also the only one that did not have a silt coating on the substrate. A silt layer is likely to inhibit periphyton growth by smothering algae. Periphyton levels were not correlated with time since last fresh at this site with the high spring result corresponding with a relatively recent (11 days prior) fresh of 7x median flow.

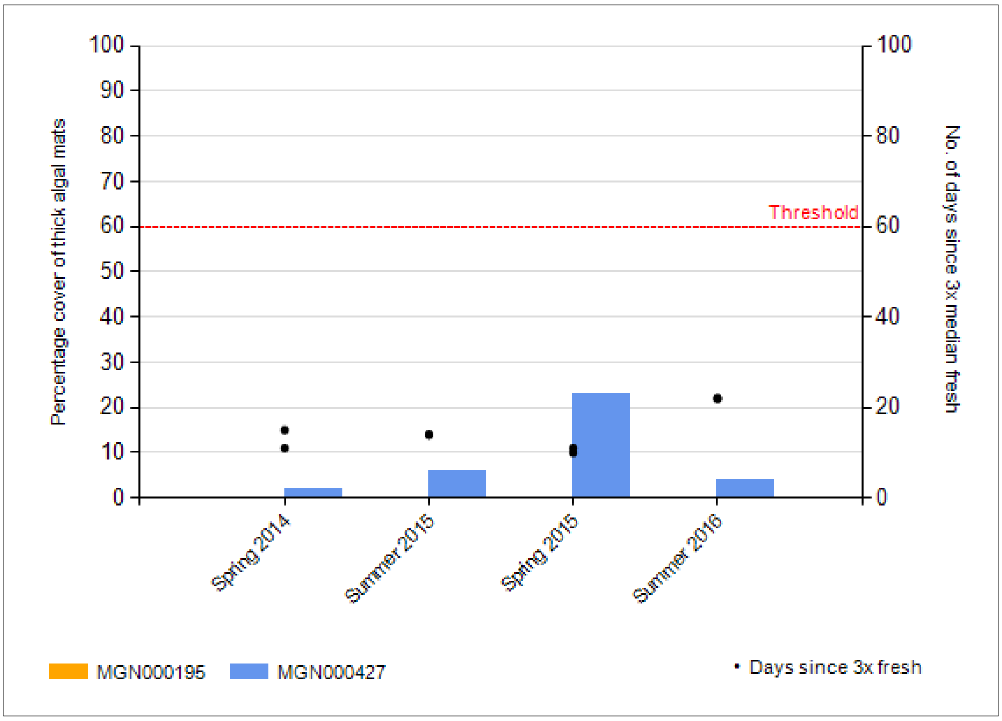


Figure 23 Percentage cover of thick mats of periphyton on the Manganui riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

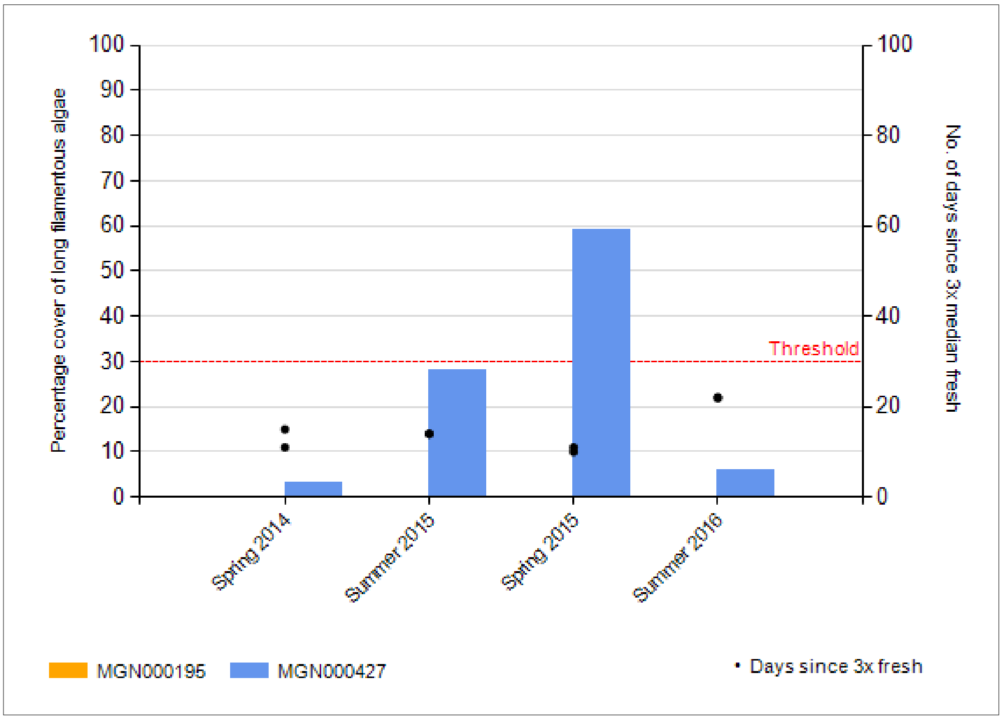


Figure 24 Percentage cover of long filamentous algae on the Manganui riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.3.3 Periphyton Index Score

The upstream site had 'very good' levels of periphyton while the downstream site had 'moderate' to 'good' levels. This is consistent with past results which show the

Manganui River typically recorded moderate differences in TRC PI between the upstream and downstream sites (Table 11). The TRC PI at the upstream site was stable throughout spring and summer, consistently scoring a 'very good' rating. Scores were similar to the historical median. The downstream site scored a lower TRC PI on every survey, particularly for both surveys conducted in 2015. There was no obvious trend between spring and summer surveys. As discussed in the periphyton coverage section, low nutrient input and good riparian shading contributed to the low levels of periphyton at the upstream site while the downstream site probably had issues with nutrient enrichment and a lack of shading.

Table 11 Median seasonal periphyton index scores for Maketawa Stream. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
MGN000195	10.0	10.0	10.0	10.0	9.8	9.8
MGN000427	7.1	5.6	4.4	8.5	6.1	6.2
Difference	2.9	4.4	5.6	1.5	3.7	3.6

2.3.4 Periphyton biomass

The results for the 2014-2016 monitoring period found extremely low levels of chlorophyll *a* at the upstream site (1-2 mg/m^2) and low to high levels at the downstream site (Figure 25). The results were largely congruent with the findings from the TRC periphyton index score which showed nuisance periphyton for the summer 2015 period was very close to breaching guideline limits for the downstream site while the while chlorophyll *a* guideline limit was just breached.

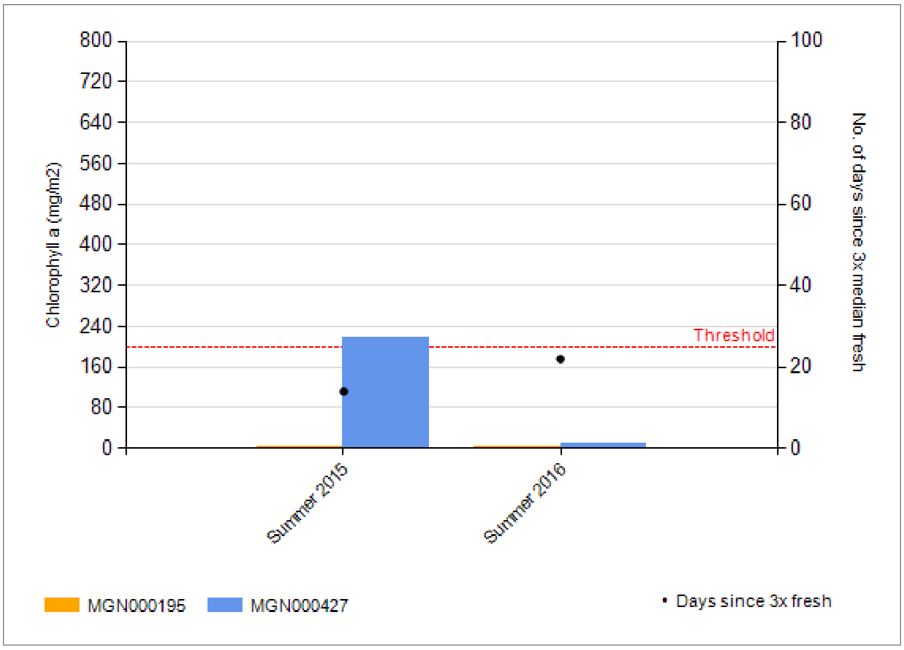


Figure 25 Periphyton biomass (chlorophyll *a*) on the Manganui riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.3.5 Summary of 2002-2016 (14 year data set)

The upper site at SH3 was generally more prone to thick algal mat than long filamentous algae growths particularly over the 2005-2007 monitoring years (Figure 26 and Figure 27). At the downstream Bristol road site the periphyton community had greater levels of long filamentous algae than thick algal mats. There were no breaches in guidelines for thick algal mats at either site over the entire 14 year period.

The upper site had no filamentous algae present. However, the lower catchment site breached long filamentous guidelines on four occasions over the 14 year period. The summer of 2004 (summer and late summer) recorded two breaches for long filamentous algae at the downstream site, while the highest breach was in summer 2006. The breach in guidelines for the spring 2015 survey was the second highest level recorded over the 14 year survey period. There was also nearly a breach for the preceding summer 2015 survey.

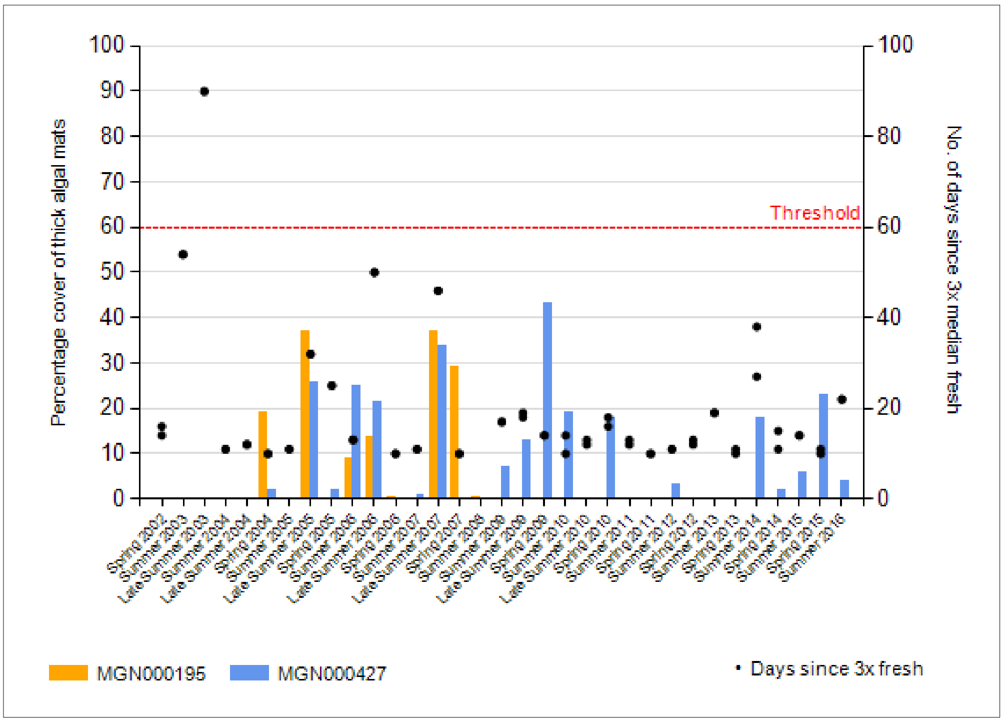


Figure 26 Percentage cover of thick mats of periphyton on the Manganui riverbed in relation to the guidelines for recreational values over the 2002-2016 period

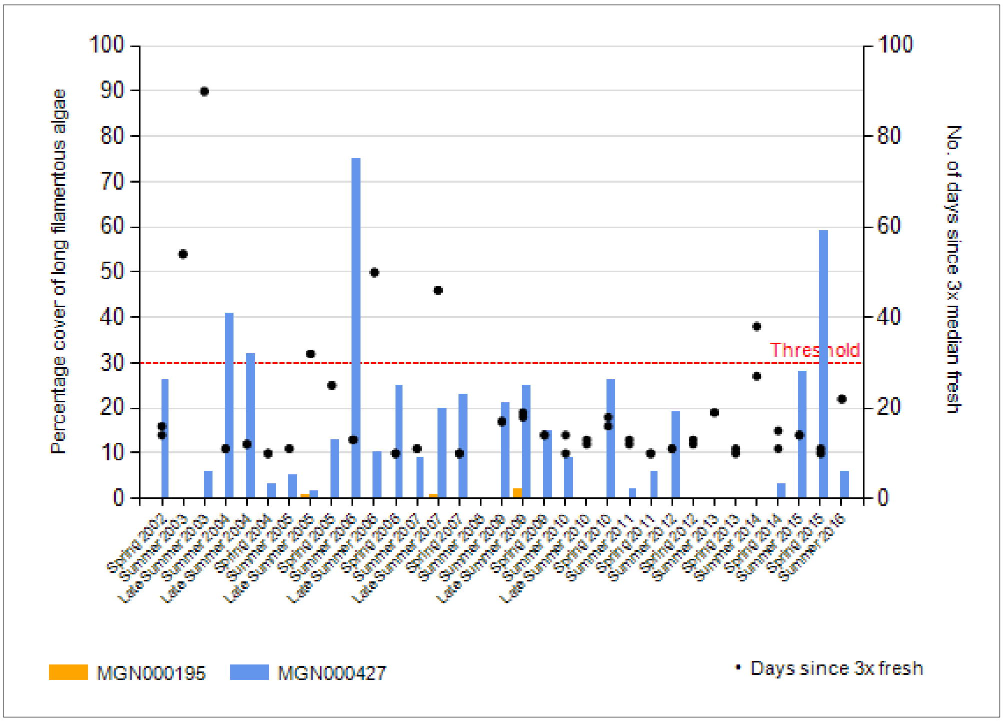
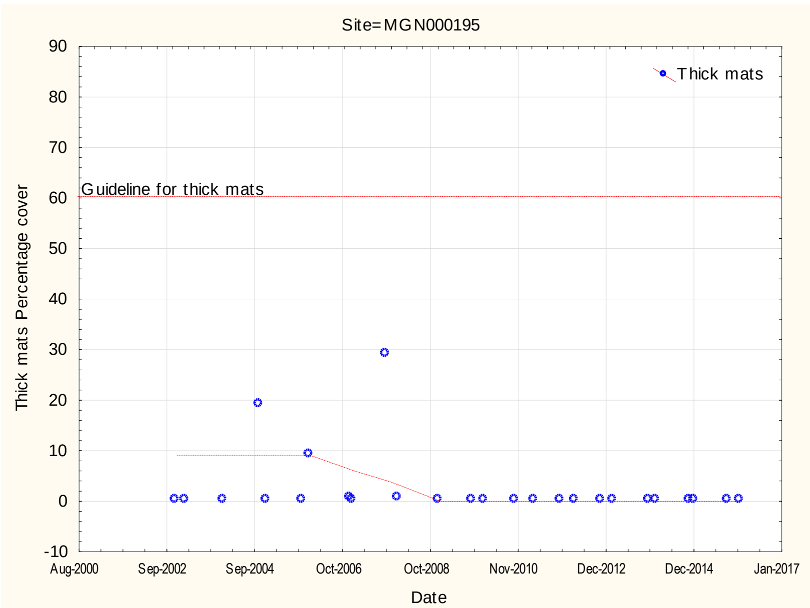


Figure 27 Percentage cover of long filamentous algae on the Manganui riverbed in relation to the guidelines for recreational values over the 2002-2016 period

2.3.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Manganui River, at SH3 and at Bristol Road, over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 28 to Figure 31).



n = 26
Kendal tau = -0.301
p-value = 0.031
FDR p-value = 0.216

Figure 28 LOWESS trend analysis of percentage cover of thick mats at Manganui River, SH3 (MGN000195)

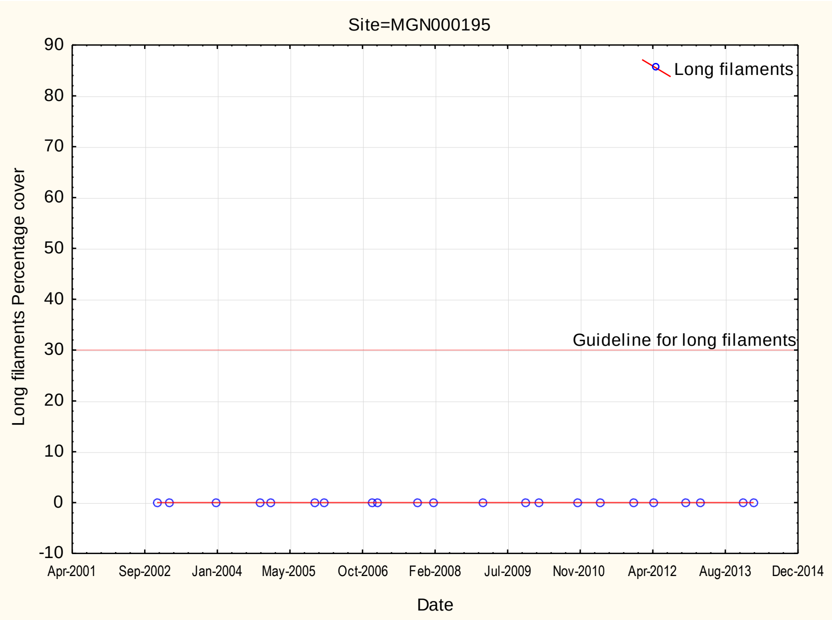
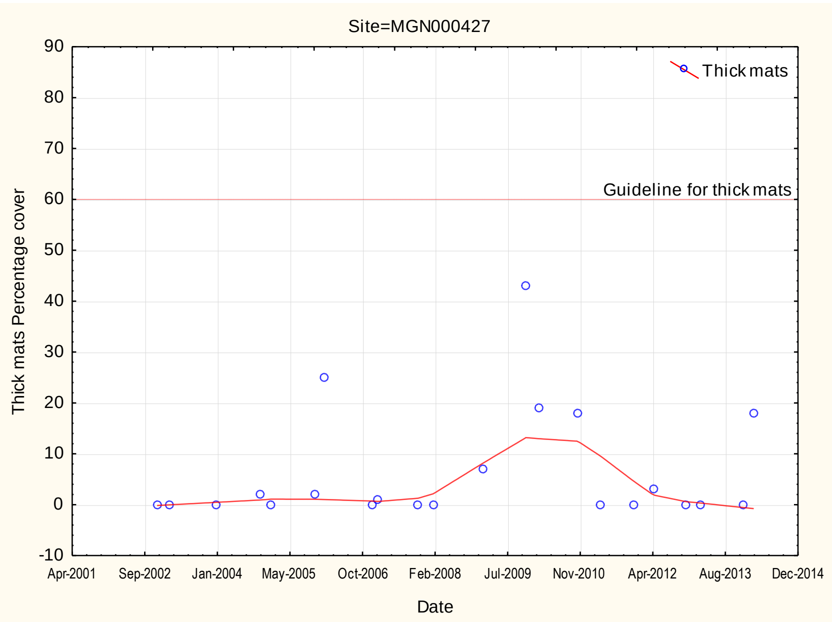


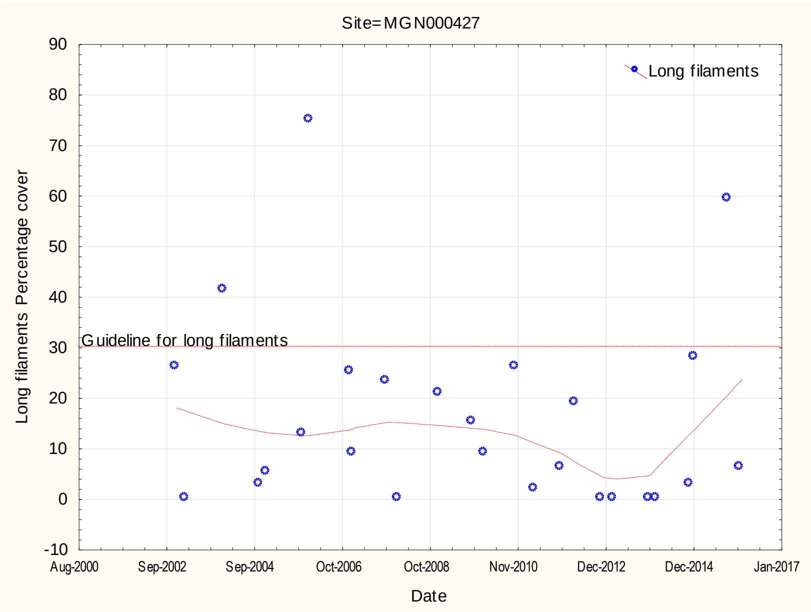
Figure 29 LOWESS trend analysis of percentage cover of long filaments at Manganui River, SH3 (MGN000195)

At SH3 (MGN000195) over the 14 year monitored period there have been no thick mats recorded at the site at the time of surveying.



n = 26
Kendal tau = 0.226
p-value = 0.106
FDR p-value = 0.337

Figure 30 LOWESS trend analysis of percentage cover of thick mats at Manganui River, Bristol Road (MGN000427)



n = 26
Kendal tau = -0.140
p-value = 0.318
FDR p-value = 0.359

Figure 31 LOWESS trend analysis of percentage cover of long filaments at Manganui River, Bristol Road (MGN000427)

At Bristol Road (MGN000427) over the 14 year monitored period there were no significant trends for thick mats (p=0.337) or long filaments (p=0.359) at the 5% level of significance after false discovery rate adjustment.

2.4 Patea River

The Patea River arises in the National Park, winding over 80 km in a curve; first heading east then south to the coast. Water quality is better in the upper reaches then deteriorates in the lower reaches as it travels through pasture and receives wastes such as treated dairy effluent and the discharge from the Stratford oxidation pond system, and is also joined by other rivers such as Mangaehu River (TRC, 1991).

The Patea has native forest in its headwaters, while the mid-low reaches comprise exotic forest and pasture. The top site (Barclay Road, PAT000200) is just below the boundary of National Park and as such the water quality here is very good (Figure 32). The lower site, at Skinner Road (PAT000360) is mid-catchment and below several discharges, including the Stratford municipal oxidation ponds, Stratford cycle power station discharge, and inputs from industrial discharge from the Kahouri Stream. The surrounding area is predominantly agricultural, and as such has a lesser water quality with a higher level of nutrients and lower clarity compared to the upper catchment site.

The lower catchment site at Skinner Road is monitored continuously for flow as part of the Council's hydrological telemetry system.

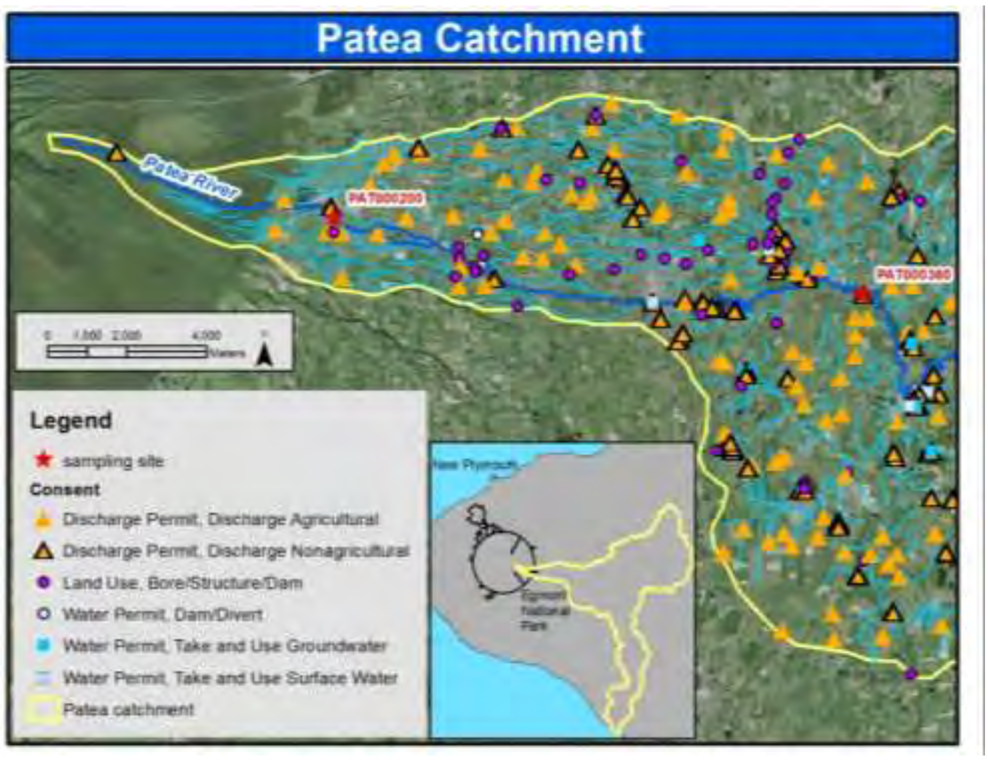


Figure 32 Monitoring site locations in relation to consents operating in the Patea River catchment

2.4.1 Flow and nutrient data and survey dates

The Patea River has a telemetered hydrological monitoring station at Skinner Road.

The spring 2014 survey was conducted on 3 December 2014 15 days after a fresh in excess of 3x median flow and 30 days after a 7x median flow. The summer 2015 survey was carried out on 14 January 2015 13 days after a fresh in excess of 3x and 7x median flows (Appendix 1).

The spring 2015 survey was conducted on 13 October 2015 11 days after a fresh in excess of 3x median flow and 30 days after a fresh of 7x median flow. The summer 2016 survey was carried out on 2 February 2016 14 days after a fresh in excess of 3x median flow and 25 days after a 7x median flow (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at sites PAT000200 and PAT000360. The upper site met the guideline for total nitrogen for an upland site but not for DRP and the lower site did not meet guidelines for total nitrogen or DRP (ANZECC 2000) (Appendix 2). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which were the likely cause of the exceedance in DRP levels at the upper site but the lower site had higher DRP and nitrogen levels which probably can be attributed to the Stratford wastewater treatment plant discharge which occurs several kilometers upstream of the lower site.

2.4.2 Periphyton cover

Nuisance periphyton at Barclay Road and Skinner Road sites did not exceed guideline levels over the reported period. The upstream site at Barclay Road did not have any nuisance periphyton recorded for all four surveys but the downstream site at Skinner Road had both thick mats and long filaments present for most of the surveys. There were well below recommended guidelines (Figure 33 and Figure 34).

For the spring 2014 monitoring year no nuisance thick mats and a low level of long filaments were recorded at the lower site at Skinner Road. A small rise in nuisance periphyton coverage was recorded for the summer 2015 survey with a very low level of thick mats and a low level of long filaments recorded. In the spring 2015 survey thick mat coverage increased but long filament coverage decreased so that total nuisance periphyton levels remained similar. For the summer 2016 survey there was a decrease in overall nuisance periphyton with no thick mats detected and only a very low level of long filaments recorded at the Skinner Road site.

Differences in algal coverage between the two sites may be explained by variations in shading and nutrient levels between the two sites. The complete shading by native riparian vegetation at the upper Barclay Road site, and for most of the upstream reach to the nearby National Park in conjunction with low nutrient level limited periphyton growth to largely thin films. The site at Skinner Road was a much more open site with less shading and was situated below the discharge from Stratford wastewater treatment plant and thus nutrient levels were relatively high. The combination of high sunlight and nutrients levels would promote the proliferation of nuisance periphyton at the Skinner Road site and nuisance periphyton levels were perhaps lower than what might be expected. The Patea River has consistency cooler water temperatures than the majority of other rivers and streams monitored for nuisance periphyton which was probably the result of the elevation the site was at (240 asl) and relatively cool water temperatures would help slow the growth of periphyton at the lower site.

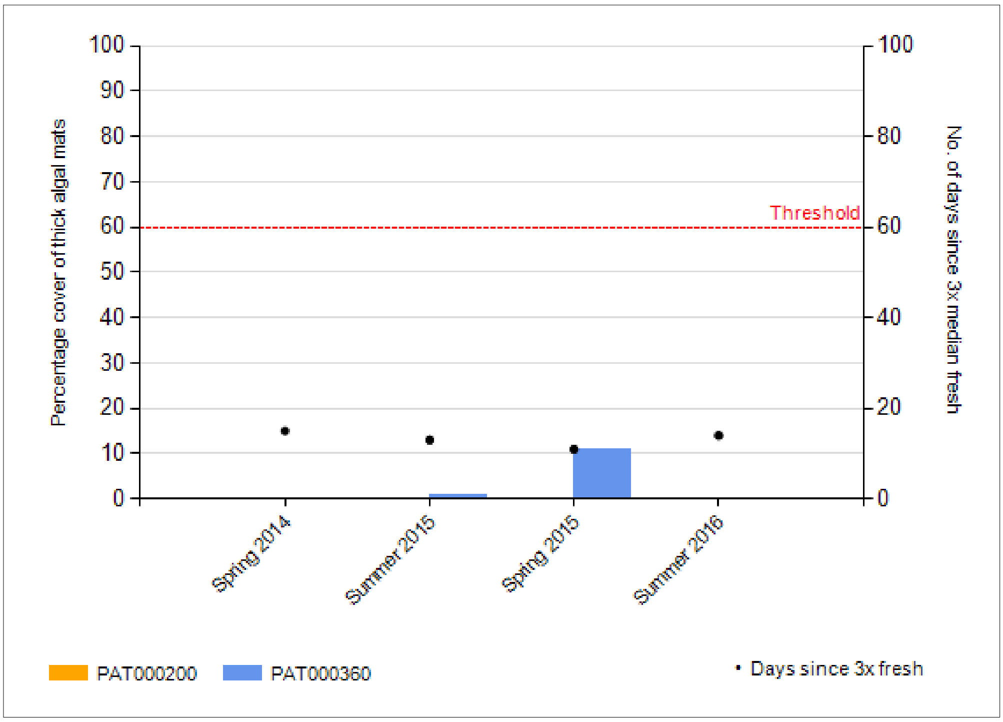


Figure 33 Percentage cover of thick mats of periphyton on the Patea riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

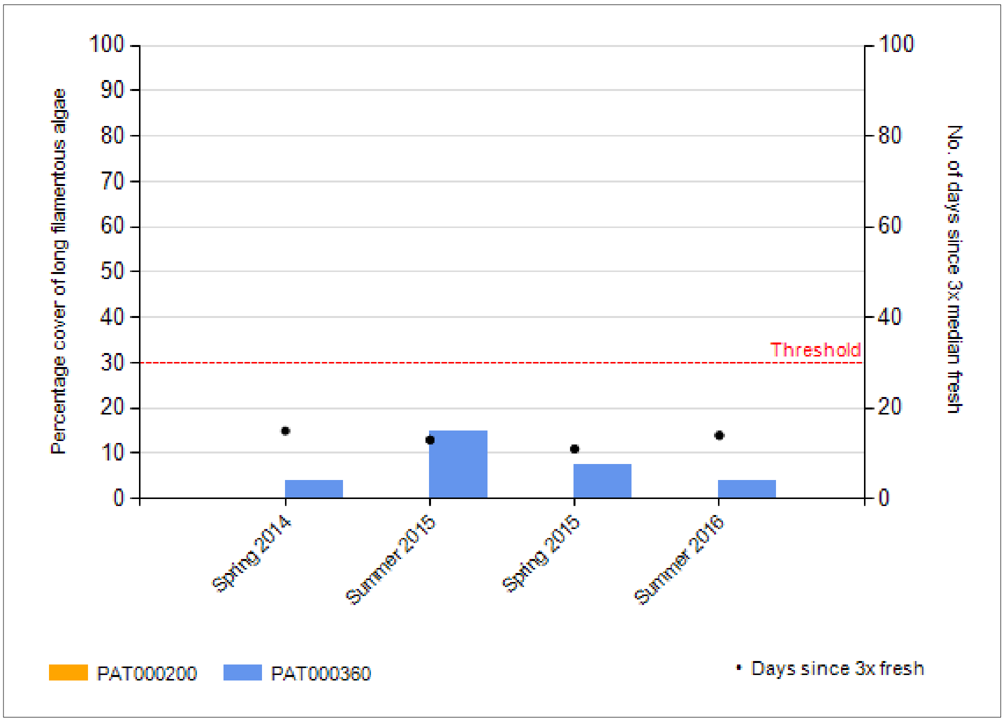


Figure 34 Percentage cover of long filamentous algae on the Patea riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.4.3 Periphyton Index Score

The upstream site on the Patea River (PAT000200) benefits from extensive riparian planting which provides complete shading at the site and in conjunction with low nutrient input consequently has a consistently 'very good' TRC PI score. In contrast, the downstream site (PAT000360) which receives runoff from agricultural pasture, and also receives the Stratford wastewater treatment plant discharge, has higher nutrient levels and generally has a 'moderate' to 'very good' TRC PI value (Table 12).

Table 12 Median seasonal periphyton index scores for the Patea River. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
PAT000200	9.9	10.0	9.4	9.9	9.6	9.8
PAT000360	7.8	7.4	8.0	8.9	7.5	5.3
Difference	2.1	2.6	1.4	1.0	2.1	3.5

The upstream site had TRC PI results similar to historical medians for all surveys (±0.1-0.3 units) but the downstream site had significantly better summer results (+ 2.1-3.6). No obvious difference between spring and summer surveys was evident which contrasts with the historical median for the lower site which had a summer median significantly lower than the spring median.

2.4.4 Periphyton biomass

The results for the 2014- 2016 monitoring period found very low levels of chlorophyll *a* (6-15 mg/m^2) at the upstream site and moderate levels (106-126 mg/m^2) at the downstream site. No site exceeded the NOF standard (chlorophyll *a* 200 mg/m^2) (Snelder et al., 2013) but the guideline to protect benthic biodiversity was exceeded for the bottom site (Table 2).

Chlorophyll *a* levels matched TRC PI scores for the upper site indicating low periphyton levels but for the lower site while chlorophyll *a* was higher for the summer 2016 survey compared with the summer 2015 survey the TRC PI score showed the opposite trend suggesting lower levels of periphyton. The previous report (TRC, 2015) also noted a lack of congruence between TRC PI and chlorophyll *a* for this site. Some variability within a site will always exist and it is important to note that areas that were viewed for periphyton cover and TRC periphyton index were not necessarily the same place rocks were taken for chlorophyll *a* analysis.

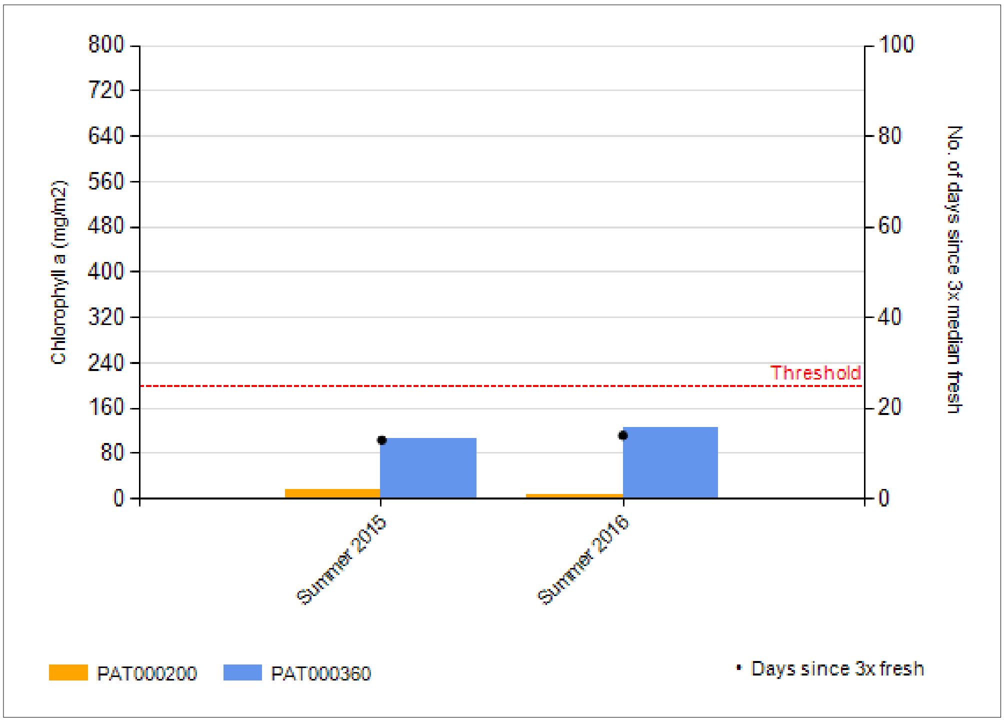


Figure 35 Periphyton biomass (chlorophyll *a*) on the Patea riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.4.5 Summary of 2002-2016 (14 year data set)

Over the entire period the Patea River had never breached thick algal mat periphyton guidelines (Figure 36). Proliferations of thick mats were usually more frequent and prolific at the lower site at Skinner Road. Thick algal mats were recorded at the upstream site at Barclay Road mostly during the 2006-2010 monitoring years, particularly over dry periods such as that of spring 2007. Over the 2010-2012 monitoring period, proliferations of thick mats only occurred at the lower site at Skinner Road. For the 2012-2014 monitoring period thick algal mats occurred at both sites, though with much higher levels at Skinner Road while for the current monitoring period no nuisance periphyton was detected at the upper site but thick mats and long filaments were recorded at the bottom site.

At the downstream site at Skinner Road, large proliferations of long filamentous algae led to many breaches throughout the 14 year period of monitoring (particularly during the earlier monitoring years) (Figure 37). There were seven breaches in long filamentous guidelines from 2002-2006. In the 2006-2010 period there was less frequent occurrences of long filamentous algae, but the two breaches recorded in summer 2007 and late summer 2009 were the highest percentages recorded over the 14 year period. The majority of the breaches corresponded to periods of low flow. There have been periods where flows have been much higher and periphyton proliferation has been lower (summer 2001 and summer 2003). After five years without a breach the last survey at the Skinner Road site in summer 2014 recorded a breach which corresponded with a long period without flushing flows. There were no breaches for the current reported period.

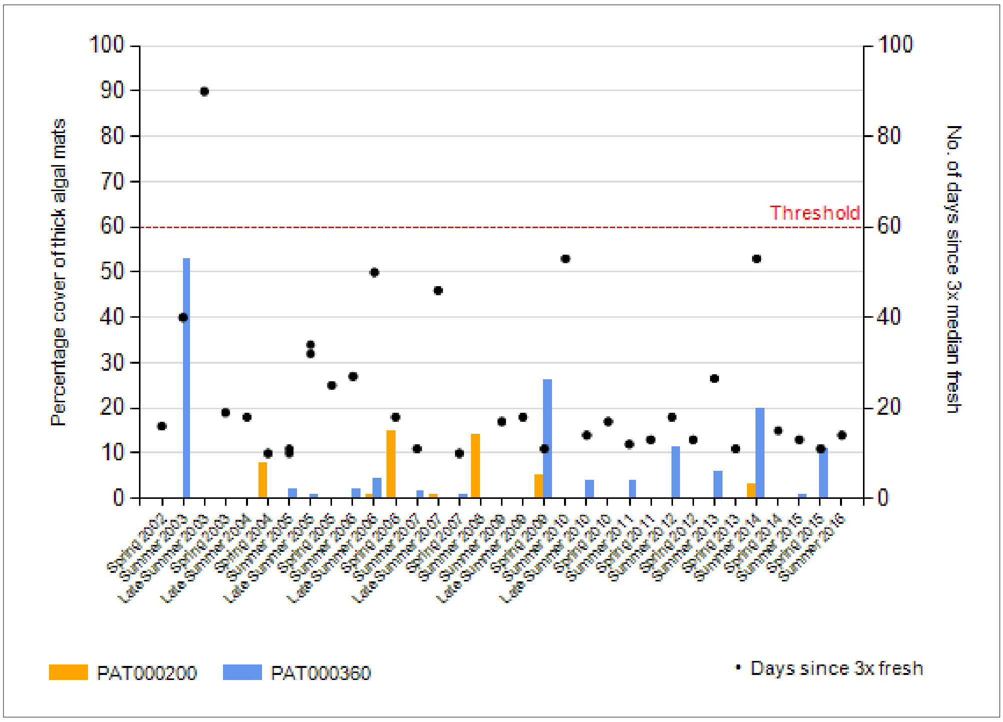


Figure 36 Percentage cover of thick mats of periphyton on the Patea riverbed in relation to the guidelines for recreational values over the 2002-2016 period

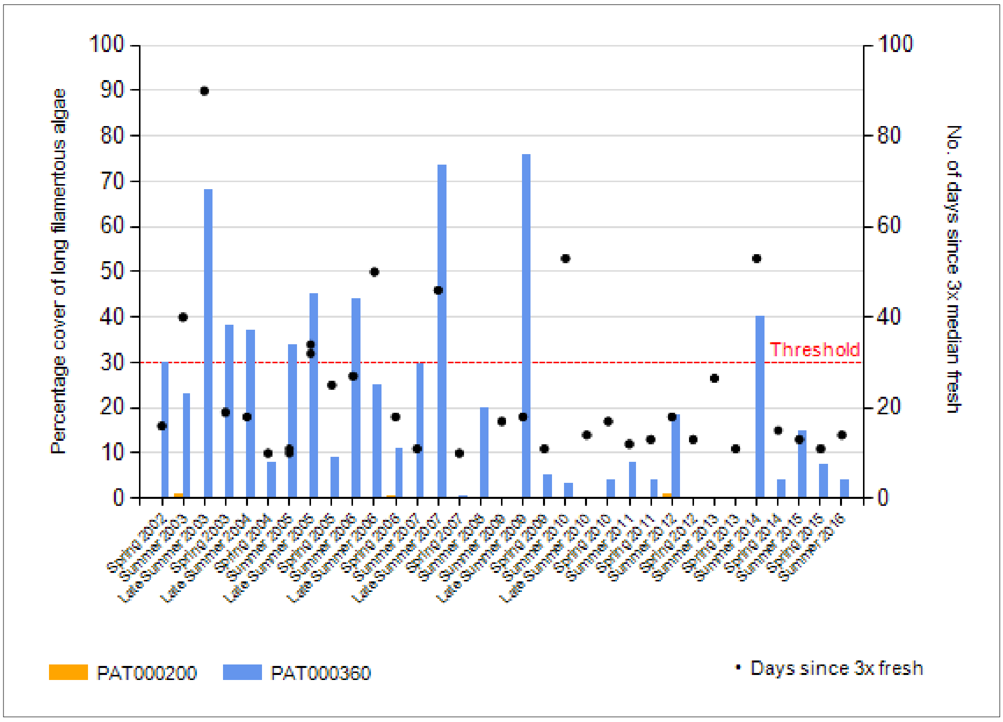
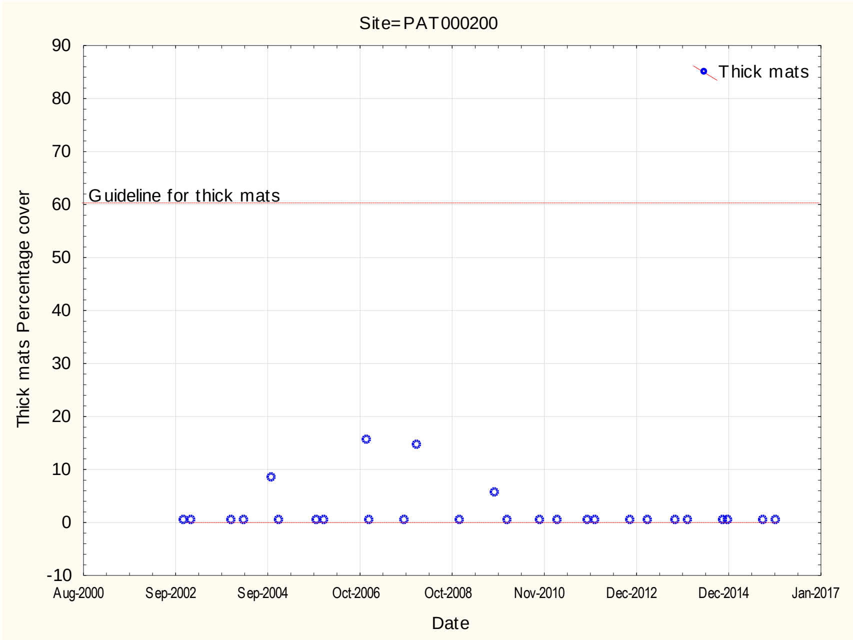


Figure 37 Percentage cover of long filamentous periphyton on the Patea River streambed in relation to the guideline for recreational values over the 2002-2016 period

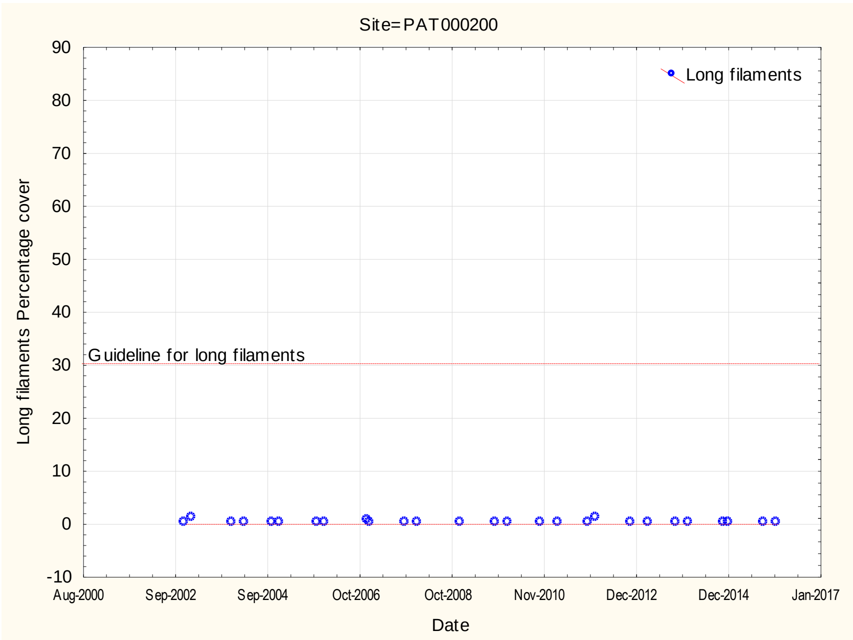
2.4.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Patea River, at Barclay Road, and Skinner Road over a 12 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 38 to Figure 41).



n = 27
Kendal tau = -0.183
p-value = 0.180
FDR p-value = 0.469

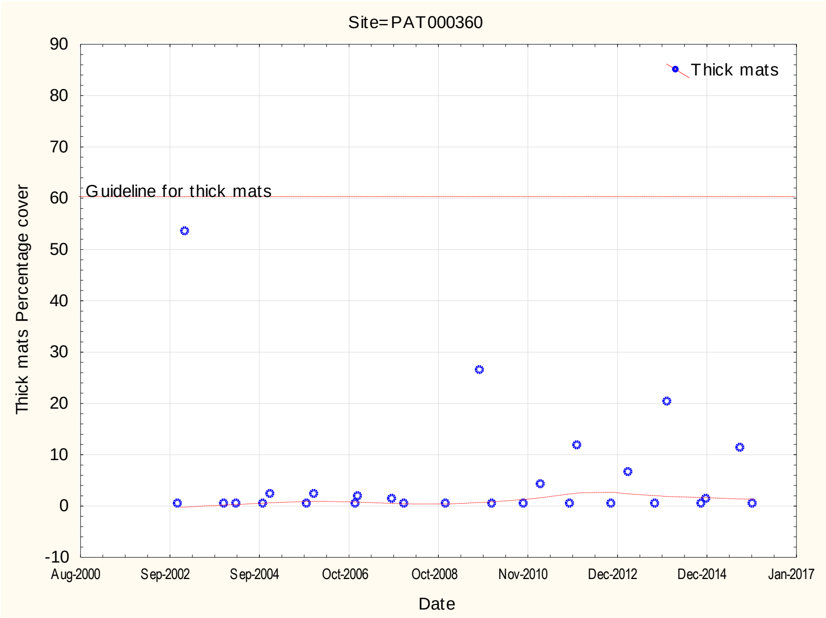
Figure 38 LOWESS trend analysis of percentage cover of thick mats at Patea River, Barclay Road (PAT000200)



n = 27
Kendal tau = -0.149
p-value = 0.276
FDR p-value = 0.359

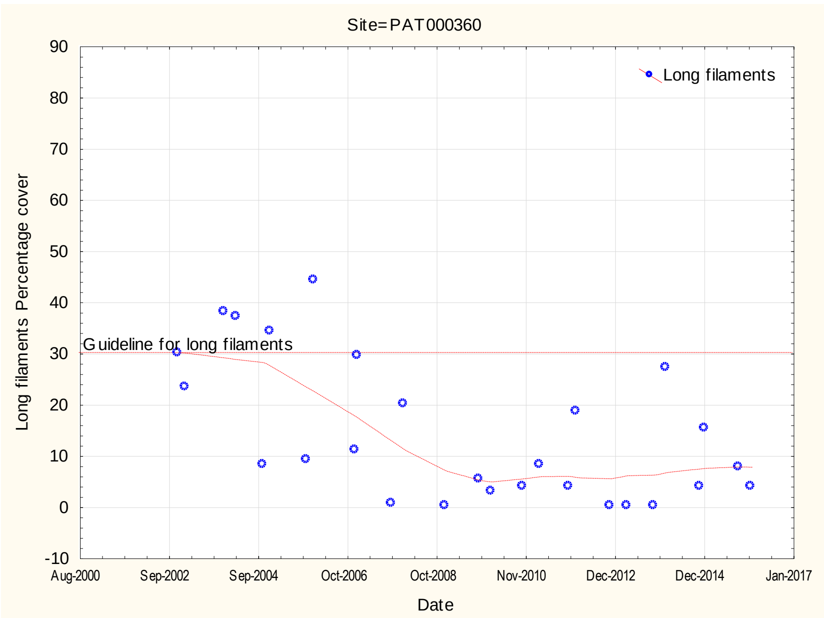
Figure 39 LOWESS trend analysis of percentage cover of long filaments at Patea River, Barclay Road (PAT000200)

At Barclay Road (PAT000200) over the 14 year monitored period there were no significant trends for thick mats (p=0.469) or long filaments (p=0.359) at the 5% level of significance after false discovery rate adjustment.



n = 27
Kendal tau = 0.096
p-value = 0.484
FDR p-value = 0.723

Figure 40 LOWESS trend analysis of percentage cover of thick mats at Patea River, Skinner Road (PAT000360)



n = 27
Kendal tau = -0.389
p-value = 0.004
FDR p-value = 0.044

Figure 41 LOWESS trend analysis of percentage cover of long filaments at Patea River, Skinner Road (PAT000360)

At Skinner Road (PAT000360) over the 14 year monitored period there was no significant trend for thick mats (p=0.723) at the 5% level of significance after false discovery rate adjustment. However, there was a significant (p=0.044) negative (tau=-0.389) trend for long filaments at the 5% level of significance after false discovery rate adjustment indicating that long filamentous algae had decreased at the site during the monitored period, possibly as a result of improvements to the Stratford oxidation pond discharges.

2.5 Waiwhakaiho River

The Waiwhakaiho River originates in the National Park, winding approximately 30 kilometres past Egmont Village in a north east direction to the coast, with the mouth of the river situated at the north end of New Plymouth. The river is representative of a large catchment with multiple impacts, with the upper catchment below the National Park boundary comprising primarily agriculture, and the lower catchment comprising urban and industrial areas.

The top sampling site (WKH000500) at SH3, Egmont Village, is representative of the mid catchment (9km downstream of National Park boundary), draining developed farmland and is immediately upstream of the major diversion site for the New Plymouth water supply and the Mangorei HEP scheme. The bottom site (WKH000920) at Constance Street is approximately two kilometres from the mouth of the river and is markedly influenced by changes in flow due to hydroelectric generation releases from the HEP scheme and various municipal and industrial impacts in the lower catchment.

A telemetered river flow recording station is present at the site located at SH3, near Egmont Village.

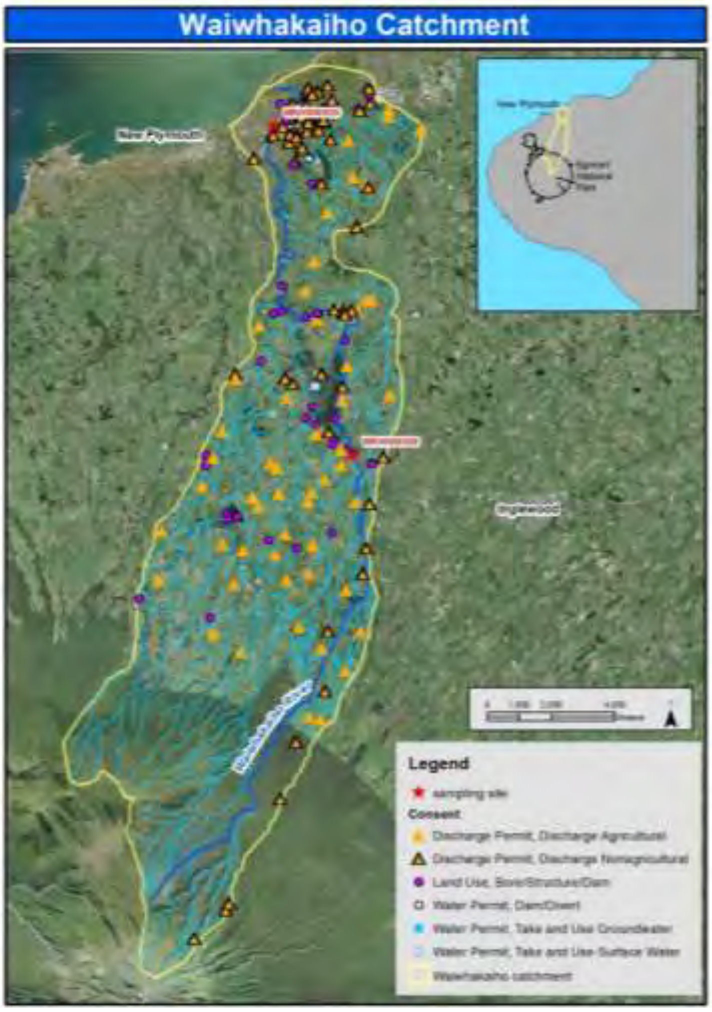


Figure 42 Monitoring site locations in relation to consents operating in the Waiwhakaiho River catchment

2.5.1 Flow and nutrient data and survey dates

The Waiwhakaiho River has a telemetered hydrological monitoring station at SH3 which coincides with the upper periphyton site and another telemetered hydrological monitoring station at the bottom of the catchment at Rimu St close to the periphyton site at Constance Street (Appendix 1).

The spring 2014 survey was conducted on 9 December 2014 13 days after a fresh in excess of 3x median flow and 32 days after a fresh of 7x median flow at both sites. The summer 2015 survey was carried out on 20 January 2015 20 days after a fresh in excess of 3x and 7x median flows at both sites (Appendix 1).

The spring 2015 survey was conducted on 13 October 2015 11 days after a fresh in excess of both 3x and 7x median flow at the SH3 site and 10 days after a fresh in excess of 3x median flow and 12 days after a fresh in excess of 7x median flow at the Constance Street site. The summer 2016 survey was carried out on 1 February 2016 13 days after a fresh in excess of 3x and 7x median flows at both sites (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at site WKH000500. The site did not meet the guideline for DRP for an upland site (ANZECC 2000) (Appendix 2). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels.

2.5.2 Periphyton cover

Nuisance periphyton at the upper SH3 site exceeded the guideline level for filamentous algae during the summer 2015 survey. During the same survey the lower site also had moderately high filamentous algae but not at a level which breached guidelines (>30%) (Figure 33 and Figure 34).

In the 2014-2015 monitoring year for the spring 2014 survey the upper site at SH3 had no nuisance periphyton and the lower site had moderate amounts of thick mats and low levels of filamentous algae. The summer 2015 survey saw a large increase in long filaments at the upper site (50% streambed coverage) resulting in a highly significant breach in the guideline limits. The lower site also had a large increase in long filaments but thick mats completely had decreased and none were recorded.

In the 2015-2016 monitoring year for the spring 2015 survey there was a decrease in long filaments at both sites and thick mats had decreased at the upper site but moderately low levels were recorded at the lower site. The summer 2016 survey showed decreased nuisance periphyton levels for both sites for thick mats and long filaments. Nuisance periphyton was absent from the bottom site and very low at the upper site.

The presence of filamentous algae, seen in greater amounts at the upper site at SH3, was not unexpected. The substrate between the two survey sites differs significantly. At SH3 the substrate was dominated by large boulders which provide a very stable substrate which was less susceptible to scouring during flood events. At Constance Street the substrate had a greater proportion of cobbles as well as fine substrates such as sand and silt which are more likely to move during floods, regulating the amount of filamentous algae through scouring of the periphyton that could otherwise accumulate on more stable substrates. The summer 2015 survey was undertaken after a relatively long period without flushing flows enabling the proliferation of long filamentous algae.

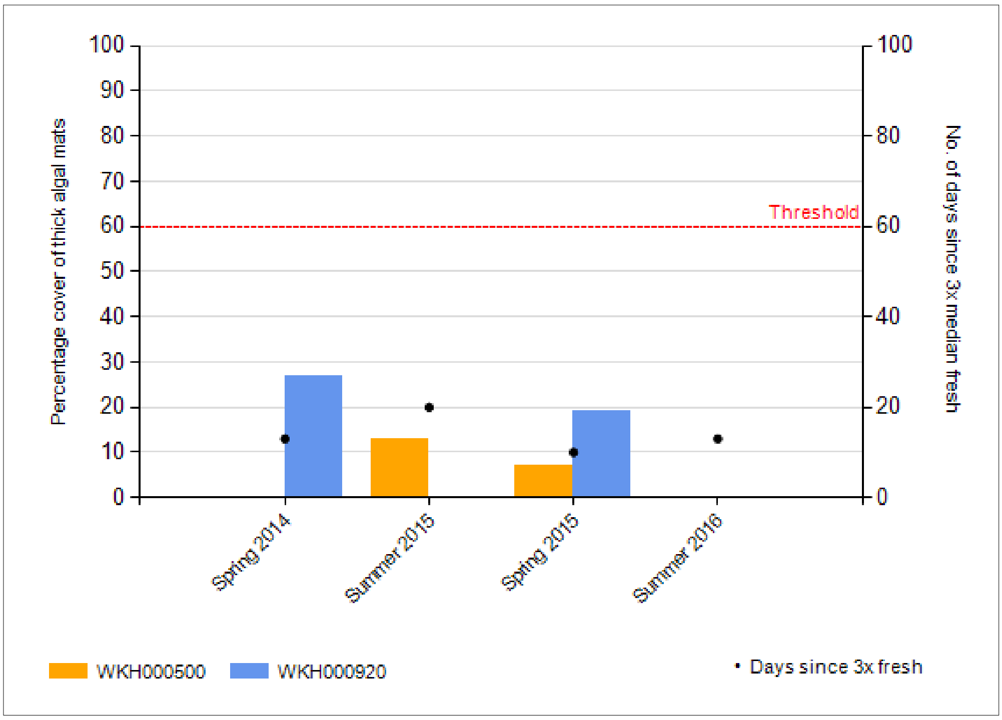


Figure 43 Percentage cover of thick mats of periphyton on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

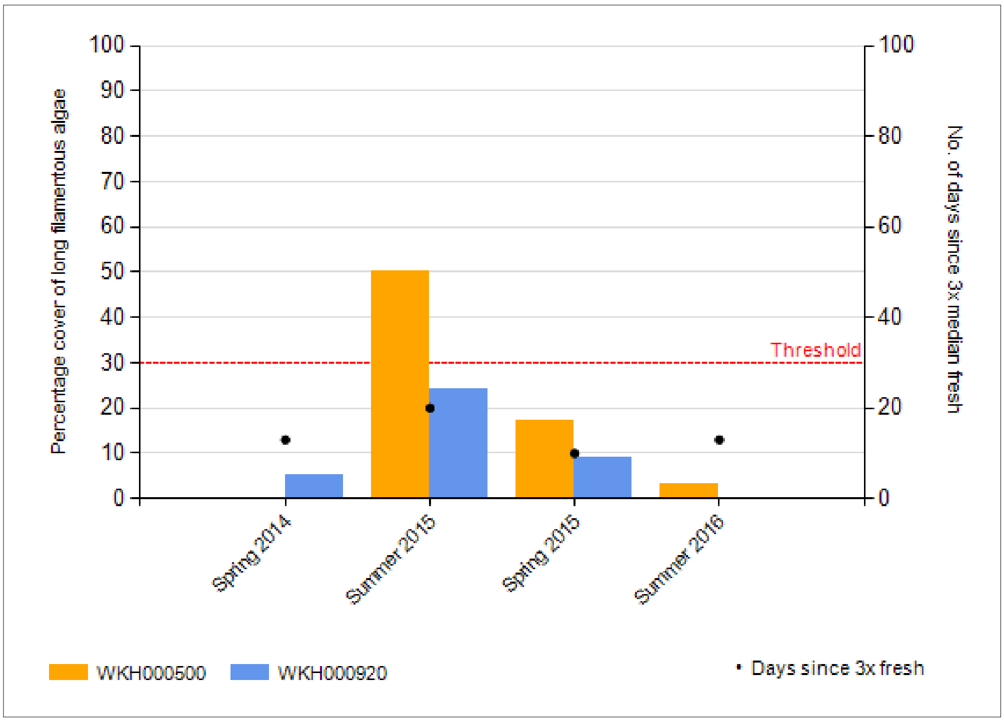


Figure 44 Percentage cover of long filamentous algae on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.5.3 Periphyton Index Score

The Waiwhakaiho River, unlike other monitored rivers in Taranaki, normally shows an improvement in TRC PI score at the downstream site compared with the upstream site for the spring survey and no difference in the summer survey but this did not occur for the two monitoring years examined in this report. Instead, the downstream TRC PI was lower for the spring surveys but significantly higher for the summer 2015 survey (Table 13).

For the 2014-2015 monitoring year the upper site had a 'very good' rating for the spring 2014 survey but this dropped to 'poor' for the subsequent summer 2015 survey which was coincident with the breach in guideline for long filaments. The bottom site had a 'good' rating for both surveys and the score was very similar between the spring and summer surveys in contrast with the upper site. Compared with historical medians the upper site except for the summer 2015 survey had better than normal TRC PI scores while the lower site generally lower scores than historical medians.

For the 2015-2016 monitoring year the upper site had a 'good' rating for the spring 2015 survey and this increased to a 'very good' rating for the subsequent summer 2016 survey. The bottom site had a 'good' rating for the spring survey which also increased to 'very good' for the summer 2016 survey. Compared with historical medians both sites had slightly lower spring TRC scores than typical but higher summer scores.

The low TRC PI score recorded at the upstream site for the summer 2015 survey was most likely related to nutrient inputs. The upstream site receives runoff from primarily agricultural land (other than that from the National Park), while land use downstream was less dominated by agriculture. This nutrient input upstream facilitates periphyton growth. The lower site was in a more urban area which had bird colonies at various points along its length which would cause some nutrient enrichment. Riparian planting was negligible at both sites and therefore there was little growth limitation by seasonal changes in light.

Table 13 Median seasonal periphyton index scores for the Waiwhakaiho River. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
WKH000500	9.4	3.7	7.5	9.4	6.7	6.7
WKH000920	6.1	6.0	7.3	8.1	8.0	6.7
Difference	3.3	-2.3	0.2	1.3	1.3	0.0

2.5.4 Periphyton biomass

The results for the period 2014-2016 showed that the upper site for the 2015 survey (chlorophyll *a* 212 mg/m^2) breached the NOF standard while the lower site was well under the NOF standard (chlorophyll *a* 70 mg/m^2) but breached the guideline to protect benthic biodiversity (Table 2) (Figure 48). Unlike other monitored rivers in the Taranaki Region where upstream sites usually had a lower periphyton biomass than downstream sites the upper site had a higher level of biomass than the downstream site though the difference between the two sites in the 2016 survey was marginal as both sites have very low levels of chlorophyll *a*.

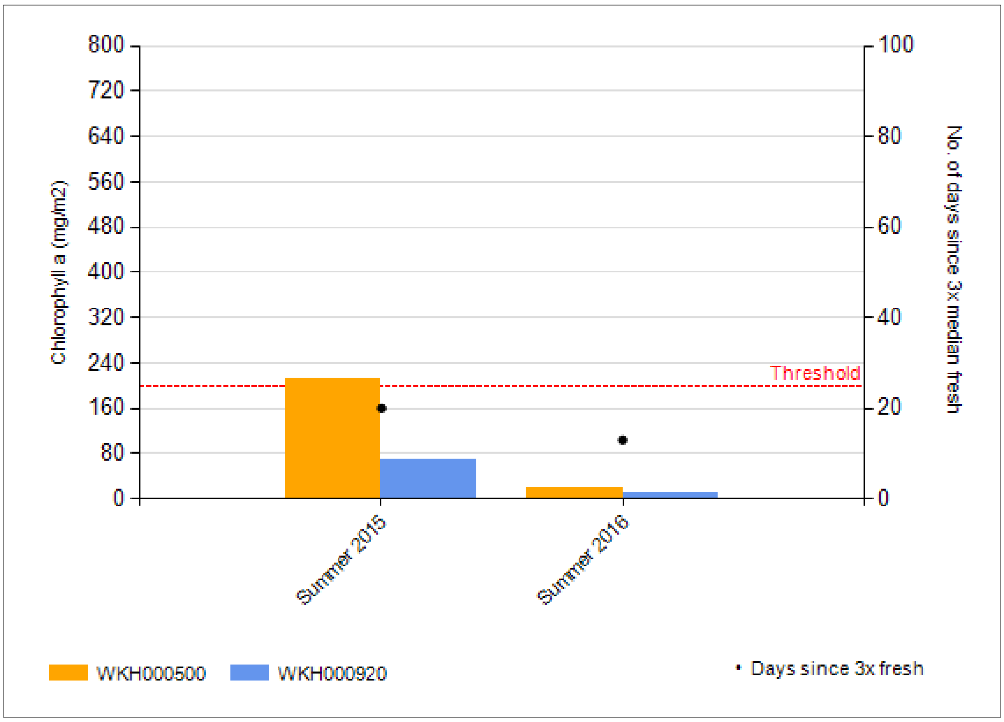


Figure 45 Periphyton biomass (chlorophyll *a*) on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.5.5 Summary of 2002-2016 (14 year data set)

Both sites never came close to having a breach in the guideline for thick algal mats. The upper site was more prone to long filamentous nuisance periphyton communities which breached guidelines on eight occasions throughout the monitoring period. In comparison, the lower site only breached guidelines on three occasions. The current period (2014-2016) recorded a breach in long filamentous algae at the upper site (Figure 46 and Figure 47). This was the first breach since the spring 2009 survey.

Overall, long filamentous algae were prone to proliferate more at the upstream site but not to the same extent or frequency as earlier monitoring years and periphyton did not reach the same dominance as in the 2002-2006 monitoring period.

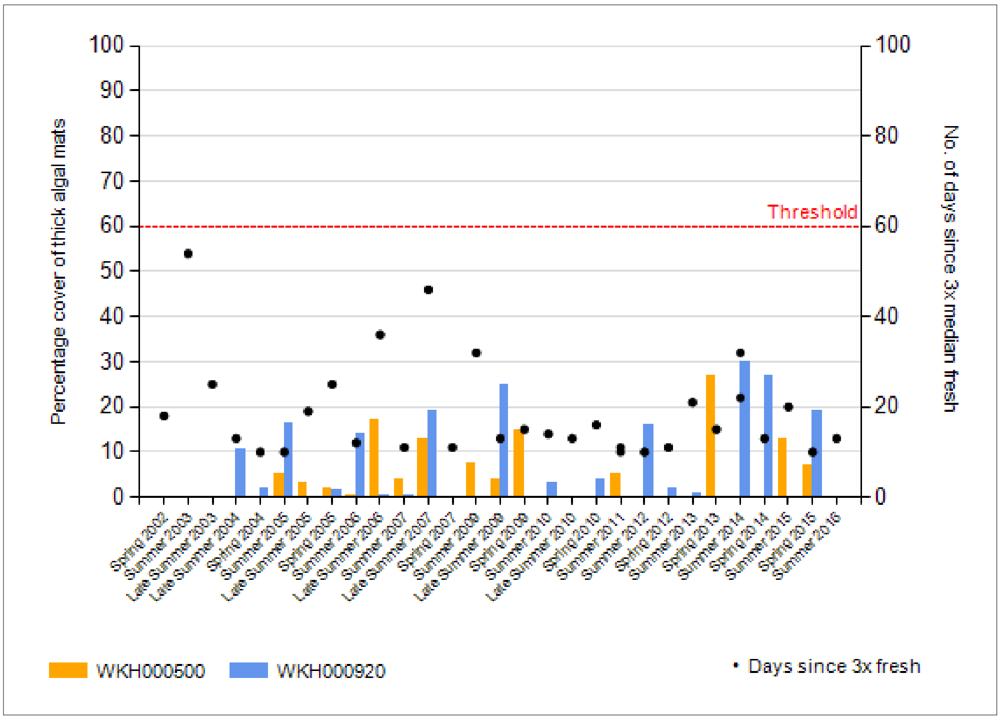


Figure 46 Percentage cover of thick mats of periphyton on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2002-2016 period

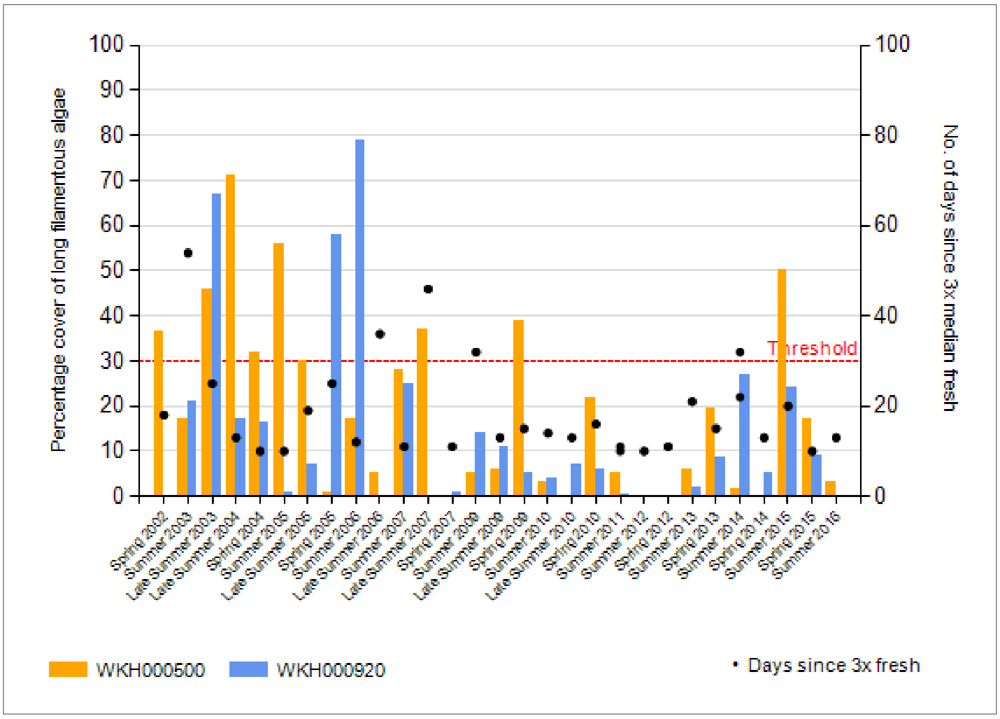
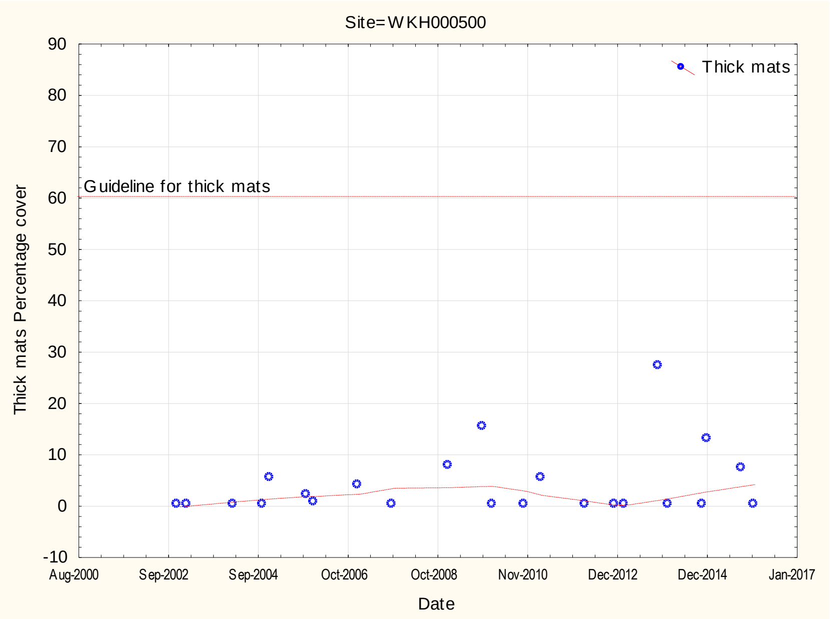


Figure 47 Percentage cover of long filamentous algae on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2002-2016 period

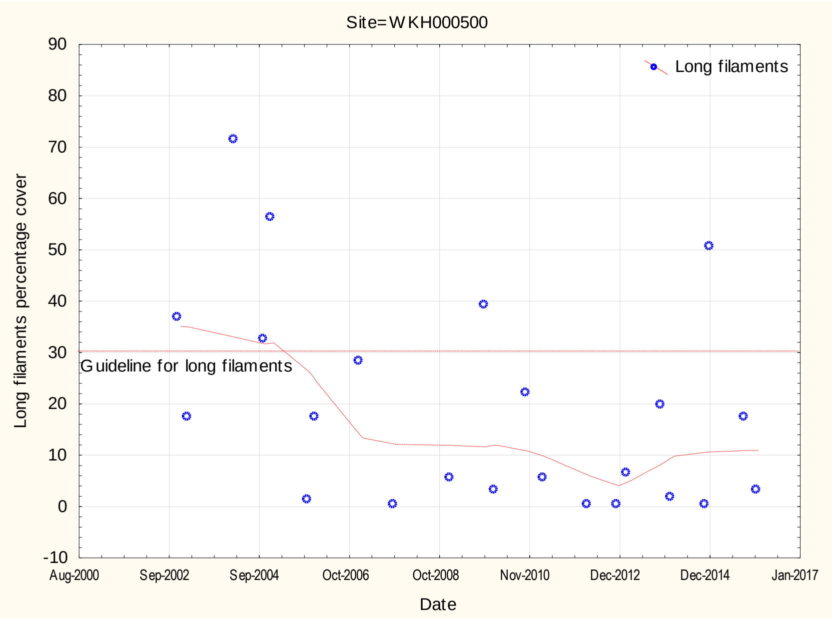
2.5.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Waiwhakaiho River, Constance Street and SH3 (Egmont Village), over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 48 to Figure 51).



n = 23
Kendal tau =0.114
p-value = 0.445
FDR p-value = 0.718

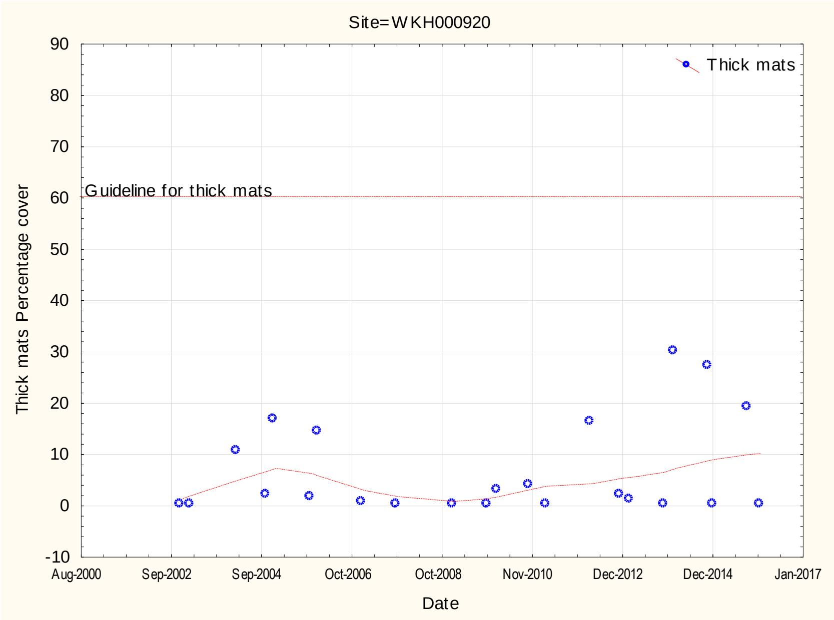
Figure 48 LOWESS trend analysis of percentage cover of thick mats at Waiwhakaiho River, SH3, Egmont Village (WKH000500)



n = 23
Kendal tau = -0.283
p-value = 0.059
FDR p-value = 0.196

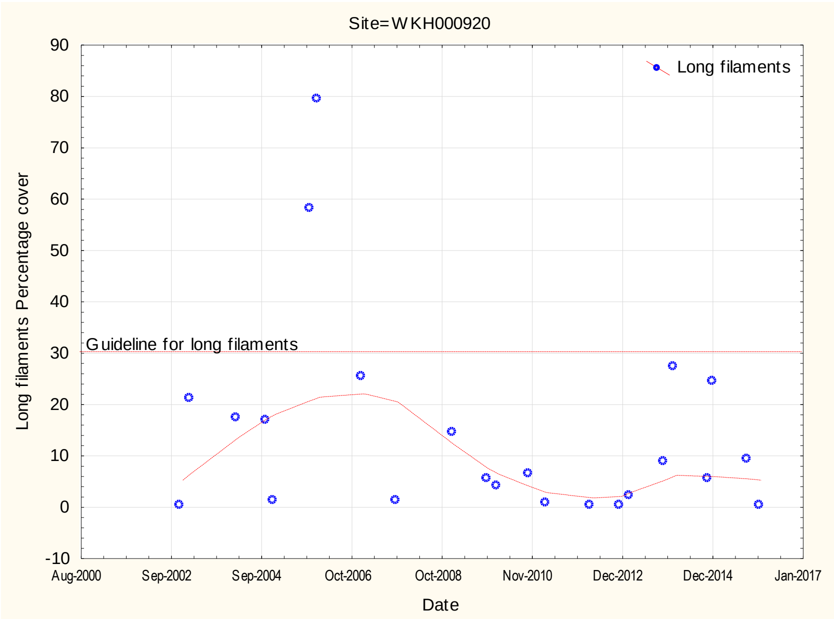
Figure 49 LOWESS trend analysis of percentage cover of long filaments at Waiwhakaiho River, SH3, Egmont Village (WKH000500)

At SH3 (Egmont Village) over the 14 year monitored period there were no significant trend for thick mats (p=0.718) or long filaments (p=0.196) at the 5% level of significance after false discovery rate adjustment.



n = 23
Kendal tau = 0.077
p-value = 0.607
FDR p-value = 0.753

Figure 50 LOWESS trend analysis of percentage cover of thick mats at Waiwhakaiho River, Constance Street, New Plymouth (WKH000920)



n = 23
Kendal tau = -0.149
p-value = 0.321
FDR p-value = 0.359

Figure 51 LOWESS trend analysis of percentage cover of long filaments at Waiwhakaiho River, Constance Street, New Plymouth (WKH000920)

At the Constance Street site (WKH000920) over the 14 year monitored period there were no significant trends for thick mats (p=0.753) or long filaments (p=0.359) at the 5% level of significance after false discovery rate adjustment.

2.6 Waingongoro River

The Waingongoro River originates in the National Park, heading south east towards Eltham where it turns south west before travelling to its mouth at Ohawe. With a total length of around 67 km (below the National Park boundary) the Waingongoro is the longest river confined to the ring plain.

Better water quality was found in the upper reaches, declining slightly in the middle and lower reaches. It is highly rated for recreational uses and values, and highly rated for aesthetic and scenic values.

The Waingongoro River is a catchment with intensive usage and as such, three sites have been located in this catchment to monitor periphyton communities (Figure 52). The top site at Opunake Road (WGG000150) is approximately six kilometres below the National Park and the catchment upstream has a very high level of riparian cover. The mid catchment site at Stuart Road (WGG000665) is located below several industrial discharges including a meatworks located at Eltham. Agricultural development is also intensified between these two sites and further downstream, which is encompassed by the lower catchment site located at Ohawe Beach (WGG000995), upstream of the river mouth.

River flow is recorded continuously at Eltham Road and SH45.

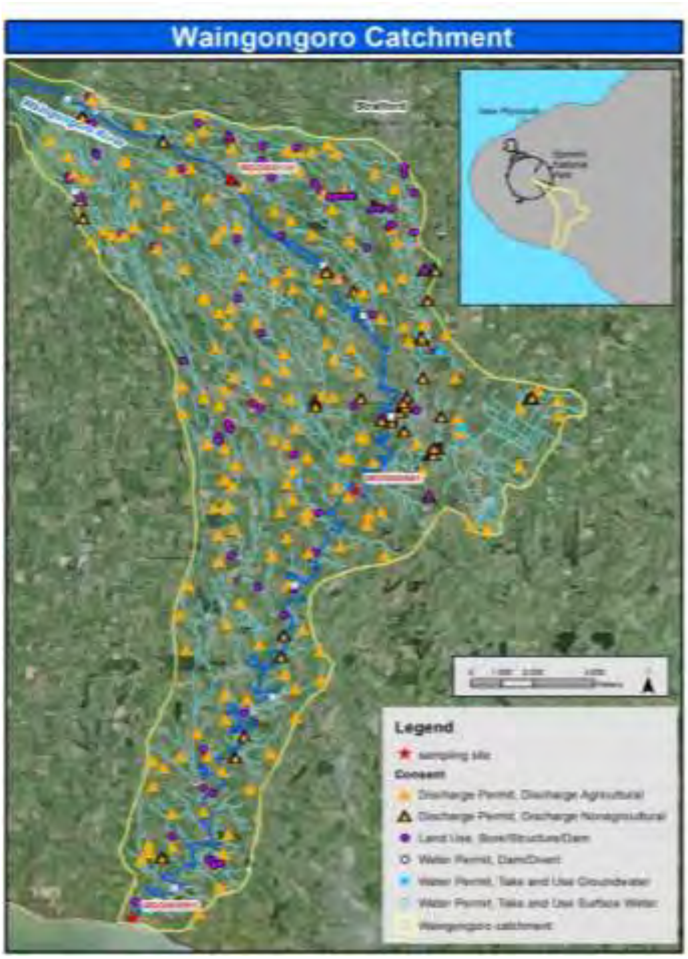


Figure 52 Monitoring site locations in relation to consents operating in the Waingongoro River catchment

2.6.1 Flow and nutrient data and survey dates

The Waingongoro River has two telemetered hydrological monitoring stations. The upper site is at Eltham Road which is used for the two upper sites and the lower site is at SH45 which is used for the Ohawe Beach site.

The spring 2014 survey was conducted on 23 October 2014 24 days after a fresh in excess of 3x median flow and 29 days after a fresh of 7x median flow at the Eltham Road site and 16 days after a fresh in excess of 3x median flow and 23 days after a fresh of 7x median flow at SH45 site. The summer 2015 survey was carried out on 16 January 2015 15 days after a fresh in excess of 3x and 7x median flow at both flow gauging sites (Appendix 1).

The spring 2015 survey was conducted on 5 October 2015 12 days after a fresh in excess of both 3x and 7x median flow at the Eltham Road site and 11 days after a fresh in excess of both 3x median flow and 22 days after a fresh of 7x median flow at the SH45 site. The summer 2016 survey was carried out on 28 January 2016 10 days after a fresh in excess of 3x median flow and 21 days after a fresh in excess of 7x median flow at the Eltham Road site and 21 days after a fresh in excess of 3x median flow and 133 days after a 7x median flow at the SH45 site (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at three sites on the Waingongoro River. Two sites where physiochemical data was collected were not at the same locations as the nuisance periphyton sites but they are close enough to provide a reliable guide as to the nutrient status as the periphyton sites. The other, upstream site, had data for the 2015-2016 monitoring year only and only four samples were collected rather than the monthly dataset collected for the two downstream sites. All three sites did not meet the guidelines for dissolved reactive phosphorus and total nitrogen (ANZECC 2000) (Appendix 2). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in dissolved reactive phosphorus levels.

2.6.2 Periphyton cover

The bottom site breached the guideline limits for periphyton cover for filamentous algae during the summer 2016 survey (Figure 53 and Figure 54).

In the 2014-2015 monitoring year, no thick algal mats or long filaments were recorded at the upper catchment site at Opunake Road. The middle site at Stuart Road had a very low level of thick algal mats and filamentous algae while the bottom site at Ohawe Beach had only a low level of thick algal mats during the summer 2015 survey. All nuisance periphyton levels were well below guideline limits.

In the 2015-2016 monitoring year the upper site again did not have any nuisance periphyton. The middle site had moderately low levels of thick mats and filamentous algae while the lower site had moderately high levels of thick algal mats during the spring 2015 survey and a high level of filamentous algae during the summer 2016 survey which breached the guideline limit.

The Ohawe Beach survey site situated at the river mouth had the most nuisance periphyton of all three sites. Usually for the site thick algal mats (mostly comprised of diatoms) will occur at greater levels than long filamentous algae but the summer 2016 survey was an exception and long filamentous algae occurred at levels approximately twice that of thick algal mats. The Ohawe Beach site is the furthest site downstream in an agricultural catchment and the cumulative effects of diffuse pollution from farms provides sufficient nutrients for excessive periphyton growth (Appendix 2).

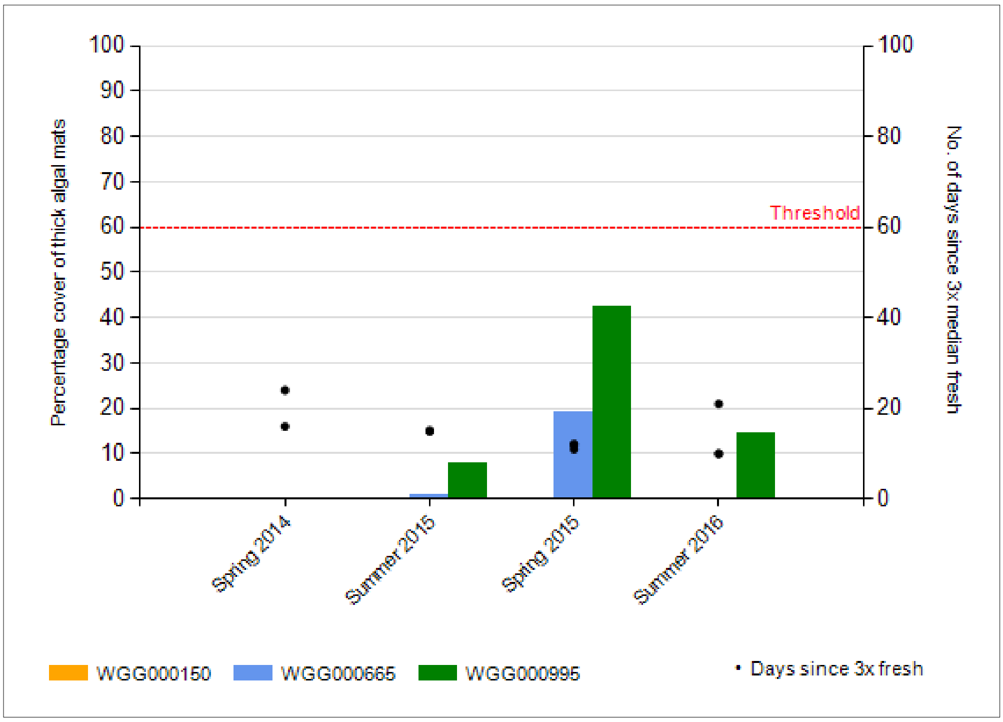


Figure 53 Percentage cover of thick mats of periphyton on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

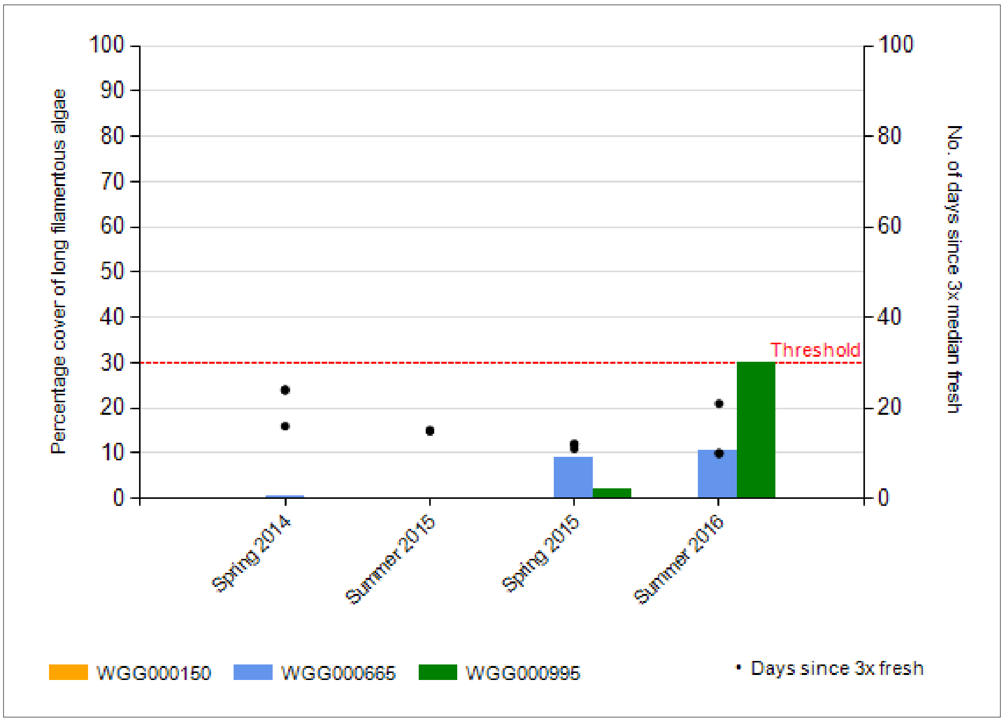


Figure 54 Percentage cover of long filamentous algae on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.6.3 Periphyton Index Score

The upper site at Opunake Road had the highest TRC PI scores in the Waingongoro River. All scores were all in the 'very good' category and there was little change between seasons (Table 14). At the middle site at Stuart Road TRC PI scores were lower and were either 'very good' or 'good'. The bottom site at Ohawe Beach had 'very good' scores during the 2014-2015 monitoring year but only 'moderate' scores for the 2015-2016 monitoring year. As expected, median scores show a decrease in TRC PI scores in a downstream direction for the period under review except between the middle and lower site for the summer 2015 survey (Table 14).

Table 14 Median seasonal periphyton index scores for Waingongoro River. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
WGG000150	10.0	9.8	9.6	9.3	8.8	9.1
WGG000665	9.6	7.4	7.7	8.4	8.5	7.8
WGG000995	8.4	8.4	6.7	4.8	9.2	7.0
Difference	1.6	1.4	2.9	4.5	-0.4	2.1

2.6.4 Periphyton biomass

The results for the period 2014- 2016 indicate that the upstream site had very low levels of periphyton biomass and the middle and bottom sites both had moderately high levels (Figure 55). No samples breached the guideline thresholds for NOF standards (Table 2) but results for the summer 2015 survey were very close to exceeding the threshold limit at both the middle (chlorophyll *a* 196 mg/mL) and bottom (chlorophyll *a* 193 mg/mL) sites. Periphyton biomass levels did not match TRC PI scores particularly well. The summer 2015 survey score for the bottom site was 'very good' yet nearly breached NOF standards and the middle site was 'good' and also nearly breached NOF standards. The summer 2016 survey for the bottom site had only a 'moderate' rating yet the periphyton biomass level was lower. This suggests that there was too much variability between periphyton cover and biomass as estimated by chlorophyll *a* to use periphyton cover as a surrogate for chlorophyll *a* at this site.

The moderately high periphyton biomass suggests that significant nutrient enrichment occurred in the mid catchment, probably from agricultural inputs and possibly from industries located in the township of Eltham. Similar moderately high biomass levels at the bottom site were probably largely driven by nutrient inputs solely from agriculture as the Waingongoro River runs through predominately agricultural land at the lower end of the catchment and no significant industrial inputs occur.

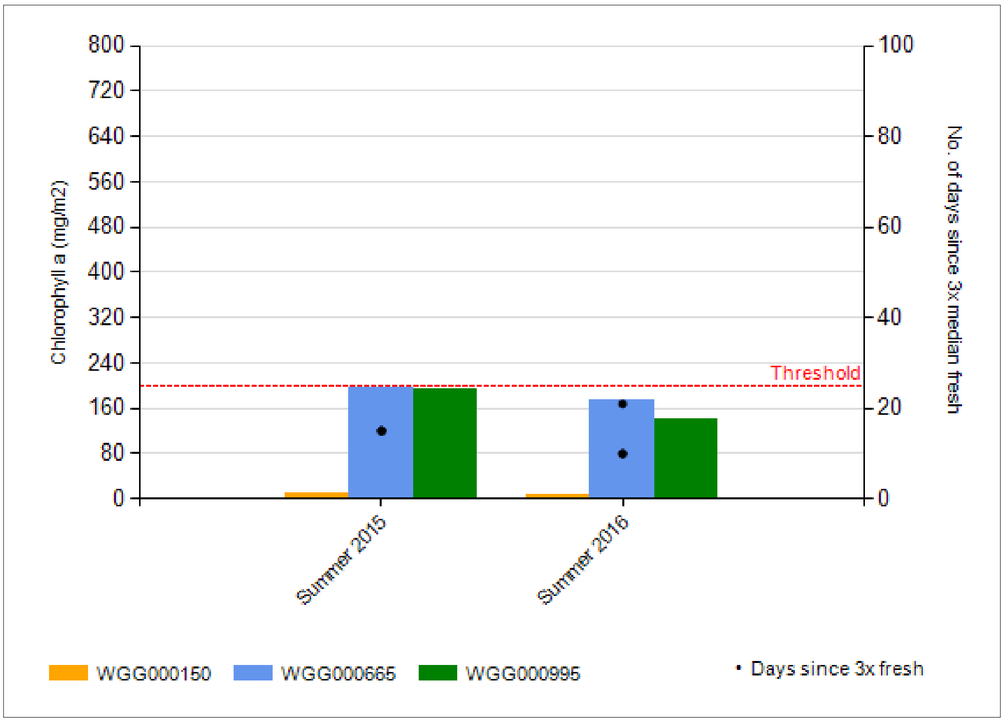


Figure 55 Periphyton biomass (chlorophyll *a*) on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.6.5 Summary of 2002-2016 (14 year data set)

Nuisance periphyton appears to have formed more prolific growths during the period 2002-2008, with thick algal mats breaching guidelines five times and filamentous algae breaching guidelines twice (Figure 56 and figure 57). Proliferation of thick mats and long filaments appeared to have decreased since 2008, particular at the two downstream sites which previously had high levels. This partially corresponds with the removal of discharges from the Eltham wastewater treatment system. The most downstream site at Ohawe Beach had higher than normal abundance of thick mats for the spring 2015 survey and filamentous algae for the summer 2016 survey suggesting an increase in nutrient levels at the site.

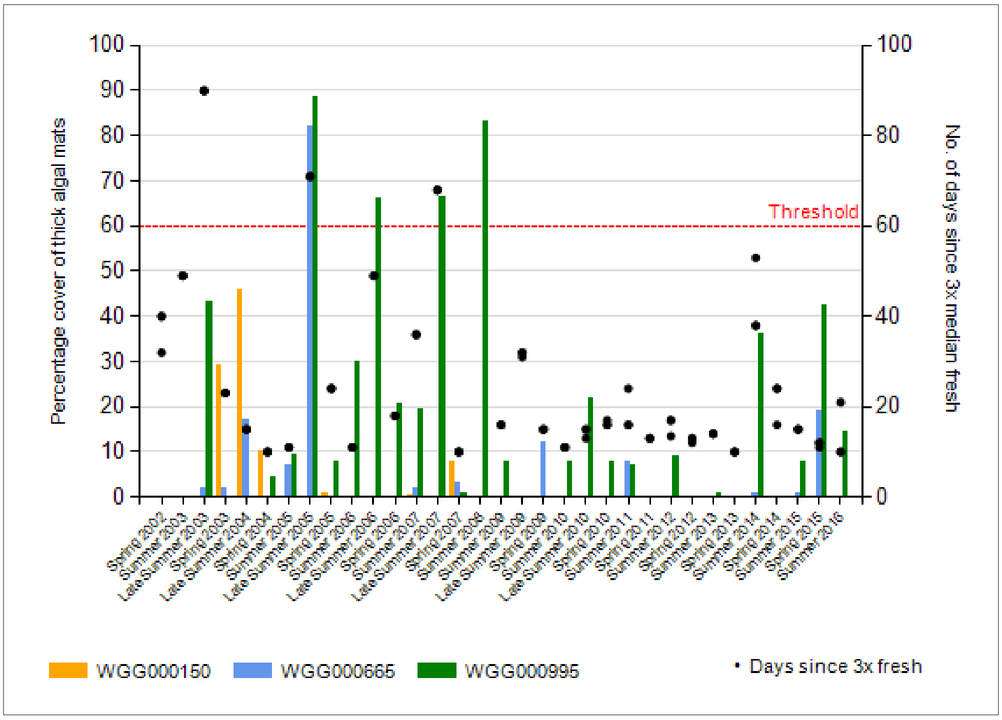


Figure 56 Percentage cover of thick mats of periphyton on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2002-2016 period

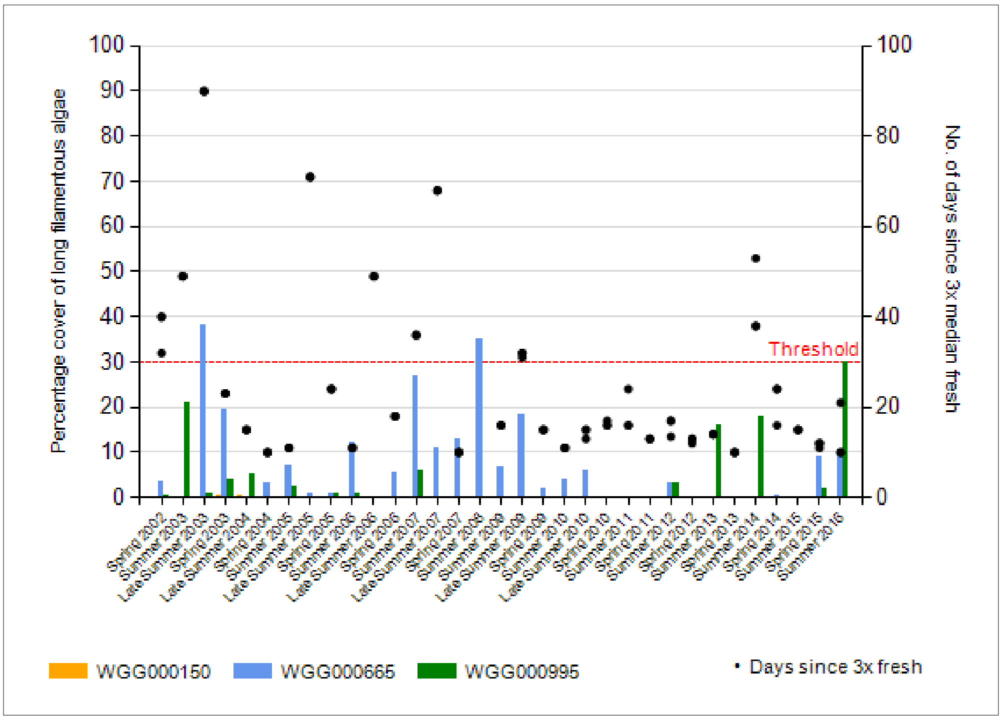
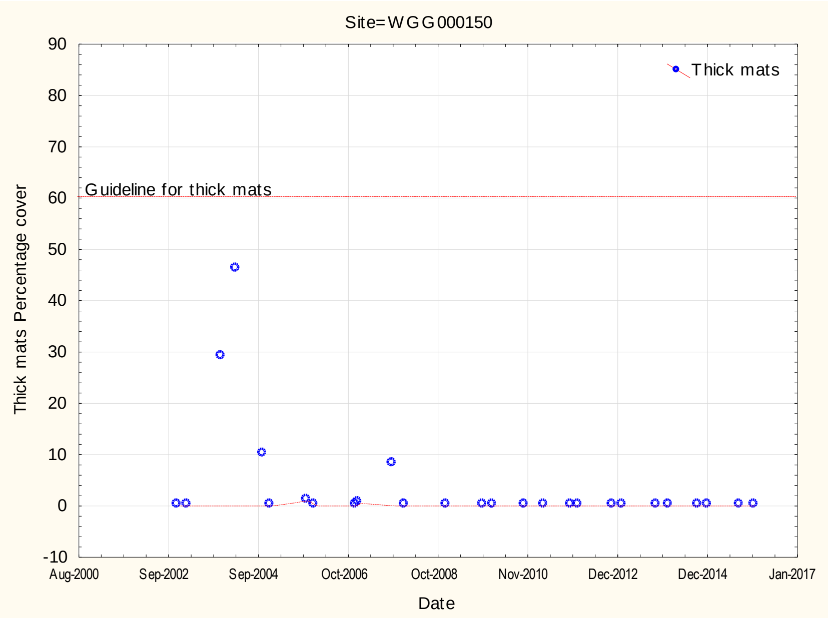


Figure 57 Percentage cover of long filamentous algae on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2002-2016 period.

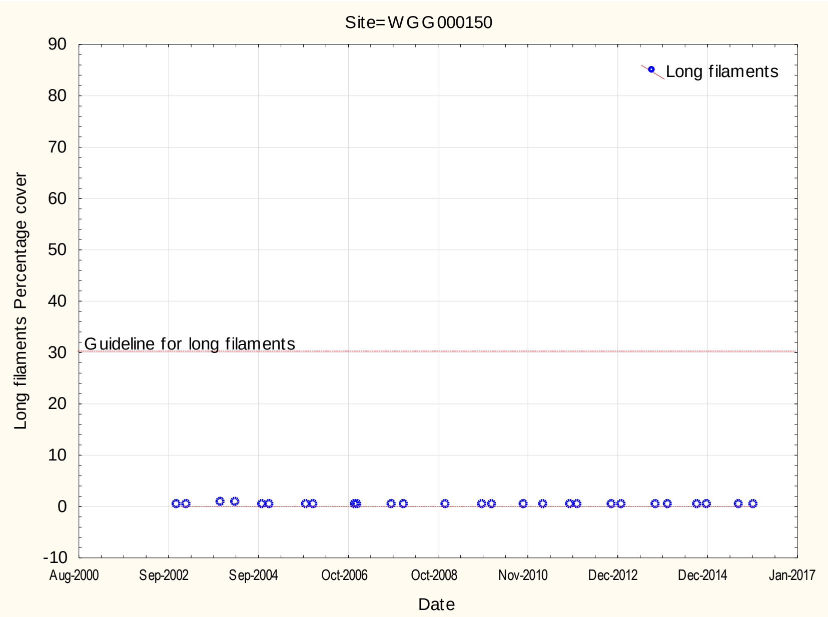
2.6.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Waingongoro River, at Opunake Road, Stuart Road and Ohawe Beach, over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 58 to Figure 63).



n = 27
Kendal tau = -0.436
p-value = 0.001
FDR p-value = 0.021

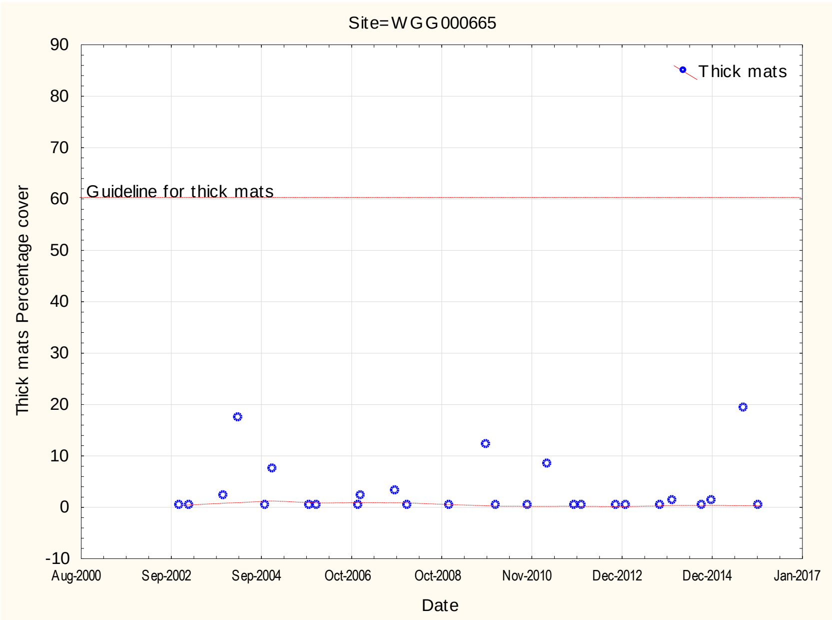
Figure 58 LOWESS trend analysis of percentage cover of thick mats at Waingongoro River, Opunake Road (WGG000150)



n = 27
Kendal tau = -0.317
p-value = 0.020
FDR p-value = 0.102

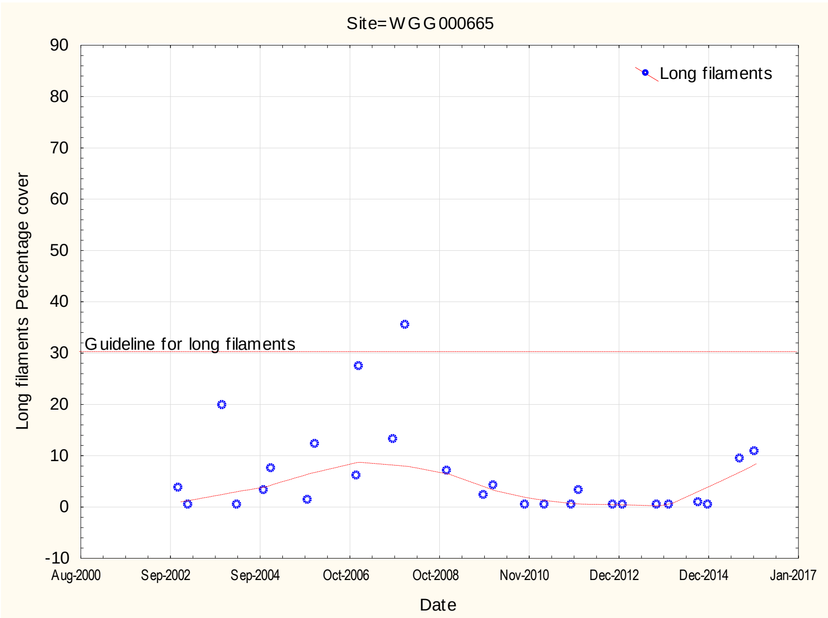
Figure 59 LOWESS trend analysis of percentage cover of long filaments at Waingongoro River, Opunake Road (WGG000150)

At Opunake Road (WGG000150) over the 14 year monitored period there was a significant (p=0.021) negative (tau=-0.436) trend for thick mats at the 5% level of significance after false discovery rate adjustment indicating that thick periphyton mats had decreased over the monitored period. Long filaments were not significant (p=0.102) at the 5% level of significance after false discovery rate adjustment.



n = 27
Kendal tau = -0.011
p-value = 0.936
FDR p-value = 0.936

Figure 60 LOWESS trend analysis of percentage cover of thick mats at Waingongoro River, Stuart Road (WGG000665)



n = 27
Kendal tau = -0.193
p-value = 0.159
FDR p-value = 0.289

Figure 61 LOWESS trend analysis of percentage cover of long filaments at Waingongoro River, Stuart Road (WGG000665)

At Stuart Road (WGG000665) over the 14 year monitored period there were no significant trends for thick mats (p=0.936) or long filaments (p=0.289) at the 5% level of significance after false discovery rate adjustment.

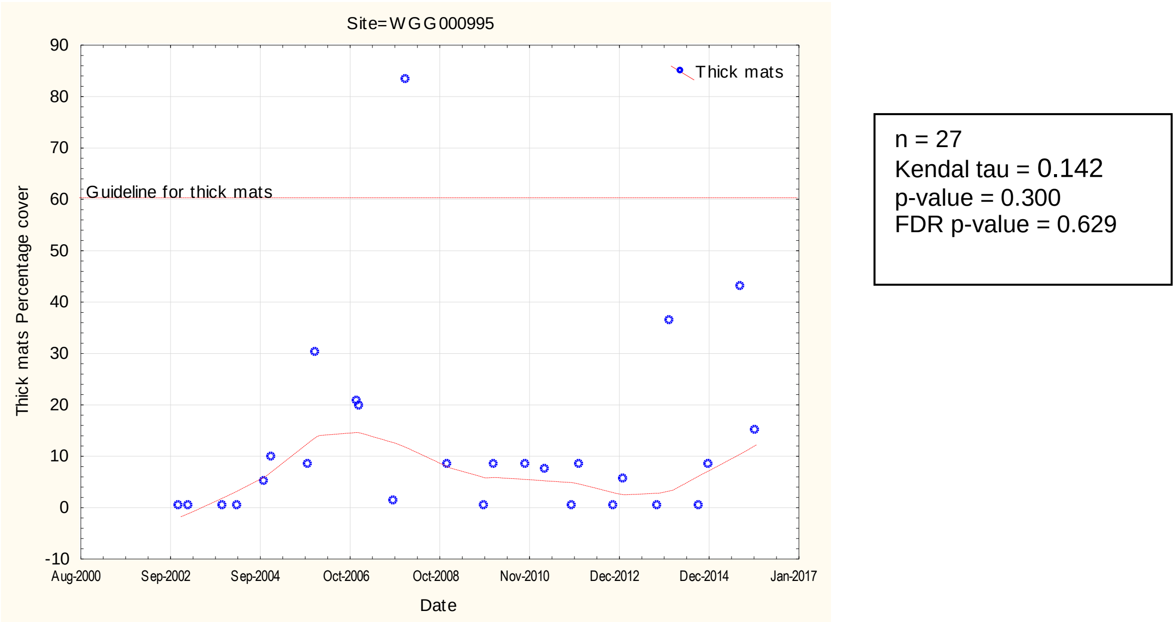


Figure 62 LOWESS trend analysis of percentage cover of thick mats at Waingongoro River, Ohawe Beach (WGG000995)

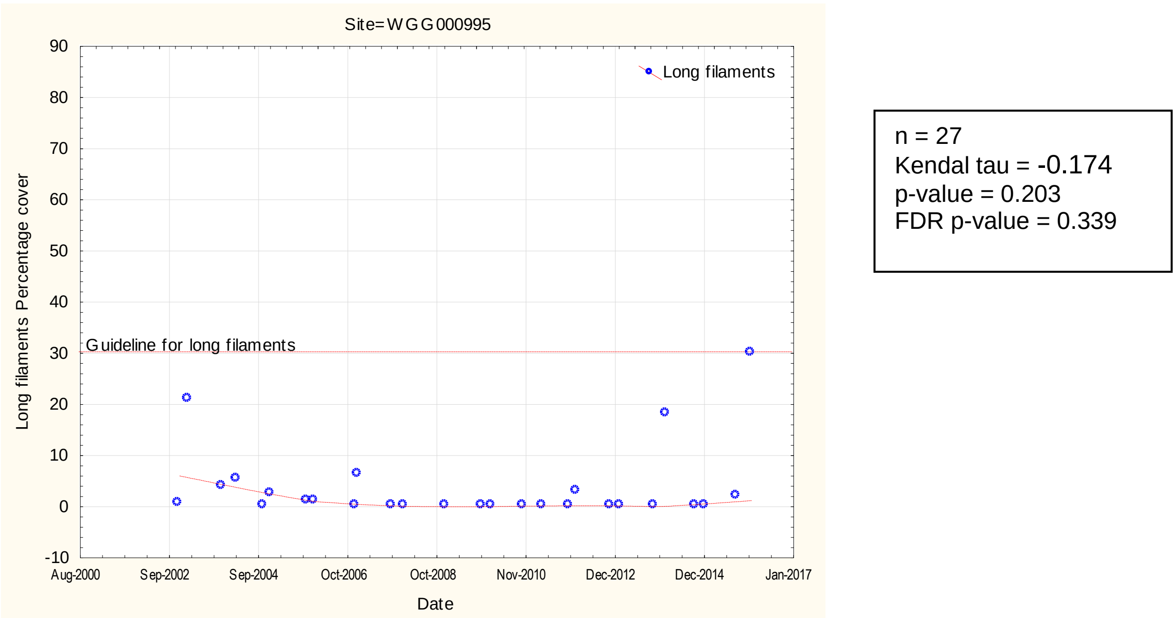


Figure 63 LOWESS trend analysis of percentage cover of long filaments at Waingongoro River, Ohawe Beach (WGG000995)

At Ohawe Beach (WGG000995) over the 14 year monitored period there were no significant trends for thick mats (p=0.629) or long filaments (p=0.339) at the 5% level of significance after false discovery rate adjustment.

2.7 Punehu Stream

The Punehu Stream arises in the National Park and heads approximately 25 kilometres in a south westerly direction to the coast; entering the sea just south of Opunake. The stream is representative of a south-western Taranaki catchment subjected primarily to intensive agricultural land use with water quality potentially affected by diffuse run-off and point source discharges from dairy shed treatment pond effluent.

The upper catchment site at Wiremu Road (PNH000200) lies approximately 2km below the National Park boundary and is representative of relatively un-impacted stream water quality (Figure 64). The lower catchment site near the coast at SH45 (PNH00090) is approximately 20km from the National Park.

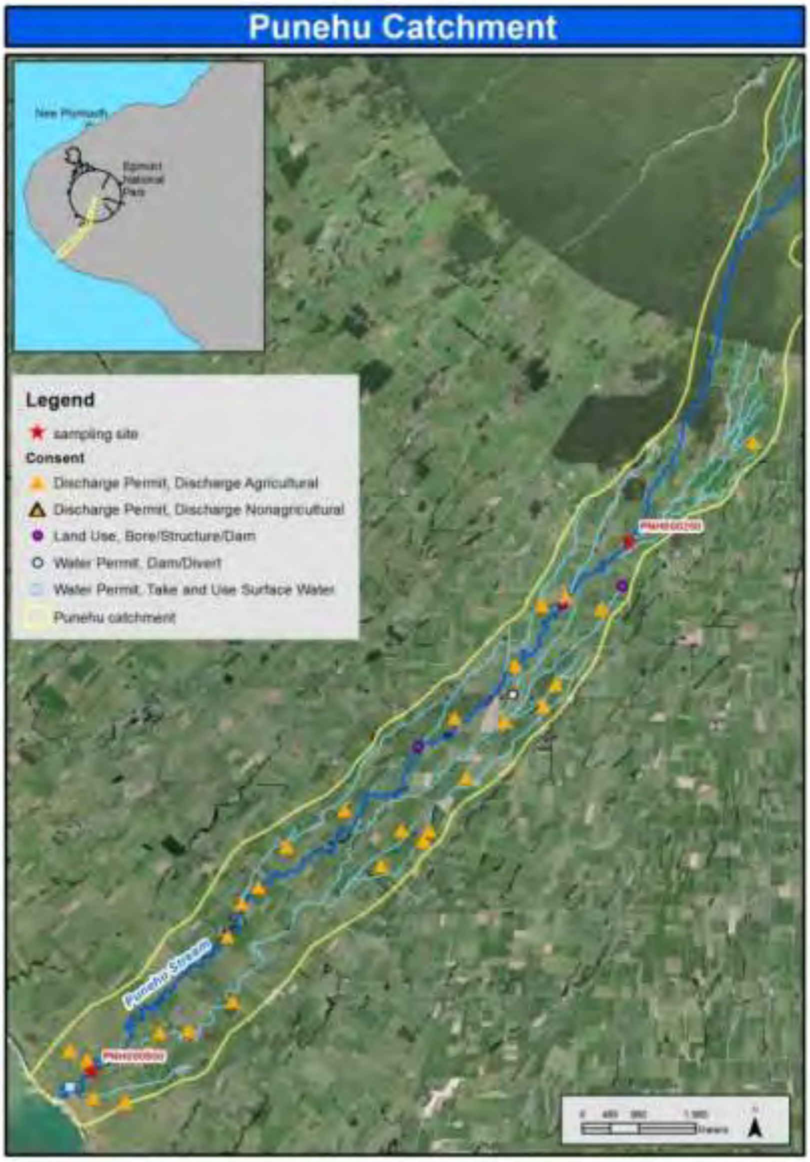


Figure 64 Monitoring site locations in relation to consents operating in the Punehu Stream

2.7.1 Flow and nutrient data and survey dates

The spring 2014 survey was conducted on 3 March 2014 35 days after a fresh in excess of 3x median flow and 36 days after a fresh in excess of 7x median flow. The summer 2015 survey was carried out on 16 January 2015 26 days after a fresh in excess of 3x median flow and 36 days after 7x median flows (Appendix 1).

The spring 2015 survey was conducted on 12 October 2015 10 days after a fresh in excess of 3x median flow and 19 days after a fresh in excess of 7x median flow. The summer 2016 survey was carried out on 3 February 2016 15 days after a fresh in excess of 3x and 7x median flows (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at both sites. The site met the guideline for total nitrogen for an upland site but not for dissolved reactive phosphorus (DRP) and the lower site did not meet guidelines for total nitrogen or DRP for a lowland site (ANZECC 2000) (Appendix 2). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels at the upland site but the lower site had higher levels of DRP than the upper site which was likely caused by agricultural inputs.

2.7.2 Periphyton cover

For the 2014-2015 monitoring period no nuisance periphyton was recorded at the upstream site at Wiremu Road (PNH000200) and only a low level of thick mats and moderately low level of filamentous algae were recorded at the bottom site at SH45 (PNH000900) (Figure 65 and Figure 66).

For the 2015-2016 monitoring period the Wiremu Road site recorded no nuisance periphyton. The downstream site at SH45 recorded no thick algal mats for both surveys but there was moderate to moderately high levels of filamentous algae recorded. However, levels of nuisance periphyton did not exceed guideline values.

Typically for the Punehu River, nuisance periphyton levels were usually higher at the downstream site compared with the upper site. The upper site had nutrient levels that would not promote excessive periphyton growth while the lower site had elevated nutrients levels (Appendix 2). Partial shading of the riverbed by overhanging vegetation and steep banks would limit periphyton growth at the lower site even though nutrient levels are at levels that will promote excessive growth. Furthermore, water clarity was usually cloudy at the bottom site which would limit light penetration and thus reduce periphyton growth and on all four periphyton surveys a silt coating was present which would also inhibit periphyton growth.

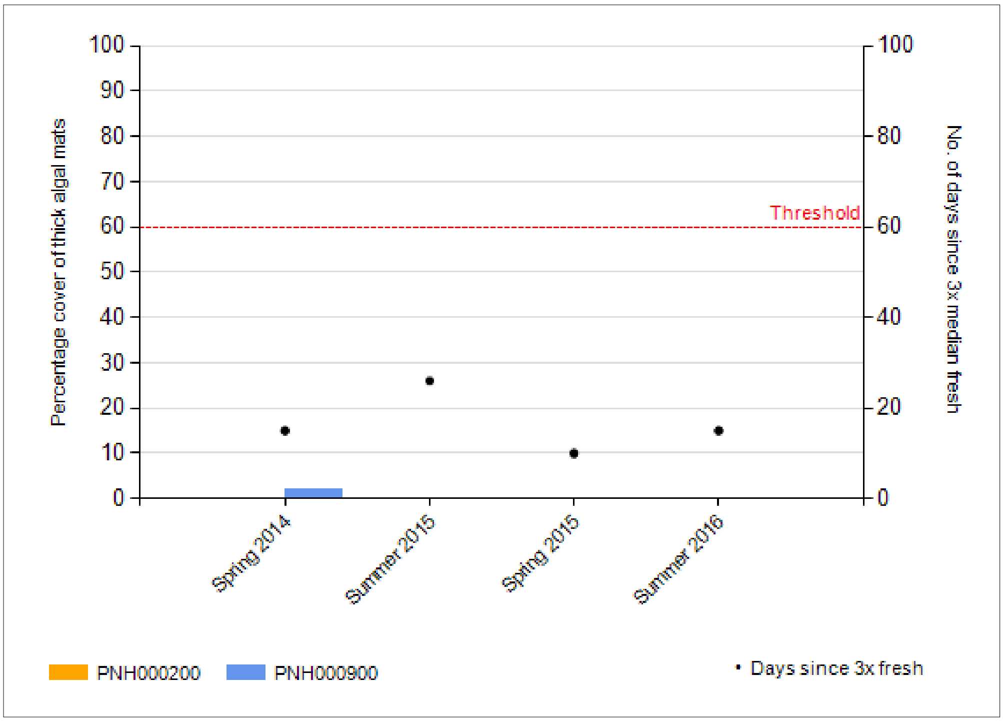


Figure 65 Percentage cover of thick mats of periphyton on the Punehu streambed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

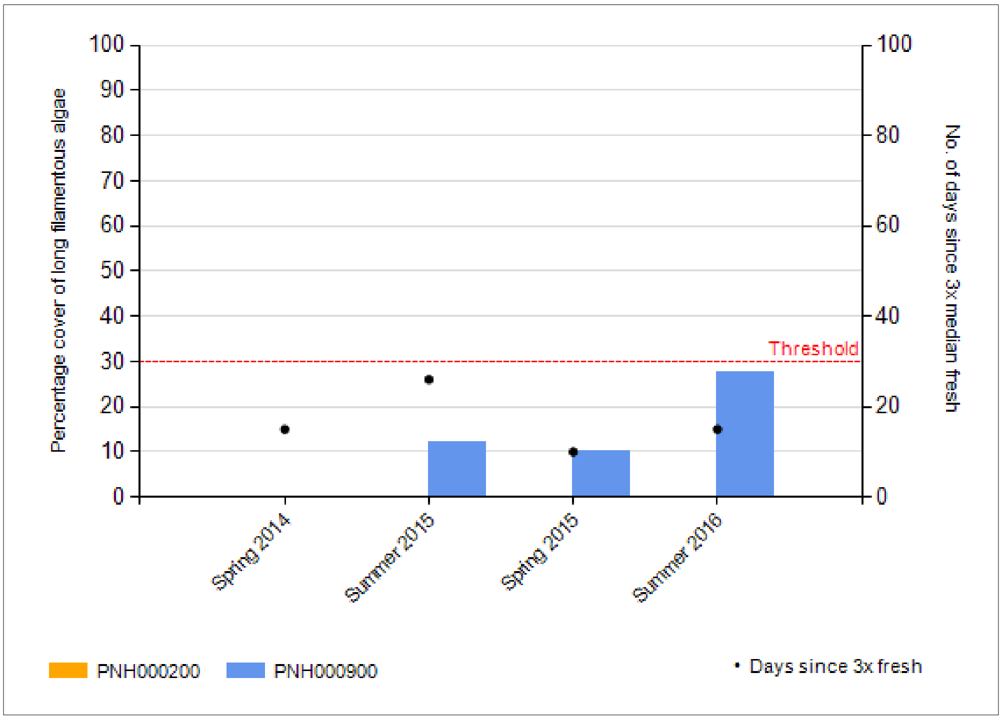


Figure 66 Percentage cover of long filamentous algae on the Punehu streambed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.7.3 Periphyton Index Score

The upstream site at Wiremu Road (PNH000200) had a 'very good' TRC PI score for all four surveys which was the normal result for the site (Table 15). During the reported period scores were equal to or slightly above historical medians.

The downstream site (PNH000900) had lower TRC PI score than the upper site on all occasions and the summer surveys had lower scores than the spring surveys which was typical for the site. Both spring surveys and the summer 2015 survey were in the 'very good' category and the summer 2016 survey in the 'good' category.

The Punehu Stream has been included in this programme as its catchment is primarily used for dairying and therefore there is the potential for an elevated nutrient input into the stream. The upstream site at Wiremu Road has no point source discharges in its headwaters and its nutrient status and periphyton community reflects this. The lower site has elevated nutrients but also has some shading from its heavily incised nature resulting in steep, tall river banks and riparian vegetation which would potentially limit periphyton growth. Furthermore, an incised riverbed may have higher flow velocities that would amplify the affect of freshes.

Table 15 Median seasonal periphyton index scores for the Punehu Stream. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
PNH000200	10.0	10.0	9.9	10.0	9.9	9.2
PNH000900	9.3	8.6	9.0	7.5	8.0	7.9
Difference	0.7	1.4	0.9	2.5	1.9	1.3

2.7.4 Periphyton biomass

The results for the 2014-2016 survey period for the upstream site showed that it had extremely low chlorophyll *a* levels with the downstream site also having low chlorophyll *a* levels (Figure 67). These values were within guideline limits to protect biodiversity, aesthetic and trout habitat/angling values and NOF standards (Table 2).

The chlorophyll *a* levels were largely congruent with the TRC PI results that showed the Punehu Stream had 'very good' periphyton communities. However, the lower site for the summer 2016 survey had moderately high levels of filamentous algae and a 'good' but not 'very good' category TRC PI category but there was no associated increase in chlorophyll *a* recorded at the site. Overall, the chlorophyll *a* levels for the same period were similar and only showed a small deterioration between upstream and downstream sites. The Punehu Stream at SH45 was the only lower catchment site to have both scores below 50 mg/m^2 even though nutrient levels recorded at the site would allow excessive periphyton growths. The low periphyton biomass recorded at the lower site was probably due to its heavily incised nature at the sampling site and riparian margins which provides partial shading at the site. The incised nature may also cause higher flow velocities during freshes which would help to maintain a low periphyton biomass at the site.

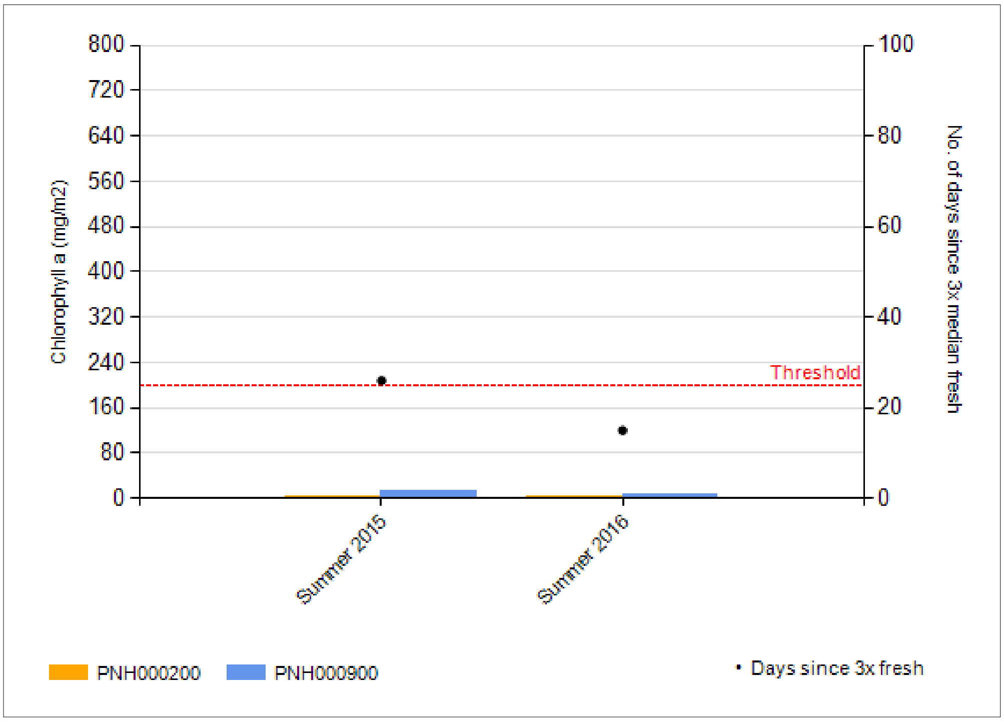


Figure 67 Periphyton biomass (chlorophyll *a*) on the Punehu riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.7.5 Summary of 2002-2016 (14 year data set)

No breaches in recreational guidelines for thick mats have been recorded at either site in the Punehu catchment over the past 14 year period (Figure 68). In the past there have been more frequent proliferations of thick mats at the downstream site although these have decreased in recent years (2006-2016).

The Punehu catchment has been subject to large proliferations of long filamentous algae over the 14 years of monitoring, especially at the downstream site (Figure 69). There have been a total of seven breaches of guidelines overall, none of which were recorded in the 2014-2016 period and only one of which was recorded in the 2006-2010 period. On this latter occasion, over 70% of the bed was covered in long filaments in summer 2008, the largest amount recorded for a nuisance growth over the entire monitoring history in this catchment. During the 2002-2006 period there were much more frequent breaches in long filamentous periphyton at the downstream site, with several of magnitude close to the summer 2008 event. There was also a breach at the upstream site after a long period of low flows in late summer 2005. These growths were not only restricted to summer months, and appeared throughout the 2002-2006 monitoring years, recording six breaches in total.

Though no breaches have occurred recently higher levels of filamentous algae have been recorded at the bottom site since 2013 compared with the period 2010-2013. The summer 2014 survey corresponded with a long period without flushes which may partially explain the elevated level but the proceeding spring 2013 survey was undertaken only a few days after the minimum 10 day limit after a 3x median base flow and therefore an increase in nutrients may have caused the increase.

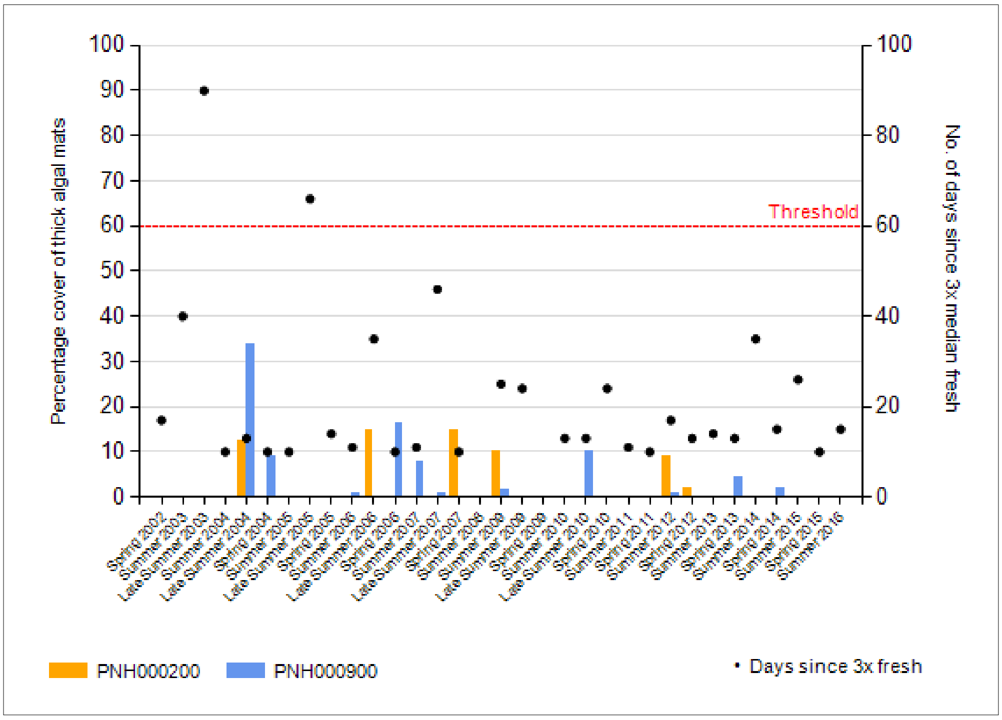


Figure 68 Percentage cover of thick mats of periphyton on the Punehu streambed in relation to the guidelines for recreational values over the 2002-2016 period

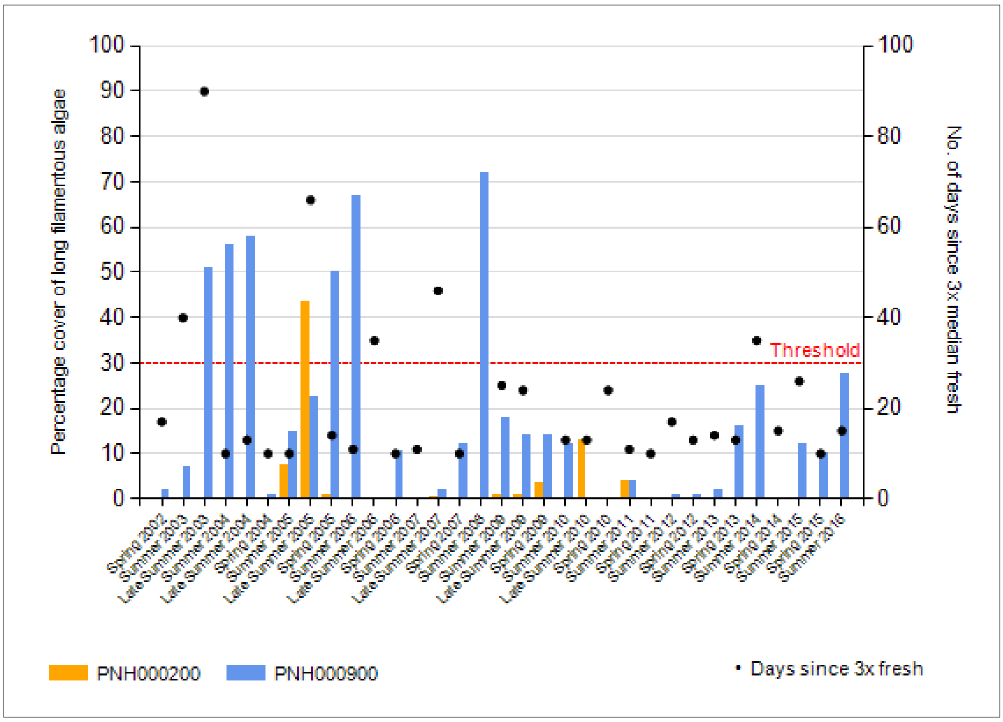
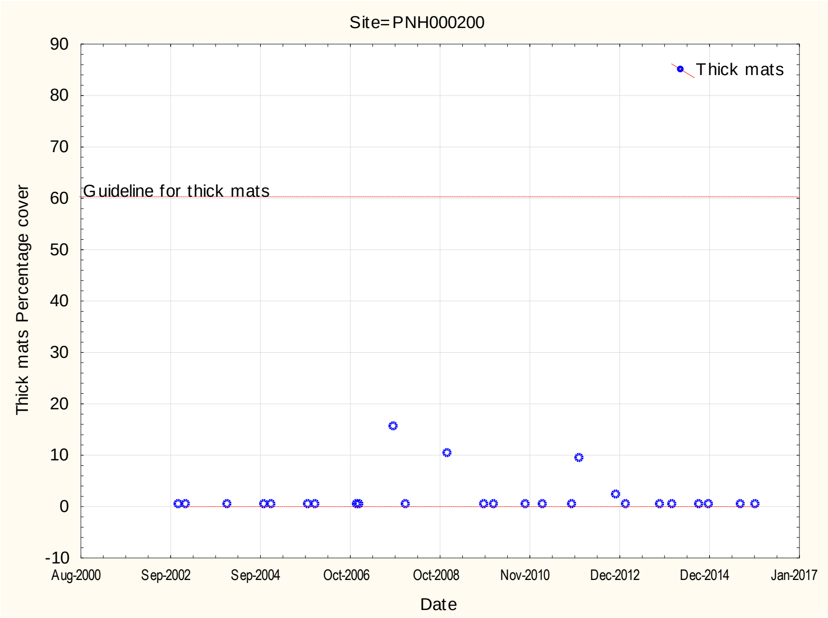


Figure 69 Percentage cover of long filamentous algae on the Punehu streambed in relation to the guidelines for recreational values over the 2002-2016 period

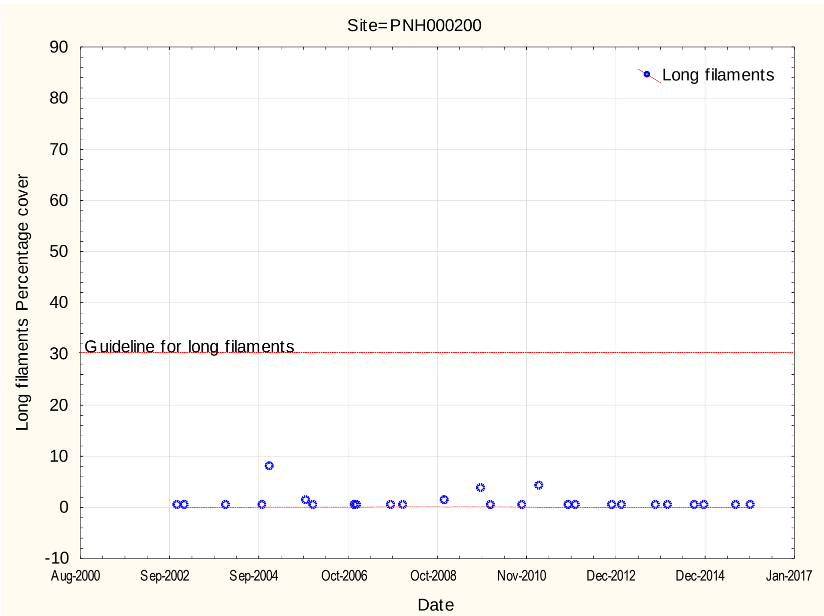
2.7.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Punehu Stream, at Wiremu Road, and SH45 over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 70 to Figure 73).



n = 26
Kendal tau = 0.023
p-value = 0.870
FDR p-value = 0.913

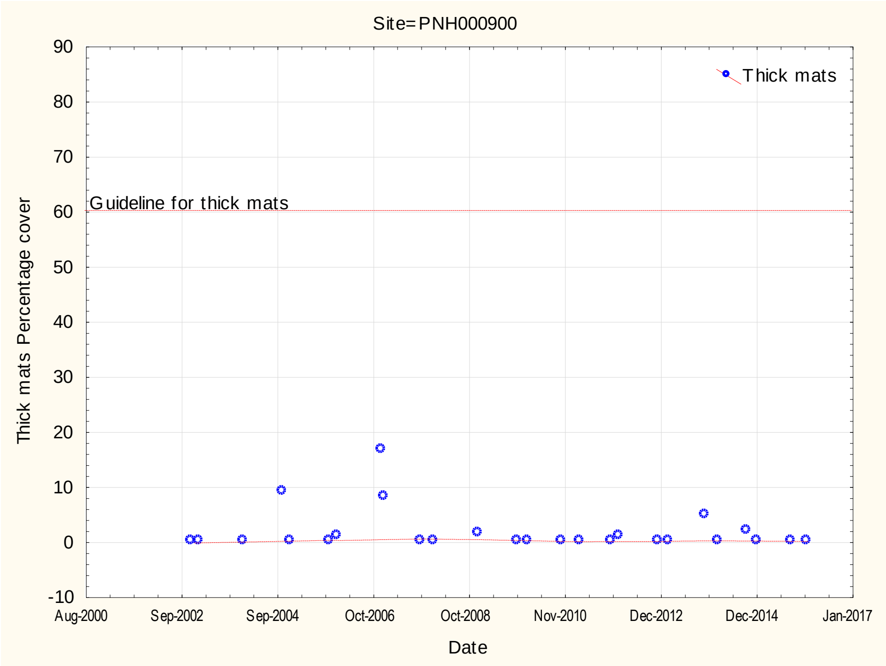
Figure 70 LOWESS trend analysis of percentage cover of thick mats at Punehu Stream, Wiremu Road (PNH000200)



n = 26
Kendal tau = -0.156
p-value = 0.264
FDR p-value = 0.359

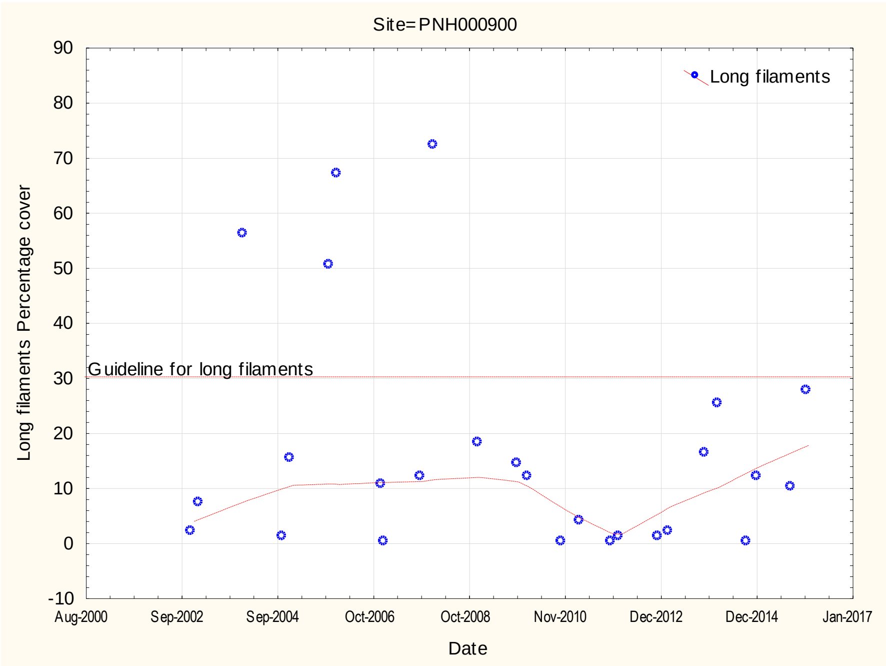
Figure 71 LOWESS trend analysis of percentage cover of long filaments at Punehu Stream, Wiremu Road (PNH000200)

At Wiremu Road (PNH000200) over the 14 year monitored period there were no significant trends for thick mats (p=0.913) or long filaments (p=0.359) at the 5% level of significance after false discovery rate adjustment.



n = 26
Kendal tau = -0.081
p-value = 0.564
FDR p-value = 0.753

Figure 72 LOWESS trend analysis of percentage cover of thick mats at Punehu Stream, SH45 (PNH000900)



n = 26
Kendal tau = -0.075
p-value = 0.589
FDR p-value = 0.620

Figure 73 LOWESS trend analysis of percentage cover of long filaments at Punehu Stream, SH45 (PNH000900)

At SH45 (PNH000900) over the 14 year monitored period there were no significant trends for thick mats (p=0.752) or long filaments (p=0.620) at the 5% level of significance after false discovery rate adjustment.

2.8 Kapoaiaia Stream

The Kapoaiaia Stream arises in the National Park, heading west approximately 25 km to the coast, entering the sea near Cape Egmont. The Kapoaiaia Stream has a narrow catchment area between the Waitotoroa Stream and the Warea River and is an example of a western catchment which has relatively poor riparian vegetation. This catchment drains agricultural land throughout its entire catchment below the National Park boundary, passing through Pungarehu township at SH45.

Three sites have been monitored in this catchment (Figure 74). The upper site, located at Wiremu Road (KPA000250), is 5.5 km downstream of the National Park boundary. A second site is located in the mid-catchment at Wataroa Road (KPA000700). A third site (KPA000950) is located at Cape Egmont, 1km upstream from the coast.

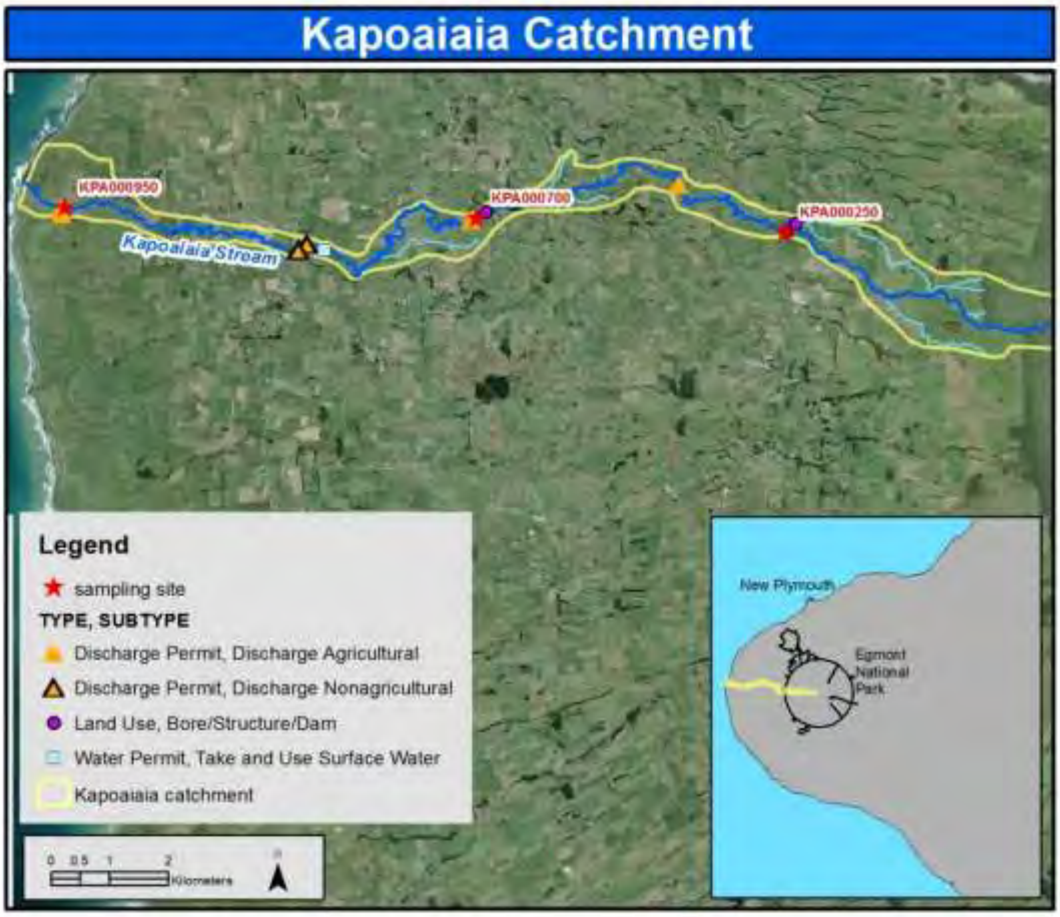


Figure 74 Monitoring site locations in relation to consents operating in the Kapoaiaia Stream catchment.

2.8.1 Flow data, nutrient data and survey dates

The Kapoaiaia River has a telemetered hydrological monitoring station at the lighthouse which is located at the very bottom of the catchment (Appendix 1).

Due to frequent fresh and flood events monitoring could not be carried out in the spring of 2014. The summer 2015 survey was conducted on 22 January 2015 21 days after a fresh in excess of both 3x median flow and 32 days after a fresh in excess of 7x median flow.

The spring 2015 survey was conducted on 3 November 2015 10 days after a very large fresh in excess of both 3x and 7x median flow. The summer 2016 survey was carried out on 3 February 2016 15 days after a fresh in excess of both 3x and 7x median flow.

Nutrient data from the SEM physiochemical programme was collected at the upstream site (KPA000250) and most downstream site (KPA000950) for the 2015-2016 year only and only four samples were collected. The upstream site did not meet the guidelines for total nitrogen and DRP for an upland site and the downstream site did not meet guidelines for a lowland site (ANZECC 2000) (Appendix 2).

2.8.2 Periphyton cover

For the 2014-2015 monitoring period the upper site at Wiremu Road (KPA000250) had low levels of long filamentous algae and no thick algal mats. Both the middle site at Wataroa Road (KPA000700) and the lower site at Cape Egmont (KPA000950) had high levels of nuisance periphyton which breached the guideline limit. Both sites had low levels of thick algal mats but high to very high levels of filamentous algae (Figure 75 and figure 76).

For the 2015-2016 monitoring period low levels of nuisance periphyton were recorded at the upper site at Wiremu Road. The middle site at Wataroa Road also had low levels of nuisance periphyton but the bottom site at Cape Egmont had high levels of long filamentous algae for the summer 2016 survey that breached the guideline limit. This result was similar to the previous reported period (2012-2014) when the downstream site had long filamentous algae at levels just below recommended guidelines for spring 2013 survey and above guideline limits for summer 2014 survey.

The Wiremu Road site had no nuisance periphyton for the 2014-2016 period. The low levels found during this reported period were possibly as a result of moving the site slightly upstream and away from the shadow of a nearby bridge. Previously it was noted that the bridge provides full shading at times to the site and that periphyton cover upstream of the site for a considerable distance was substantially greater.

The Kapoaiaia Stream only had minor levels of riparian vegetation where it flows through farmland. The streambed was largely open with high sunlight levels and relatively warm water temperatures. Furthermore, there was little buffering for nutrient inputs. These factors can contribute to periphyton growth. Consequently, nuisance periphyton levels at the lower sites were often high. Summer results were often higher than spring results as a result of warmer temperatures and less flushing flows, especially large flushing flows. The high summer 2015 result for the middle site corresponded with a period of 20 days without any significant flushing flows (> 3x median flow) and 32 days without a large flushing flow (> 7x median flow). However, flushing flows do not fully explain the results as the bottom site had higher nuisance periphyton levels for the summer 2016 survey compared with the 2015 summer survey which had a large flushing flow (> 7 x median flow) only 15 days before the periphyton survey.

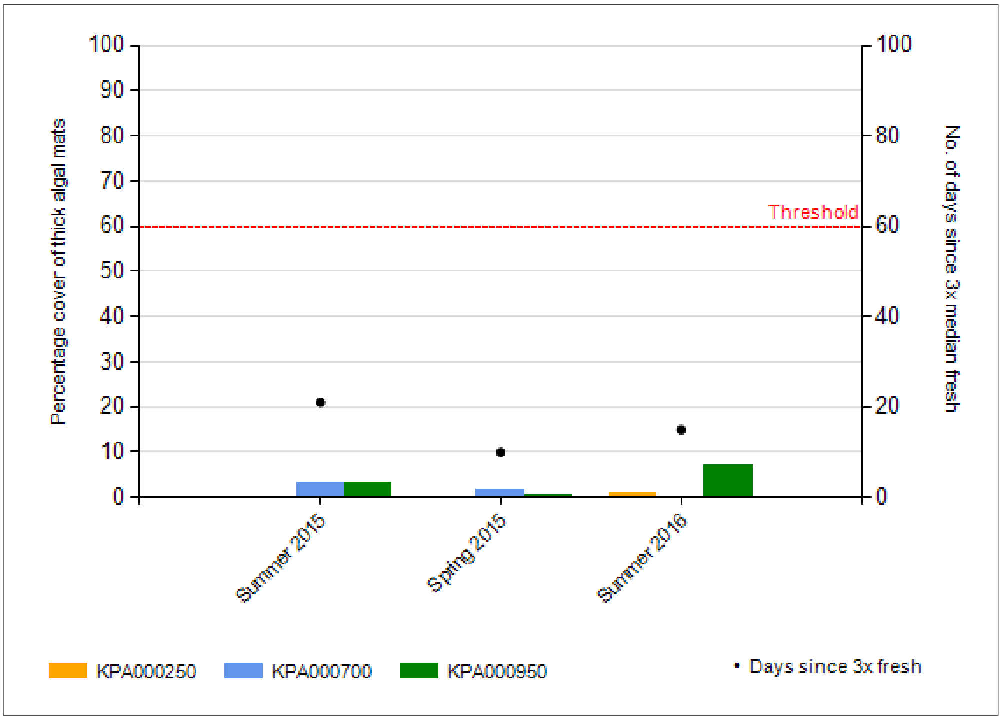


Figure 75 Percentage cover of thick mats of periphyton on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

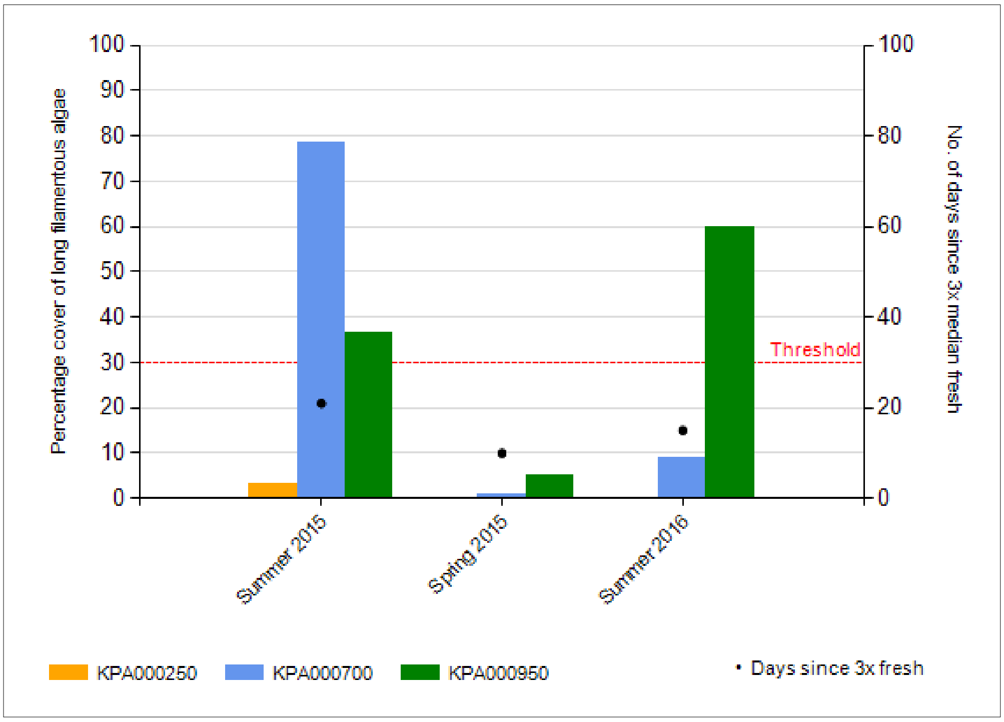


Figure 76 Percentage cover of long filamentous algae on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.8.3 Periphyton Index Score

The Kapoaiaia Stream showed a lot of variation in TRC PI scores among sites (Table 16). The upstream site (KPA000250) always had a high TRC PI score which were slightly higher than historical means. The mid-catchment site (KPA000700) had a low TRC PI score corresponding with a 'poor' rating for the summer 2015 survey which was coincident with the very high filamentous algae levels found at the site. Subsequent scores were all 'very good' which were also coincident with low filamentous algae at the site. The downstream site (KPA000950) had a lot of variation among surveys with a 'good', 'very good' and 'moderate' scores. Though there were largely congruent with filamentous algae levels the 'good' and 'moderate' scores both corresponded with a breach in filamentous algae levels.

Similarly to the 2010-2012, 2006-2010 and 2012-2014 results, the upstream site had improved dramatically from the 2002-2006 period from 'poor' to 'very good'. The middle and bottom sites had TRC PI scores that were similar to generally better than historical medians apart from the 2.9 score at the middle site for the summer 2015 survey.

Table 16 Median seasonal periphyton index scores for the Kapoaiaia Stream. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
KPA000250	9.4	10.0	9.8	9.8	5.9
KPA000700	2.9	9.4	8.7	8.5	6.8
KPA000950	6.8	9.2	5.3	6.8	5.2
Difference	2.6	0.8	4.5	3.0	0.7

2.8.4 Periphyton biomass

The results for the 2014- 2016 survey period for the upstream site showed that it had extremely low chlorophyll *a* levels with the mid catchment site having extremely high to moderately high chlorophyll *a* levels and the downstream site having moderate chlorophyll *a* levels (Figure 77).

The summer 2015 survey at the middle site breached guidelines to protect trout habitat/angling values (Table 2) and NOF standards (MfE, 2014) by a highly significant amount and was the highest chlorophyll *a* level recorded at any site since chlorophyll *a* measurements have been undertaken in Taranaki (2011-2016). The high chlorophyll *a* level for the summer 2015 survey also corresponded with the lowest TRC PI score (2.9) recorded for the period 2014-2016.

All recorded chlorophyll *a* levels for the summer 2016 survey were below the NOF limit. The middle site had moderately high chlorophyll *a* levels which breached guidelines to protect benthic biodiversity, trout habitat/angling values and aesthetics/recreation and the bottom site breached the guideline to protect benthic biodiversity (Table 2). The middle site had higher chlorophyll *a* levels than the bottom site yet had a significantly better TRC PI score and lower level of filamentous algae and thick algae mats. In particular the 'very good' TRC PI rating and moderately low chlorophyll *a* level did not correspond with the high level of filamentous algae found at the bottom site.

The results suggest that nutrients were driving periphyton biomass in the Kapoaiaia Stream as the stream runs through predominately agricultural land and nutrient levels would be sufficiently high at the middle catchment site to cause excessive periphyton growth.

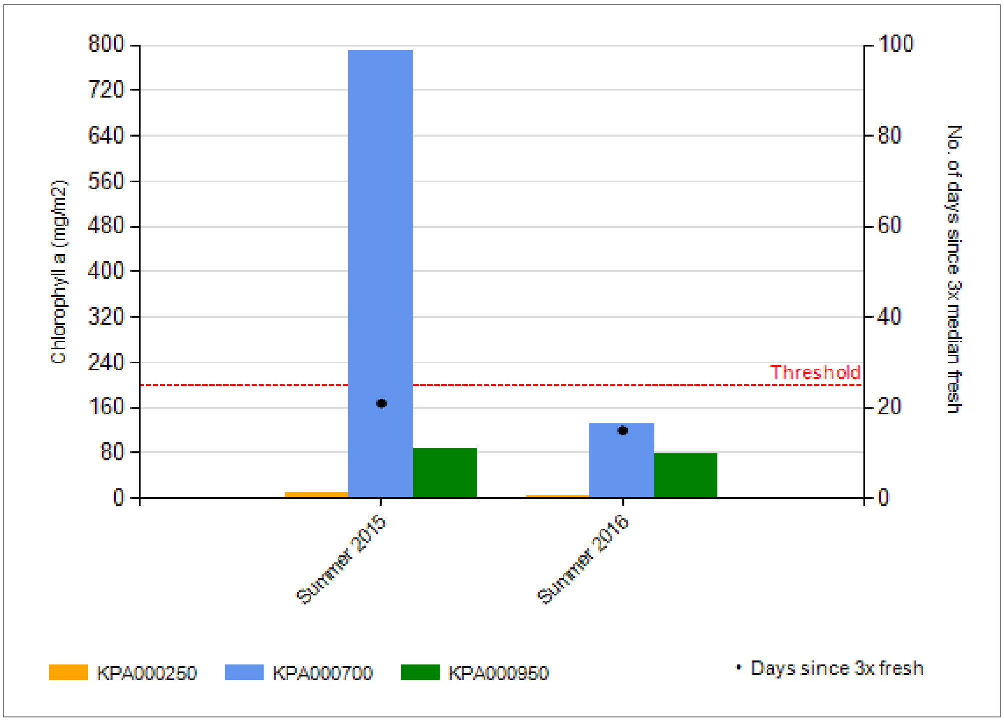


Figure 77 Periphyton biomass (chlorophyll *a*) on the Kapoaiaia riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.8.5 Summary of 2002-2016 (14 year data set)

The Kapoaiaia catchment has been monitored over a 14 year period. There have been four breaches in the guidelines in respect of thick algal mats over the three sites, none of which occurred in the 2014-2016 monitoring period (Figure 78).

The middle and bottom sites breached thick mat guideline limits twice each over the 2002-2016 period. There have also been some large proliferations of algal mats at the upstream site which have come close to breaching guidelines, particularly between the 2002- 2006 monitoring period. During the current reporting period (2014-2016) only low levels of thick algal mats were detected at any of the Kapoaiaia Stream sites.

There have been a significant number of breaches over the 14 year monitoring period for long filamentous nuisance growths (28 in total) (Figure 79). Overall there has been a significant decrease in long filamentous growths at the upper and mid catchment sites (2008-2012) but the current reported period (2014-2016) saw an increase in filamentous algae and three breaches in guidelines occurred. This followed higher filamentous algae levels at the bottom site during the previous reported period (2012-2014). The bottom site had high levels of long filamentous growth with a breach in guidelines recorded for the summer 2014 survey at the site and the spring 2013 survey was close to being breaching the guideline level.

This catchment has the highest amount of nuisance growths for long filaments within a catchment out of all the catchments monitored over the 14 year period. There is still a significant level of work required in the Kapoaiaia catchment to reduce nutrient levels down and increase riparian cover.

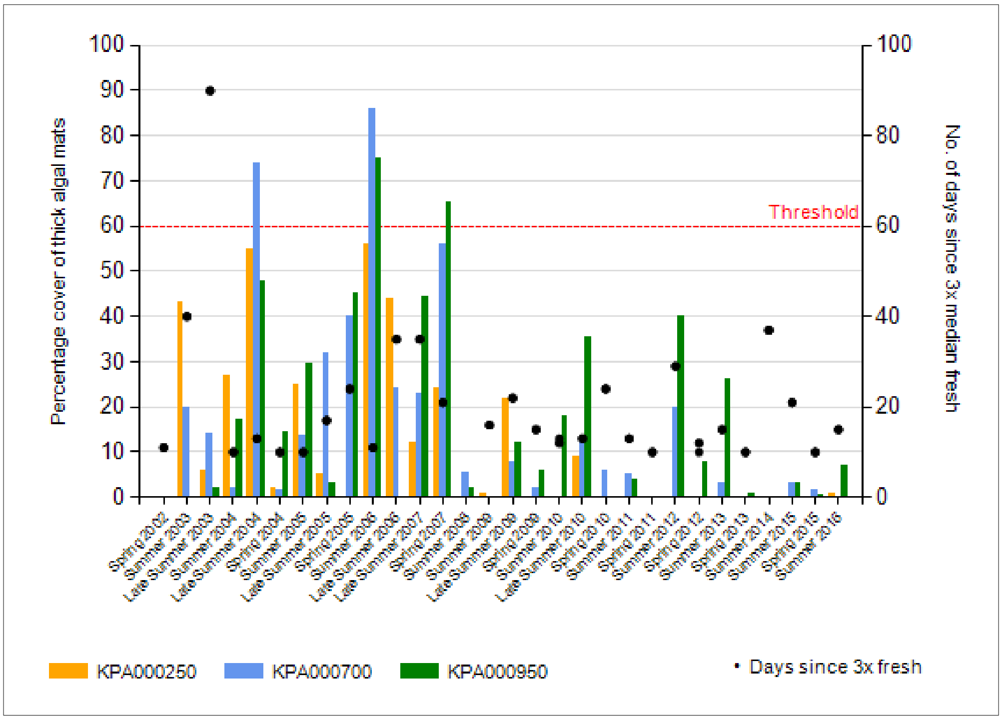


Figure 78 Percentage cover of thick mats of periphyton on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2002-2016 period

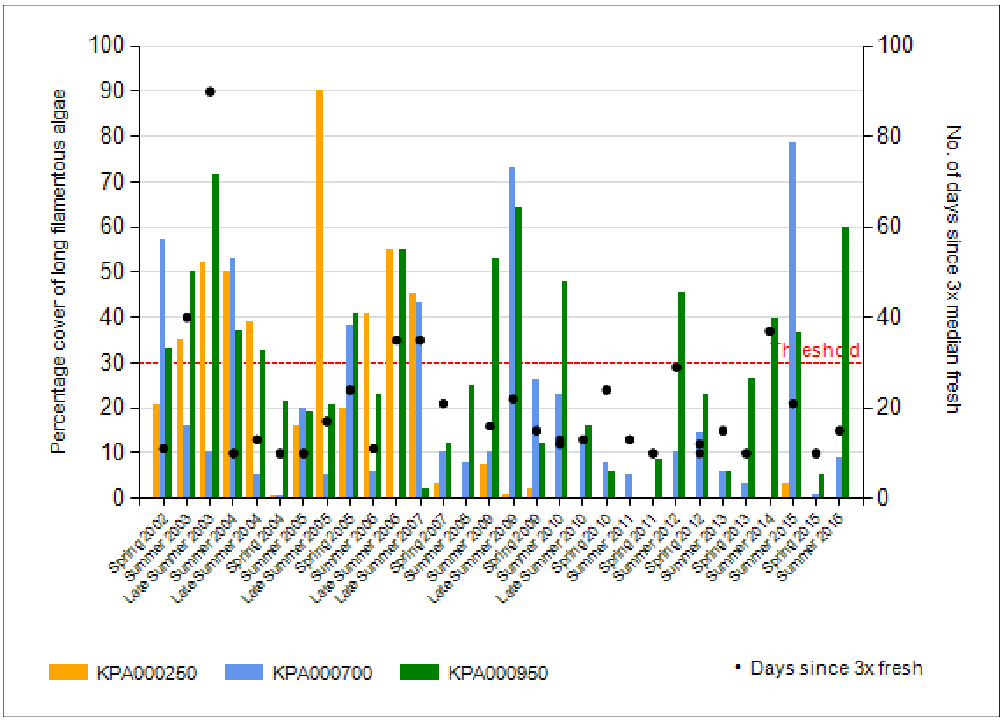
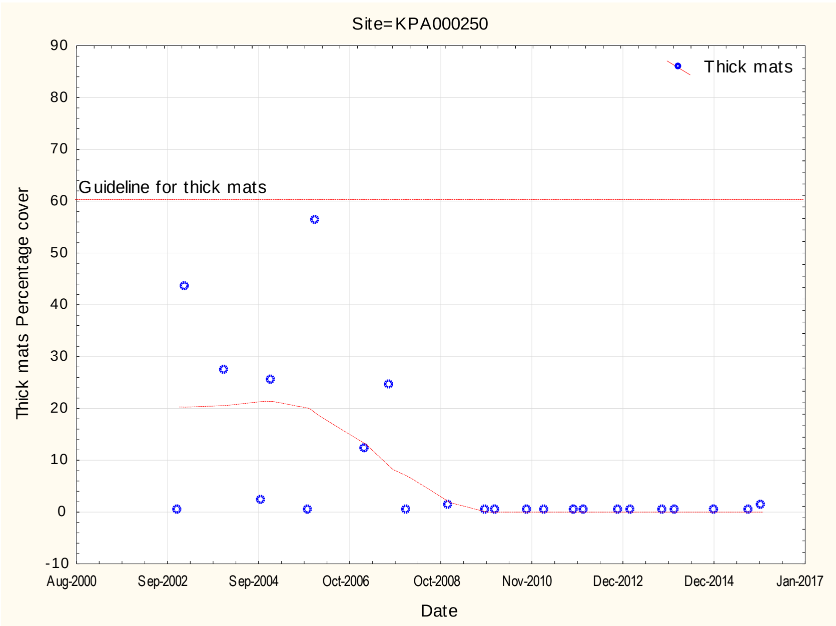


Figure 79 Percentage cover of long filamentous algae on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2002-2016 period

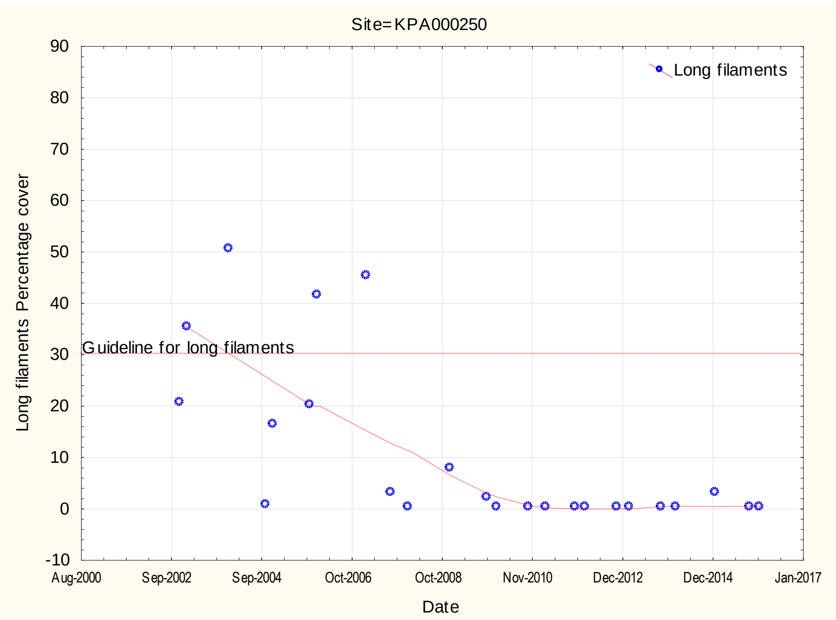
2.8.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at three sites on the Kapoaiaia Stream; Wiremu Road, Wataroa Road and at Cape Egmont. Monitoring was carried out over a 14 year period and trend analysis was carried out by testing the significance using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 80 to Figure 85).



n = 24
Kendal tau = -0.452
p-value = 0.002
FDR p-value = 0.021

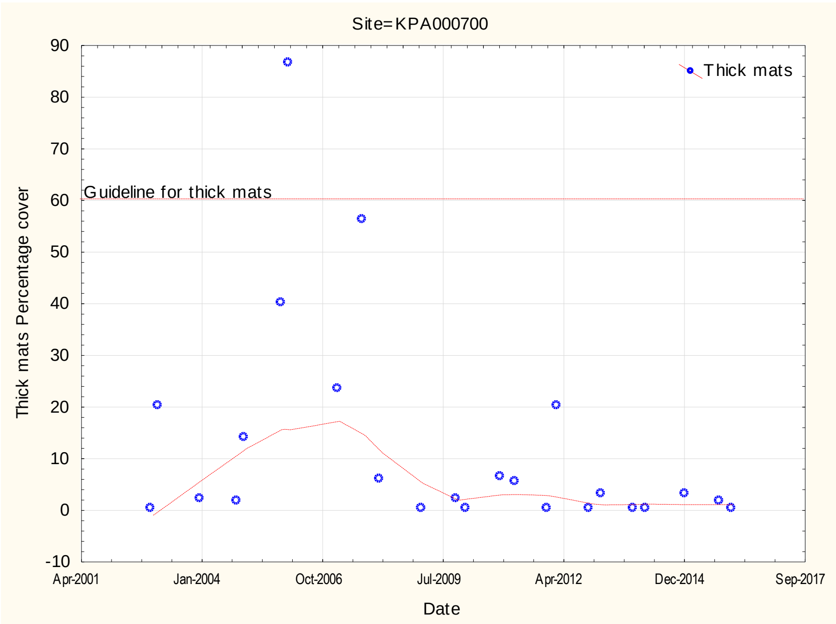
Figure 80 LOWESS trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Wiremu Road (KPA000250)



n = 24
Kendal tau = **-0.579**
p-value < 0.001
FDR p-value = 0.001

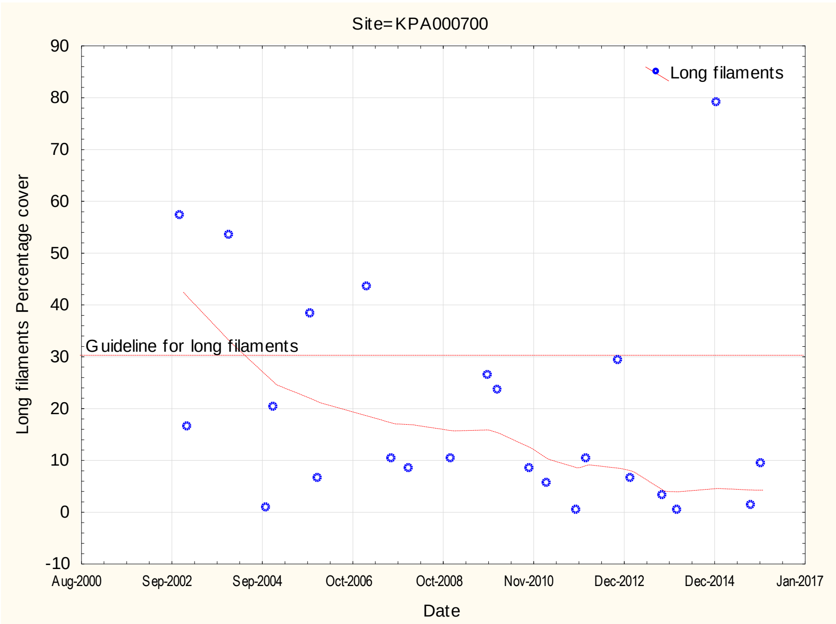
Figure 81 LOWESS trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Wiremu Road (KPA000250)

At Wiremu Road (KPA000250) over the 14 year monitored period there was a significant (p=0.021) negative (tau=-0.452) trend for thick mats and a significant (0.001) negative (tau=-0.579) trend for long filaments at the 5% level of significance after false discovery rate adjustment indicating that both nuisance periphyton types had decreased over the monitored period.



n = 24
Kendal tau = -0.293
p-value = 0.045
FDR p-value = 0.236

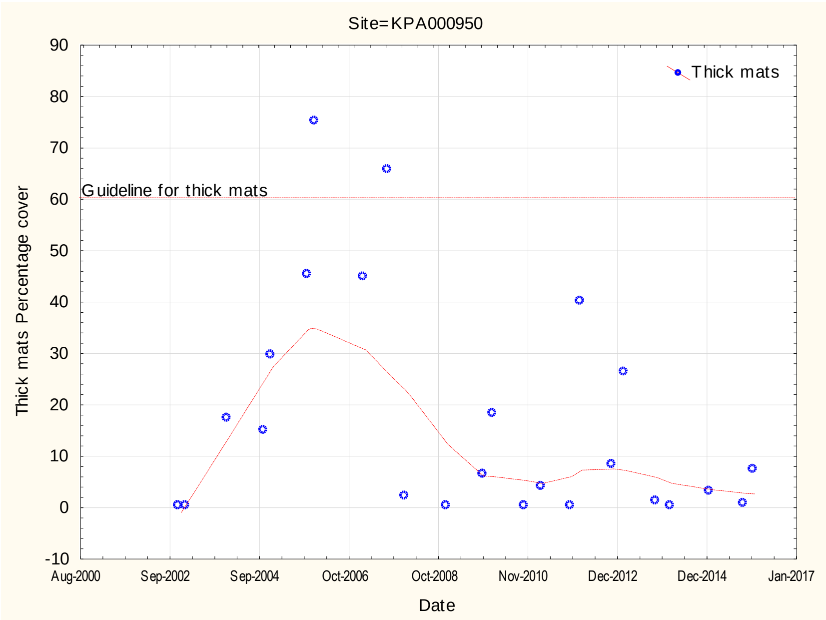
Figure 82 LOWESS trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Wataroa Road (KPA000700)



n = 24
Kendal tau = -0.300
p-value = 0.040
FDR p-value = 0.159

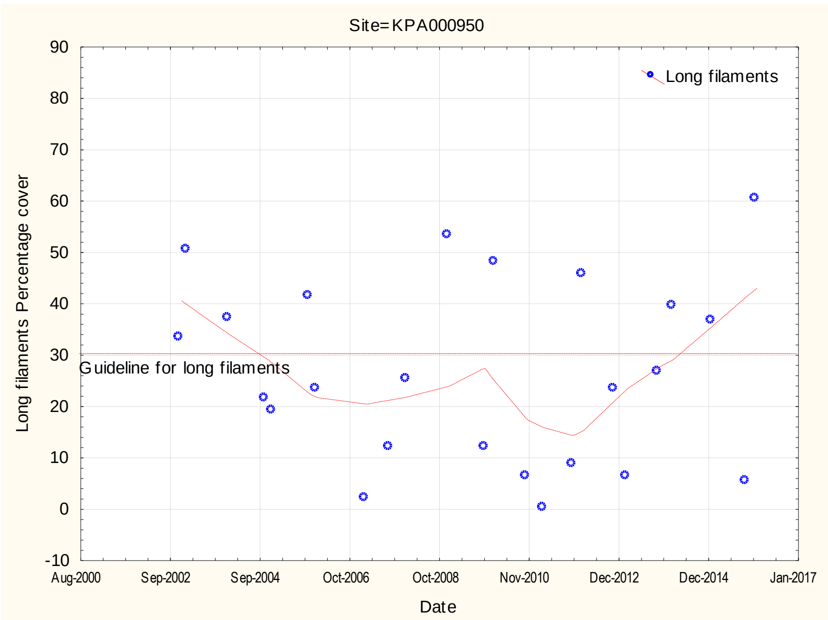
Figure 83 LOWESS trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Wataroa Road (KPA000700)

At Wataroa Road (KPA000700) over the 14 year monitored period there was no significant trend for thick mats (p=0.237) or long filamentous algae (p=0.159) at the 5% level of significance after false discovery rate adjustment.



n = 24
Kendal tau = **-0.138**
p-value = 0.345
FDR p-value = 0.659

Figure 84 LOWESS trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Cape Egmont (KPA000950)



n = 24
Kendal tau = -0.139
p-value = 0.672
FDR p-value = 0.672

Figure 85 LOWESS trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Cape Egmont (KPA000950)

At Cape Egmont (KPA000950) over the 14 year monitored period there were no significant trends for thick mats (p=0.659) or long filaments (p=0.672) at the 5% level of significance after false discovery rate adjustment.

2.9 Waiongana River

The Waiongana Stream arises in the National Park tracking north east towards Inglewood then north to the coast; approximately 35 kilometres in total. The catchment covers a large area and includes numerous tributaries (Figure 86).

The top sampling site (WGA000260) at SH3a is located mid-catchment, situated just north of Inglewood. The second site (WGA000450), at Devon Road is located approximately 3 kilometres from the coastal mouth of the stream.

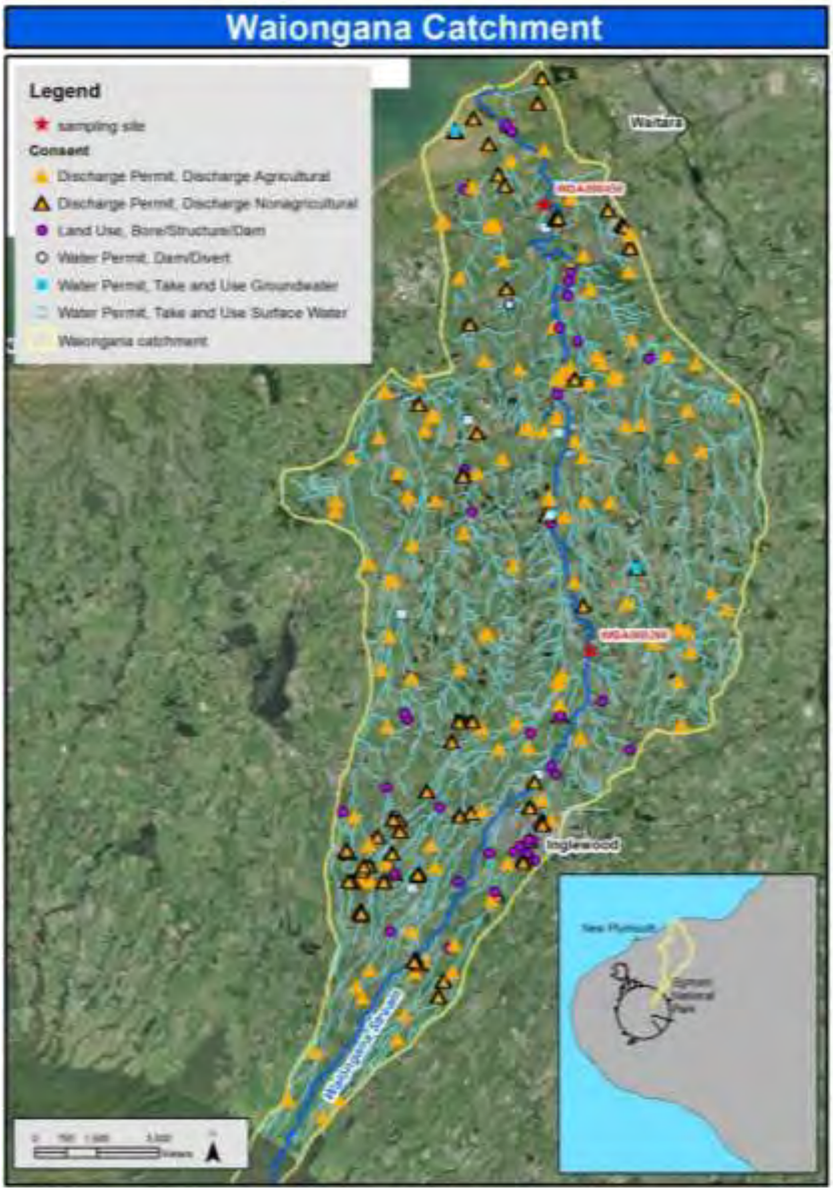


Figure 86 Monitoring site locations in relation to consents operating in the Waiongana Stream catchment

2.9.1 Flow data, nutrient data and survey dates

There is a telemetered hydrological monitoring station on the Waiongana River at SH3a in the lower middle of the catchment (Appendix 1).

The spring 2014 survey was conducted on 9 December 2014 13 days after a fresh in excess of 3x and 14 days after a fresh exceeding 7x median flow. The summer 2015 survey was carried out on 20 January 2015 15 days after a fresh in excess of 3x and 7x median flows (Appendix 1).

The spring 2015 survey was conducted on 13 October 2015 11 days after a fresh in excess of 3x median flow and 12 days after 7x median flow. The summer 2016 survey was carried out on 2 February 2016 13 after a fresh in excess of 3x and 7x median flows (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at the upstream site (WGA000260) for the 2015-2016 year only and only four samples were collected. The site did not meet the guidelines for total nitrogen and DRP for a lowland site (ANZECC 2000) (Appendix 2).

2.9.2 Periphyton cover

There were two breaches in the guideline for long filamentous algae in the 2014-2015 monitoring period (Figure 87 and Figure 88). One breach occurred at the upper site situated mid-way down the catchment (WGA000260) during the summer 2015 survey and the other breach occurred at the lower end of the catchment (WGA000450) during the spring 2014 survey. No breaches occurred for thick algal mats but the lower site did have moderately low levels of thick algal mats for both surveys and total levels of nuisance periphyton at the bottom site was high though no breach occurred during the summer 2015 survey.

For the 2015-2016 monitoring period no breaches occurred. The upstream site at SH3a had moderately low levels of thick algal mats and very low levels of long filaments during spring 2015 survey and no nuisance periphtyon for the summer 2016 survey. The bottom site at Devon Road had thick mats and long filamentous algae recorded from both surveys. Nuisance periphyton was at low levels except for the summer 2016 survey for long filaments that was at a level approaching the threshold limit.

High nuisance periphyton levels do not correspond with long periods without flushing flows and therefore nutrient enrichment is the most likely explanation for the periphyton levels recorded during the 2014-2016 period.

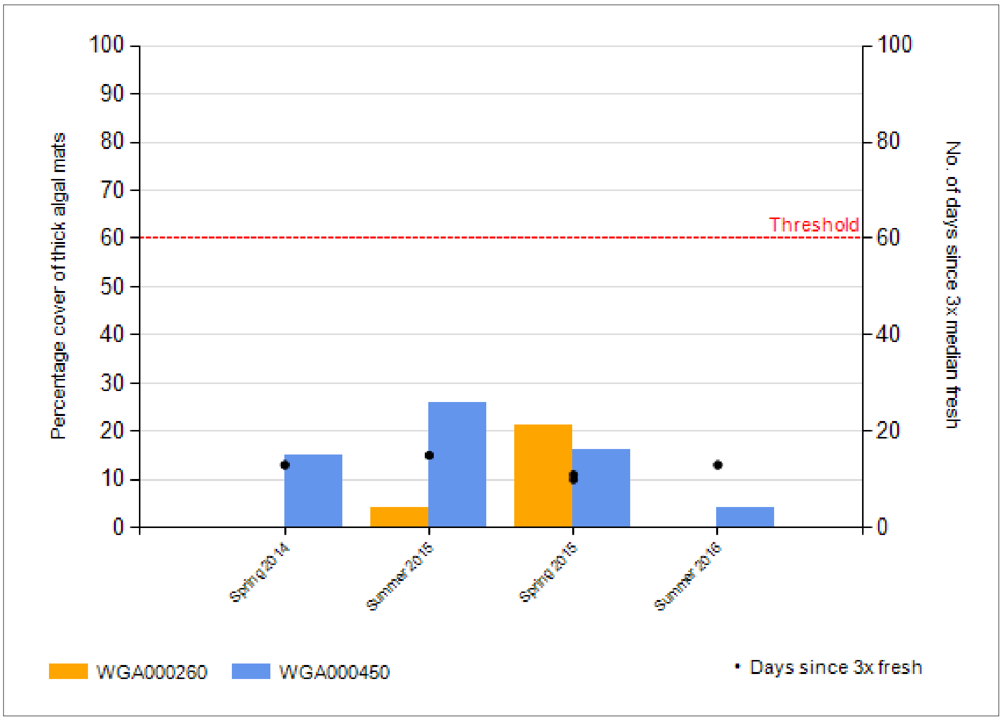


Figure 87 Percentage cover of thick mats of periphyton on the Waiongana riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

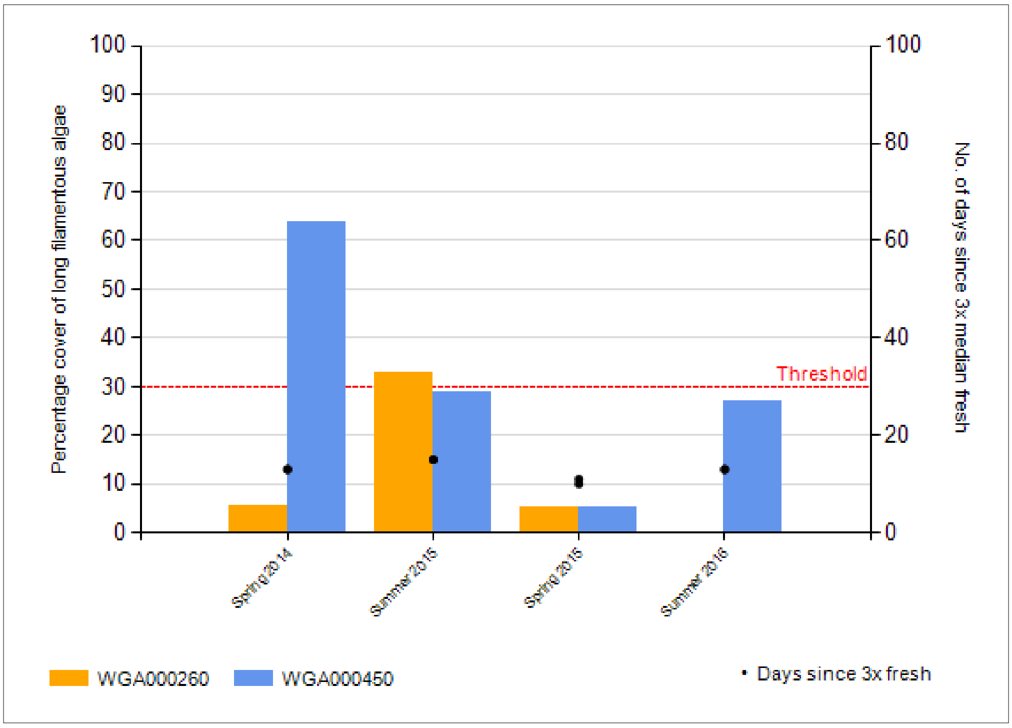


Figure 88 Percentage cover of long filamentous algae on the Waiongana riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.9.3 Periphyton Index Score

TRC PI scores were highly variable across both monitoring periods and between the two sites surveyed but generally reflected levels of nuisance periphyton recorded.

For the 2014-2015 monitoring year the upstream site had a 'good' score for the spring 2014 survey and a 'moderate' score for the summer 2015 survey (Table 17). The bottom site for the corresponding surveys had 'poor' and 'moderate' scores which closely matched filamentous algae levels. Scores were mostly below historical medians for both sites except for the spring 2014 survey for the upper site.

For the 2015-2016 monitoring year the upstream site had a 'good' score for the spring 2015 survey and a 'very good' score for the summer 2016 survey (Table 17). The bottom site for the corresponding surveys had 'very good' and 'good' scores. Scores were mostly above historical medians for both sites except for the summer 2016 survey for the lower site.

For the spring 2015 survey the bottom site had a higher TRC PI score than the upper site. The decrease in TRC PI score at the upstream site has in the past, as indicated by the historic median scores, been attributed to a change from higher intensive land use in the upper catchment to a less intensive land use in the lower catchment. There was no obvious seasonal trend which was also congruent with historical medians which indicated that there was not a large decrease in summer surveys compared with spring surveys.

Table 17 Median seasonal periphyton index scores for the Waiongana River. The difference given is the TRC PI for the most upstream site minus the TRC PI for the most downstream site

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
WGA000260	7.2	4.7	7.6	9.0	6.6	6.0
WGA000450	2.7	4.6	8.2	6.4	7.2	7.1
Difference	4.5	0.1	-0.6	2.6	-0.6	-0.9

2.9.4 Periphyton biomass

The results for the 2015 survey for the mid catchment upstream site showed that it had high chlorophyll *a* levels which breached NOF standards (Figure 89). The bottom site had exceptional high chlorophyll *a* levels which also breached NOF standards (Table 7).

For the summer 2016 survey both sites were within the NOF standards (Table 7). However, the upper site breached guidelines to protect benthic biodiversity values and the bottom site breached guidelines to protect trout habitat/angling values and benthic biodiversity values (Table 2).

The high chlorophyll *a* level for the bottom site during the summer 2015 survey also corresponded with a 'poor' TRC PI score (2.7) but the upper site also had a high chlorophyll *a* level but a 'good' TRC PI score (7.2).

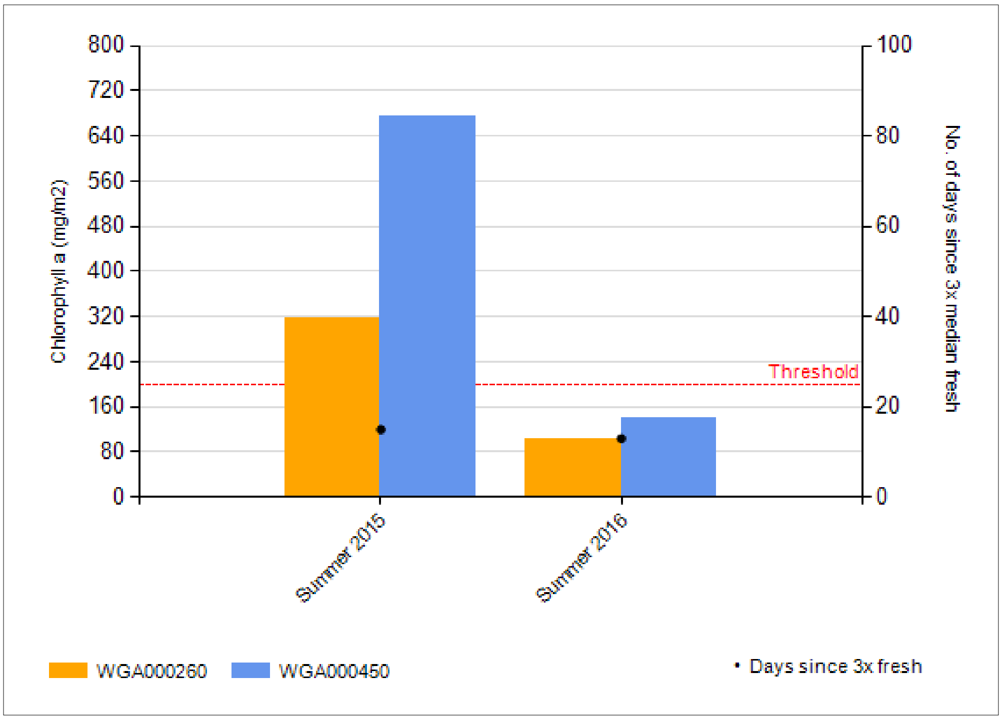


Figure 89 Periphyton biomass (chlorophyll *a*) on the Waiongana riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.9.5 Summary of 2002-2016 (14 year data set)

The Waiongana catchment over the 14 year data set has had no breaches in thick algal mats at either of the sites surveyed (Figure 90). There have been more significant growths of thick mats at the downstream site than the upstream site over more recent years (2014-2016). This contrasts to what was recorded in the 2006-2010 period, when greater proliferations were observed at the upstream site.

Long filamentous algae had intermittently breached guidelines throughout the entire record at both the upstream and downstream sites (Figure 91). The majority of the breaches at the upstream site tended to be after long periods without flushing flows, such as late summer 2007, summer 2008 and summer 2014. There have not been as many breaches at the lower catchment site compared with the upper catchment site but since 2008 three of the last four breaches were at the downstream site. This was largely due to improvements at the upstream site rather than the downstream site having more breaches.

The Waiongana catchment was the only catchment where breaches in periphyton guidelines increased between the 2002-2006 and 2006-2010 surveys and this trend has continued, especially at the downstream site. One breach occurred in the 2012-2014 surveys at the bottom site. In the most recent reported period there were two breaches for the long filamentous algae guideline, one for the upstream site and one for the downstream site but two other surveys for the downstream site were also very close to breaching the guideline limit.

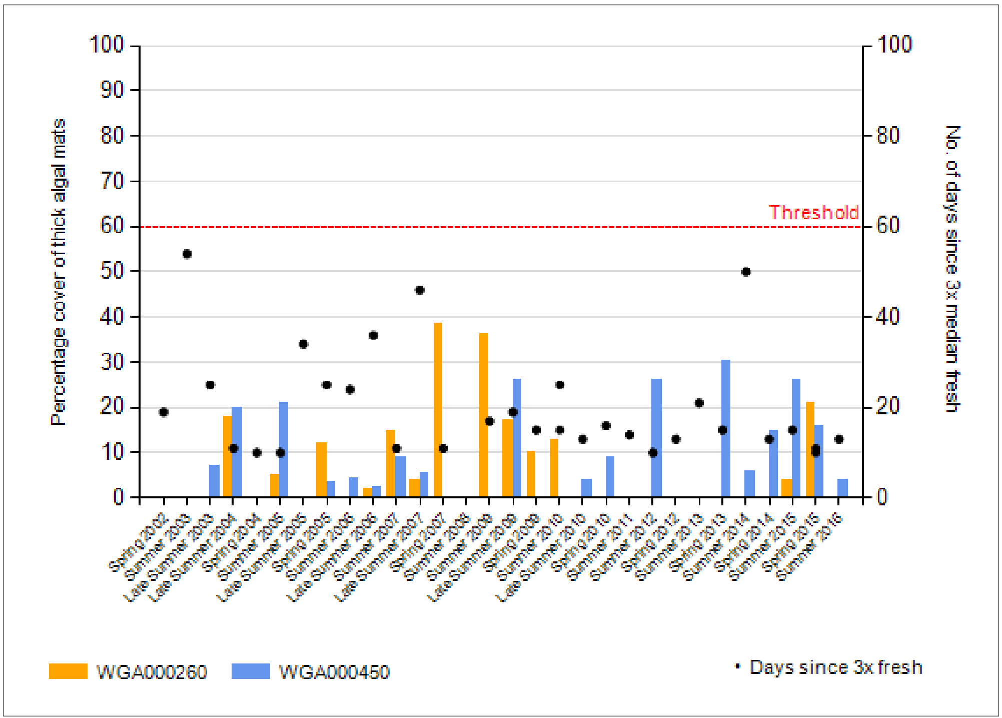


Figure 90 Percentage cover of thick mats of periphyton on the Waiongana riverbed in relation to the guidelines for recreational values over the 2002-2016 period

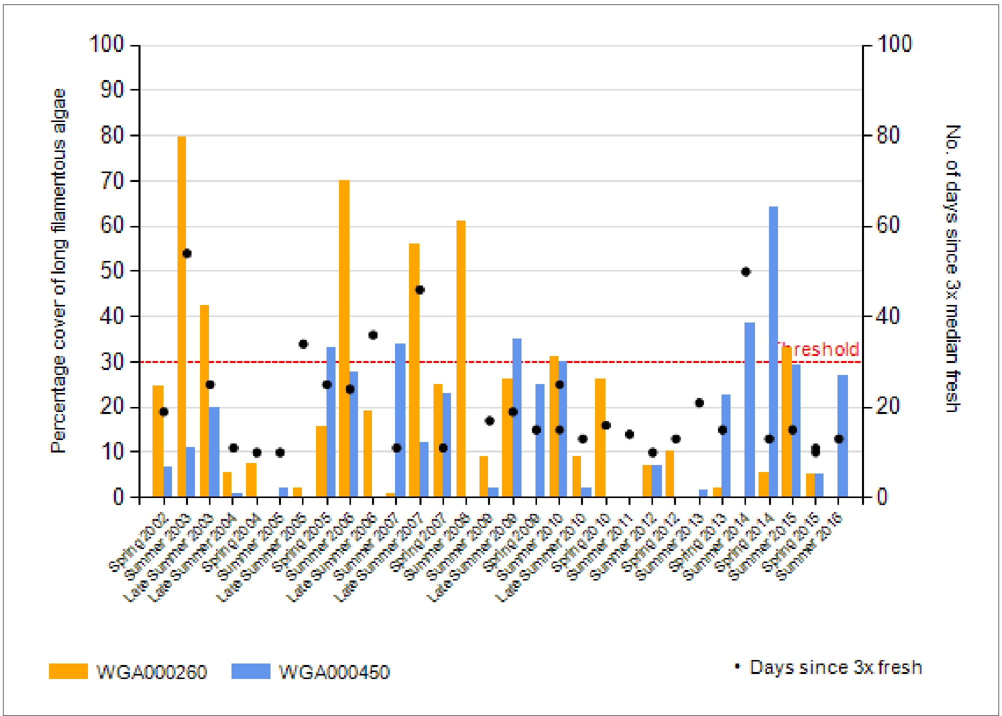
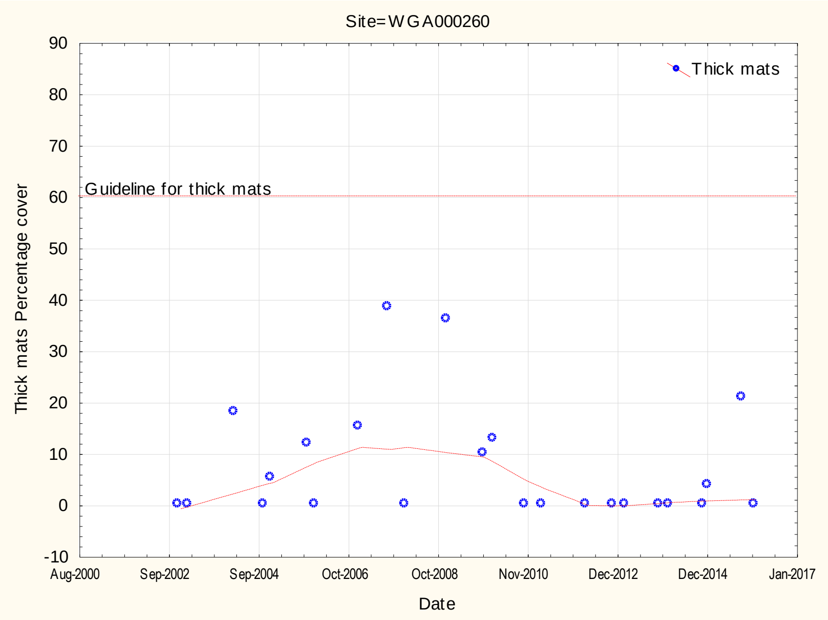


Figure 91 Percentage cover of long filamentous algae on the Waiongana riverbed in relation to the guidelines for recreational values over the 2002-2016 period

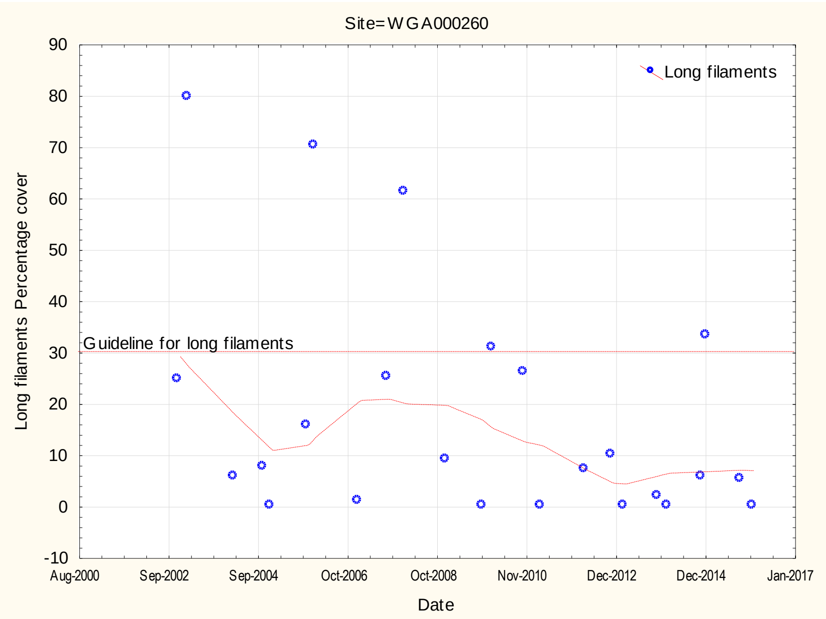
2.9.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Waiongana River, at SH3a and Devon Road, over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 92 to Figure 95).



n = 24
Kendal tau = -0.119
p-value = 0.413
FDR p-value = 0.718

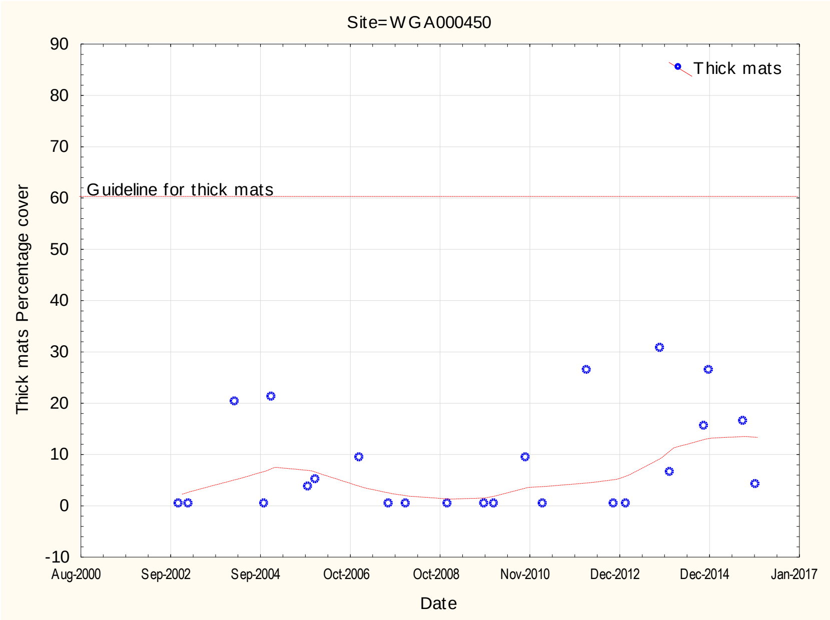
Figure 92 LOWESS trend analysis of percentage cover of thick mats at Waiongana River, SH3a (WGA000260)



n = 24
Kendal tau = -0.254
p-value = 0.082
FDR p-value = 0.235

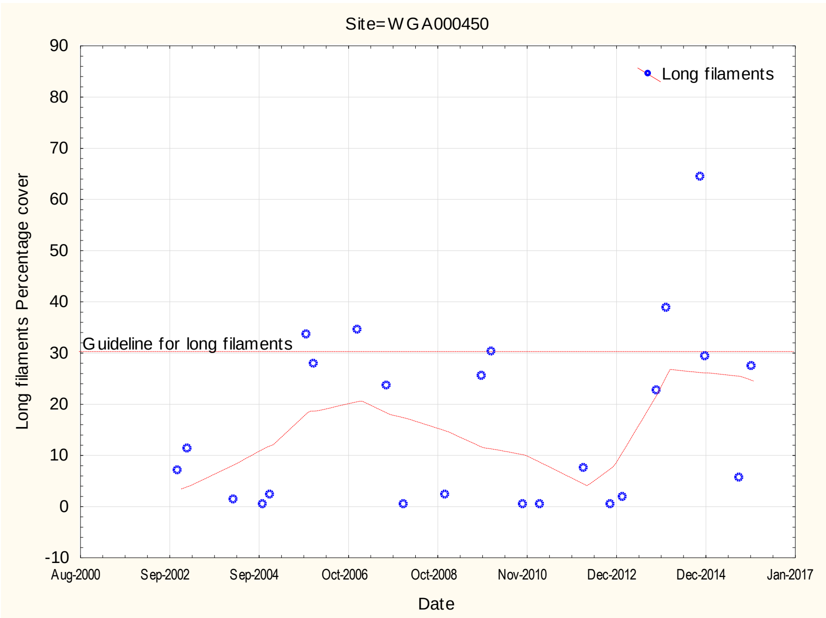
Figure 93 LOWESS trend analysis of percentage cover of long filaments at Waiongana River, SH3a (WGA000260).

At SH3a (WGA000260) over the 14 year monitored period there were no significant trends for thick mats (p=0.718) or long filaments (p=0.235) at the 5% level of significance after false discovery rate adjustment.



n = 24
Kendal tau = 0.232
p-value = 0.112
FDR p-value = 0.337

Figure 94 LOWESS trend analysis of percentage cover of thick mats at Waiongana River, Devon Road (WGA000450)



n = 24
Kendal tau = 0.144
p-value = 0.324
FDR p-value = 0.359

Figure 95 LOWESS trend analysis of percentage cover of long filaments at Waiongana River, Devon Road (WGA000450)

At Devon Road (WGA000450) over the 14 year monitored period there were no significant trends for thick mats (p=0.337) or long filaments (p=0.359) at the 5% level of significance after false discovery rate adjustment.

2.10 Mangaehu River

The Mangaehu River represents a typical eastern hill country river. Arising approximately 10 km south of Whangamomona it runs in a south-westerly direction for around 30 km through predominantly agricultural land before discharging into the Patea River.

The river typically has a relatively poor visual appearance, with low black disc clarity due to fine, colloidal suspended particles (TRC, 2012). This is due to the eastern hill country catchment geology that this river drains, which is very different from the stony ring plain streams around Mt Taranaki.

One monitoring site (MGH000950 at Raupuha Road) is monitored in this catchment, about 10 km upstream of the confluence of the Mangaehu River with the Patea River (Figure 96).

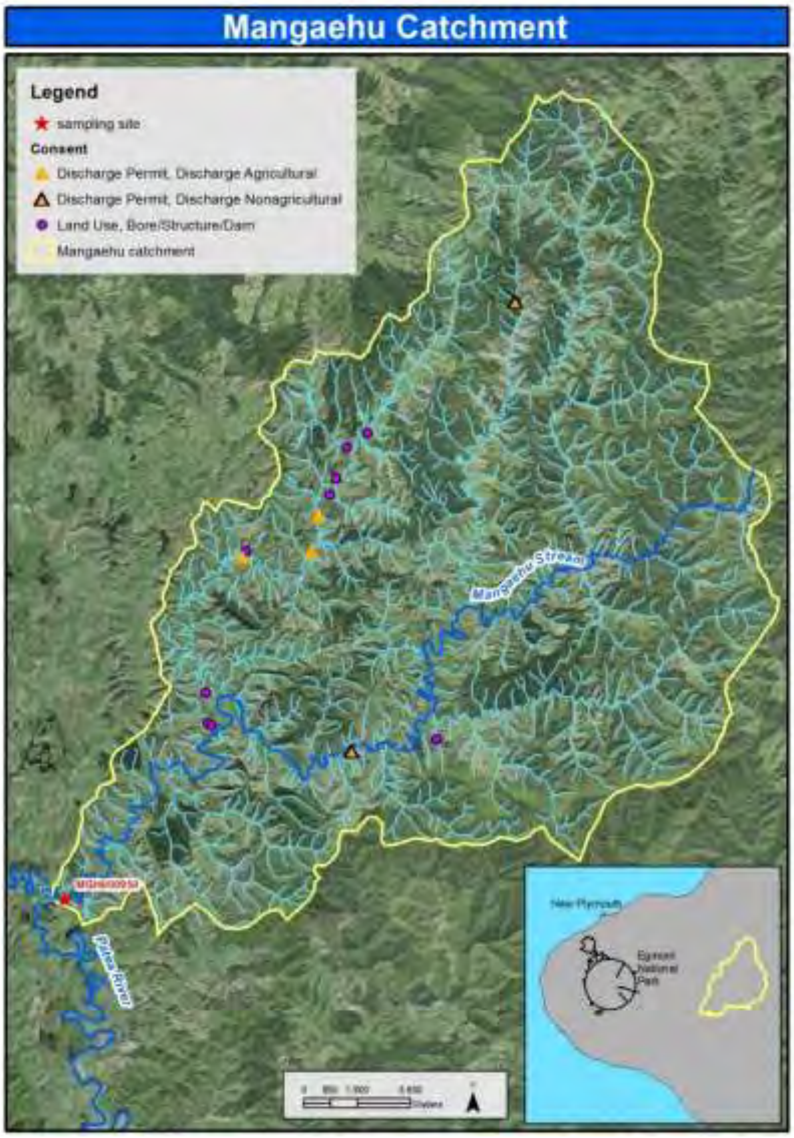


Figure 96 Monitoring site in the Mangaehu River catchment

2.10.1 Flow data, nutrient data and survey dates

There is a telemetered hydrological monitoring station on the Mangaehu River at the Raupuha Road Bridge. This is the same site where the periphyton monitoring survey is conducted (Appendix 1).

The spring 2014 survey was conducted on 3 December 2014 15 days after a fresh in excess of 3x median flow and 30 days after a fresh in excess of 7x median flow. The summer 2015 survey was carried out on 14 January 2015 23 days after a fresh in excess of 3x median flow and 72 days after a fresh in excess of 7x median flow (Appendix 1).

The spring 2015 survey was conducted on 16 October 2015 11 days after a fresh in excess of 3x median flow and 25 days after a fresh of 7x median flow. The summer 2016 survey was carried out on 2 February 2016 13 days after a fresh in excess of 3x median flow and 160 days after 7x median flow (Appendix 1).

Nutrient data from the SEM physiochemical programme was collected at the site. The site met the guidelines for total nitrogen and DRP for a lowland site (ANZECC 2000) (Appendix 2). The site was the only one out of the 21 sites examined for nuisance periphyton that was not located on the Taranaki ringplain and hence did not have naturally high phosphorus levels.

2.10.2 Periphyton cover

Only one site was surveyed in the Mangaehu River. Located at the road bridge on Raupuha Road, it is situated near the lower end of the catchment just above the confluence with the Patea River. Nuisance periphyton breached guidelines on two out of the four surveys (Figure 97 and Figure 98).

For the 2014-2015 monitoring period no nuisance periphyton was recorded for the spring 2014 survey and only low levels of thick mats and moderately low levels of long filamentous algae were recorded during the summer 2015 survey.

For the 2015-2016 monitoring period there was a breach in the thick algal mat guideline for the spring 2015 survey and a further breach in the long filamentous algae guideline for the summer 2016 survey which was also accompanied by moderately low levels of thick algal mats. The thick algal mats were comprised of a mixture of green algae and diatoms with no cyanobacteria detected and were therefore not a health hazard.

The breaches in nuisance periphyton guidelines were unrelated to available nutrients which were low for both phosphorus and nitrogen. Flows in excess of three time median flow or in excess of seven times median flow did not seem to be significantly influencing nuisance periphyton levels at the site. The low nuisance periphyton levels for the summer 2015 survey occurred after 72 says since a flow in excess of seven times median flow yet the high levels for the subsequent spring 2015 survey occurred after 25 days since a fresh in excess of seven time median flow. Very large flows are probably needed to scour the riverbed of periphyton at this site.

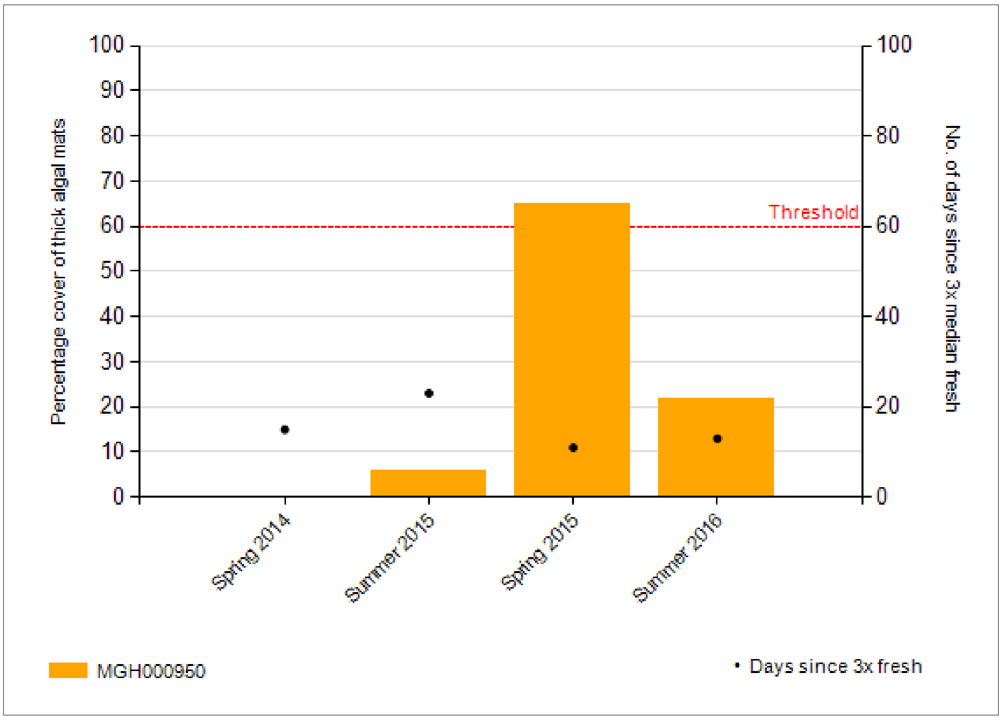


Figure 97 Percentage cover of thick mats of periphyton on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

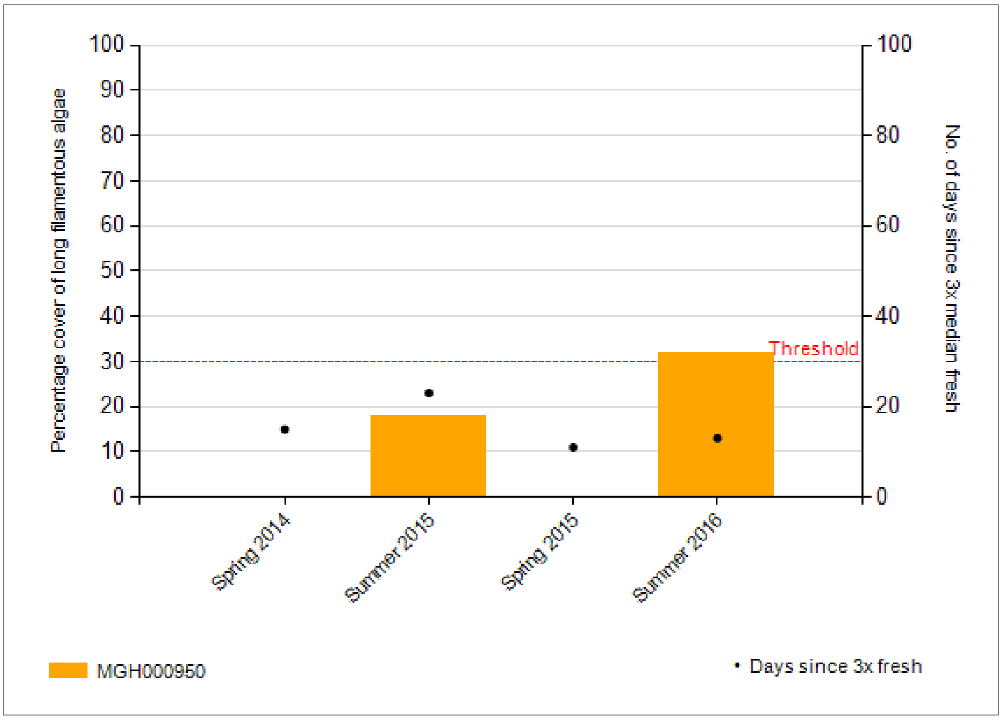


Figure 98 Percentage cover of long filamentous algae on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2014-2016 monitoring period and number of days since 3x median fresh

2.10.3 Periphyton Index Score

The Mangaehu River is subject to high sediment loads, as it drains the eastern hills of Taranaki. This is a factor not present for the other rivers in this programme, and it may have an influence on periphyton growth. Only one site is surveyed in this programme, so downstream changes cannot be discussed. There was some variability with season, with spring surveys having higher TRC PI scores than summer surveys. This result was typical for the site based on the large differences between the historical medians between spring and summer (Table 18).

In spring 2014 a 'very good' TRC PI score was recorded which was well above the historical median and in summer 2015 a 'moderate' score was recorded that was also above the historical median. Between spring 2014 and summer 2015 surveys the PI score dropped by 3.0 units which was consistent with previous results.

In spring 2015 a 'moderate' TRC PI score was recorded which was below the historical median and in summer 2016 a 'moderate' score was recorded that was close to the historical median. Because of the uncharacteristically low spring 2015 score only a small decrease occurred between the spring and summer survey.

No 'poor' ratings occurred for the 2014-2016 period which was an improvement on the previous reported period 2014-2016 where the summer 2014 survey was rated 'poor' for the site. Furthermore, three of the four surveys had scores higher than historic medians. The decrease in TRC PI scores during the summer surveys can be attributed to the proliferation of long green filamentous algae over the warmer summer period coupled with longer periods without flushing flows. The 'moderate' score for the spring 2015 survey was caused by large amounts of thick mats which was unrelated to available nutrients which were low. The survey occurred after only 11 days since a fresh in excess of 3 times median flow but there was a substantially longer (25 days) period prior to a large fresh occurring in excess of 7 times median flow.

Table 18 Median seasonal periphyton index scores for the Mangaehu River

Site	TRC PI Spring 2014	TRC PI Summer 2015	TRC PI Spring 2015	TRC PI Summer 2016	TRC PI Historical spring median	TRC PI Historical summer median
MGH000950	8.8	5.8	5.3	4.6	7.2	4.5

2.10.4 Periphyton biomass

The results for the 2014- 2016 period showed moderate to high chlorophyll *a* levels (Figure 99). The summer 2016 survey breached guidelines to protect trout habitat/angling values (Table 2) and the NOF bottom line (MfE, 2014).

The chlorophyll *a* levels reflected nuisance peripyton levels and to a lesser extent TRC PI levels which showed both summer surveys to be 'moderate' yet nuisance periphyton and chlorophyll *a* levels were nearly twice as high for the summer 2016 survey compared with the summer 2015 survey.

A possible reason for the lack of a relationship include large amounts of dead periphyton present at the site that would not contain chlorophyll *a* but would still count for periphyton cover or a substrate bias where high levels of periphyton occurred on larger rocks that were not easily sampled for chlorophyll *a* due to lifting constraints. Smaller rocks could be more easily turned over from smaller freshes and hence have lower periphyton cover. A substrate size class has been noted in the past when large boulders were found to have high levels of periphyton but were not able to be sampled for chlorophyll *a* at another site (Scott Cowperthwaite pers. comm.).

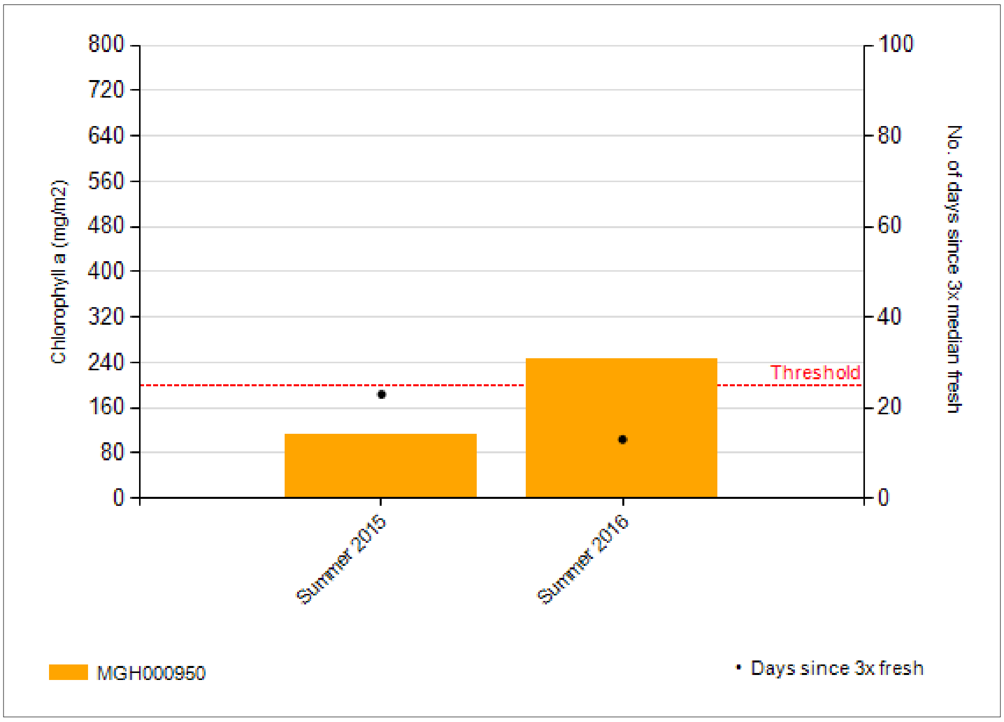


Figure 99 Periphyton biomass (chlorophyll *a*) on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2014-2016 period

2.10.5 Summary of 2002-2016 (14 year data set)

The Mangaehu River has usually had high levels of nuisance periphyton in the form of both thick algal mats and filamentous algae (Figure 100 and Figure 101). There had been only one pervious breach of thick mats at the site though several survey results had come close to breaching the guideline. For the current survey period (2014-2016) there was a thick mat breech in the guidelines with three out of the four surveys recording thick algal mats at above 50% of total streambed cover. Though thick algal mats are often moderately high at the site the breach was only the second time thick algal mats exceeded the guideline and the first time in six years that there had been a breach in filamentous algae. The thick algal mats tended to increase from spring to summer, which indicates that growths follow temperature and sunlight increases and decreasing rainfall to some extent.

Long filamentous algae proliferate on a regular basis at this site, and have breached the recreational guidelines six times over the 12 year monitoring period but the last breach was several years ago in the summer 2009 survey. These occurrences were restricted to summer periods. During the 2002-2006 period there were four breaches in long filamentous algae compared to only two breaches in the 2006-2010 period in the same number of surveys. No breaches of long filamentous algae occurred in the 2012-2014 monitoring period though the summer 2014 survey came close to breaching guidelines.

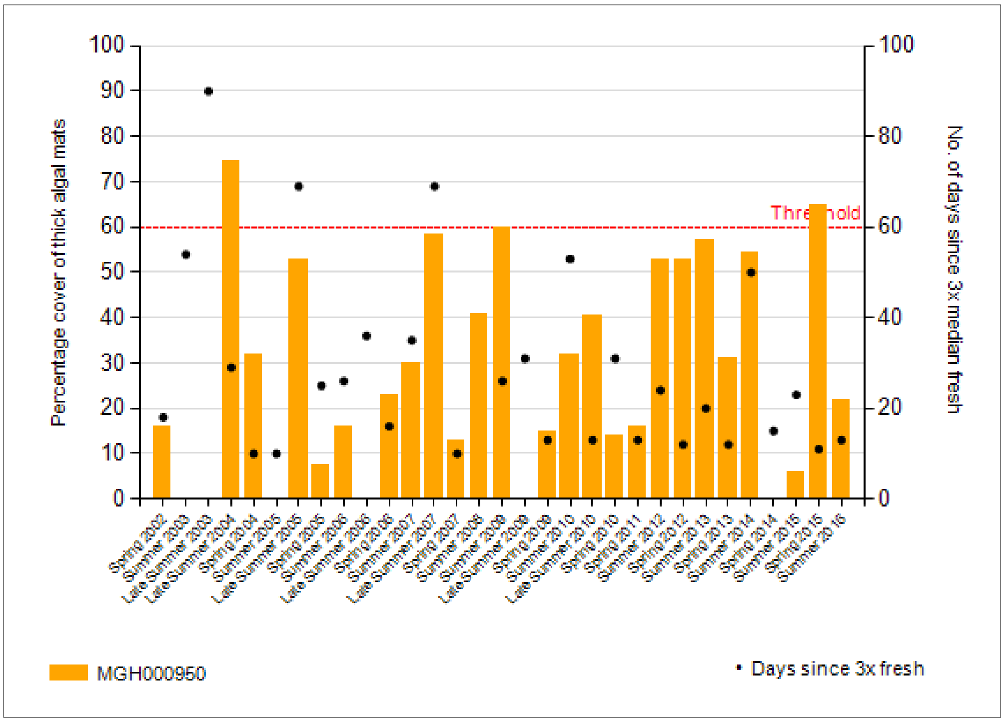


Figure 100 Percentage cover of thick mats of periphyton on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2002-2016 period

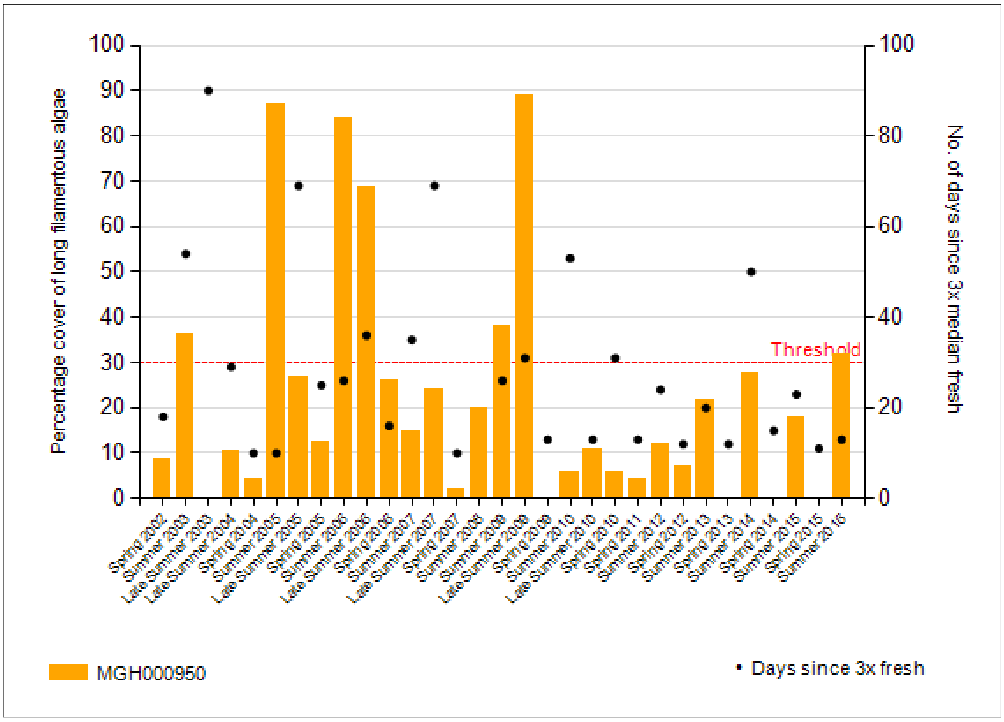
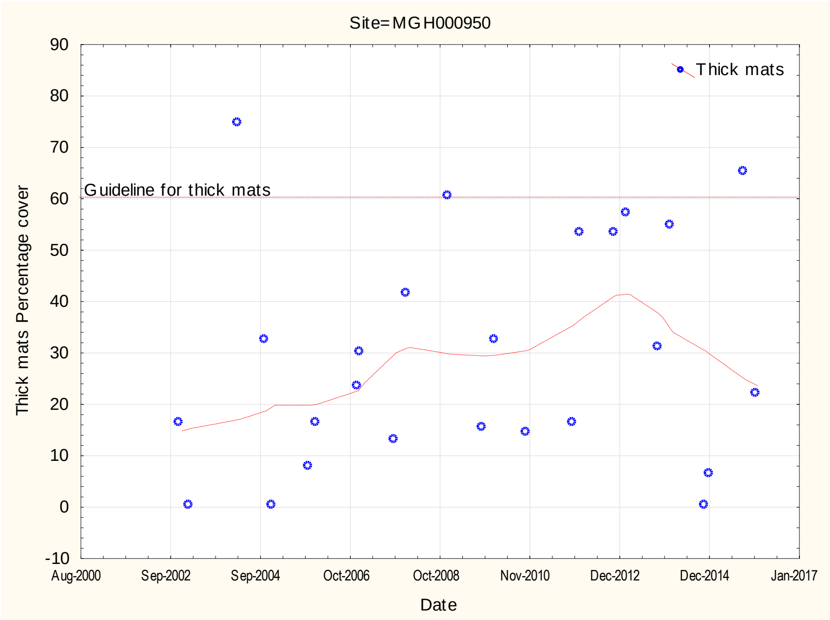


Figure 101 Percentage cover of long filamentous periphyton on the Mangaehu riverbed in relation to the recreational guideline over the 2002-2016 monitoring period

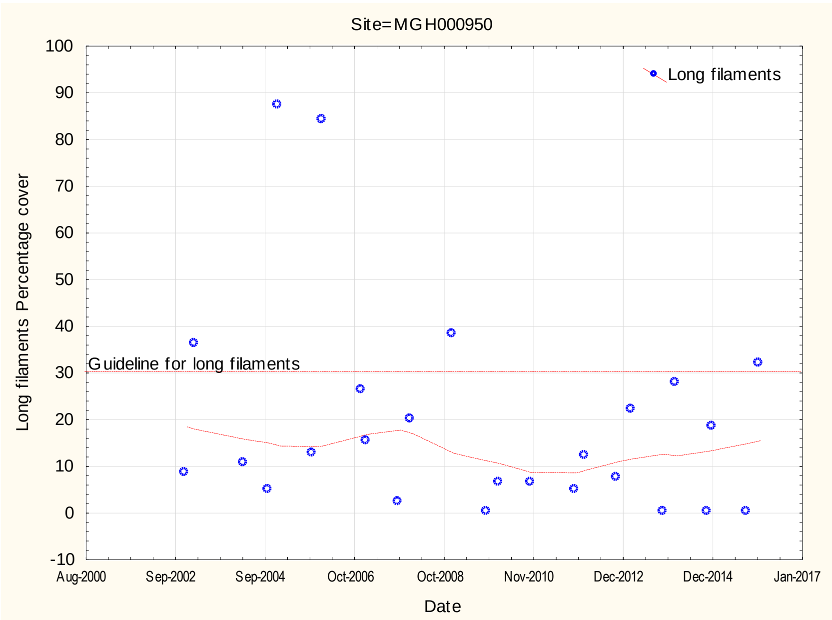
2.10.6 Long term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton at the Mangaehu River, at Raupuha Road over a 14 year period and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis (Figure 102 and Figure 103).



n = 25
Kendal tau = 0.182
p-value = 0.201
FDR p-value = 0.469

Figure 102 LOWESS trend analysis of percentage cover of thick mats at Mangaehu River, Raupuha Rd (MGH000950)



n = 25
Kendal tau = -0.162
p-value = 0.256
FDR p-value = 0.359

Figure 103 LOWESS trend analysis of percentage cover of long filaments at Mangaehu River, Raupuha Rd (MGH000950).

At Raupuha Road (MGH000950) over the 14 year monitored period there were no significant trends for thick mats (p=0.469) or long filaments (p=0.359) at the 5% level of significance after false discovery rate adjustment.

3. General summary

3.1 Periphyton cover

During the 2014-2016 monitoring period 21 sites were monitored for periphyton on four occasions; spring 2014, summer 2015, spring 2015 and summer 2016 (Table 19). For the spring 2014 period five sites were not surveyed due to frequent flooding.

Table 19 Nuisance periphyton coverage at 21 sites over the 2014-2016 monitoring period

River/Stream	Site	Distance from Nat Park (km)	Nuisance periphyton percentage cover							
			Spring 2014		Summer 2015		Spring 2015		Summer 2016	
			Mats	Filaments	Mats	Filaments	Mats	Filaments	Mats	Filaments
Hangatahua	Mangatete Road	7.3	NS	NS	0	0	0	0	0	0
(Stony)	SH45	12.5	NS	NS	0	0	0	0	0	0
Maketawa	Derby Rd	2.3	0	0	0	0	0	1	0	0
	Tarata Road	15.5	0	0	0	0	21	0	0	0
Manganui	SH3	8.7	0	0	0	0	0	0	0	0
	Bristol Road	37.9	2	3	6	28	23	59*	4	6
Patea	Barclay Road	1.9	0	0	0	0	0	0	0	0
	Skinner Road	19.2	0	4	1	15	11	8	0	4
Waiwhakaiho	SH3 (Egmont Village)	10.6	0	0	13	50*	7	17	0	3
	Constance St, NP	26.6	27	5	0	24	19	9	0	0
Waingongoro	Opunake Road	7.2	0	0	0	0	0	0	0	0
	Stuart Road	29.6	0	1	1	0	19	9	0	11
	Ohawe Beach	66.6	0	0	8	0	43	2	15	30*
Punehu	Wiremu Road	4.4	0	0	0	0	0	0	0	0
	SH45	20.9	2	0	0	12	0	10	0	28
Kapoaiaia	Wiremu Road	5.7	NS	NS	1	3	0	0	1	0
	Wataroa Road	13.5	NS	NS	3	79*	2	1	0	9
	Cape Egmont	25.2	NS	NS	3	37*	1	5	7	60*
Waiongana	SH3a	16.1	0	6	4	33*	21	5	0	0
	Devon Road	31.2	15	64*	26	29	16	5	4	27
Mangaehu	Raupuha Road	NA	0	0	6	18	65*	0	22	32*
Average			3	5	3	16	12	6	3	10

*Exceeded guideline levels (MfE, 2000), NA = not applicable and NS = no survey

Over the 2014-2016 monitoring period there was one breach in the thick algal mat guideline (less than 60% coverage) and nine breaches in the long filamentous algae guideline (less than 30% coverage). The nine breaches occurred at seven sites at some time during the four surveys. Only one breach, at the Devon Road site on the Waiongana, occurred in the spring 2014 survey. Fours breaches occurred during the summer 2015 survey. There were two breaches during the spring 2015 and three breaches during the summer 2016 survey. Only two sites, Mangaehu River at Raupuha Road and Kapoaiaia River at Cape Egmont, had more than one breach during the reported period (Table 19).

If the thick algal mat and filamentous algae guidelines were combined so that a composite guideline for nuisance periphyton was created (e.g. 60% streambed cover for %thick algal mats +%long filamentous algae x 2) then a couple of additional sites would also have nuisance levels of periphyton at some time: Manganui at Bristol Rd and Waiongana at Devon Road over the summer 2015 survey.

Sites with higher levels of nuisance periphyton were located at the lower end of the catchment. All sites located within 10 km of the National Park boundary had low or no nuisance periphyton. A number of factors were likely to contribute to this situation including nutrient levels, hydrology, shading, temperature, substrate composition and invertebrate grazing pressure. The strongest correlation with factors known to affect periphyton levels was probably nutrient levels. Taranaki waterbodies at higher altitudes around the ringplain have naturally high phosphorus levels due to the volcanic geology and are therefore unlikely to be limited by phosphorus levels (Biggs and Kilroy, 2004) which has been reported for other North Island regions with volcanic geology (Death, et al. 2007). However, further down the ring plain phosphorus levels drop and it is likely that phosphorus is in fact the limiting nutrient in the areas that periphyton enrichment does occur. Most of the surveyed streams and rivers flowed through intensive agricultural areas and nutrients were at levels known to cause excessive periphyton growths at some of the lower catchment sites based on the ANZECC (2000) guidelines.

Other factors that may also cause increased levels of nuisance periphyton at lower catchment sites would include a lack of shading due to either limited riparian vegetation (more common at lowland sites on the Taranaki Ringplain) and/or a wider, more open bed where shading from banks was reduced (river are often wider at lower elevations). Rivers and streams at higher altitudes were also more likely to have higher flood peaks when heavy rainfall occurs. Further downstream floods peaks become somewhat attenuated. High flood peaks will promote scouring of the streambed which will reduce periphyton biomass. Downstream sites also had higher water temperatures which also promotes faster periphyton growth. Differences in invertebrate grazer abundances among sites would also affect periphyton biomass.

Summer surveys often have higher levels of nuisance periphyton due to higher water temperatures which enables faster periphyton growth, longer daylight hours which promotes photosynthesis and longer periods without freshes or floods to scour away periphyton. The summer of 2015 had the highest combined levels of nuisance periphyton and in particular the highest long filamentous algae coverage, which is more problematic than thick mats, and the summer 2016 survey had the next highest levels of filamentous algae but levels of thick mats were the same for two spring and the summer 2016 survey and only marginally higher for the summer 2015 survey.

Statistical analyses of factors influencing the TRC PI found few significant correlations. Regression analyses of time since 3x median flow and 7x median flow compared with the TRC PI score as the response variable shows that there was only a significant relationship for the summer 2016 survey results in response to time since a flow in excess of 7x median flow (N=21, F value = 15.47, FDR p value <0.01). There was also a significant relationship between distance from the National Park boundary and the spring 2015 survey TRC PI (N=20, F value = 18.84, p value <0.01) and summer 2016 survey TRC PI results (N=20, F value = 38.62, p value <0.01) but not the spring 2014 or summer 2015 survey results. The lack of statistical significant results was due to the broad range of sites surveyed which behaved differently under different circumstances and possibly lack of sample size. The results do indicate that at times large freshes over 7x median flow can increase TRC PI scores by scouring periphyton off the streambed and that sites further away from the National Park boundary will often have lower TRC PI scores.

3.2 TRC periphyton index

There were no limits for the TRC periphyton index scores but ratings give an indication of the level of nutrient enrichment at a site. TRC periphyton index scores ranged from 'poor' to 'very good' over the reported period (Table 20). For the spring 2014 survey 69% of sites were 'very good', 25% were 'good' and 6% 'poor' rating (five sites were not sampled due to frequent floods).

Table 20 TRC PI scores for 21 sites over the 2014-2016 monitoring period

River/ Stream	Site	Distance from Nat Park (km)	TRC Periphyton Index Score								Median rating 2014-2016	
			Spring 2014		Summer 2015		Spring 2015		Summer 2016			
			TRC PI	Rating	TRC PI	Rating	TRC PI	Rating	TRC PI	Rating	TRC PI	Rating
Hangatahua	Mangatete Road	7.3	NA	NA	9.7	Very good	10	Very good	10	Very good	10	Very good
(Stony)	SH45	12.5	NA	NA	9.9	Very good	9.6	Very good	10	Very good	9.9	Very good
Maketawa	Derby Rd	2.3	10	Very good	10	Very good	9.5	Very good	9.8	Very good	9.9	Very good
	Tarata Road	15.5	8.1	Very good	9.7	Very good	8.5	Very good	8.5	Very good	8.5	Very good
Manganui	SH3	8.7	10	Very good	10	Very good	10	Very good	10	Very good	10	Very good
	Bristol Road	37.9	7.1	Good	5.6	Moderate	4.4	Moderate	8.5	Very good	6.4	Good
Patea	Barclay Road	1.9	9.9	Very good	10	Very good	9.4	Very good	9.9	Very good	9.9	Very good
	Skinner Road	19.2	7.8	Good	7.4	Good	8	Very good	8.9	Very good	7.9	Good
Waiwhakaiho	SH3 (Egmont Village)	10.6	9.4	Very good	3.7	Poor	7.5	Good	9.4	Very good	8.5	Very good
	Constance St, NP	26.6	6.1	Good	6	Good	7.3	Good	8.1	Very good	6.7	Good
Waingongoro	Opunake Road	7.2	10	Very good	9.8	Very good	9.6	Very good	9.3	Very good	9.7	Very good
	Stuart Road	29.6	9.6	Very good	7.4	Good	7.7	Good	8.4	Very good	8.1	Very good
	Ohawe Beach	66.6	8.4	Very good	8.4	Very good	6.7	Good	4.8	Moderate	7.6	Good
Punehu	Wiremu Road	4.4	10	Very good	10	Very good	9.9	Very good	10	Very good	10	Very good
	SH45	20.9	9.3	Very good	8.6	Very good	9	Very good	7.5	Good	8.8	Very good
Kapoaiaia	Wiremu Road	5.7	NA	NA	9.4	Very good	10	Very good	9.8	Very good	9.8	Very good
	Wataroa Road	13.5	NA	NA	2.9	Poor	9.4	Very good	8.7	Very good	8.7	Very good
	Cape Egmont	25.2	NA	NA	6.8	Good	9.2	Good	5.3	Moderate	6.8	Good
Waiongana	SH3a	16.1	7.2	Good	4.7	Moderate	7.6	Good	9	Very good	7.4	Good
	Devon Road	31.2	2.7	Poor	4.6	Moderate	8.2	Very good	6.4	Good	5.5	Moderate
Mangaehu	Raupuha Road	NA	8.8	Very good	5.8	Moderate	5.3	Moderate	4.6	Moderate	5.6	Moderate

For the summer 2015 survey 57% of sites were ‘very good’, 19% were ‘good’, 19% ‘moderate and 10% ‘poor’ rating. For the spring 2015 survey 62% of sites were ‘very good’, 29% were ‘good’ and 10% ‘moderate’. For the summer 2016 survey 62% of sites were ‘very good’, 29% were ‘good’, and 10% ‘moderate’ (Table 20).

No sites had a median score that would place it in the two lowest categories of ‘poor’ or ‘very poor’ and only two sites had median scores placing them in the ‘moderate’ category indicating that no sites had consistency high periphyton levels. However, some sites did have large fluctuations among surveys within the reported period and two sites did receive a ‘poor’ rating for one survey. All sites within the two streams selected for their high conservation values and all sites located within 10 km of the National Park boundary had ‘very good’ ratings.

3.3 Periphyton biomass (chlorophyll *a*)

Periphyton biomass levels as estimated by chlorophyll *a* showed significant variation among sites with a range from 1 to 790 mg/m² over the reported period (Table 21). However, most sites showed little within site fluctuation between years, especially sites with low chlorophyll *a* levels. It was unlikely that a site with a very low reading one year would have a high reading for another year though the Manganui at Bristol Road and the Waiwhakaiho River at SH3 were exceptions. Sites with higher levels of chlorophyll *a*, such as the Kapoaiaia Stream at Wataroa Road (790 mg/m² and 132 mg/m²), were more likely to show significant variation between surveys. A change in methodology may account for some of this variation and technically the two years are not directly comparable, though in practice the change in methodology would only affect samples with very high chlorophyll *a* levels. There was a decrease in the average level of chlorophyll *a* from 2015 to 2016 with five sites exceeding NOF guidelines in 2015 but only one site in 2016. Temporal trend analysis requires a minimum of 10 years of data. As the methodology changed between 2015 and 2016 it would be more appropriate to use data from the 2016 survey onwards and not include the 2011-2015 data in any analysis. Therefore, no comment can be made whether sites are significantly improving or deteriorating using the chlorophyll *a* metric.

Table 21 Periphyton biomass as estimated by chlorophyll *a* (mg/m²) for 21 sites over the 2014-2016 monitoring period

River/Stream	Site name	Distance from Nat Park (km)	Periphyton biomass (chlorophyll *a* mg/m²)	
			Summer 2015	Summer 2016
Hangatahua (Stony)	Mangatete Road	7.3	5	4
	SH45	12.5	5	4
Maketawa	Derby Rd	2.3	2	1
	Tarata Road	15.5	10	28
Manganui	SH3	8.7	2	1
	Bristol Road	37.9	219*	10
Patea	Barclay Road	1.9	15	6
	Skinner Road	19.2	106	126
Waiwhakaiho	SH3 (Egmont Village)	10.6	212*	19
	Constance St, NP	26.6	70	10
Waingongoro	Opunake Road	7.2	9	7
	Stuart Road	29.6	196	173
	Ohawe Beach	66.6	193	140
Punehu	Wiremu Road	4.4	3	2
	SH45	20.9	12	8
Kapoaiaia	Wiremu Road	5.7	10	2
	Wataroa Road	13.5	790*	132
	Cape Egmont	25.2	86	78
Waiongana	SH3a	16.1	318*	104
	Devon Road	31.2	674*	140
Mangaehu	Raupuha Road	NA	112	246*
Average			145	59

*Exceeds NOF bottom line (D band)

Chlorophyll *a* levels were generally congruent with other periphyton indices with the lowest levels recorded at sites located within 10 km of the National Park boundary higher and sites situated on the two high conservation value waterbodies; Stony

River and Maketawa Stream. All these sites recorded chlorophyll *a* levels below 50 mg/m^2 which would put them within the A band for the NOF standards (Table 7) and would be fully complement with standards suggested by the MfE (Table 2).

The Punehu Stream at SH45 was the only lower catchment site to have a score consistently below 50 mg/m^2. This may be due to its heavily incised nature at the sampling site and riparian margins which provides partial shading at the site. The incised nature may also cause higher flow velocities during freshes which would help to maintain a low periphyton biomass at the site. The lower catchment sites on the Kapoaiaia Stream at Cape Egmont, Waiwhakaiho River at Constance Street and the Waingongoro River at Ohawe Beach had chlorophyll a levels below 200 mg/m^2 while the other sites at the Manganui, Mangaehu and Waiongana Rivers had at least one score above 200 mg/m^2 for the reported monitoring period.

Statistical analyses of factors influencing chlorophyll *a* levels found few significant correlations, and a very high degree of variability in correlations from one survey to the next. Regression of time since 3x median flow and 7x median flow compared with chlorophyll *a* as the response variable shows that there was only a significant relationship for the summer 2016 survey results in response to time since a flow in excess of 7x median flow (N=21, F value = 10.67, p value <0.01). There was also a significant relationship between distance from the National Park boundary and the summer 2016 TRC PI results (N=20, F value = 8.74, p value <0.01) but not the summer 2015 survey results. When using the full dataset total nitrogen was not significant but when the Mangaehu River (low flows) and lower Punehu River (shading) sites were removed due to known factors influencing periphyton biomass then for the 2015 year (N=8, F value = 4.43, p value =0.08) the result was close to being significant and for the 2016 year (N=12, F value = 63.25, p value <0.01) the result was highly significant.

The results do indicate that at times large freshes over 7x median flow can reduce periphyton biomass by scouring periphyton off the streambed but the significance of this result was largely due to two outliers; the Mangaehu River and Waingongoro River at Ohawe Beach that had 160 and 133 days respectively without a fresh in exceedances of 7 x median flow. Sites further away from the National Park boundary have higher periphyton biomasses and the main correlation for this would appear to be the increased nitrogen found at sites further away from the park boundary which is due to agricultural inputs, sewerage schemes, meat processors and other industries. Correlations with phosphorus varied from indeterminate to almost statistically significant.

3.4 Long term trends

This programme has been implemented to establish the state of certain selected rivers, with regard to their periphyton proliferation and any trends arising. It is designed to detect and record differences in periphyton proliferation within a river, changes in periphyton proliferation with season, and also to eventually see changes over time, as other activities begin to take effect, e.g. riparian planting. This is the fourth report to be written for this programme, and is the second to include analysis of trends. Trend analysis has been performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the percentage cover of thick mats, and long filaments of periphyton and by testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis. Trend analysis was carried out for all streams, using a 14 year data set.

Table 22 Kendall Tau correlations for periphyton (thick mats) for data from 2002-2016. A significant trend at $p<0.05$ is shown in orange text, and $p<0.01$ in red text

Site	No.	Kendall Tau	Z	p-value	FDR adjustment
KPA000250	24	-0.452425	-3.09731	0.001953	0.020505
KPA000700	24	-0.292863	-2.00494	0.044969	0.236088
KPA000950	24	-0.137856	-0.943767	0.345289	0.659188
MGH000950	25	0.182449	1.27833	0.201134	0.469312
MGN000195	26	-0.301324	-2.15854	0.030886	0.216203
MGN000427	26	0.225788	1.617436	0.105784	0.337391
MKW000200	26	-0.071319	-0.510891	0.609427	0.752822
MKW000300	26	-0.236208	-1.69207	0.090632	0.337391
PAT000200	27	-0.183321	-1.34141	0.179788	0.469312
PAT000360	27	0.095677	0.70010	0.483867	0.7258
PNH000200	26	0.022885	0.16394	0.869780	0.913269
PNH000900	26	-0.080596	-0.577350	0.563703	0.752822
STY000300	23	-0.053615	-0.35825	0.720157	0.795963
STY000400	23	-0.053615	-0.35825	0.720157	0.795963
WGA000260	24	-0.119488	-0.81801	0.413349	0.718328
WGA000450	24	0.231845	1.587216	0.112464	0.337391
WGG000150	27	-0.436022	-3.19049	0.001420	0.020505
WGG000665	27	-0.010972	-0.08028	0.936012	0.936012
WGG000995	27	0.141757	1.03727	0.299609	0.62918
WKH000500	23	0.114387	0.76432	0.444679	0.718328
WKH000920	23	0.076999	0.514496	0.606905	0.752822

Long term trend analysis of the 21 sites monitored for thick periphyton mats found only two sites with significant trends at the 5% level once *p* values had the FDR adjustment applied to them. The upper Kapoaiaia Stream site at Wiremu Road and the upper Waingongoro River site at Opunake Road both had a decline (reduction) in thick mats during the monitored period. No significant reduction in mats occurred for the other downstream sites for both waterways (
Table **22**).

In total eight sites out of the 21 monitored had an increasing trend for thick periphyton mats but none of these trends were statistically significant.

Long term trend analysis of the 21 sites monitored for long filamentous algae found only two sites with significant trends at the 5% level once *p* values had the FDR adjustment applied to them (Table **23**). The upper Kapoaiaia Stream site at Wiremu Road and the lower Patea River site at Skinner Road had a decline (reduction) in long filamentous algae during the monitored period. In total only two sites had an increasing trend for filamentous algae, neither of which were significant.

Table 23 Kendall Tau correlations for periphyton (long filaments) for data from 2002-2016. A significant trend at $p<0.05$ is shown in orange text, and $p<0.01$ in red text

Site	Valid N	Kendall Tau	Z	p-value	FDR adjustment
KPA000250	24	-0.578745	-3.96210	0.000074	0.001486
KPA000700	24	-0.300384	-2.05644	0.039740	0.158962
KPA000950	24	-0.061932	-0.423985	0.671576	0.671576
MGH000950	25	-0.162177	-1.13629	0.255835	0.359469
MGN000195	26	-	-	-	-
MGN000427	26	-0.139524	-0.999484	0.317560	0.359469
MKW000200	26	0.210843	1.510373	0.130948	0.28127
MKW000300	26	-0.364101	-2.60824	0.009101	0.060673
PAT000200	27	-0.148916	-1.08966	0.275863	0.359469
PAT000360	27	-0.389039	-2.84670	0.004417	0.044175
PNH000200	26	-0.155857	-1.11648	0.264215	0.359469
PNH000900	26	-0.075369	-0.539906	0.589262	0.620276
STY000300	23	-0.239688	-1.60156	0.109254	0.273135
STY000400	23	-0.220513	-1.47343	0.140635	0.28127
WGA000260	24	-0.253844	-1.73782	0.082242	0.234977
WGA000450	24	0.144207	0.987245	0.323523	0.359469
WGG000150	27	-0.317038	-2.31985	0.020349	0.101746
WGG000665	27	-0.192547	-1.40892	0.158859	0.288835
WGG000995	27	-0.173914	-1.27257	0.203170	0.338617
WKH000500	23	-0.282898	-1.89028	0.058720	0.195734
WKH000920	23	-0.148614	-0.993013	0.320704	0.359469

There has been a significant amount of riparian vegetation and fencing implemented throughout the Taranaki region since periphyton monitoring began. There has generally been an increase in all catchments, and this may have led to the reduction of nuisance growths at the large number of sites (62% for thick mat measurements, 90% for filamentous measurements) where negative (reducing) trends for periphyton are apparent.

4. Conclusions

In general, the Taranaki streams surveyed for nuisance periphyton have displayed some key points.

- Generally, the monitored sites usually complied with nuisance periphyton guidelines with 99% and 89% of surveys complying with the periphyton guideline for thick mats and long filaments respectively.
- All rivers received a rating of at least 'moderate' for the TRC periphyton index score over all four surveys except for the Waiongana River at Devon Rd and the Kapoaiaia River at Wataroa Rd which both received one 'poor' rating.
- Periphyton biomass results were generally poorer than TRC PI results. The NOF standard (200 mg/m^2) was breached at five sites for the summer 2015 survey and at one site for the summer 2016 survey and the guideline to protect benthic biodiversity (50 mg/m^2) was breached at eleven sites for the summer 2015 survey and eight sites for the summer 2016 survey.
- The data used for nuisance periphyton guidelines (thick algal mats and long filaments) overlaps slightly with the periphyton index score but was potentially completely different from the periphyton biomass data as rocks viewed for periphyton cover are not necessarily, and probably unlikely, to be the same ones used to collect periphyton biomass. Therefore, even though ten replicates were used, results can potentially differ significantly between the two methods. Furthermore, periphyton coverage examines both live and dead periphyton while periphyton biomass uses chlorophyll *a* which is contained within live material only. These differences probably account for discrepancies between results.
- True 'upstream sites' with little agriculture in their catchment had low levels of periphyton while sites located further down the catchment had higher levels of periphyton which occasionally breached guidelines.
- Due to the number of variables involved (e.g. nutrients, sunlight, temperature, substrate type, time since last fresh or flood, water clarity, level of invertebrate grazing etc) and interaction affects between variables it can be difficult to ascertain the main factors driving periphyton biomass.
- The cumulative affects of agricultural discharges via point source or diffuse pollution is likely to be a leading cause of algae proliferation in middle and lower catchment sites.
- Flood flows can cause a reduction in periphyton growth but the degree of this effect is not consistent within streams or seasons.
- The time trend analyses reveal that for the majority of sites nuisance periphyton was decreasing but the trends were not statistically significant. There was a significant trend at three sites which all showed long term decreasing levels of nuisance periphyton with the upper Kapoaiaia and Waingongoro River sites having decreasing levels of thick algal mats and the upper Kapoaiaia and lower Patea River sites having decreasing levels of long filamentous algae.
- There has been a significant amount of riparian vegetation and fencing implemented throughout the Taranaki region since periphyton monitoring began. There has generally been an increase in all catchments, and this may have led to the indications of reductions in nuisance growths at most sites.

5. Additional monitoring: *Didymosphenia geminata*

In 2004, an issue regarding periphyton in New Zealand came to light: the invasion of the diatom *Didymosphenia geminata*.

Didymo (*Didymosphenia geminata*), is a freshwater diatom native to Northern Europe that was first found in New Zealand in October 2004 (Photo 5). It has spread to numerous rivers in the South Island but has not yet been detected in the North Island. Didymo is spread very easily. It attaches to the streambed by stalks and forms a thick brown layer which can smother substrate and submerged plants, which in turn affects native invertebrates, fish and birds.

Photo 5 A *Didymosphenia geminate* covered rock

The invasion of *Didymosphenia geminata* has led to the instigation of the Didymo monitoring programme undertaken by Council.

The sites in Table 24 and Figure 104 are popular freshwater recreational sites in Taranaki and are monitored during the spring/summer season on an annual basis. DNA is extracted from the algae samples collected during monitoring and is analysed to confirm there is no Didymo (‘rock snot’) present at the representative sites monitored. Since monitoring began to date there has been **no** evidence to suggest that Didymo is in the Taranaki region.

Table 24 Sites monitored for *Didymosphenia geminate*

River	Site Code	Site
Waiwhakaiho River	Constance Street	WKH000920
Manganui River	Bristol Road	MGN000427
Patea River	Skinner Road	PAT000360
Waingongoro River	Ohawe Beach	WGG000995
Kaupokonui River	Upper Glen Road	KPK000880
Kapuni Stream	SH45	KPN000450
Stony River	Mangatete Road	STY000300
Mangaoraka Stream	Corbett Road	MRK000420

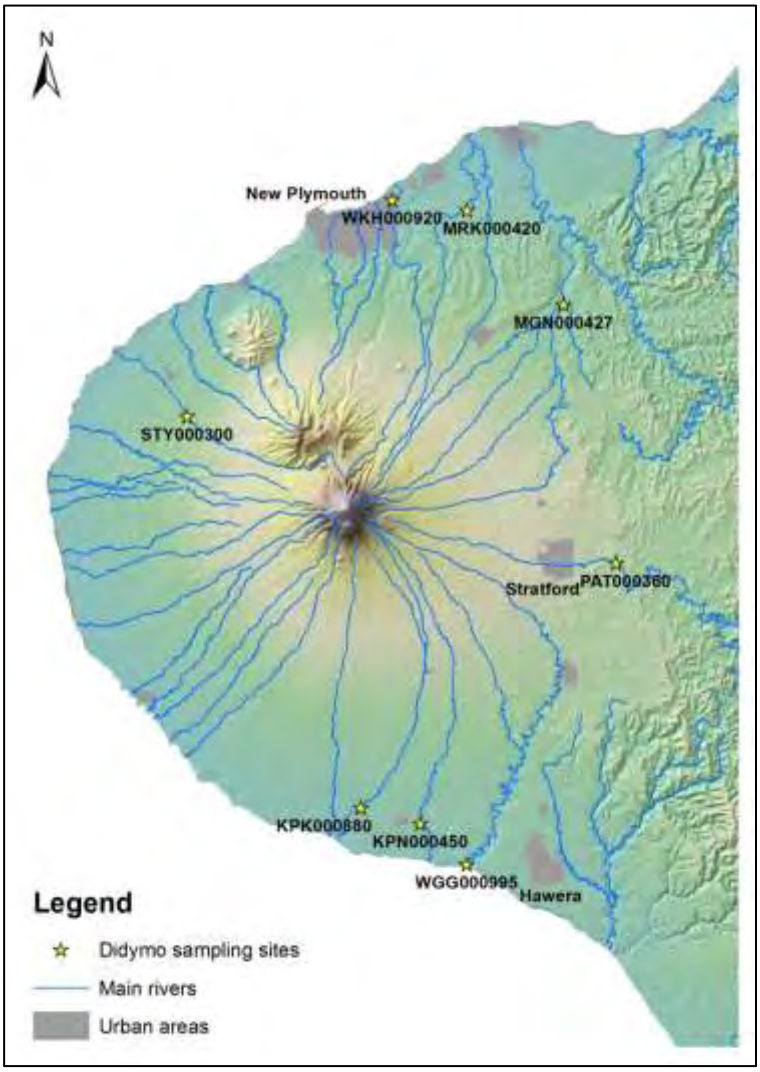


Figure 104 Sites to be monitored for *Didymosphenia geminate*

6. Recommendations

1. THAT monitoring of the periphyton communities in the Stony, Maketawa, Manganui, Patea, Waiwhakaiho, Waingongoro, Punehu, Kapoaiaia, Waiongana and Mangaehu Rivers is continued for periphyton cover.

2. THAT in the 2016-2018 monitoring period, the Waiwhakaiho, Manganui, Patea, Waingongoro, Stony and Kaupokonui Rivers and Kapuni and Mangaoraka Streams are monitored for the invasive alga *Didymosphenia geminata*.

3. THAT the periphyton survey results are included in the next SEM 5 yearly state of environment report.

4. THAT programmes designed to limit nutrient input into Taranaki streams and rivers continue to be implemented such as riparian planting/fencing and disposal of dairy shed effluent to land in order to reduce periphyton levels in lowland streams and rivers in agriculturally dominated catchments.

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TRC, 2011: Fresh Water Macroinvertebrate Fauna Biological Monitoring Programme Annual State of the Environment Monitoring Report 2010-2011. Technical Report 2011-38.

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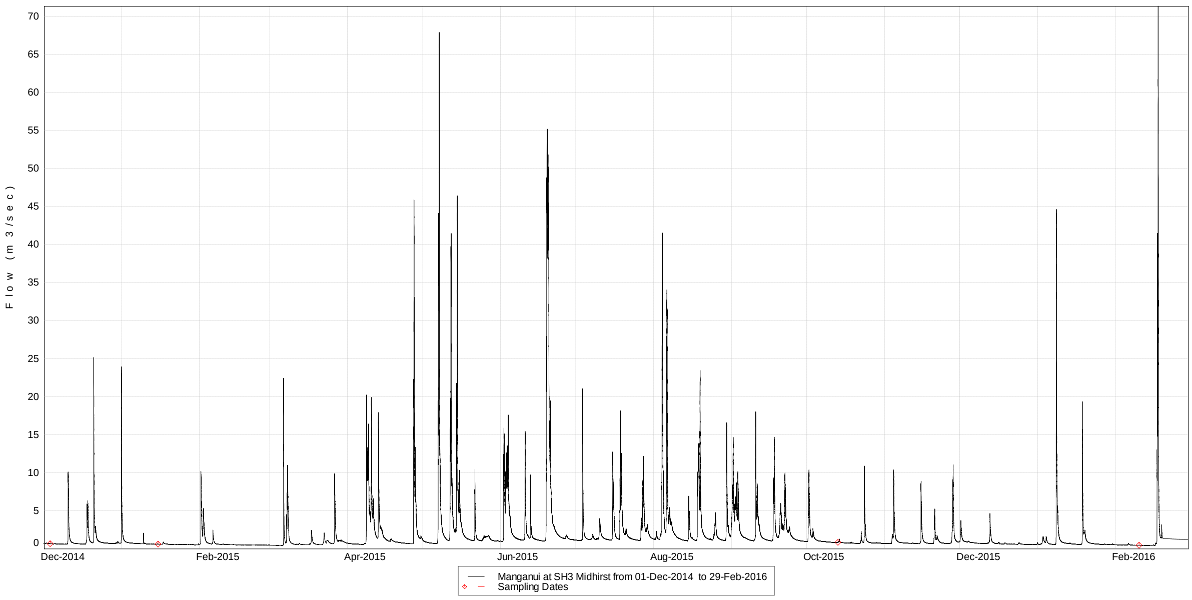
TRC, 2014: Freshwater Nuisance Periphyton Monitoring Programme (Periphyton monitoring in relation to amenity values) State of the Environment Monitoring Report 2010-2012.Technical Report 2013-20.

TRC, 2015: Freshwater Nuisance Periphyton Monitoring Programme (Periphyton monitoring in relation to amenity values) State of the Environment Monitoring Report 2012-2014.Technical Report 2015-99.

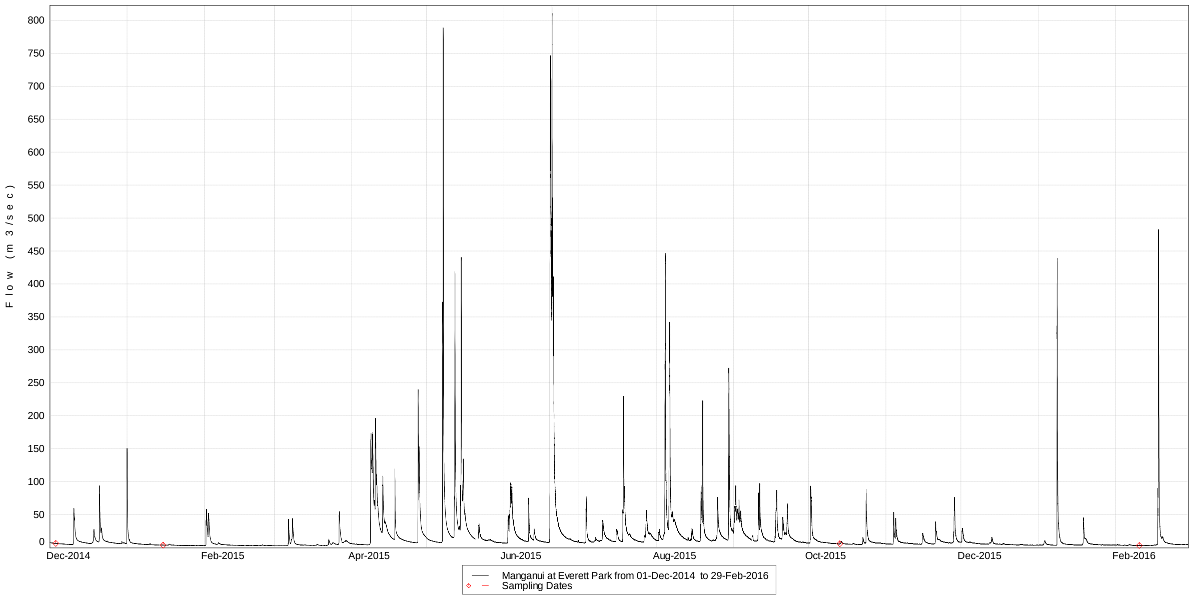
TRC, 2015: Draft Freshwater and Land Management Plan for Taranaki (2015).

Appendix I

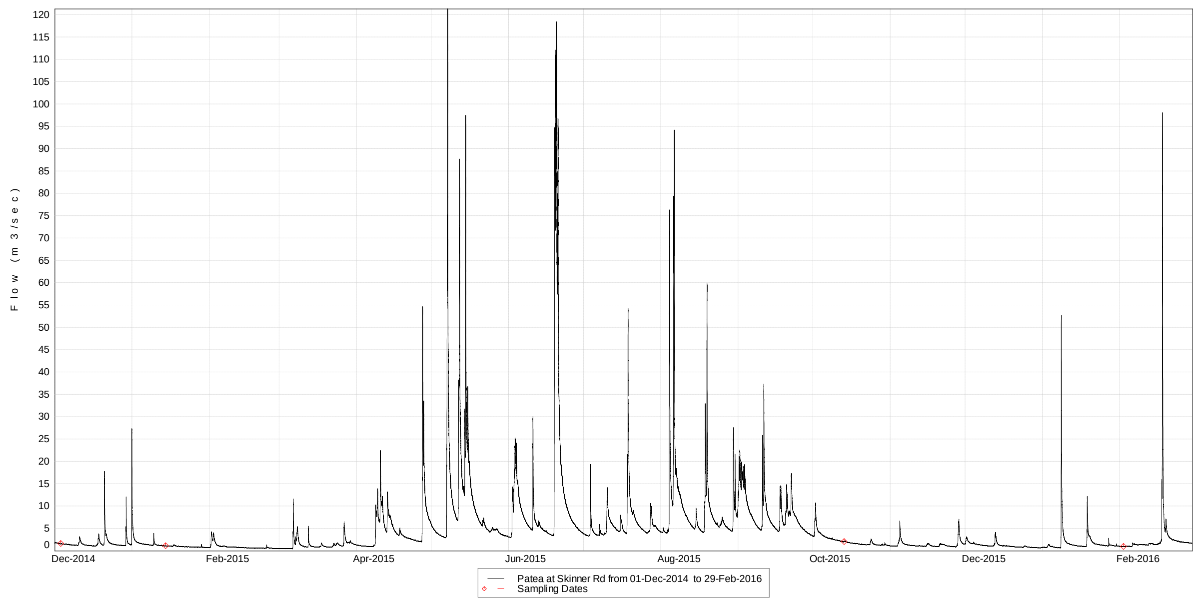
Flow data 2014-2016



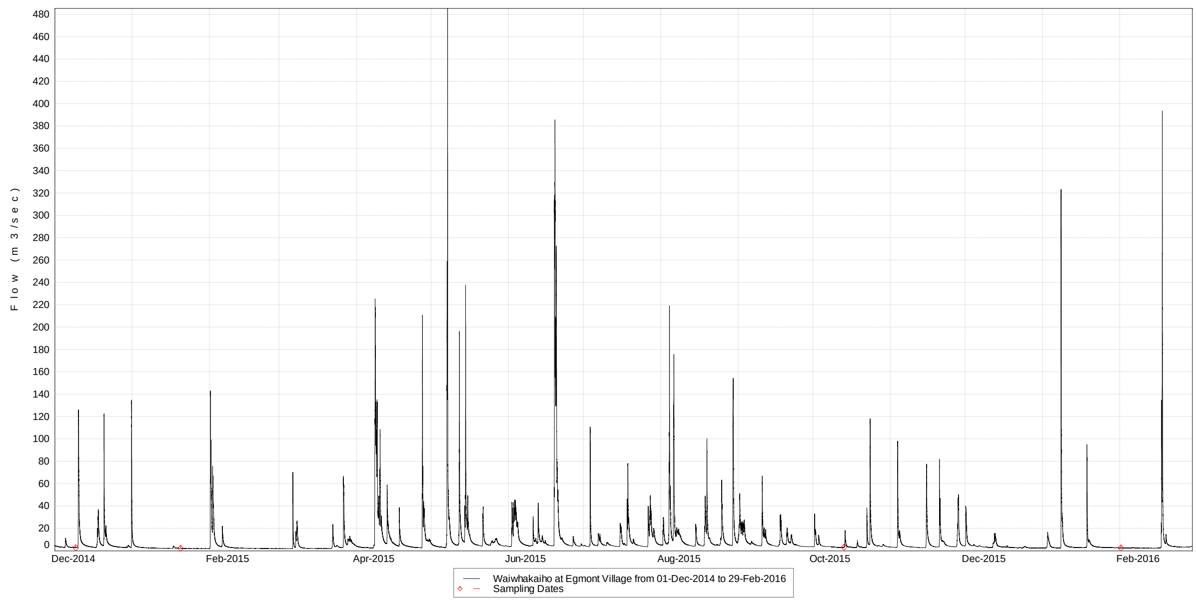
Flow in Manganui River at SH3 over the 2014-2016 sampling period



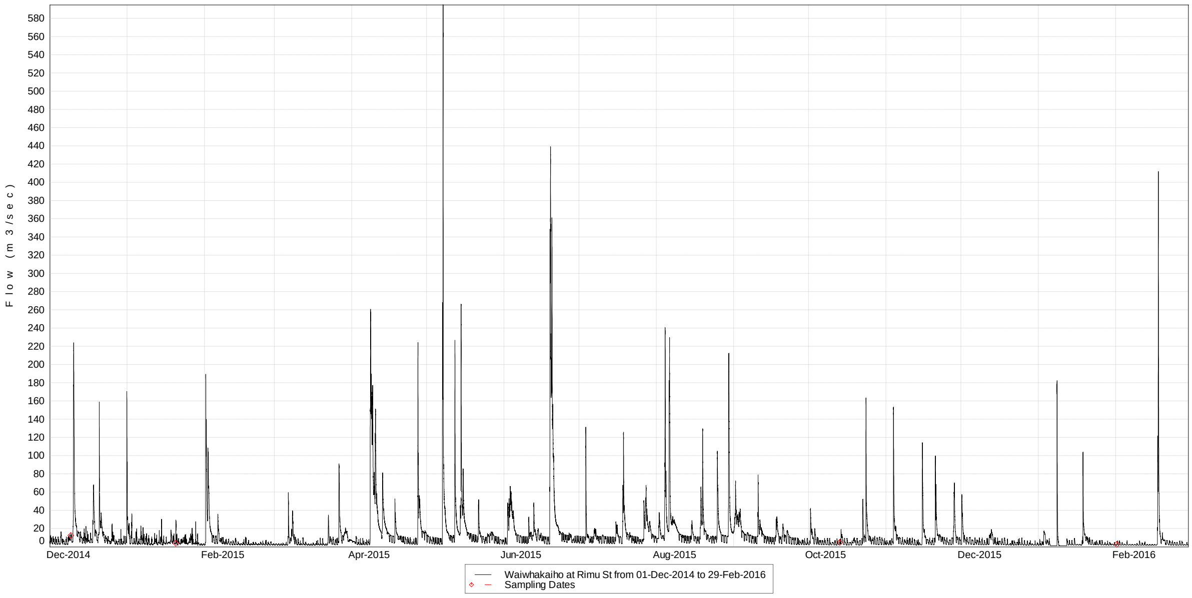
Flow in Manganui River at Everett Park over the 2014-2016 sampling period



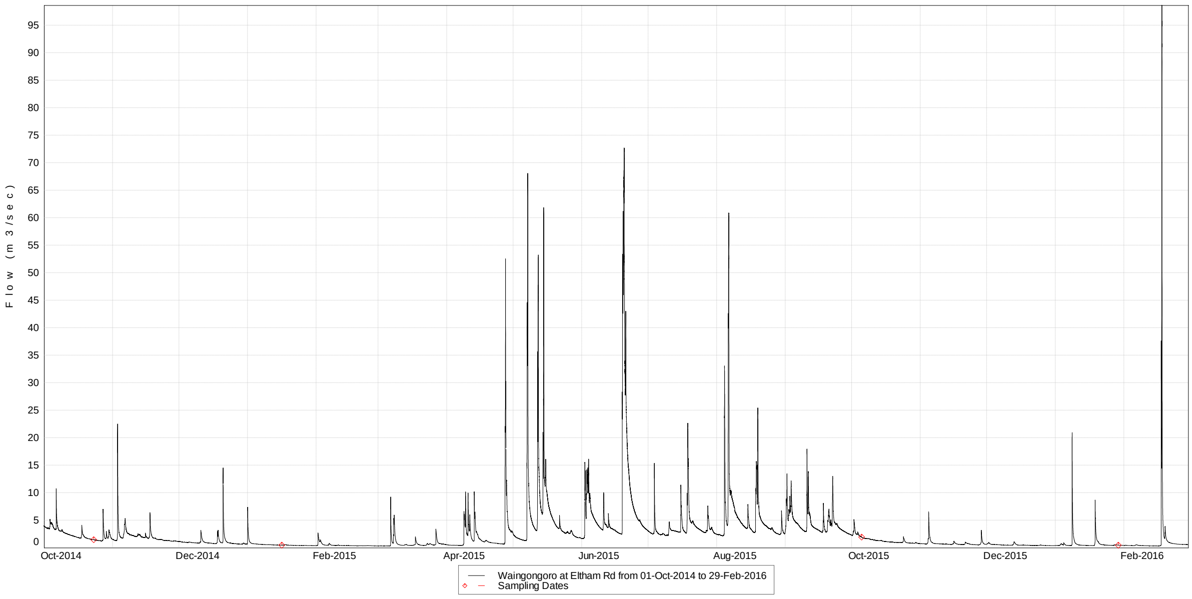
Flow in the Patea River over the 2014-2016 sampling period



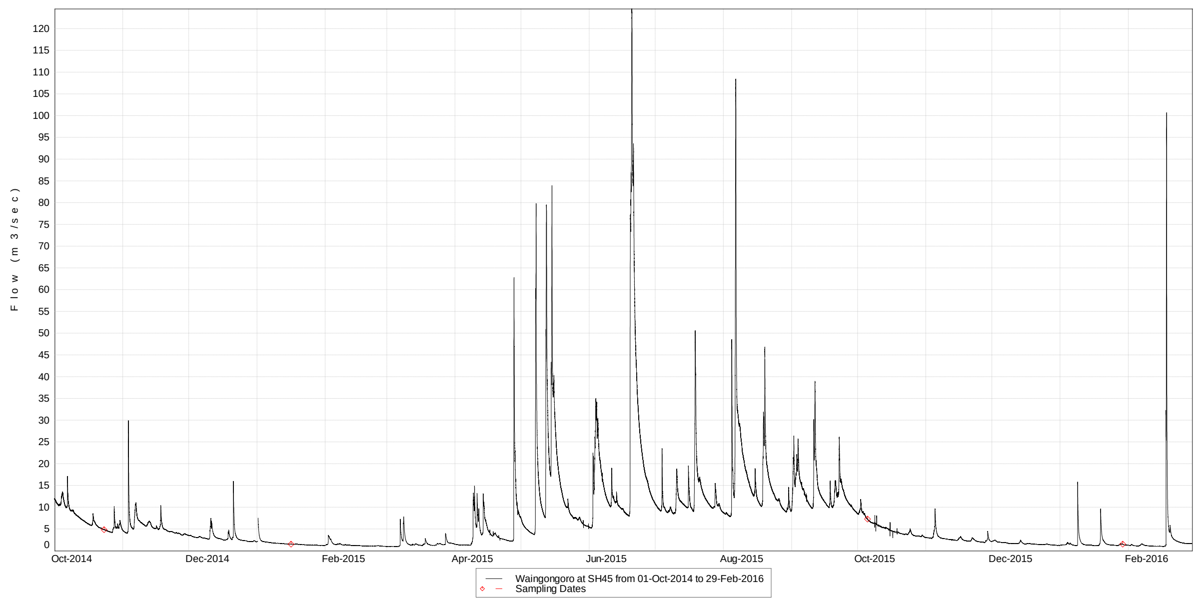
Flow in the Waiwhakaiho River at Egmont Village during the 2014-2016 sampling period



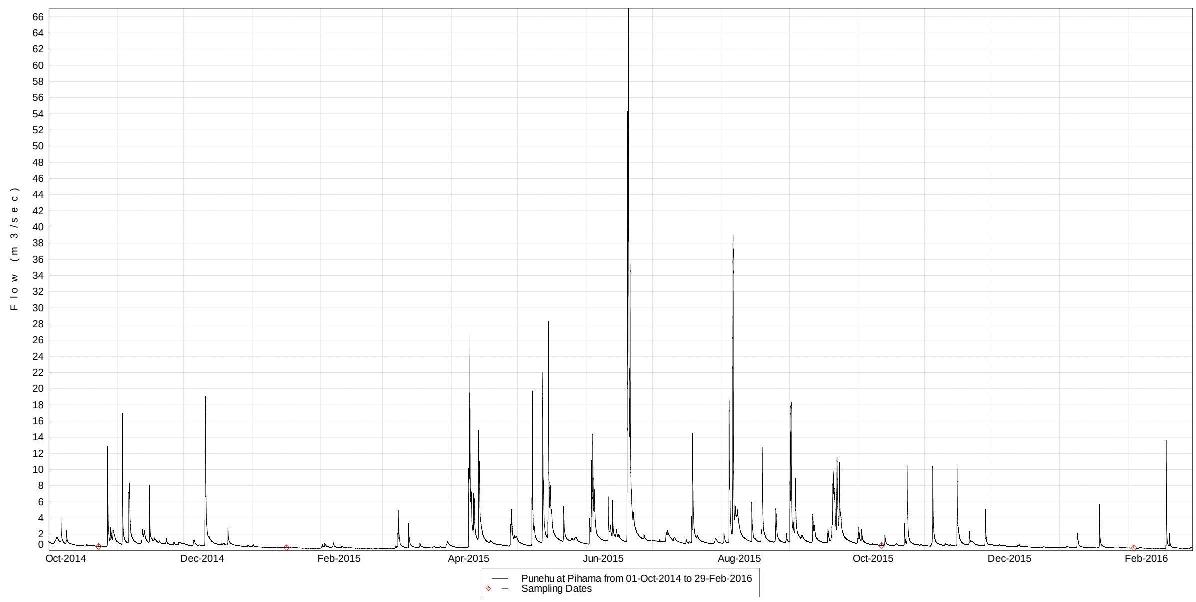
Flow in the Waiwhakaiho River at Rimu Street during the 2014-2016 sampling period



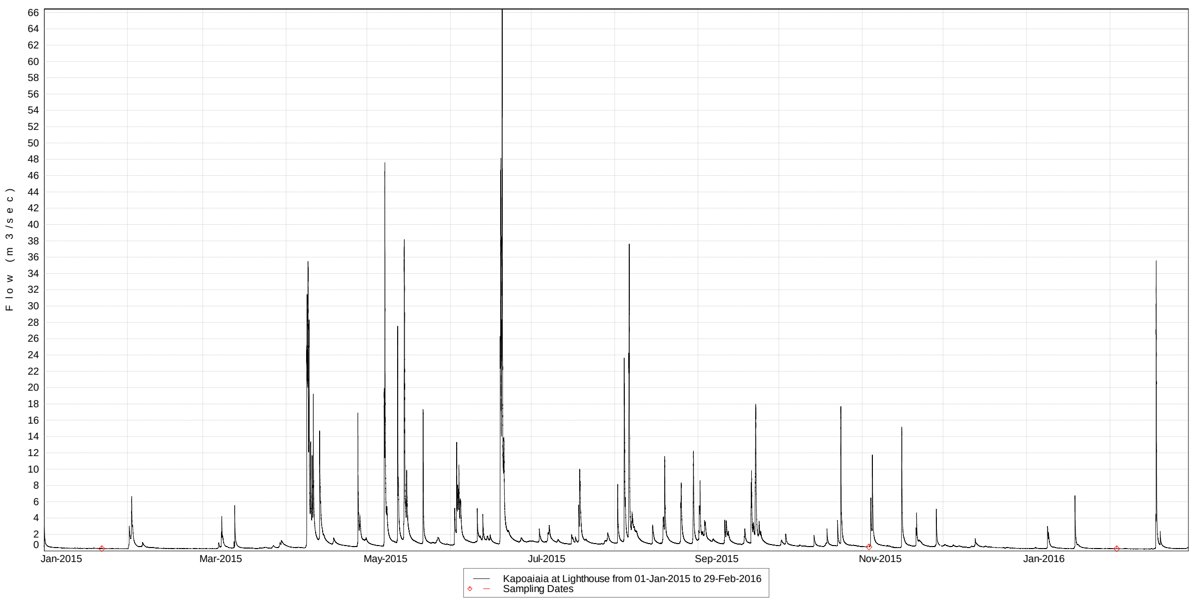
Flow in the Waingongoro River at Eltham Road during the 2014-2016 sampling period



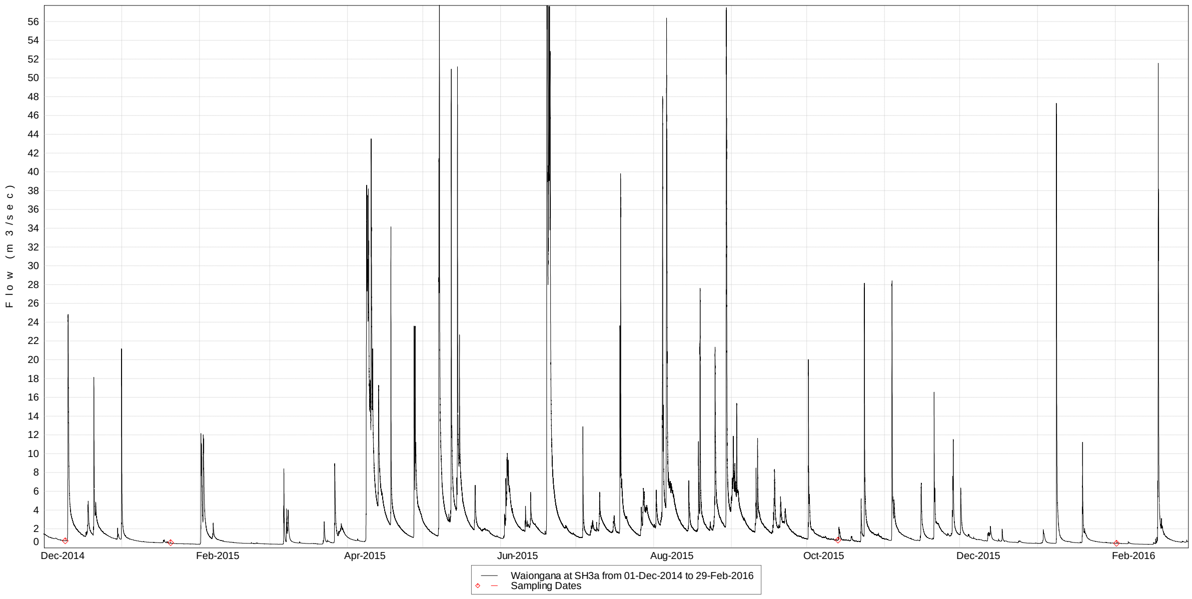
Flow in the Waingongoro River at SH45 during the 2014-2016 sampling period



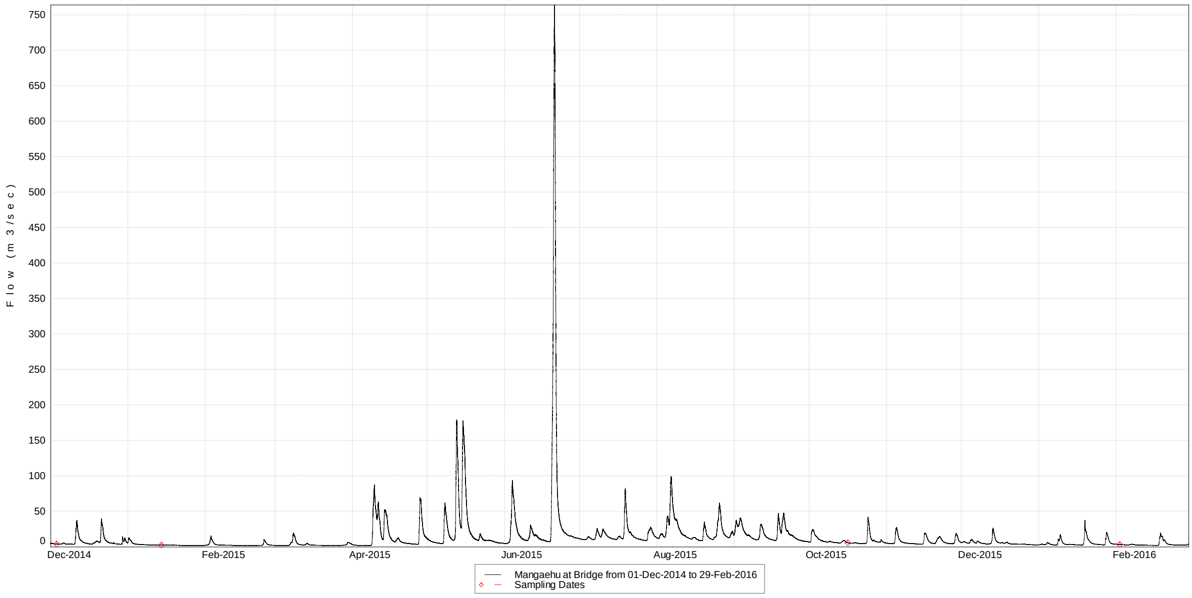
Flow in the Punehu Stream during the 2014-2016 sampling period



Flow in the Kapoaiaia Stream during the 2014-2016 monitoring period



Flow in the Waiongana River at SH3a during the 2014-2016 monitoring period



Flow in the Mangaehu River during the 2014-2016 survey period

Appendix II

Nutrient data 2014-2016

Nutrient data showing median values for physiochemical samples for dissolved reactive phosphorus, dissolved inorganic nitrogen and total nitrogen. Prevention of undesirable growths for upland rivers (>150m) total phosphorus (DRP) <0.009 mg/L and total nitrogen (TN) <0.295 mg/L and for lowland rivers (≤150m) total phosphorus (DRP) <0.010 mg/L and total nitrogen (TN) <0.614 mg/L (ANZEEC, 2000) and prevention of excessive *Phormidium* growths DIN <0.1 mg/L (NZSSC, 2015)

River/Stream	Site	Altitude (m)	2014-2015			2015-2016		
			DRP	DIN	TN	DRP	DIN	TN
Hangatahua (Stony)	Mangatete Road	160	0.016*	0.020	0.110	0.020*	0.040	0.070
	SH45	70	n/a	n/a	n/a	n/a	n/a	n/a
Maketawa	Derby Rd	380	n/a	n/a	n/a	n/a	n/a	n/a
	Tarata Road	150	0.029*	0.338*	0.400	0.032*	0.260*	0.370
Manganui	SH3	330	n/a	n/a	n/a	n/a	n/a	n/a
	Bristol Road	140	n/a	n/a	n/a	n/a	n/a	n/a
Patea	Barclay Road	500	0.024*	0.023	0.100	0.026*	0.023	0.080
	Skinner Road	240	0.033*	0.890*	1.175*	0.044*	0.930*	1.110*
Waiwhakaiho	SH3 (Egmont Village)	175	0.0255	0.143	0.19	0.1665*	0.173*	0.18
	Constance St, NP	20	n/a	n/a	n/a	n/a	n/a	n/a
Waingongoro	Opunake Road	380	n/a	n/a	n/a	0.02	0.391	0.445
	Stuart Road+	180	0.029*	1.274*	1.470*	0.021*	0.980*	1.255*
	Ohawe Beach+	10	0.051*	1.920*	2.230*	0.048*	1.755*	1.707*
Punehu	Wiremu Road	270	0.025	0.044	0.180	0.021	0.030	0.140
	SH45	20	0.057*	1.569*	1.990*	0.036*	1.120*	1.435*
Kapoaiaia	Wiremu Road	240	n/a	n/a	n/a	0.0265*	0.224*	0.295*
	Wataroa Road	140	n/a	n/a	n/a	n/a	n/a	n/a
	Cape Egmont	20	n/a	n/a	n/a	0.0265*	0.4575*	0.675*
Waiongana	SH3a	140	n/a	n/a	n/a	0.03*	0.595*	0.815*
	Devon Road	20	n/a	n/a	n/a	n/a	n/a	n/a
Mangaehu	Raupuha Road	120	0.006	0.099	0.285	0.005	0.091	0.200

+ No nutrient data was available for the Waingongoro sites but sites located close to the periphyton sites on the Waingongoro River did have nutrient data and these are displayed.
* Exceedance of suggested guideline or value.