Freshwater Periphyton
Monitoring Programme
(Periphyton monitoring in relation to amenity values)
State of Environment Monitoring Report
2016-2018

Technical Report 2018-7

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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 2016-2018.

Periphyton is the layer of slime that can form on stream beds and on submerged objects. It consists of 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 to absorb nutrients and organic compounds for growth, and subsequently becoming 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. To Maori, water is life, is linked to conception, and sustains the growth of crops, animals and people. Rivers represent the tipuna (ancestor) of the Tangata Whenua. Water and every river (awa) therefore has its own mana. Water also has its own mauri (life force) and wairua (spirituality). If the mauri or wairua of a waterbody is interfered with by way of pollution or desecration, then the spirit of the tipuna are affected and the waterbody will lose its vitality, its fruitfulness and its mana. Water, like all other natural resources, is considered by Maori to be a taonga to be valued, used with respect and passed on to future generations in as good or better condition than at present. In a physical sense, water is valued by hapu and whanau for the provision of sustenance through mahinga kai, or food resources eg, tuna (eel), piharau (lamprey), kahawai, inanga and other whitebait species. These values would be adversely affected by excessive periphyton growth.

Twenty-one sites are surveyed in ten rivers/streams 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).

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 ten days since a fresh of 3x median 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 were 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 2016-2017 monitoring year showed that on one occasion at one site there was a breach of the thick mat guideline and on five occasions across four separate sites there was a breach of the long filaments guideline, out of a total of 64 site surveys. Ten sites could not be surveyed in spring 2016 due to high water levels. For the 2017-2018 monitoring year there were two occasions where there was a breach of the thick mat guidelines and three occasions where there was a breach of the long filaments guideline (Table 1), out of a total of 84 site surveys. No site failed more than one guideline in the 2017-2018 period. Two sites failed the thick mat guideline and six sites in total failed the long filamentous algae on one or more occasions during the two years under review. Out of the 168 surveys over the two years, 157 surveys (93%) found nuisance periphyton levels 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 Kapoaiaia River at Wataroa Rd (a mid-catchment site), which had two surveys with 'poor' ratings out of 4 surveys.

For the TRC Periphyton Index, the median index value for 2016-2018 monitoring showed that eleven sites (52%) recorded a 'very good' rating, seven sites (33%) recorded a 'good' rating, and three sites (14%) 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 2016-2018 monitoring period

River/Stream	Site	Distance from Nat Park (km)	Median TRC Periphyton Index	Trend		Periphyton cover		Periphyton biomass (chlorophyll *a* mg/m^2)	
				Thick mats	Long filaments	Thick mats	Long filaments	2017	2018
Hangatahua (Stony)	Mangatete Road	7.3	Very good	Increasing	Decreasing	3/3	3/3	16	1
	SH45	12.5	Very good	Decreasing	Decreasing	3/3	3/3	33	7
Kapoaiaia	Wiremu Road	5.7	Very good	Decreasing	Decreasing*	4/4	4/4	19	25
	Wataroa Road	13.5	Moderate	Decreasing	Decreasing	4/4	$2/4^{+}$	237^{n}	115^{+}
	Cape Egmont	25.2	Good	Decreasing	Decreasing	4/4	$3/4^{+}$	133^{+}	17
Maketawa	Derby Rd	2.3	Very good	Increasing	Increasing	3/3	3/3	3	3
	Tarata Road	15.5	Very good	Decreasing	Decreasing	3/3	3/3	25	132^{+}
Mangaehu	Raupuha Road	NA	Moderate	Increasing	Decreasing	$2/4^{+}$	4/4	375^{n}	89^{+}
Manganui	SH3	8.7	Very good	Decreasing	NA	3/3	3/3	5	3
	Bristol Road	37.9	Good	Increasing	Decreasing	3/3	3/3	90^{+}	NA
Patea	Barclay Road	1.9	Very good	Decreasing	Decreasing	4/4	4/4	5	5
	Skinner Road	19.2	Very good	Increasing	Decreasing*	4/4	4/4	29	117^{+}
Punehu	Wiremu Road	4.4	Very good	Increasing	Decreasing	4/4	4/4	45	1
	SH45	20.9	Good	Increasing	Decreasing	4/4	$2/4^{+}$	98^{+}	21
Waingongoro	Opunake Road	7.2	Very good	Decreasing	Decreasing	4/4	4/4	21	11
	Stuart Road	29.6	Very good	Increasing	Decreasing	4/4	4/4	152^{+}	167^{+}
	Ohawe Beach	66.6	Good	Increasing	Increasing	$3/4^{+}$	4/4	90^{+}	20
Waiongana	SH3a	16.1	Good	Decreasing	Decreasing	3/3	$2/3^{+}$	185^{+}	119^{+}
	Devon Road	31.2	Good	Increasing	Increasing	3/3	$2/3^{+}$	73^{+}	221^{n}
Waiwhakaiho	SH3 (Egmont Village)	10.6	Good	Increasing	Decreasing	3/3	$2/3^{+}$	46	186^{+}
	Constance St, NP	26.6	Moderate	Increasing	Decreasing	3/3	3/3	70^{+}	237^{n}

* Significant trend at $p<0.05$ after FDR adjustment, ^{n} above NOF standard, $^{+}$ exceeds Biggs, 2000 guideline

Periphyton biomass was in excess of the NOF standard (200 mg/m^2) at two sites for the summer 2017 surveys and another two sites for the summer 2018 survey (but see further on NOF compliance below), and was in excess of the guideline to protect benthic biodiversity (50 mg/m^2) at ten sites for the summer 2017 survey and nine sites for the summer 2018 surveys.

Periphyton biomass results generally reflected nuisance periphyton percentage cover levels and to a lesser extent TRC PI scores. There were four sites with chlorophyll *a* levels in exceedance of the NOF bottom line criterion but for each of the four 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, as three years of systematically scheduled monthly data is required to produce a NOF rating, and therefore the site cannot be said to be compliant or non-compliant. Furthermore, the NOF protocol allows sites to have one sample per year for non-productive waterbodies (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 thick mats levels were fluctuating among sites and long filamentous algae levels were predominantly decreasing, although only two sites had statistically significant trends after FDR adjustment (a rigorous test for statistical confidence). Nine sites (about half) had decreases for thick mats and 17 sites (almost all) had decreases for long filaments. The two significant trends were at the upper Kapoaiaia and lower Patea River sites, both 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 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.

Generally, ringplain streams and rivers closer to the Egmont National Park boundary had less periphyton than those further downstream. The majority of ringplain sites located further than 10 km from the National Park boundary and the Mangaehu River site had moderate to high levels of periphyton for at least one of the four surveys based on either periphyton coverage or biomass. A regression analysis also found a statistically significant correlation between distance from the park boundary and chlorophyll *a* levels for the summer 2018 survey. This indicates that 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 periphyton proliferation.

The difference between spring and summer surveys was not significant. Summer surveys often have considerably higher periphyton levels than spring surveys (e.g. TRC, 2014) but the average TRC PI score was within one unit for all four surveys (7.4-8.2 TRC PI). Average thick mat and long filamentous algae levels were within 1-2 percentage points between the spring the summer surveys which again indicated no seasonal difference in periphyton levels. There was a seasonal bias for breaches in guidelines with eight breaches occurring in summer against three breaches occurring in spring. However, it should be noted that in the monitoring period under review, ten spring surveys could not be performed during the spring 2016 period due to high flows, which will slightly bias the relative results.

No *Didymosphenia geminata* was found for the monitoring period under review. Didymo, or 'rock snot', is a highly prolific and invasive diatom alage that forms blooms resembling dirty cotton wool. It has spread to nuisance proportions in a number of South Island high country streams and rivers.

Overall, the following conclusions can be made:

1. Generally, the monitored sites complied with nuisance periphyton guidelines, with 96% and 89% of surveys complying with the periphyton guideline for thick mats and long filaments respectively equating to an overall compliance rate of 93% for nuisance periphyton surveys.
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, light level, temperature, substrate type, time since last fresh, 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, together with wider, less shaded stream widths and slower flow velocities, were probably the main cause of algae proliferation in 'downstream' catchment sites.
5. High flows can cause a reduction in periphyton growth but the degree of this effect is not consistent between streams.

From these conclusions, a number of recommendations are made in the report. Monitoring of the streams should continue as previously performed. The Council has also initiated a separate periphyton/chlorophyll *a* programme as per the NOF protocols, at sites considered representative of Freshwater Management Units

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

Table of contents

List of tables

List of figures

List of photographs

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

The government has issued the National Policy Statement for Freshwater Management (2014), or NPS-FM, amended in 2017. The NPS-FM includes a National Objectives Framework, or NOF, that specifies various metrics for measuring water quality together with standardised protocols for determining those metrics. The NPS-FM requires the Council to safeguard and measure the life-supporting capacity and ecosystem processes of fresh water. The NOF specifies a maximum concentration of chlorophyll *a* as a bottom line for ecosystem health, together with particular protocols around sampling and data analysis. The Council has initiated a NOF-compliant monitoring programme, but in the meantime is continuing its long-standing existing arrangements.

The programme recognises and provides for Maori perspectives on fresh water. To Maori, water is life, is linked to conception, and sustains the growth of crops, animals and people. Rivers represent the tipuna (ancestor) of the Tangata Whenua. Every river (awa) therefore has its own mana (status). Water also has mauri (life force) and wairua (spirituality). If the mauri or wairua of a waterbody is interfered with by way of pollution or degradation, then the spirit of the tipuna are affected and the waterbody will lose its vitality, its fruitfulness and its mana. Water, like all other natural resources, is considered by Maori to be a taonga to be valued, used with respect and passed on to future generations in as good or better condition than at present. In a physical sense, water is valued by hapu and whanau for the provision of sustenance through mahinga kai, or food resources e.g., tuna (eel), piharau (lamprey), kahawai, inanga and other whitebait species. These values would be adversely affected by periphyton growth that was excessive.

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

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)

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 the major source of food to stream and river foodwebs.

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 otherwise provide significant shade to limit periphyton growth. Shading from high 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.

- Flow regimes – the frequency of freshes (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 allow periphyton to grow faster, whereas colder temperatures may limit growth. Water temperature is influenced by shading from riparian vegetation, altitude and sunlight hours.
- Invertebrate grazers such as snails reduce periphyton growth by directly feeding on periphyton.
- Substrate type - periphyton generally occurs on hard surfaces such as boulders and cobbles and is less likely 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 may occur in the absent of any anthropogenic effects. For example, long, wide, shallow rivers may have some growths during late summer when temperatures are high and flows are low. 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 **Error! Reference source not found.**.

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 eutrophic (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.

<table>
<tr><th>Alert level[a]</th><th>Actions</th></tr>
<tr><td>Alert (amber mode)
20–50% coverage of potentially toxigenic cyanobacteria attached to substrate.</td><td>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.</td></tr>
<tr><td>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.</td><td>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.</td></tr>
</table>

[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 (within the interval 15 September – 31 December) and
- summer (within the interval 1 January – 15 April).

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

- spring (September, October, November, or 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 described 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 calculated 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.

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 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. 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 (2016-2018).

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 prior to 2016 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 (**Error! Reference source not found.**). 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* exceeded for no more the 8% of the time for non-productive streams, which corresponds with no more than once in a 12 month sampling year. Therefore, the NOF categorisation cannot be applied to the sites sampled annually or biannually for the nuisance periphyton programme.

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 in 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 development, 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

Sites				
River/Stream	Location	Site Code	Distance from Nat Park (km)	Altitude (m)
Hangatahua (Stony)	Mangatete Road	STY000300	7.3	160
	SH45	STY000400	12.5	70
Kapoaiaia	Wiremu Road	KPA000250	5.7	240
	Wataroa Road	KPA000700	13.5	140
	Cape Egmont	KPA000950	25.2	20
Maketawa	Derby Rd	MKW000200	2.3	380
	Tarata Road	MKW000300	15.5	150
Mangaehu	Raupuha Road	MGH000950	NA	120
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
Punehu	Wiremu Road	PNH000200	4.4	270
	SH45	PNH000900	20.9	20
Waingongoro	Opunake Road	WGG000150	7.2	380
	Stuart Road	WGG000665	29.6	180
	Ohawe Beach	WGG000995	66.6	10
Waiongana	SH3a	WGA000260	16.1	140
	Devon Road	WGA000450	31.2	20
Waiwhakaiho	SH3 (Egmont Village)	WKH000500	10.6	175
	Constance St, NP	WKH000920	26.6	20

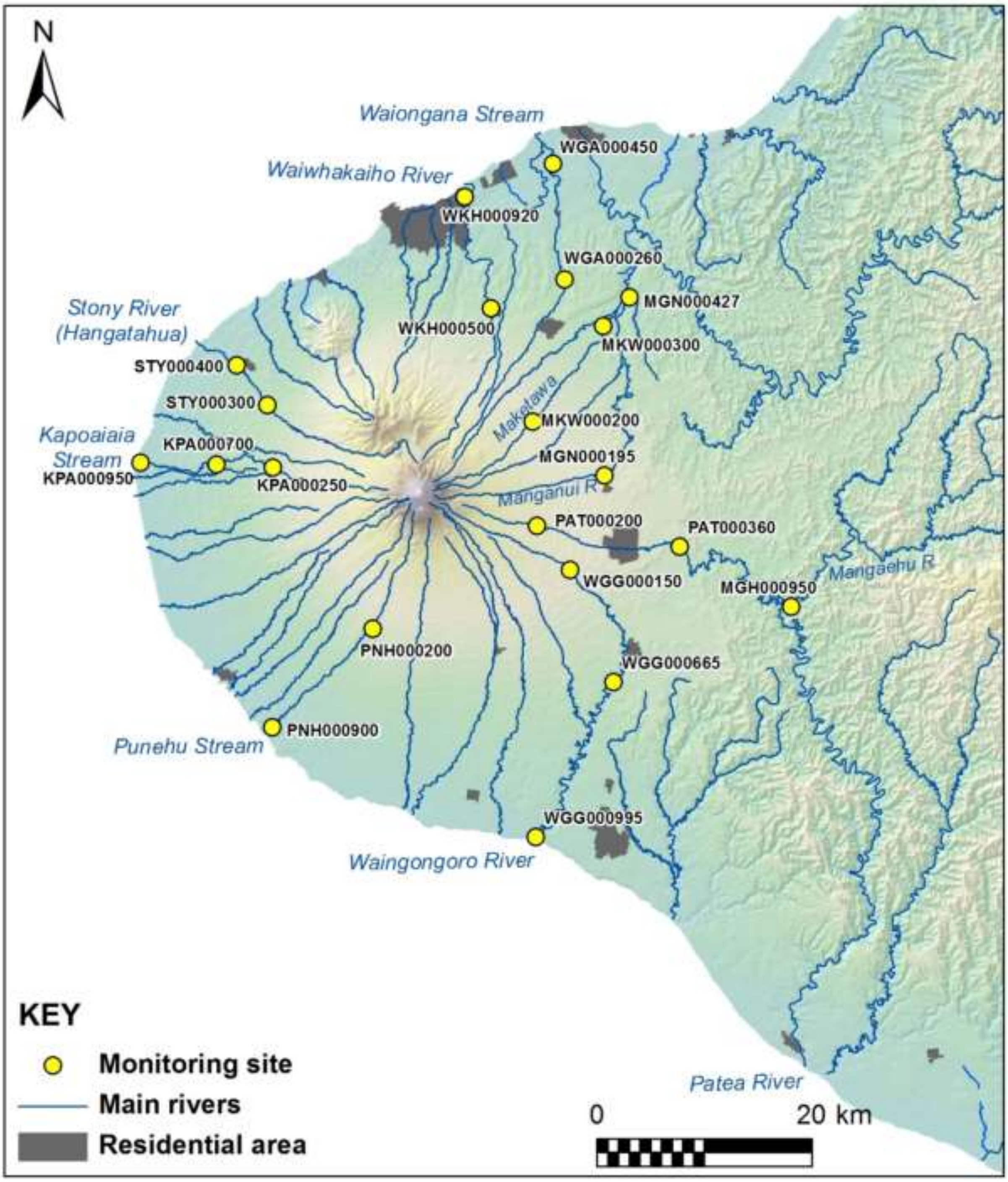


Figure 1 Sampling site locations

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.

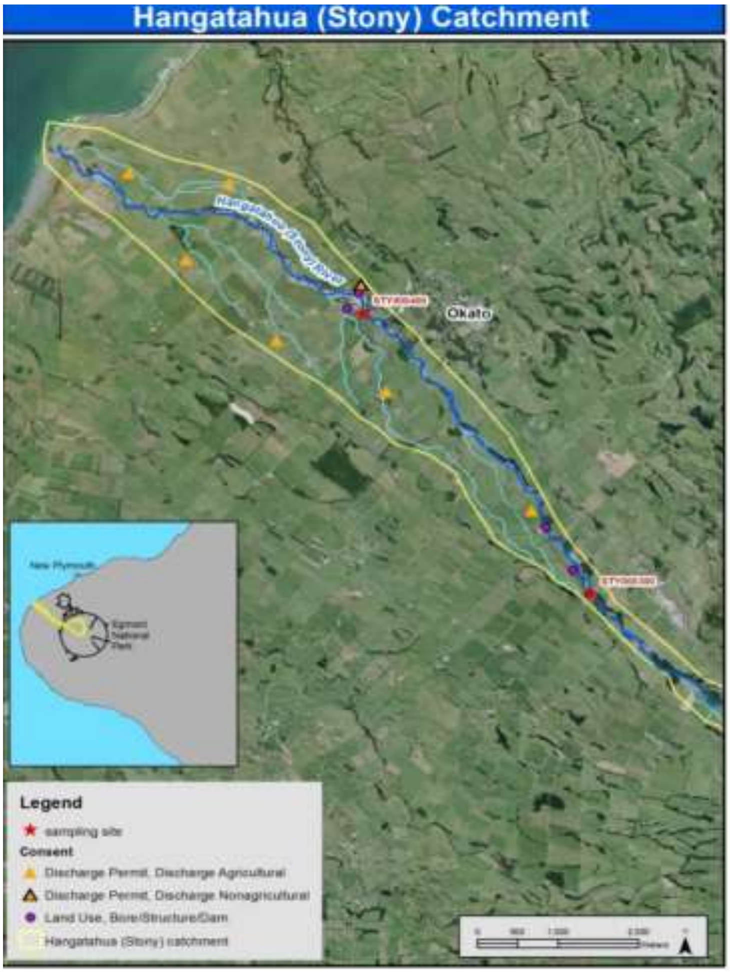


Figure 2 Monitoring site locations in relation to consents operating in the Stony River catchment

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).

Information regarding time of surveys and freshes are presented in Table 9. The spring 2016 survey was not conducted due to persistently high spring flows.

Table 9 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	NA	NA	NA
Summer	7/03/2017	28	32
Spring	1/11/2017	18	23
Summer	30/01/2018	11	12

Nutrient data from the SEM physiochemical programme was collected at site STY000300. 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 undisturbed (reference) upland site but not for dissolved reactive phosphorus (DRP) (ANZECC 2000) (Table 10). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels.

Table 10 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Stoney River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
Mangatete Road	160	0.023*	0.049	0.08	0.021*	0.026	0.025
SH45	70	n/a	n/a	n/a	n/a	n/a	n/a

*Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

2.1.2 Periphyton cover

The Stony River is generally characterised by a low periphyton biomass throughout its catchment. For the 2016-2017 there was very minor levels of thick mats and filamentous algae at the Mangatete Road site during the spring survey only and no thick mats or filamentous algae at the SH45 site. In the 2017-2018 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 low and the periphyton results for the 2016-2018 monitoring period support this.

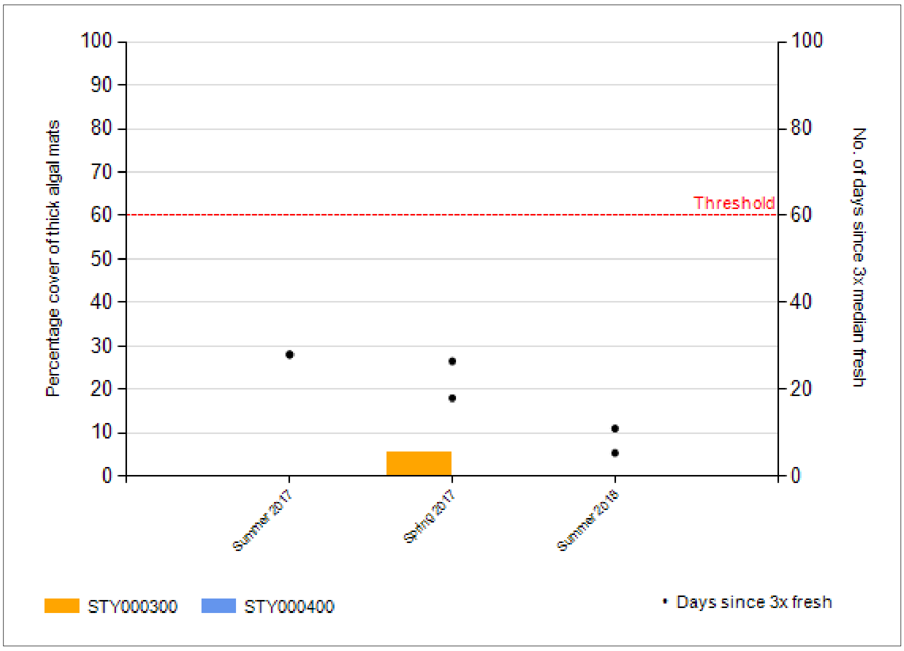


Figure 3 Percentage cover of thick mats of periphyton on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

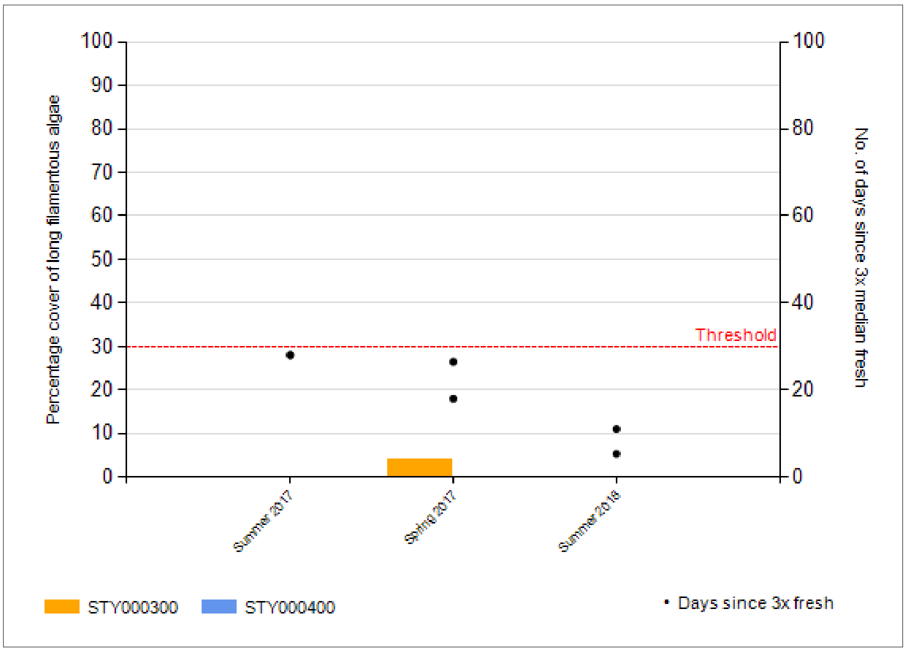


Figure 4 Percentage cover of long filamentous algae on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

Based on historical monitoring data, it appears unlikely that periphyton growths will develop to nuisance levels 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 2016-2018 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 2016-2017 monitoring year there was a small decrease between the upstream site and downstream site; scoring high scores for summer (Table 11). For the 2017-2018 monitoring period there was again a small decrease in TRC PI at the downstream for the spring period. There was virtually no difference in the summer survey with both sites getting very high scores.

The historical median for the upstream and downstream site are nearly the same with both in the 'very good' category indicating no difference between upstream and downstream condition (Table 11).

Table 11 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 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historic spring median	TRC PI Historic summer median
STY000300	9.2	10.0	9.8	10.0	10.0
STY000400	8.1	8.6	10.0	10.0	9.9
Difference	1.1	1.4	-0.2	0	0.1

2.1.4 Periphyton biomass

The results for the summer of 2017 and 2018 for both sites had low recorded chlorophyll *a* levels (1-33 mg/m^2) (Figure 5). These values are within guidelines to protect biodiversity, aesthetic and trout habitat/angling values (**Error! Reference source not found.**) and NOF guidelines (Snelder et al., 2013). The low chlorophyll *a* levels are congruent with the periphyton cover results and reinforces the findings that the Stony River has outstanding water quality.

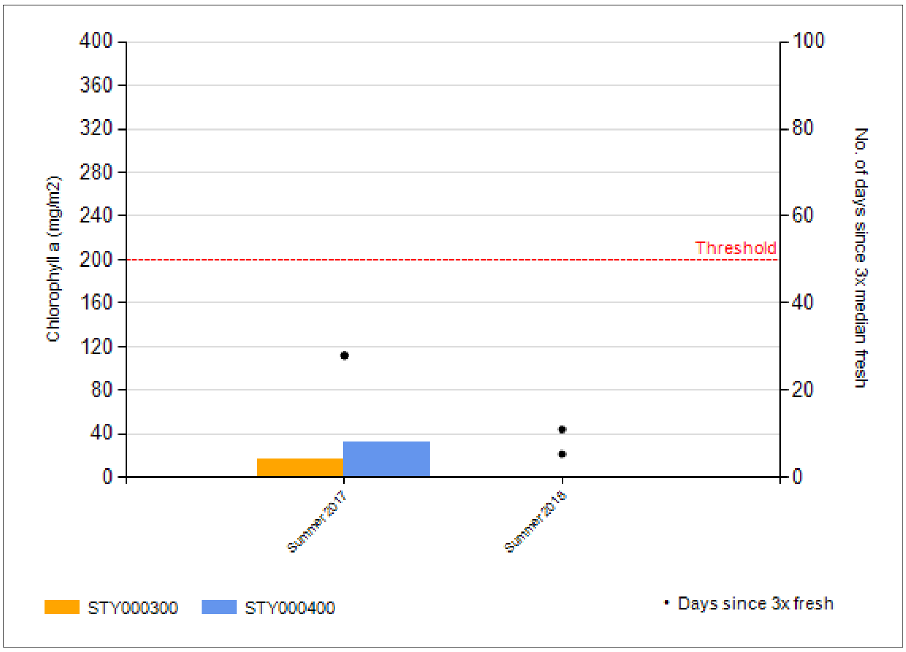


Figure 5 Periphyton biomass (chlorophyll a) on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.1.5 Summary of 2002-2018 (16 year data set)

Over the 16 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 16 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.

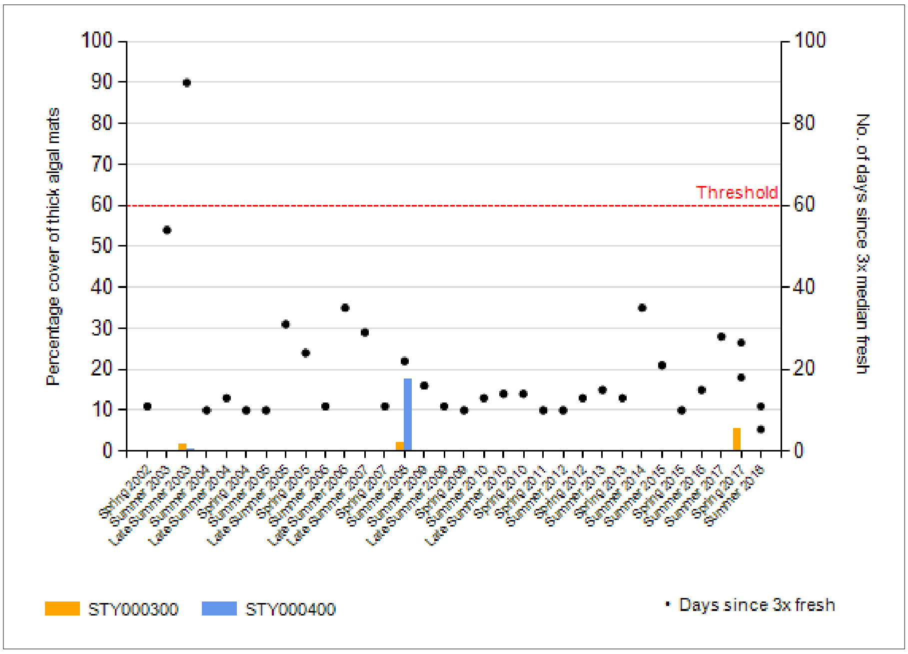


Figure 6 Percentage cover of thick mats of periphyton on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2002-2018 period

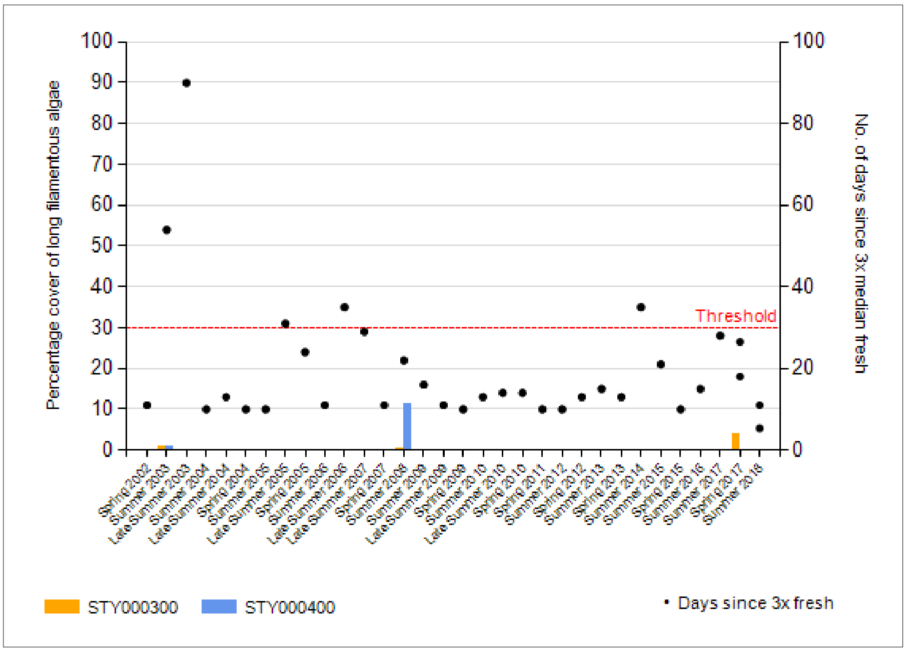
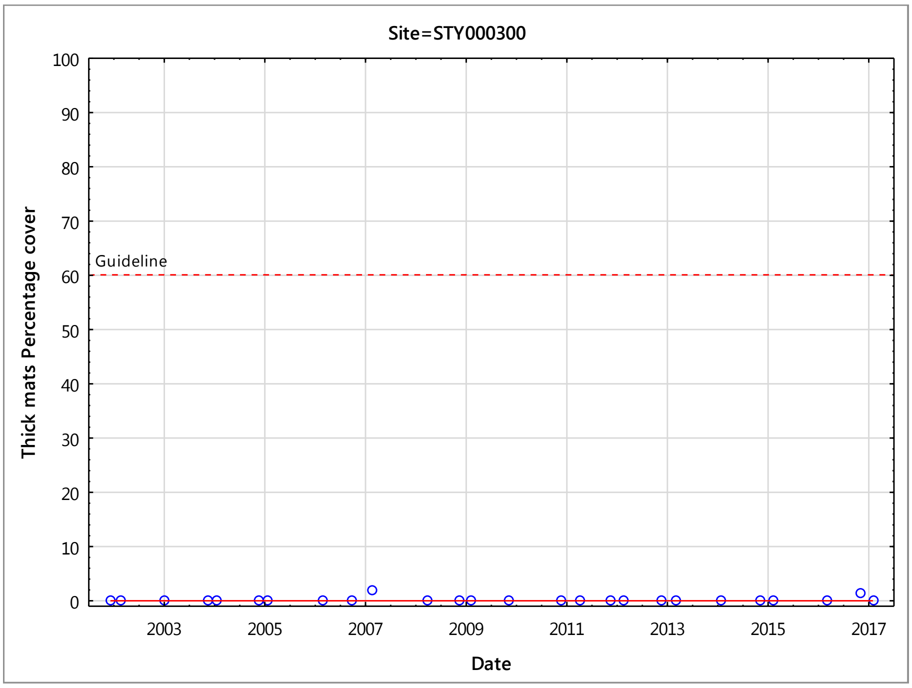


Figure 7 Percentage cover of long filamentous algae on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values over the 2002-2018 period

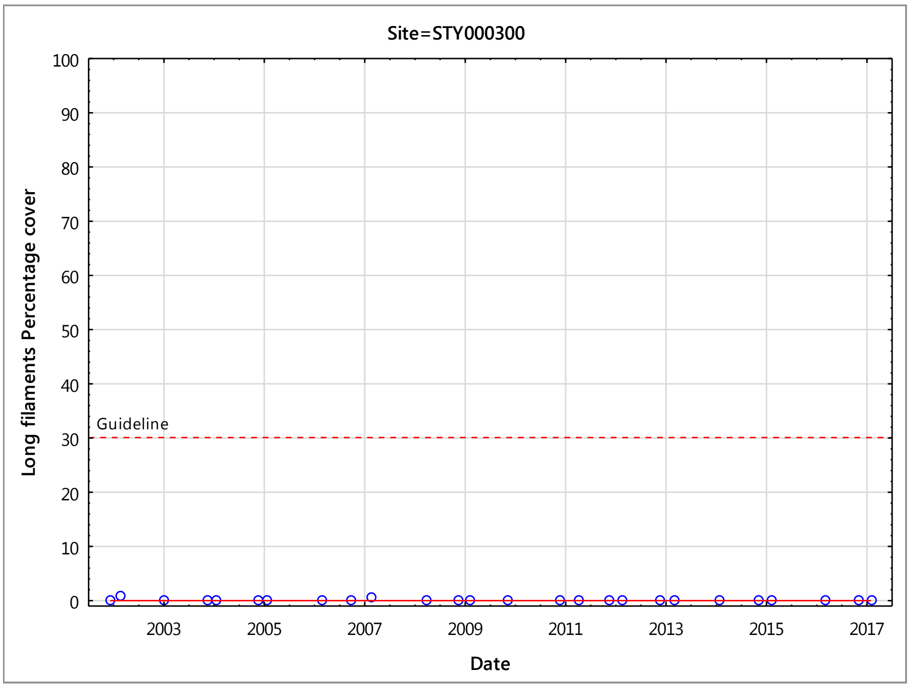
2.1.6 Long term trend analysis

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 16 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 = 26
Kendal tau = 0.12
p-value = 0.39
FDR p-value = 0.46

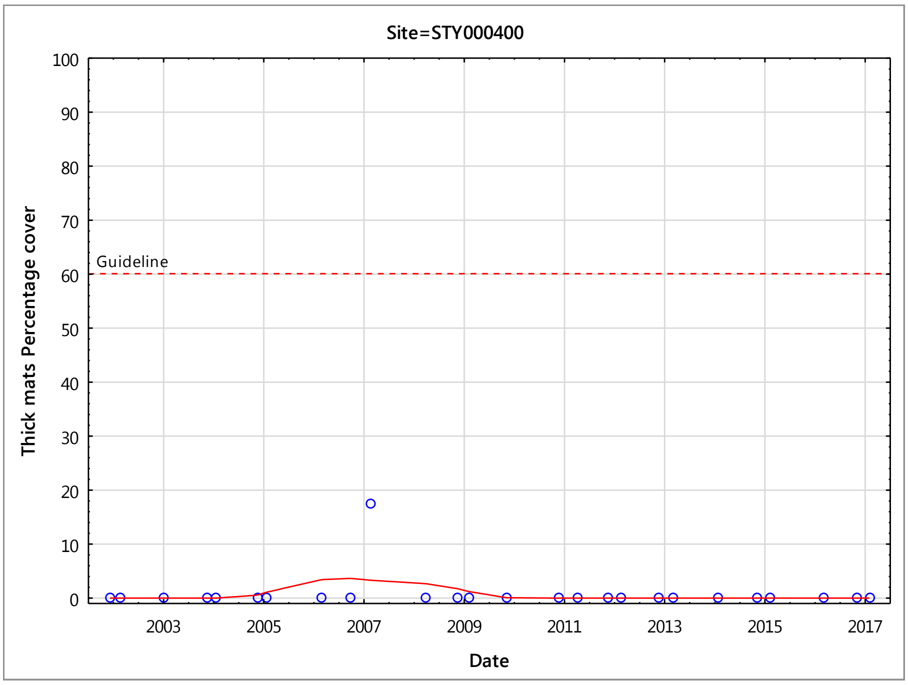
Figure 8 LOWESS trend analysis of percentage cover of thick mats at Stony River, Mangatete Road (STY000300)



n = 26
Kendal tau = -0.25
p-value = 0.08
FDR p-value = 0.28

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

At Mangatete Road (STY000300) over the 16 year monitored period there were no significant trends for thick mats (p=0.46) or long filaments (p=0.28) at the 5% level of significance after false discovery rate adjustment.



n = 26
Kendal tau = -0.56
p-value = 0.58
FDR p-value = 0.61

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

n = 26
Kendal tau = -0.23
p-value = 0.10
FDR p-value = 0.28

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

At SH45 (STY000400) over the 16 year monitored period there were no significant trends for thick mats (p=0.61) or long filaments (p=0.28) at the 5% level of significance after false discovery rate adjustment.

2.2 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 12). 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.

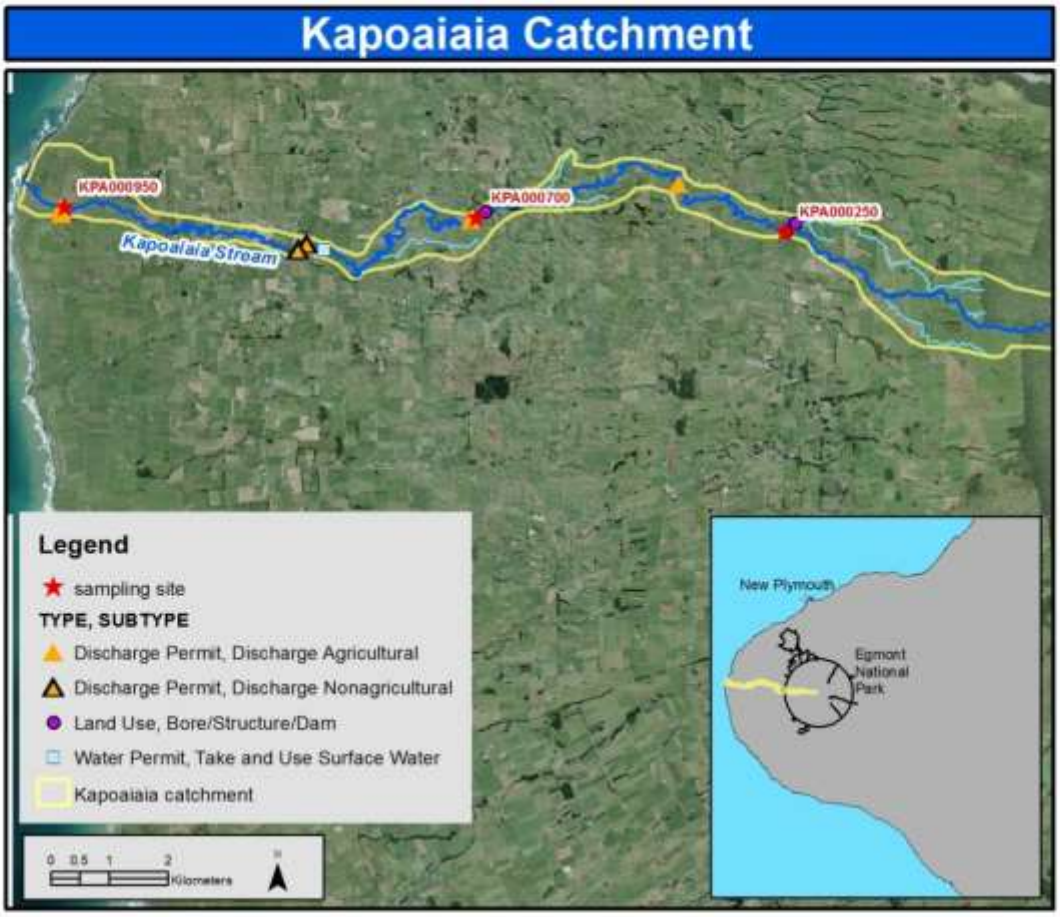


Figure 12 Monitoring site locations in relation to consents operating in the Kapoaiaia Stream catchment

2.2.1 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). Information regarding time of surveys and freshes are presented in Table 12.

Table 12 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	19/10/2016	10	14
Summer	02/03/2017	26	37
Spring	01/11/2017	18	23
Summer	30/01/2018	11	11

These sites are not included in the SEM physicochemical programme.

2.2.2 Periphyton cover

The upstream Wiremu Road site had low levels of thick mats and filamentous algae throughout the monitoring period except for the summer survey in 2017 where filamentous algae levels approached the recommended guideline threshold. The middle site at Wataroa Road shared a similar pattern to the Wiremu Road site with low to moderately low levels of thick mats throughout the monitoring period but filamentous algae levels in both summer surveys were very high and breached the guideline value. The lower site near Cape Egmont also had low to moderately low levels of thick mats throughout the monitoring period. Filamentous algae levels in both summer surveys were high with the summer 2017 survey breaching the guideline value (Figure 13 and Figure 14).

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 can often be 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 2017 results corresponded with a period of 28 days without any significant flushing flows (> 3x median flow) and 37 days without a large flushing flow (> 7x median flow). However, flushing flows do not fully explain the results as the middle site had high nuisance periphyton levels for the summer 2018 survey where a large flushing flow (> 7 x median flow) occurred only 11 days before the periphyton survey.

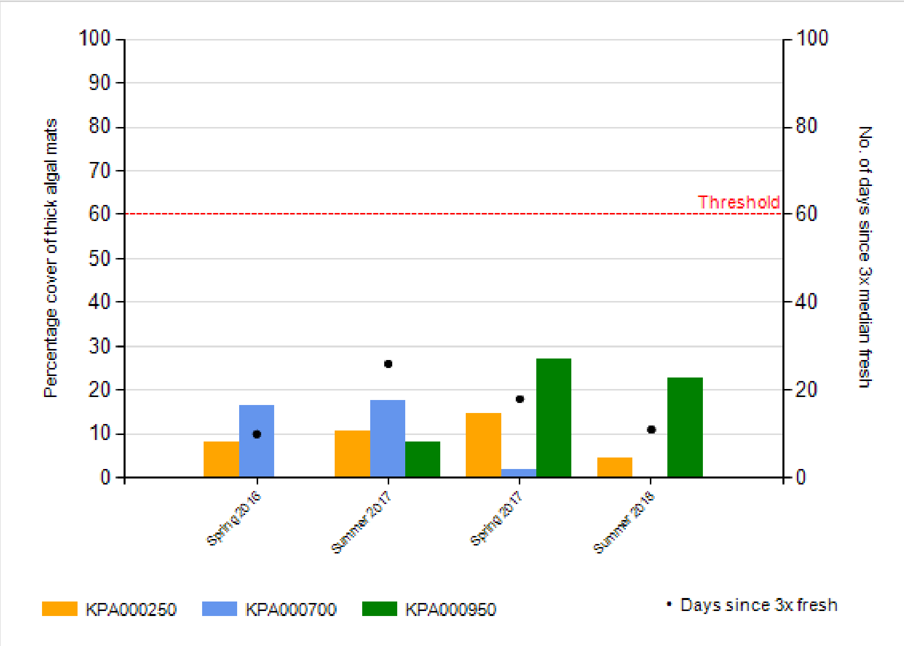


Figure 13 Percentage cover of thick mats of periphyton on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

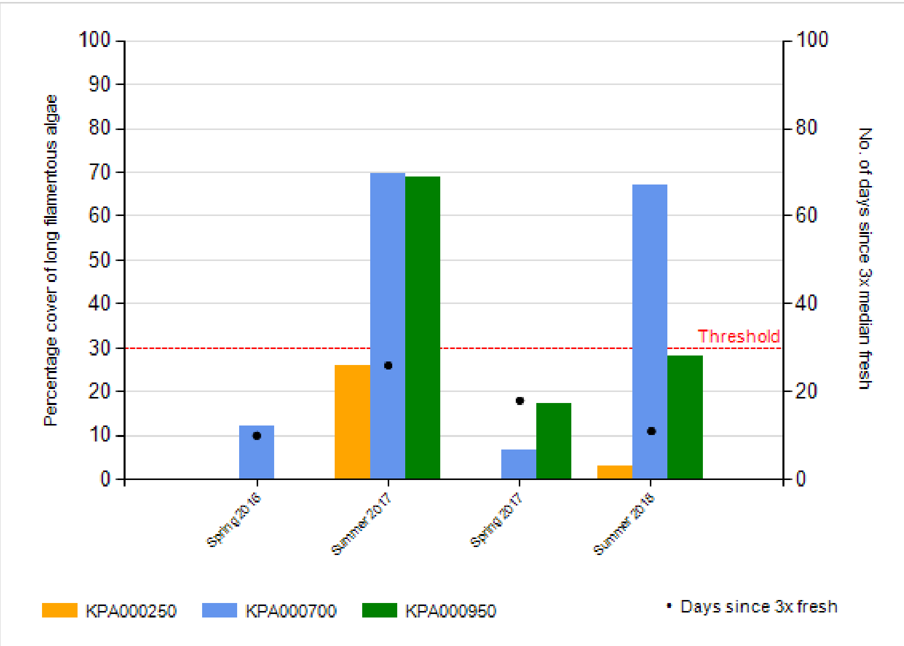


Figure 14 Percentage cover of long filamentous algae on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.2.3 Periphyton Index Score

The Kapoaiaia Stream showed a lot of variation in TRC PI scores among sites (Table 13). The upstream site (KPA000250) had 'good' to 'very good' TRC PI scores which were similar to historical medians. The mid-catchment site (KPA000700) had two low TRC PI scores corresponding with a 'poor' rating for both summer surveys which was coincident with the very high filamentous algae levels found at the site. The downstream site (KPA000950) had a similar pattern to the middle site but scores were slightly higher for the summer surveys with both having ‘moderate’ ratings.

Overall, scores dropped considerably in a downstream direction for all four surveys during the monitoring period.

Table 13 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 Spring 2016	TRC PI Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
KPA000250	9.6	6.7	9.4	9.1	9.9	6.0
KPA000700	8.1	3	8.8	3.5	8.7	6.8
KPA000950	8.1	4	7.4	5.7	7.6	6.0
Difference	1.5	2.7	2.0	3.4	2.3	0

2.2.4 Periphyton biomass

The results for the 2016- 2018 survey period for the upstream site showed that it had low chlorophyll *a* levels with the mid catchment site having high to moderate chlorophyll *a* levels and the downstream site having moderately high to low chlorophyll *a* levels (Figure 15).

The summer 2017 survey at the middle site breached guidelines to protect trout habitat/angling values (**Error! Reference source not found.**) and the NOF limit (MfE, 2014) while the lower site breached the guideline to protect benthic biodiversity. The high chlorophyll *a* level for the summer 2017 survey at the middle site also corresponded with the lowest TRC PI score (3.0) recorded for the period 2016-2018 for all sites.

All recorded chlorophyll *a* levels for the summer 2018 survey were below the NOF limit. The middle site had moderate chlorophyll *a* levels which breached guidelines to protect benthic biodiversity (**Error! Reference source not found.**).

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 promote excessive periphyton growth.

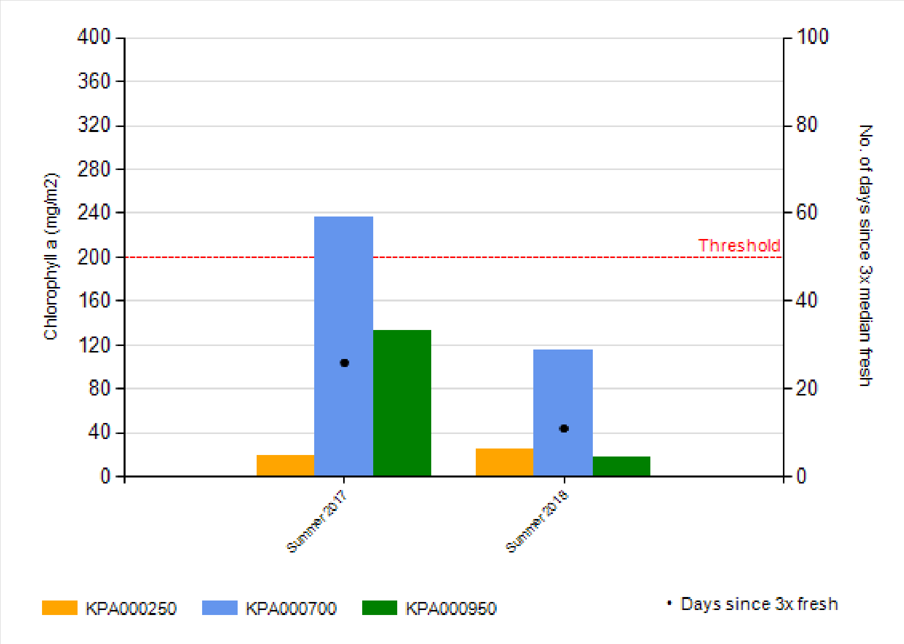


Figure 15 Periphyton biomass (chlorophyll *a*) on the Kapoaiaia riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.2.5 Summary of 2002-2018 (16 year data set)

The Kapoaiaia catchment has been monitored over a 16 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 2016-2018 monitoring period (Figure 16).

The middle and bottom sites breached thick mat guideline limits twice each in earlier years during the 2002-2018 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 only low to moderately 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 16 year monitoring period for long filamentous nuisance growths (31 in total) (Figure 17). Overall, there had been a significant decrease in long filamentous growths at the upper and mid catchment sites (2008-2012) but more recently levels have increased (2012-2018). For the current reported period there were three breaches.

The Kapoaiaia Stream has the highest amount of nuisance growths for long filaments out of all the rivers and streams monitored over the 16 year period. There is still a significant level of work required in the Kapoaiaia catchment to reduce nutrient levels down and increase riparian cover.

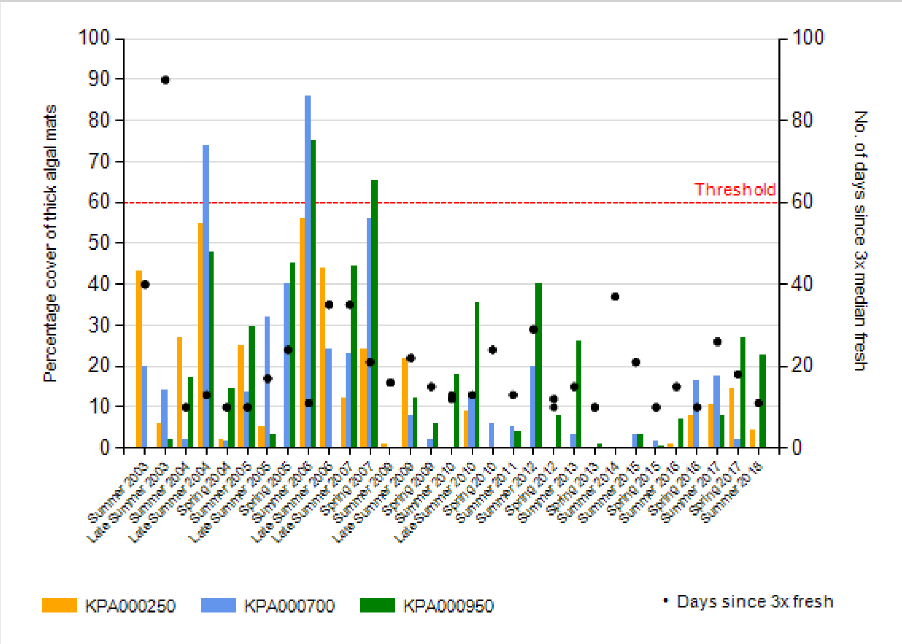


Figure 16 Percentage cover of thick mats of periphyton on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2002-2018 period

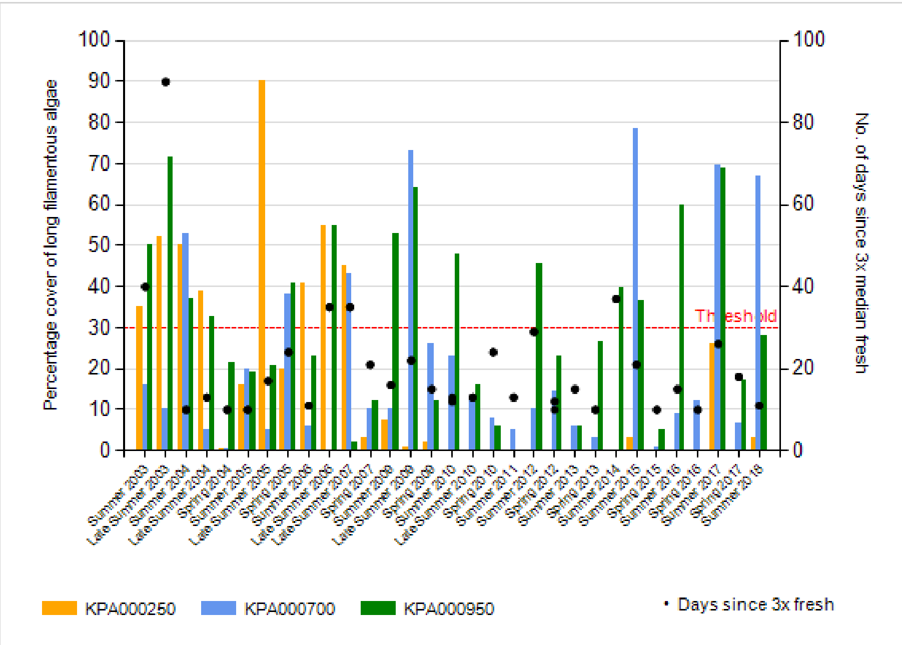
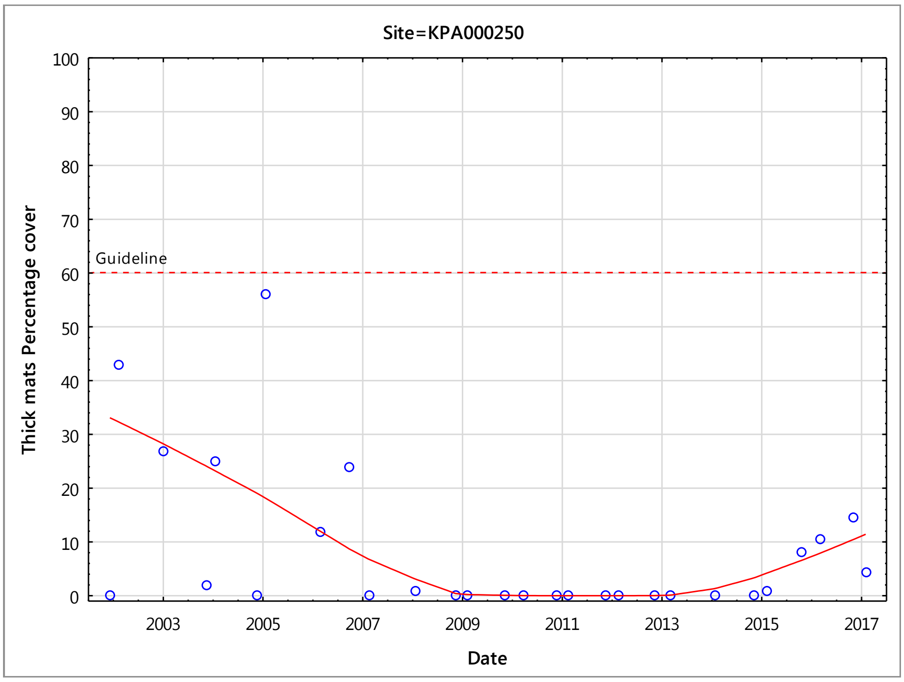


Figure 17 Percentage cover of long filamentous algae on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2002-2018 period

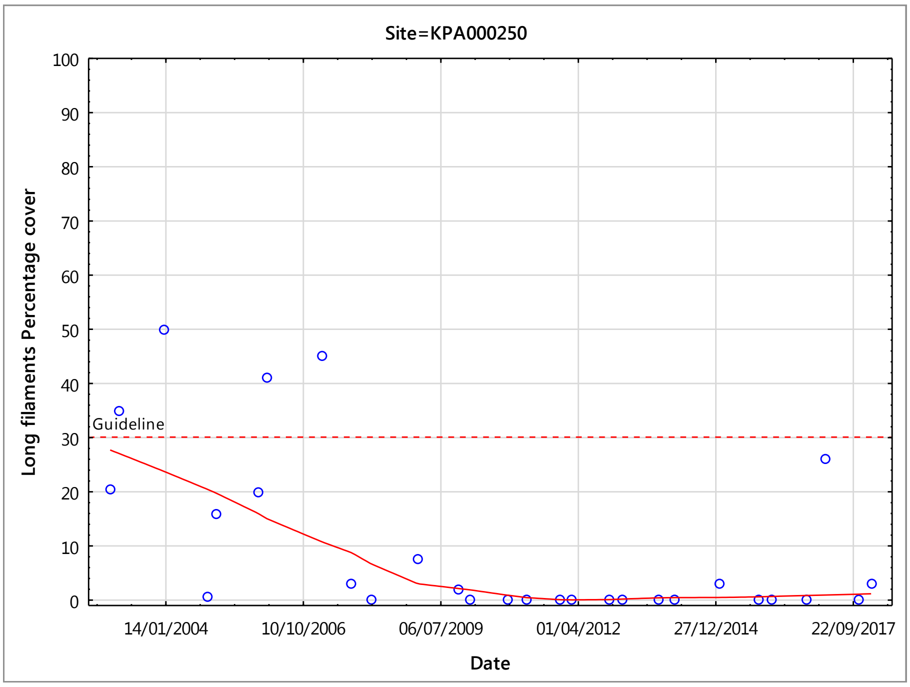
2.2.6 Long term trend analysis

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 three sites on the Kapoaiaia Stream; Wiremu Road, Wataroa Road and at Cape Egmont. Monitoring was carried out over a 16 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 18 to Figure 23).



n = 28
Kendal tau = -0.15
p-value = 0.26
FDR p-value = 0.35

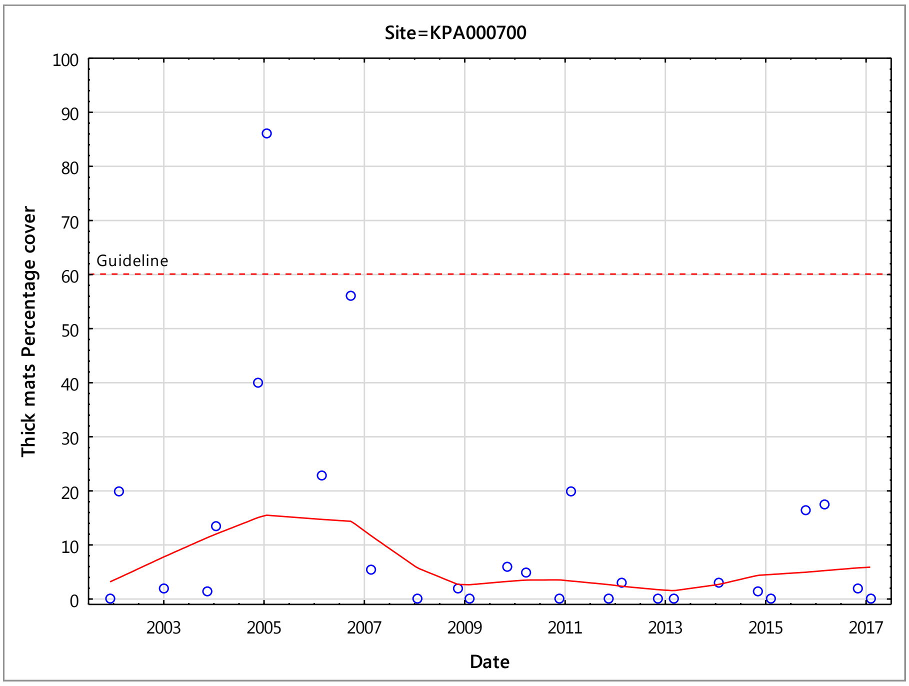
Figure 18 LOWESS trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Wiremu Road (KPA000250)



n = 28
Kendal tau = -0.43
p-value < 0.01
FDR p-value = 0.03

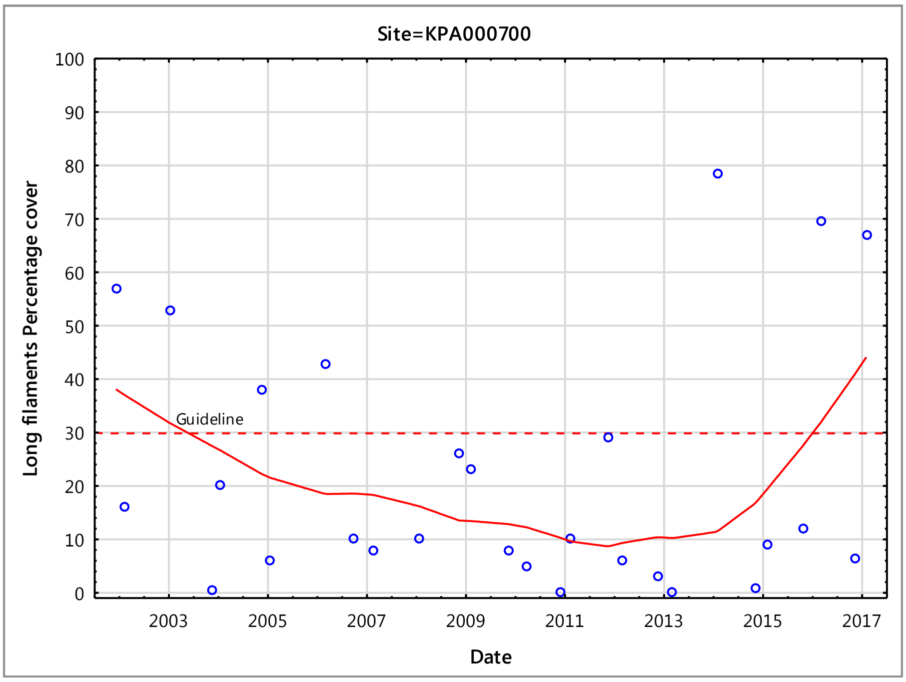
Figure 19 LOWESS trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Wiremu Road (KPA000250)

At Wiremu Road (KPA000250) over the 16 year monitored period there was a non-significant (p=0.35) trend for thick mats and a significant (p=0. 03) negative (tau=-0.43) trend for long filaments at the 5% level of significance after false discovery rate adjustment indicating that long filamentous algae has decreased over the monitored period.



n = 28
Kendal tau = -0.21
p-value = 0.12
FDR p-value = 0.21

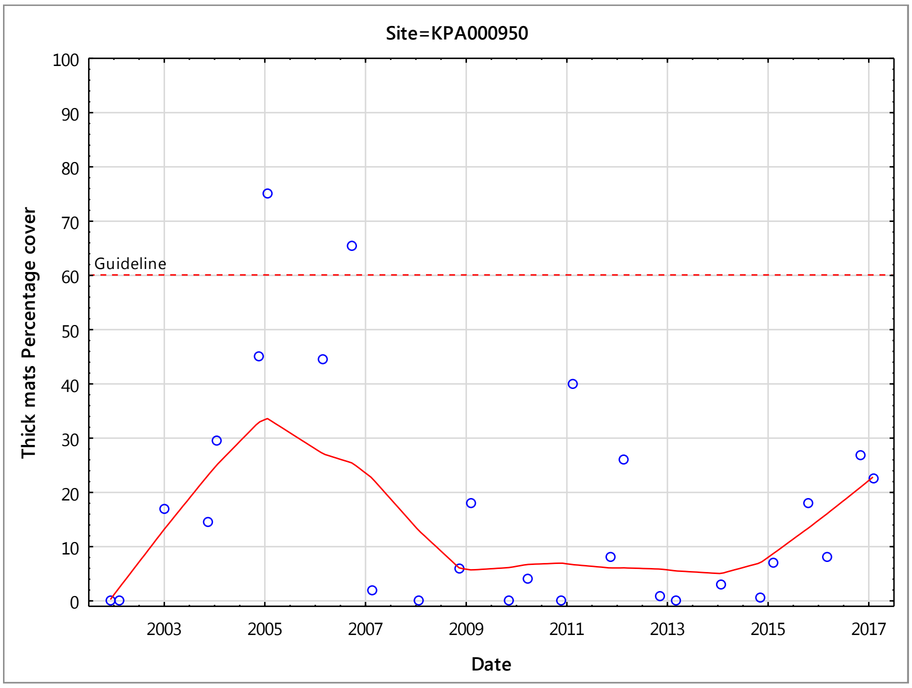
Figure 20 LOWESS trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Wataroa Road (KPA000700)



n = 28
Kendal tau = -0.11
p-value = 0.040
FDR p-value = 0.54

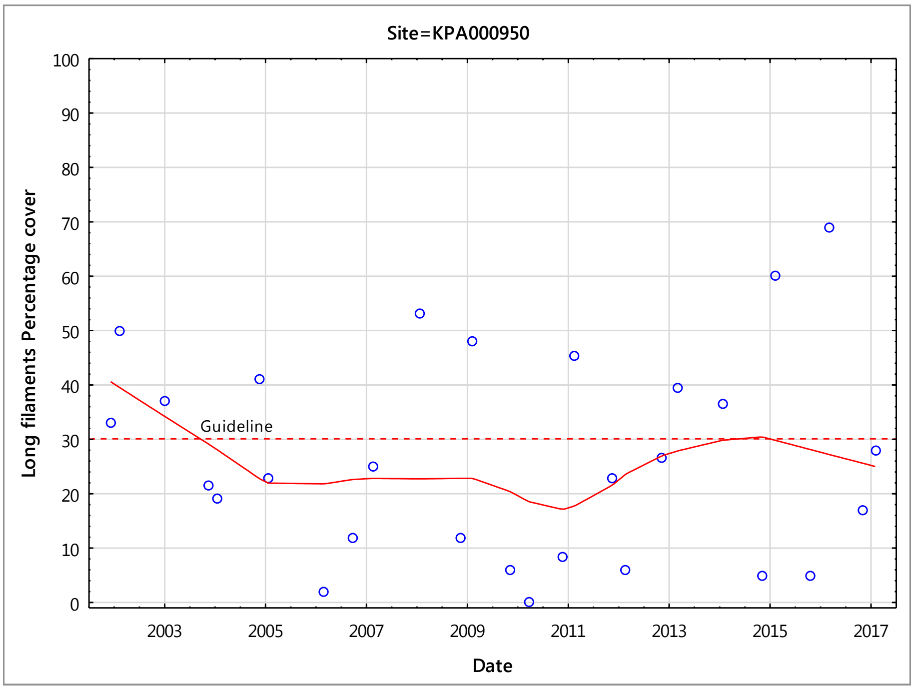
Figure 21 LOWESS trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Wataroa Road (KPA000700)

At Wataroa Road (KPA000700) over the 16 year monitored period there was no significant trend for thick mats (p=0.21) or long filamentous algae (p=0.54) at the 5% level of significance after false discovery rate adjustment.



n = 28
Kendal tau = 0.00
p-value = 0.98
FDR p-value = 0.98

Figure 22 LOWESS trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Cape Egmont (KPA000950)



n = 28
Kendal tau = -0.4
p-value = 0.78
FDR p-value = 0.82

Figure 23 LOWESS trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Cape Egmont (KPA000950)

At Cape Egmont (KPA000950) over the 16 year monitored period there were no significant trends for thick mats (p=0.98) or long filaments (p=0.82) at the 5% level of significance after false discovery rate adjustment.

2.3 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 24). 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. 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).

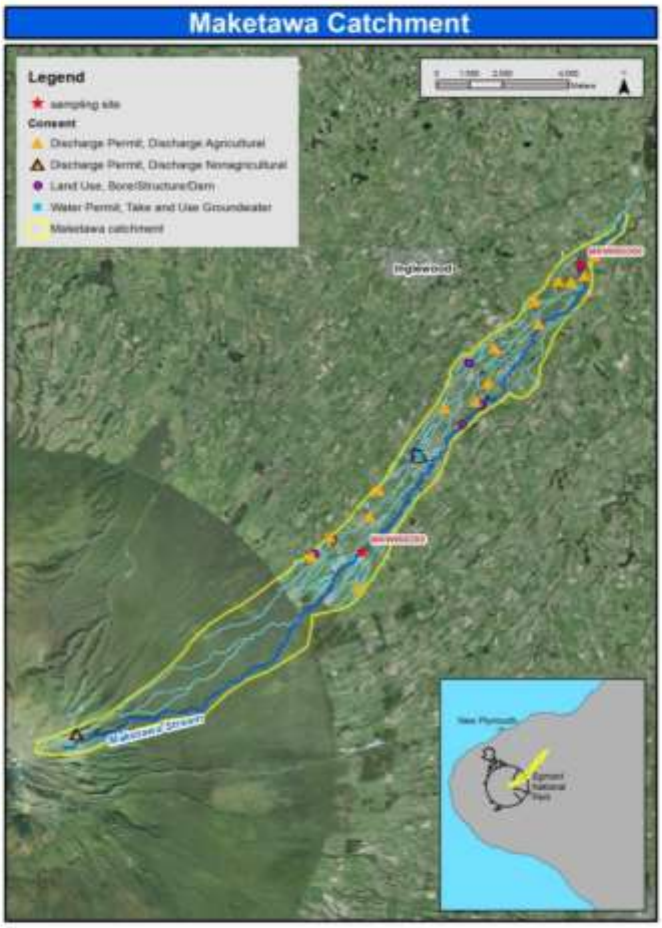


Figure 24 Monitoring site locations in relation to consents operating in the Maketawa Stream catchment Manganui River

2.3.1 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).

Information regarding time of surveys and freshes are presented in Table 14. The spring 2016 survey was unable to be completed due to persistently high spring flows.

Table 14 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	NA	NA	NA
Summer	15/02/2017	12	12
Spring	11/12/2017	33	33
Summer	05/04/2018	12	12

Nutrient data from the SEM physicochemical programme was collected at site MKW000300. The site did not meet the guideline for DRP for a undisturbed (reference) lowland site (ANZECC 2000) (Table 15). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels.

Table 15 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Maketawa Stream

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
Derby Road	380	0.028*	0.449*	0.50*	0.037*	0.423*	0.47*
Tarata Road	150	NA	NA	NA	NA	NA	NA

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

2.3.2 Periphyton cover

During the current monitoring period very low levels of nuisance periphyton were detected at both sites which were well below guideline levels (Figure 25 and Figure 26).

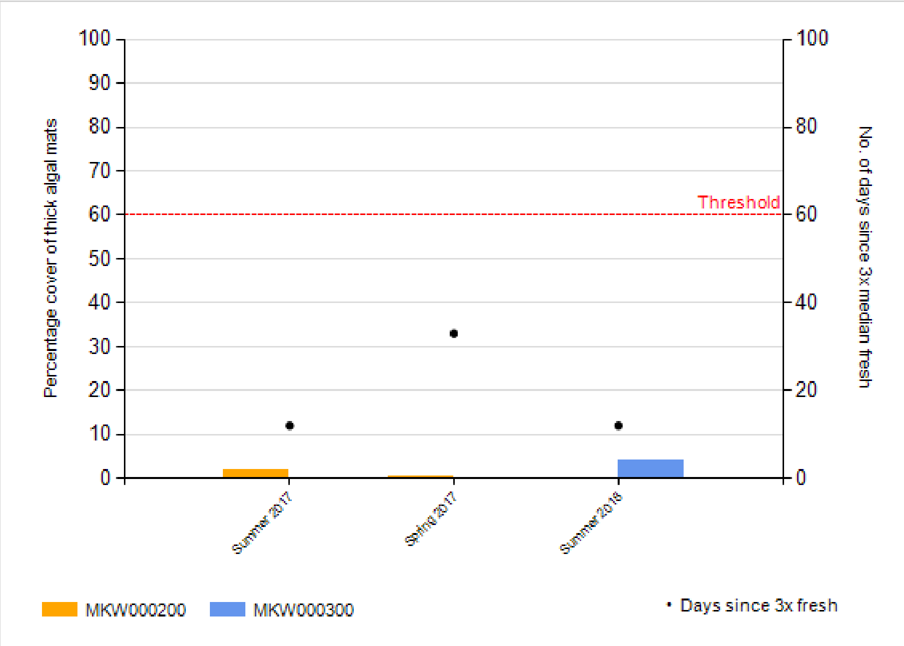


Figure 25 Percentage cover of thick mats of periphyton on the Maketawa streambed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

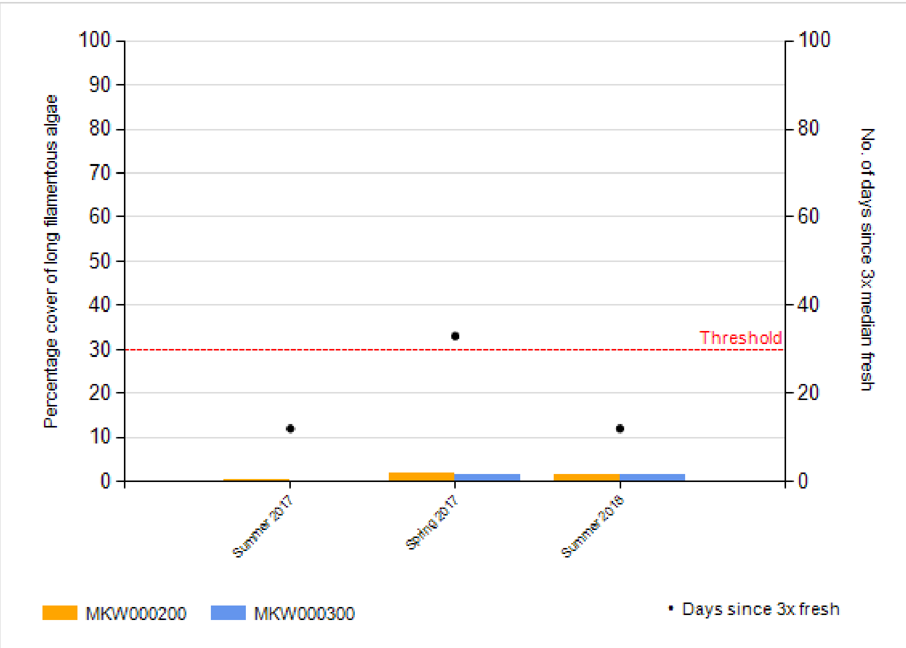


Figure 26 Percentage cover of long filamentous algae on the Maketawa streambed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.3.3 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 16). TRC PI scores were either similar to historical medians for the upstream site while they were higher for the downstream site indicating better than usual periphyton communities and/ or a lack of periphyton coverage. As reflected by both the current monitoring period results and the historical medians, the downstream site (MKW000300) had a consistently lower TRC PI rating but this smaller than in previous years. 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 (Table 16). Historically, 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 16 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 Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
MKW000200	9.7	9.6	9.6	9.9	9.7
MKW000300	9.2	9.3	9.1	8.6	7.5
Difference	0.5	0.3	0.5	1.3	2.2

2.3.4 Periphyton biomass

The results for the current monitoring period found extremely low levels of chlorophyll *a* (3 and 3 chlorophyll *a* mg/m^2) at the upstream site. The downstream levels were higher (25 and 132 chlorophyll *a* mg/m^2) though still well below the NOF standard (Figure 27) but the 2018 sample was above the guideline to protect benthic biodiversity (**Error! Reference source not found.**). The results are congruent with TRC PI scores indicating that the Maketawa Stream generally has only low levels of periphyton but the downstream site has higher levels than the upstream site.

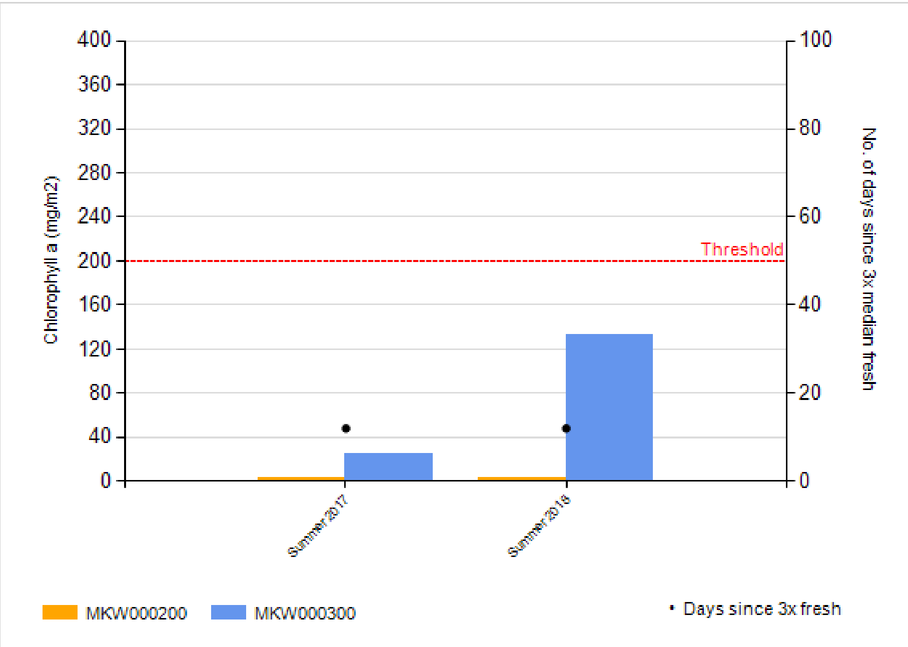


Figure 27 Periphyton biomass (chlorophyll *a*) on the Maketawa riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.3.5 Summary of 2002-2018 (16 year data set)

Thick algal mats have never breached recreational guidelines at the two Maketawa Stream sites surveyed (Figure 28). 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 29). 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. Recently there has been the occasional proliferations of thick algal mats recorded at the downstream site but these have been well below guideline levels.

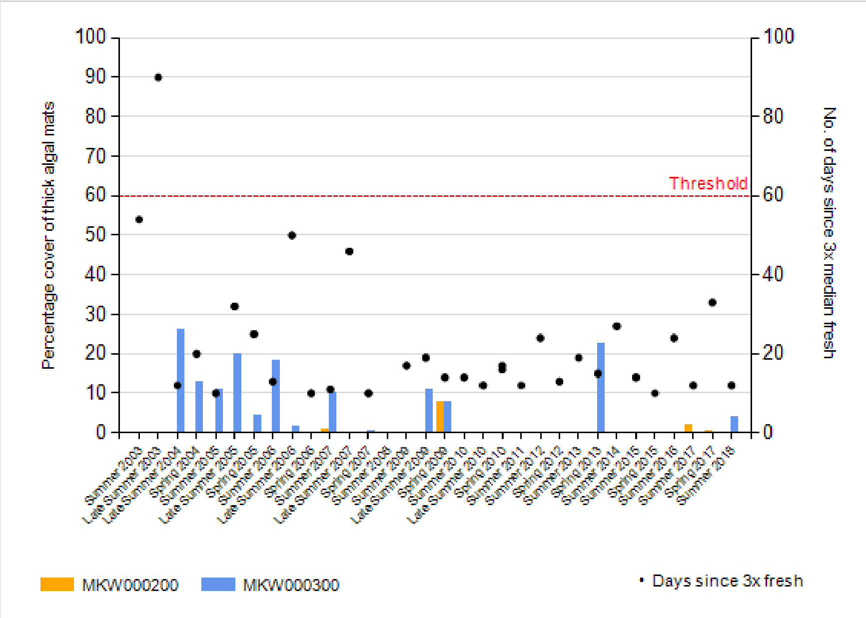


Figure 28 Percentage cover of thick mats of periphyton on the Maketawa streambed in relation to the guidelines for recreational values over the 2002-2018 period

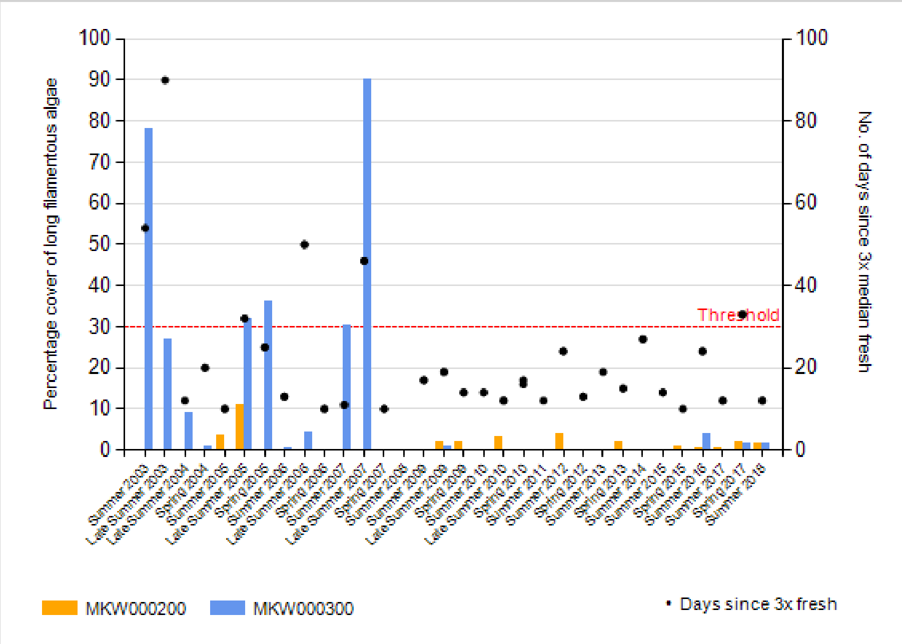
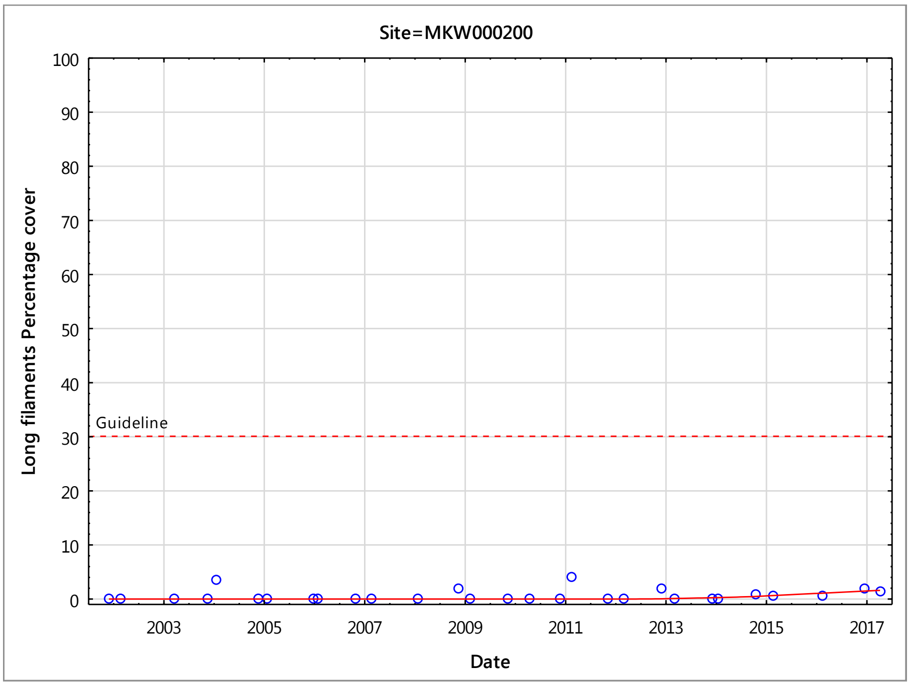


Figure 29 Percentage cover of long filamentous algae on the Maketawa streambed in relation to the guidelines for recreational values over the 2002-2018 period

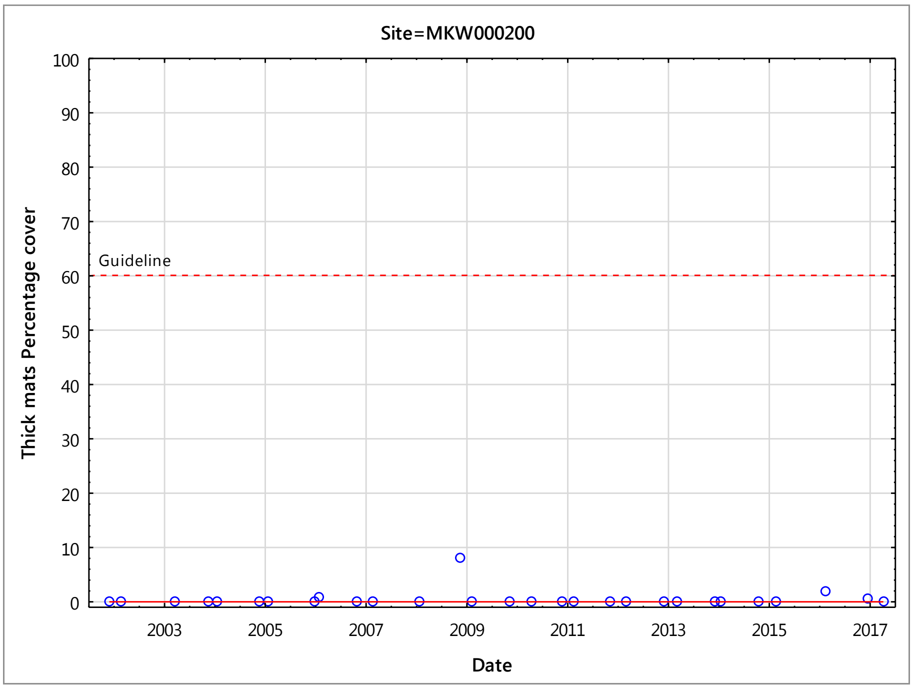
2.3.6 Long term trend analysis

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 Maketawa Stream, at Derby Road and Tarata Road over a 16 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 30 to Figure 33).



n = 29
Kendal tau = 0.15
p-value = 0.24
FDR p-value = 0.35

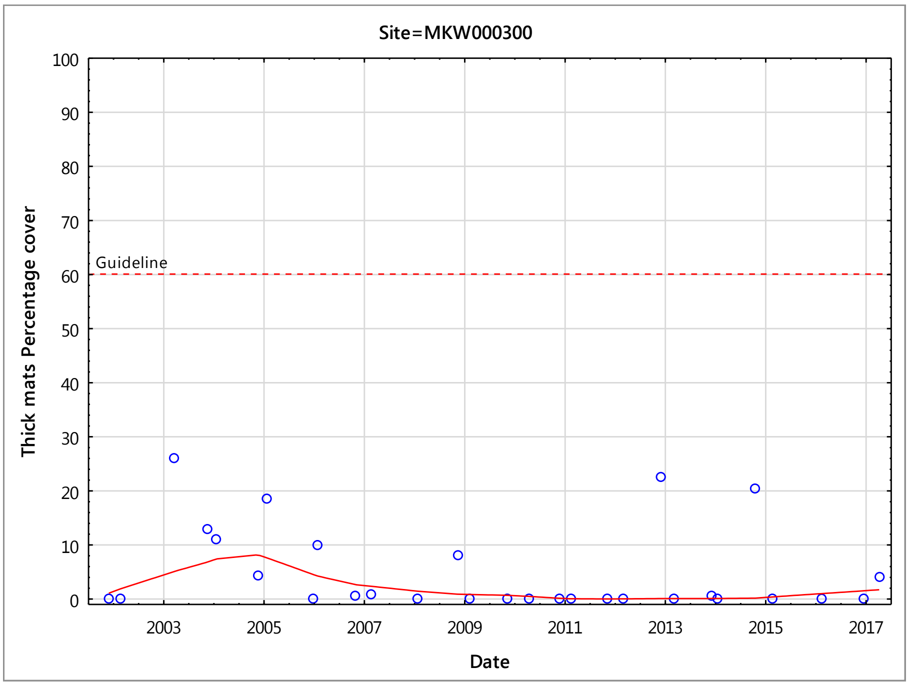
Figure 30 LOWESS trend analysis of percentage cover of thick mats at Maketawa Stream, Derby Road (MKW000200)



n = 29
Kendal tau = 0.33
p-value = 0.01
FDR p-value = 0.07

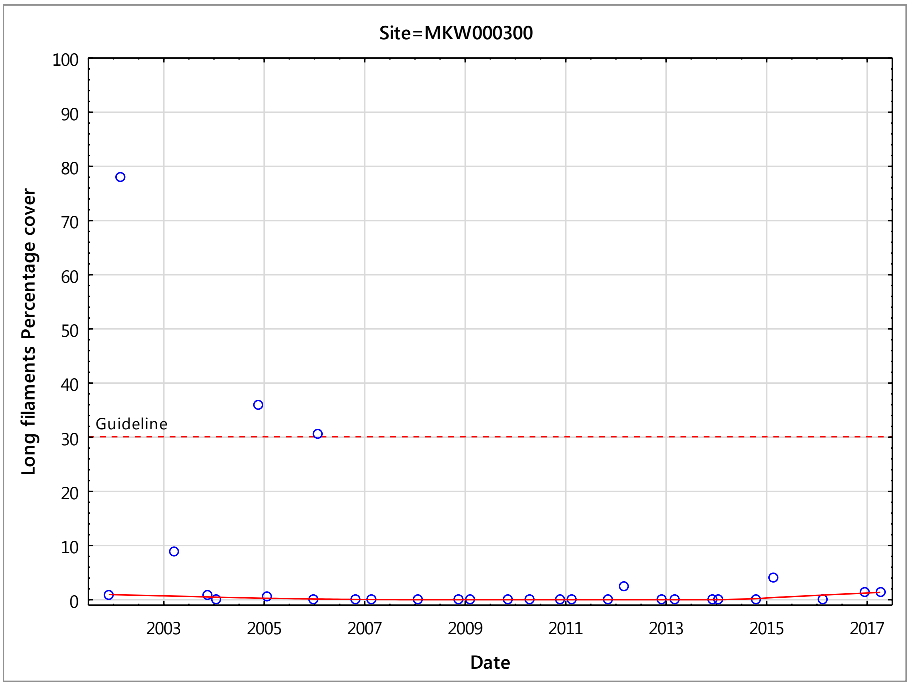
Figure 31 LOWESS trend analysis of percentage cover of long filaments at Maketawa Stream, Derby Road (MKW000200)

At Derby Road (MKW000200) over the 16 year monitored period there were no significant trends for thick mats (p=0.35) or long filaments (p=0.07) at the 5% level of significance after false discovery rate adjustment.



n = 29
Kendal tau = -0.23
p-value = 0.08
FDR p-value = 0.20

Figure 32 LOWESS trend analysis of percentage cover of thick mats at Maketawa Stream, Tarata Road (MKW000300)



n = 29
Kendal tau = -0.22
p-value = 0.10
FDR p-value = 0.28

Figure 33 LOWESS trend analysis of percentage cover of long filaments at Maketawa Stream, Tarata Road (MKW000300)

At Tarata Road (MKW000300) over the 16 year monitored period there was no significant trend for thick mats (p=0.20) or long filaments (p=0.28) at the 5% level of significance after false discovery rate adjustment.

2.4 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 34).

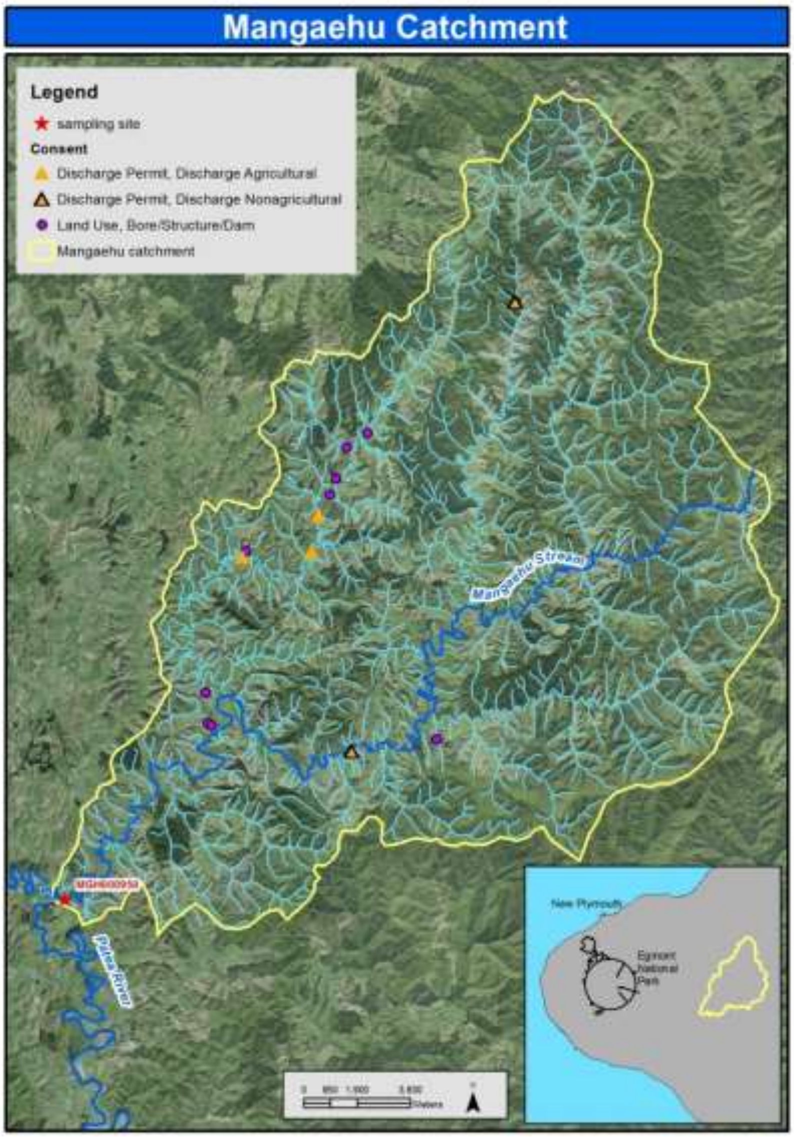


Figure 34 Monitoring site in the Mangaehu River catchment

2.4.1 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). Information regarding time of surveys and freshes are presented in Table 17.

Table 17 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	15/12/2016	25	88
Summer	06/01/2017	48	110
Spring	08/11/2017	40	40
Summer	14/02/2018	37	39

Nutrient data from the SEM physicochemical programme is collected at the site. The site met the guidelines for DIN (dissolved inorganic nitrogen, or ammonium+nitrate), total nitrogen and DRP for an undisturbed (reference) lowland site (ANZECC 2000) (Table 18). 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.

Table 18 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Stoney River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
Raupuha Road	120	0.001	0.141	0.31	0.007	0.176	0.28

2.4.2 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 35 and Figure 36).

For the 2016-2017 monitoring period both thick mats and long filaments came very close to breaching the guidelines for the spring 2016 survey and thick mats breached guidelines during the summer 2017 survey. For the 2017-2018 monitoring period thick mats breached guidelines during the spring 2017 survey and while there was no breaches during the summer 2018 survey.

There was a long period between high flows and surveys which would have allowed periphyton proliferation though in previous reports (e.g. TRC 2016), freshes did not seem to be significantly influencing nuisance periphyton levels and very large flows well in excess of 7x median flow are probably needed to scour the riverbed of periphyton at this site.

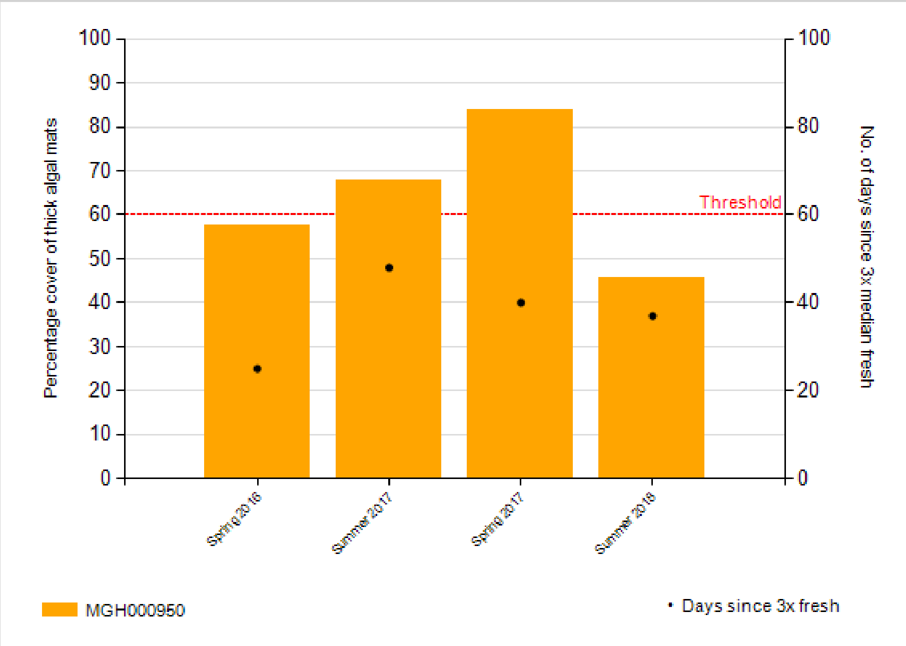


Figure 35 Percentage cover of thick mats of periphyton on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

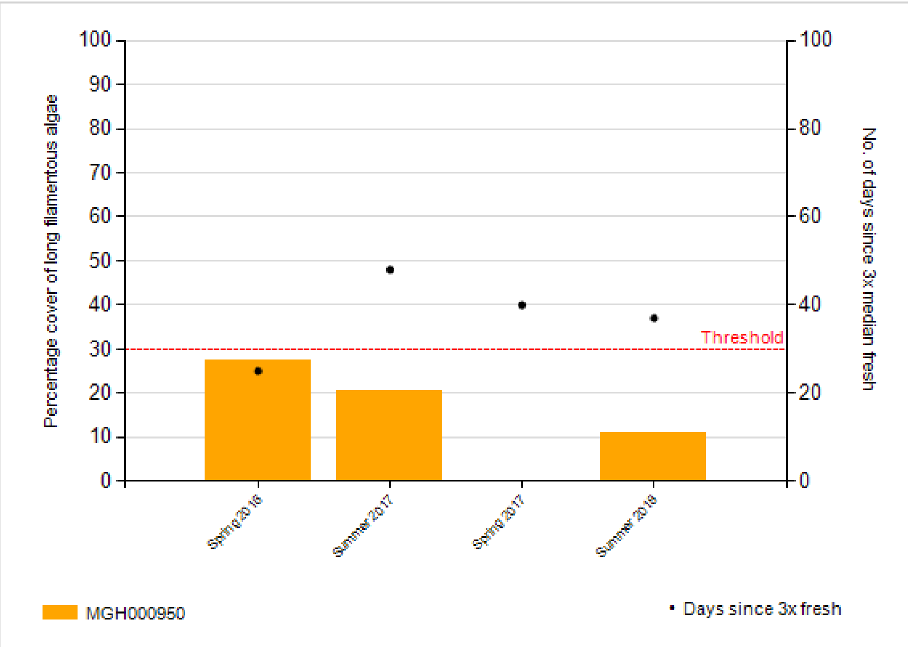


Figure 36 Percentage cover of long filamentous algae on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.4.3 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 among surveys but no discernible pattern between spring and summer surveys (Table 19).

In spring 2016 a 'moderate' TRC PI score was recorded which was well below the historical spring median and in summer 2017 a 'moderate' score was also recorded that was close to the historical summer median. In spring 2017 a 'moderate' TRC PI score was recorded which was below the historical spring median and in summer 2016 a 'good' score was recorded that was above the summer the historical median.

No 'poor' ratings occurred for the 2016-2018 period which was consistent with the previous reported period 2014-2016. The moderately low TRC PI scores for the first three surveys were generally caused by an abundance of thick mats but long filamentous algae was also present, particularly in the spring 2016 survey.

Table 19 Median seasonal periphyton index scores for the Mangaehu River

Site	TRC PI Spring 2016	TRC PI Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
MGH000950	4.0	4.3	4.9	6.8	7.2	4.5

2.4.4 Periphyton biomass

The results for the 2016- 2018 period showed moderate to high chlorophyll *a* levels (Figure 37). The summer 2017 survey breached guidelines to protect trout habitat/angling values (**Error! Reference source not found.**) and the NOF bottom line (MfE, 2014) while the summer 2018 survey breached the benthic biodiversity value (**Error! Reference source not found.**).

The chlorophyll *a* levels somewhat reflected nuisance periphyton and TRC PI levels though the relationship was not linear.

A possible reason for the lack of a strong relationship included 1) large amounts of dead periphyton present at the site that would not contain chlorophyll *a* but would still count for periphyton cover or 2) 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.).

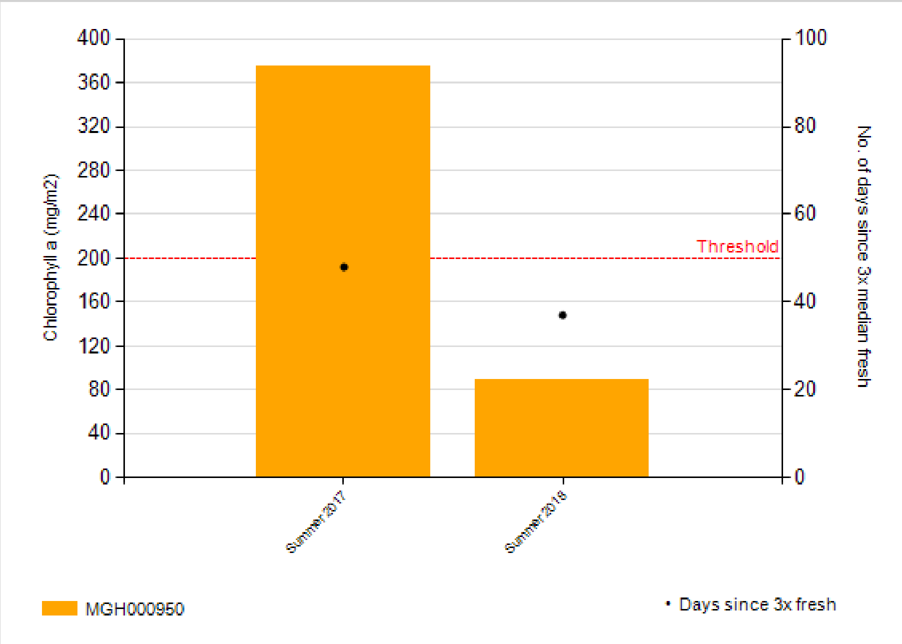


Figure 37 Periphyton biomass (chlorophyll *a*) on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.4.5 Summary of 2002-2018 (16 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 38 and Figure 39). There had been two pervious breaches of thick mats at the site though several survey results had come close to breaching the guideline. For the current survey period there were two thick mat breeches in the guidelines with all four surveys recording thick algal mats above 45% of total streambed cover. 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 16 year monitoring period but the last breach was several years ago, in the summer 2009 survey. These occurrences were restricted to summer periods. No breaches of long filamentous algae occurred in the 2016-2018 monitoring period though the spring 2016 survey came close to breaching guidelines.

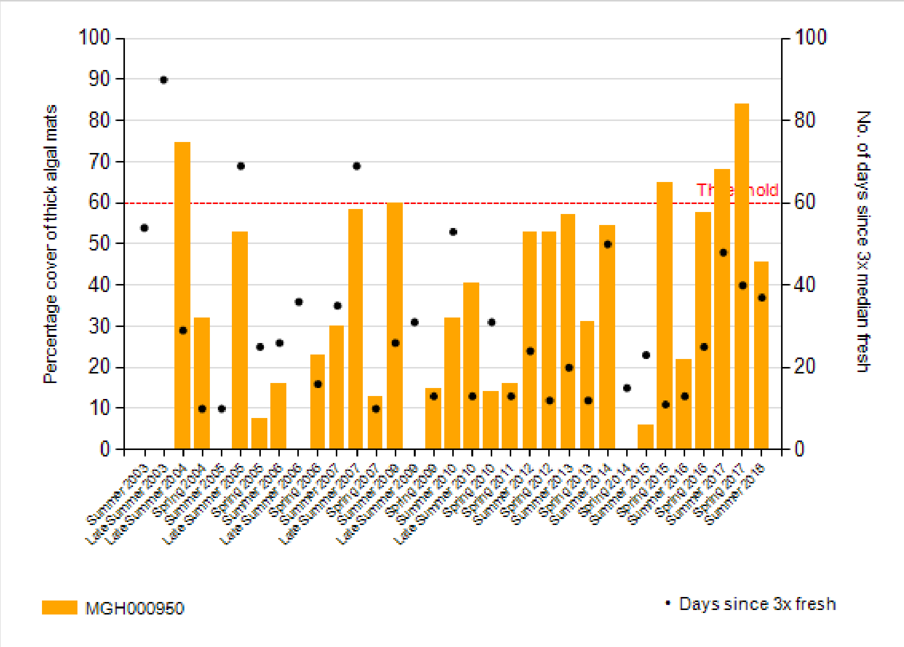


Figure 38 Percentage cover of thick mats of periphyton on the Mangaehu riverbed in relation to the guidelines for recreational values over the 2002-2018 period

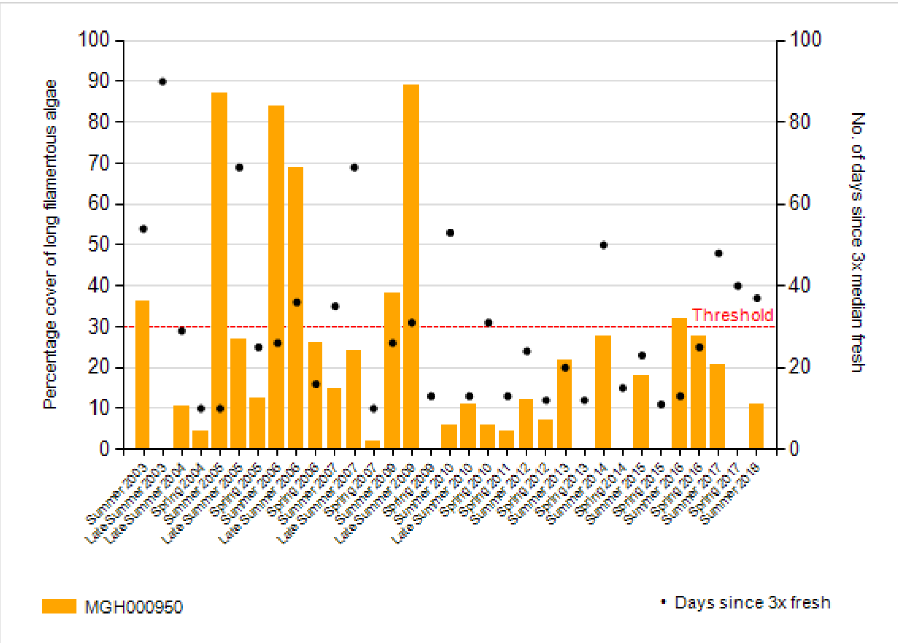
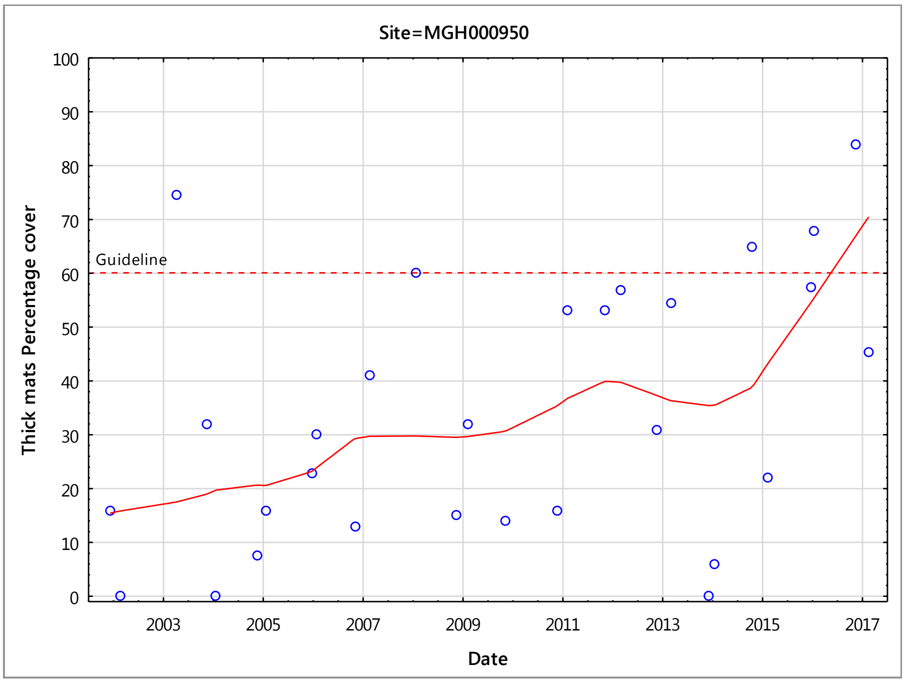


Figure 39 Percentage cover of long filamentous periphyton on the Mangaehu riverbed in relation to the recreational guideline over the 2002-2018 monitoring period

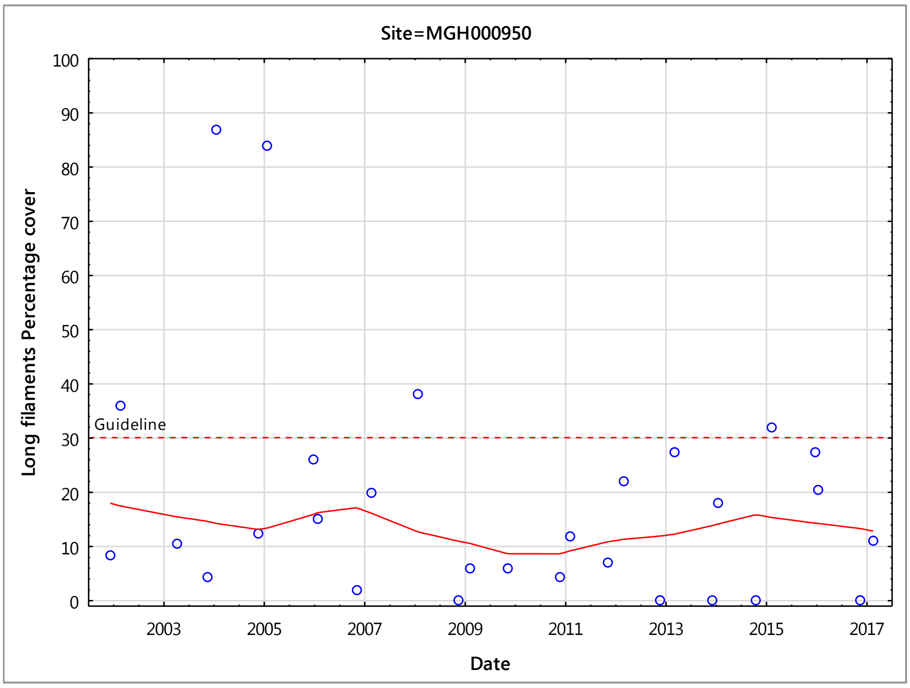
2.4.6 Long term trend analysis

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 Mangaehu River, at Raupuha Road over a 16 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 40 and Figure 41).



n = 29
Kendal tau = 0.33
p-value = 0.01
FDR p-value = 0.11

Figure 40 LOWESS trend analysis of percentage cover of thick mats at Mangaehu River, Raupuha Rd (MGH000950)



n = 29
Kendal tau = -0.13
p-value = 0.33
FDR p-value = 0.47

Figure 41 LOWESS trend analysis of percentage cover of long filaments at Mangaehu River, Raupuha Rd (MGH000950).

At Raupuha Road (MGH000950) over the 16 year monitored period there were no significant trends for thick mats (p=0.11) or long filaments (p=0.47) at the 5% level of significance after false discovery rate adjustment.

2.5 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 42). 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.

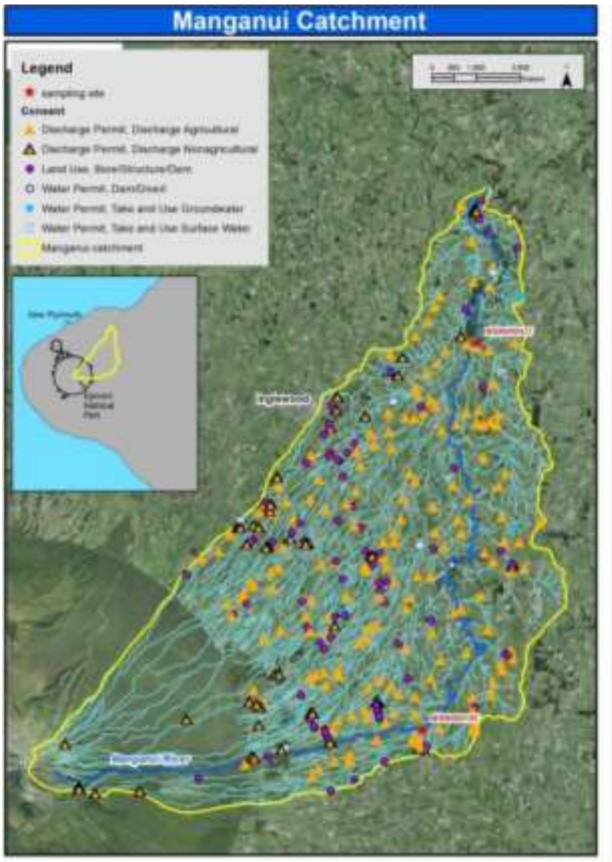


Figure 42 Monitoring site locations in relation to consents operating in the Manganui River catchment

2.5.1 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).

Information regarding time of surveys and freshes are presented in Table 20. The spring 2016 survey was not able to be completed due to persistently high spring flows.

Table 20 Date, and time since three and seven times median flow

Season	Date	3x	7x
Spring	NA	NA	NA
Summer	14/02/2017	12	12
Spring	11/12/2017	33	33
Summer	03/04/2018	12	12

NIWA collects physicochemical water quality data at the Manganui River at SH 3 as part of their long term national river networks program. A range of parameters are collected including dissolved reactive phosphorus (DRP), nitrate (NO_3), nitrite (NO_2), ammonia (NH4-N) and total nitrogen (TN). The site met the guideline for total nitrogen for an undisturbed (reference) upland site but not for dissolved reactive phosphorus (ANZECC 2000) (Table 21). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels.

Table 21 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Manganui River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
SH3#	330	0.010*	0.161*	0.202	0.010*	0.118*	0.178
Bristol Road	140	n/a	n/a	n/a	n/a	n/a	n/a

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

NIWA data up to 31st December 2017.

2.5.2 Periphyton cover

The Manganui River had no nuisance periphyton in the upper catchment at SH3 and low levels of nuisance periphyton at the lower site at Bristol Road (Figure 43 and Figure 44).

In the 2016-2017 monitoring year the downstream site had very low levels of long filaments during the summer 2017 survey. In the 2017-2018 monitoring year the downstream site extremely low levels of long filaments during the spring 2017 survey and low levels of thick mats and long filaments during the summer 2018 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 and nutrient levels has caused significant nuisance periphyton growth at this site in the past. However, only low levels of nuisance periphyton were detected for all four surveys during the current monitoring period.

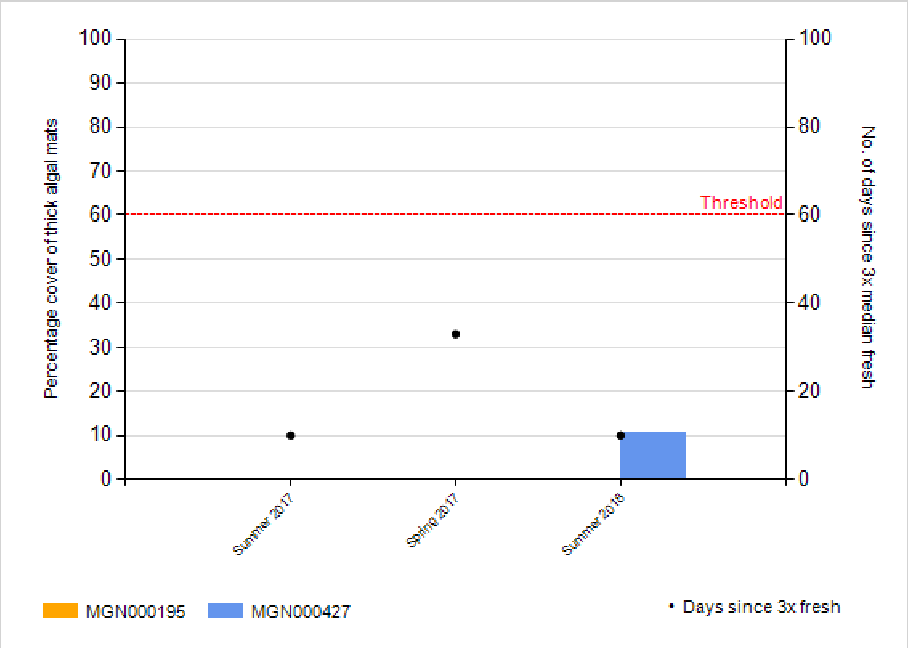


Figure 43 Percentage cover of thick mats of periphyton on the Manganui riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

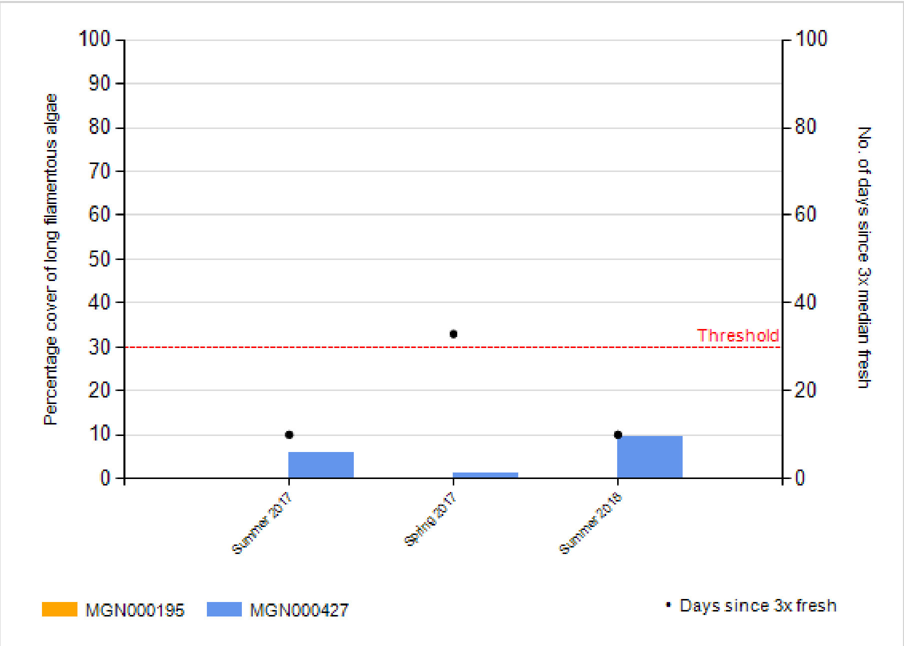


Figure 44 Percentage cover of long filamentous algae on the Manganui riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.5.3 Periphyton Index Score

The upstream site had 'very good' levels of periphyton while the downstream site had 'very good' to 'good' levels. This was relatively consistent with past results as indicated by the spring and summer historical medians though the lower sited had slightly higher TRC PI values than was typical for the site.

Manganui River typically recorded moderate differences in TRC PI between the upstream and downstream sites (Table 22). 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. There was a small difference between spring and summer surveys but the lack of a spring 2016 survey makes any comparison difficult. 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 22 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 Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
MGN000195	10	10	10	9.9	9.8
MGN000427	8.3	6.7	7.1	6.1	6.2
Difference	1.7	3.3	3.9	3.8	3.6

2.5.4 Periphyton biomass

The results for the 2016-2018 monitoring period found extremely low levels of chlorophyll *a* at the upstream site (3-5 mg/m^2) and a moderate level at the downstream site during the summer 2017 survey which breached the guideline for benthic biodiversity protection (**Error! Reference source not found.**) (Figure 45). The summer 2018 survey sample for the downstream site was lost while in the laboratory and an additional sample could not be taken as the surveying period had finished. The results were largely congruent with the findings from the TRC periphyton index score.

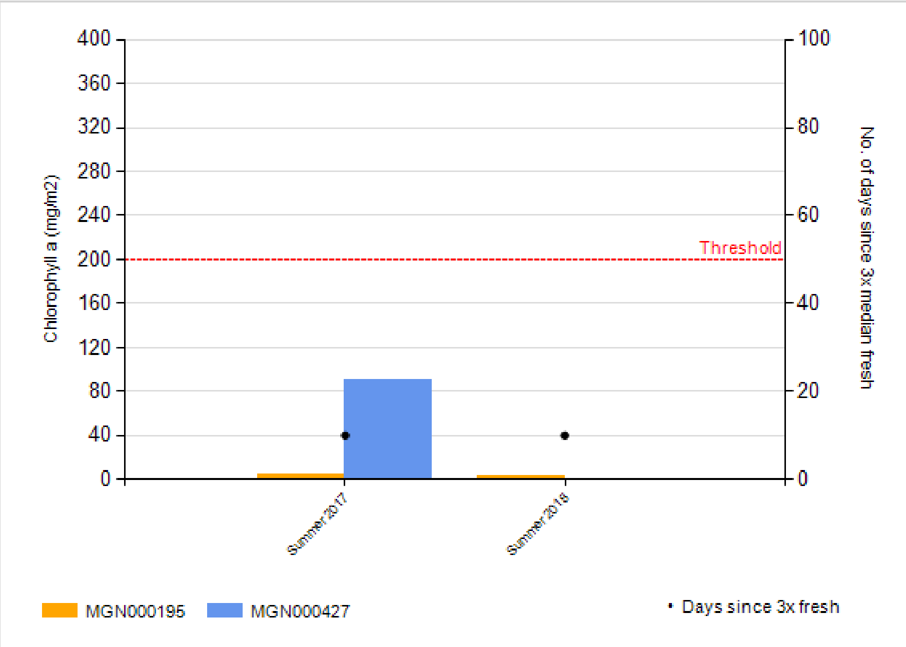


Figure 45 Periphyton biomass (chlorophyll *a*) on the Manganui riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.5.5 Summary of 2002-2018 (16 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 46 and Figure 47). 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 16 year period.

The upper site had no filamentous algae present. However, the lower catchment site breached long filamentous guidelines on four occasions in earlier years over the 16 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 16 year survey period. There was also nearly a breach for the preceding summer 2015 survey.

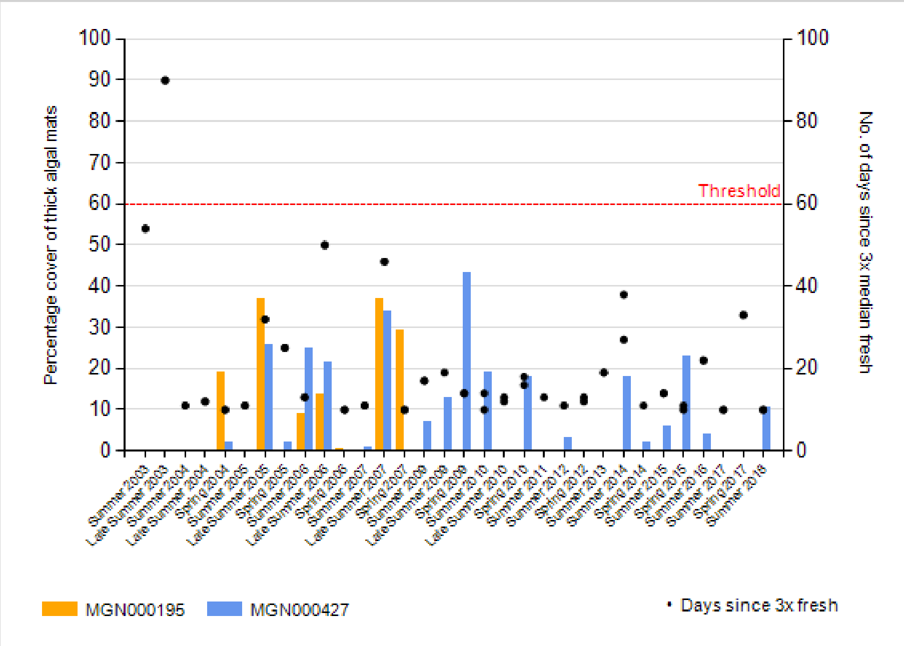


Figure 46 Percentage cover of thick mats of periphyton on the Manganui riverbed in relation to the guidelines for recreational values over the 2002-2018 period

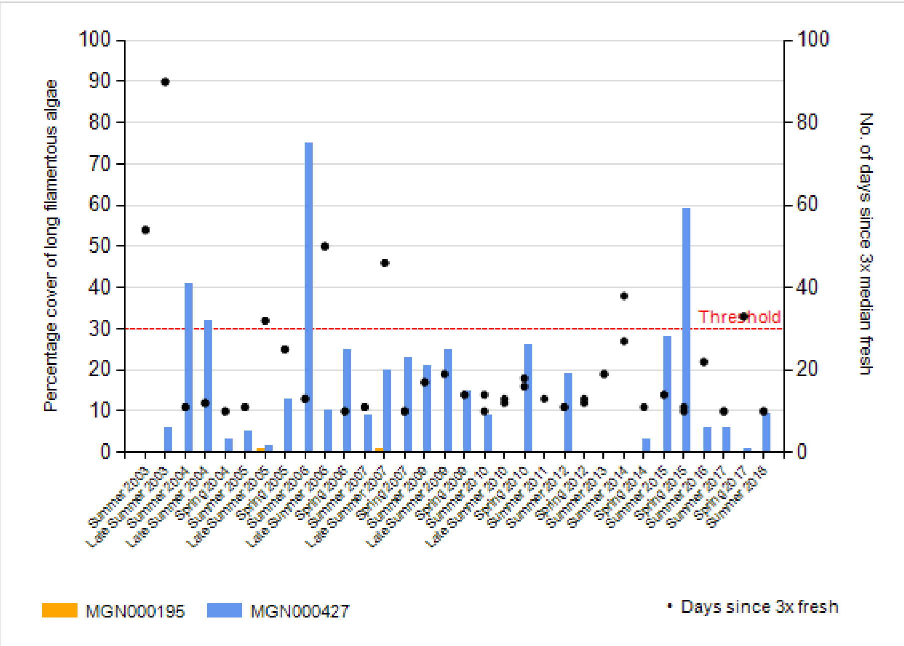
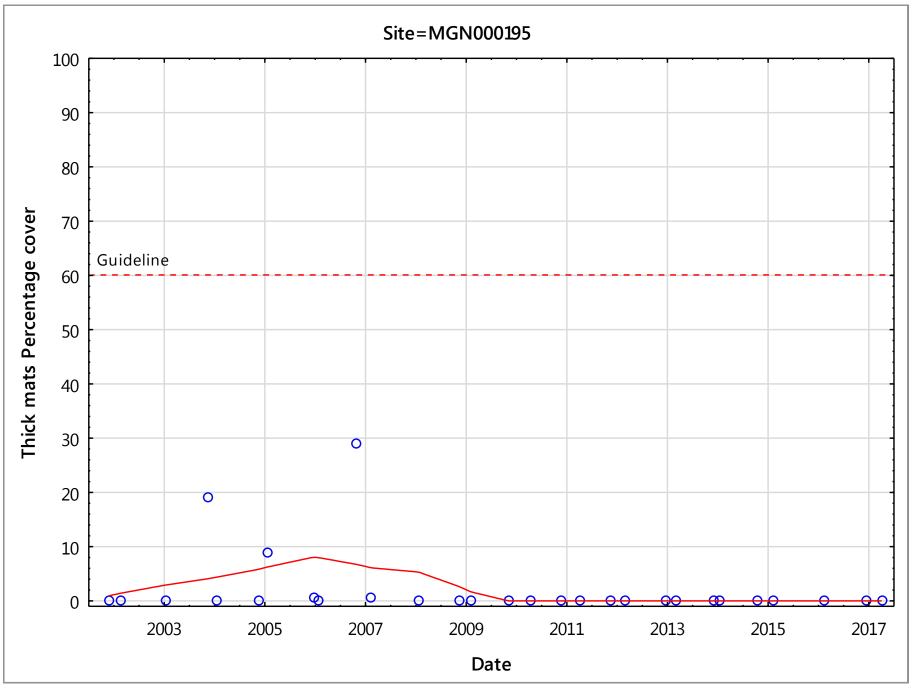


Figure 47 Percentage cover of long filamentous algae on the Manganui riverbed in relation to the guidelines for recreational values over the 2002-2018 period

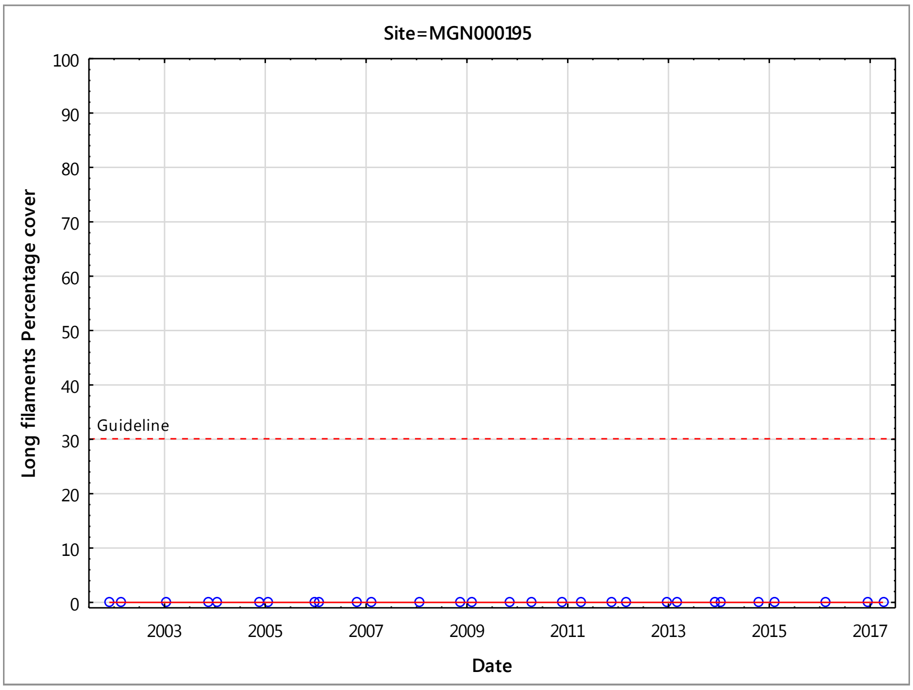
2.5.6 Long term trend analysis

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 Manganui River, at SH3 and at Bristol Road, over a 16 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 = 29
Kendal tau = -0.32
p-value = 0.02
FDR p-value = 0.11

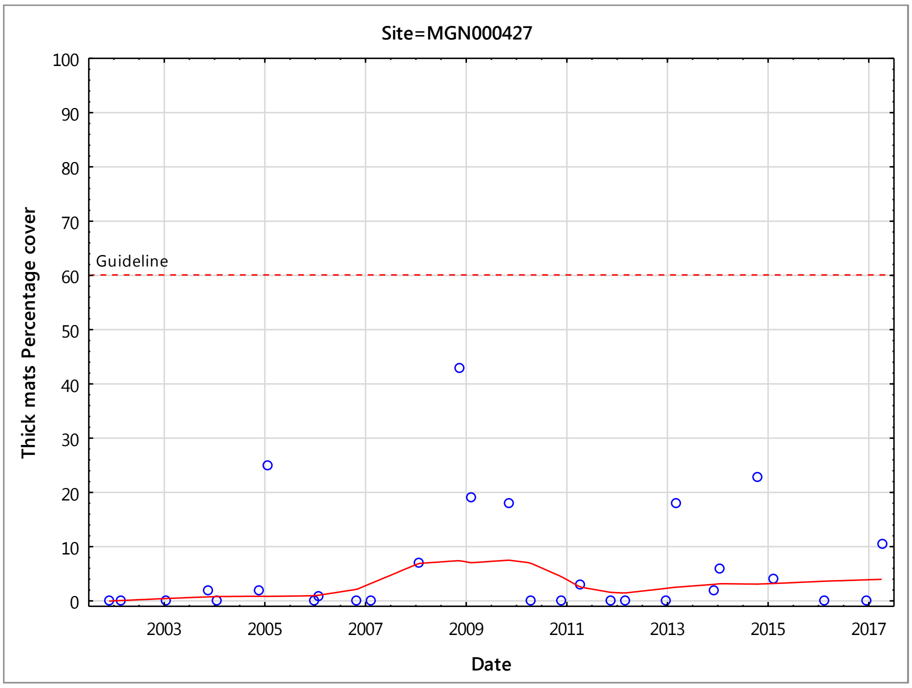
Figure 48 LOWESS trend analysis of percentage cover of thick mats at Manganui River, SH3 (MGN000195)



n = 29
Kendal tau =
p-value =
FDR p-value =

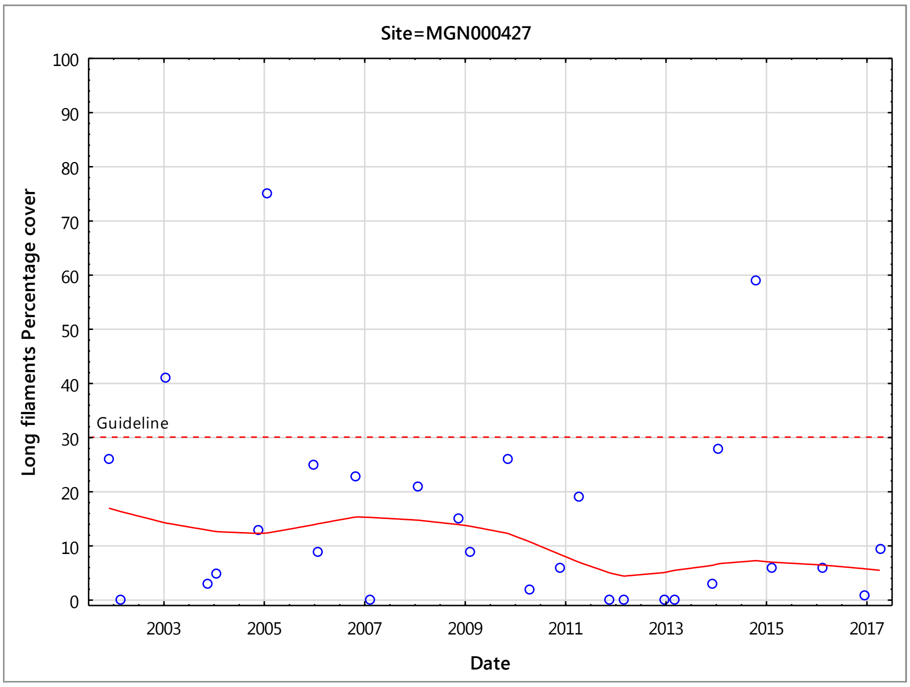
Figure 49 LOWESS trend analysis of percentage cover of long filaments at Manganui River, SH3 (MGN000195)

At SH3 (MGN000195) over the 16 year monitored period there have been no significant trend for thick mats (p=0.11) and no long filaments were recorded at the site. It should be noted that only spring and summer surveys were used in the analysis and therefore late summer surveys, which occurred between 2002- 2012, are not included in the analysis. These did have some very minor levels of long filamentous algae present.



n = 29
Kendal tau = 0.15
p-value = 0.26
FDR p-value = 0.35

Figure 50 LOWESS trend analysis of percentage cover of thick mats at Manganui River, Bristol Road (MGN000427)



n = 29
Kendal tau = -0.15
p-value = 0.26
FDR p-value = 0.43

Figure 51 LOWESS trend analysis of percentage cover of long filaments at Manganui River, Bristol Road (MGN000427)

At Bristol Road (MGN000427) over the 16 year monitored period there were no significant trends for thick mats (p=0.35) or long filaments (p=0.43) at the 5% level of significance after false discovery rate adjustment.

2.6 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 52). 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.

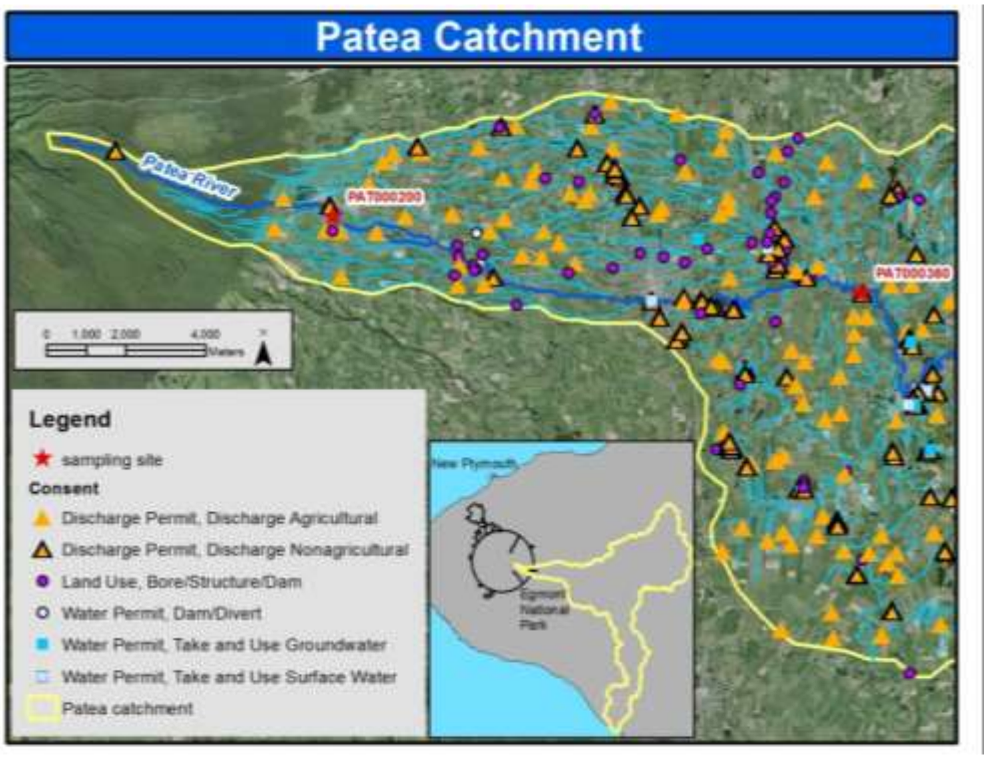


Figure 52 Monitoring site locations in relation to consents operating in the Patea River catchment

2.6.1 Flow and nutrient data and survey dates

The Patea River has a telemetered hydrological monitoring station at Skinner Road. Information regarding time of surveys and freshes are presented in Table 23.

Table 23 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	22/12/2016	11	26
Summer	06/01/2017	14	14
Spring	24/10/2017	13	15
Summer	03/04/2018	10	27

Nutrient data from the SEM physicochemical programme is collected at sites PAT000200 and PAT000360. The upper site met the guideline for total nitrogen for an undisturbed (reference) upland site but not for DRP and the lower site did not meet guidelines for undisturbed (reference) site total nitrogen or DRP (ANZECC 2000) (Table 24). 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 both higher DRP and nitrogen levels which probably can be attributed to the cumulative point source discharge from the Stratford wastewater treatment plant and agricultural inputs.

Table 24 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Patea River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
Barclay Road	500	0.020*	0.022	0.06	0.022*	0.022	0.06
Skinner Road	240	0.035*	1.111*	1.22*	0.043*	0.920*	1.18*

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

2.6.2 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 any of the four surveys but the downstream site at Skinner Road had low levels of both thick mats and long filaments present for all of the surveys which fluctuated slightly in level between surveys. These were well below recommended guidelines (Figure 53 and Figure 54).

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 although 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 of the site (240m asl) and relatively cool water temperatures which would help slow the growth of periphyton at the lower site.

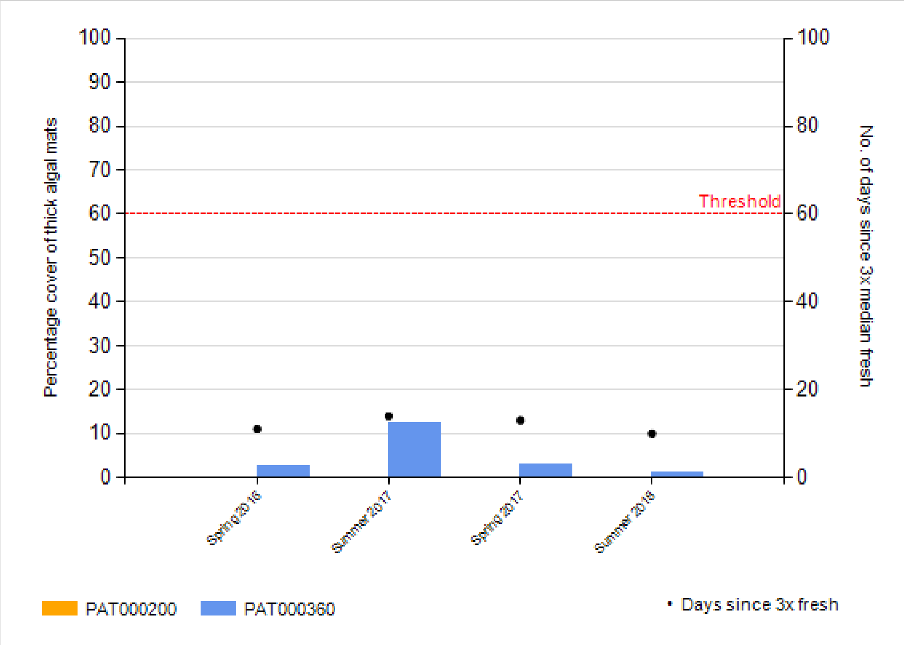


Figure 53 Percentage cover of thick mats of periphyton on the Patea riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

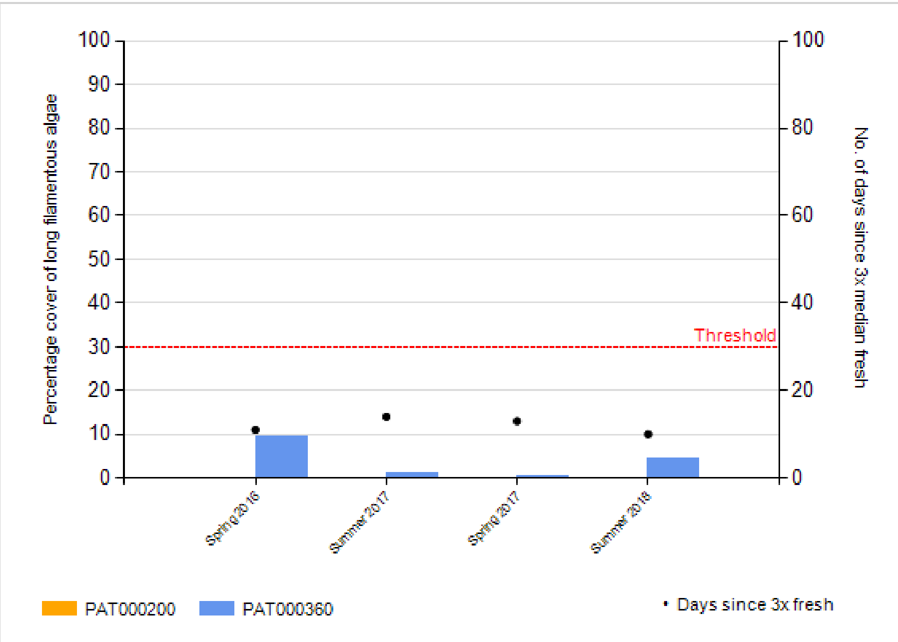


Figure 54 Percentage cover of long filamentous algae on the Patea riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.6.3 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 scores. 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 25).

Table 25 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 2016	TRC PI Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
PAT000200	9.8	10.0	9.8	10.0	9.6	9.8
PAT000360	7.7	8.4	9.5	8.0	7.8	5.2
Difference	2.1	1.6	0.3	2.0	1.8	4.6

The upstream site had TRC PI results similar to historical medians for all surveys but the downstream site had significantly better summer results. 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.

2.6.4 Periphyton biomass

The results for the 2016- 2018 monitoring period found very low levels of chlorophyll *a* (5 mg/m^2) at the upstream site and moderate levels (29-117 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 (**Error! Reference source not found.**) was exceeded for the bottom site during the summer 2018 survey.

Chlorophyll *a* levels matched TRC PI scores for the upper site indicating very low periphyton levels. For the lower site while chlorophyll *a* was considerably higher for the summer 2018 survey compared with the summer 2017 survey (107 mg/m^2) while there was only minimal difference in in the TRC PI score. The previous report (TRC, 2016) 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.

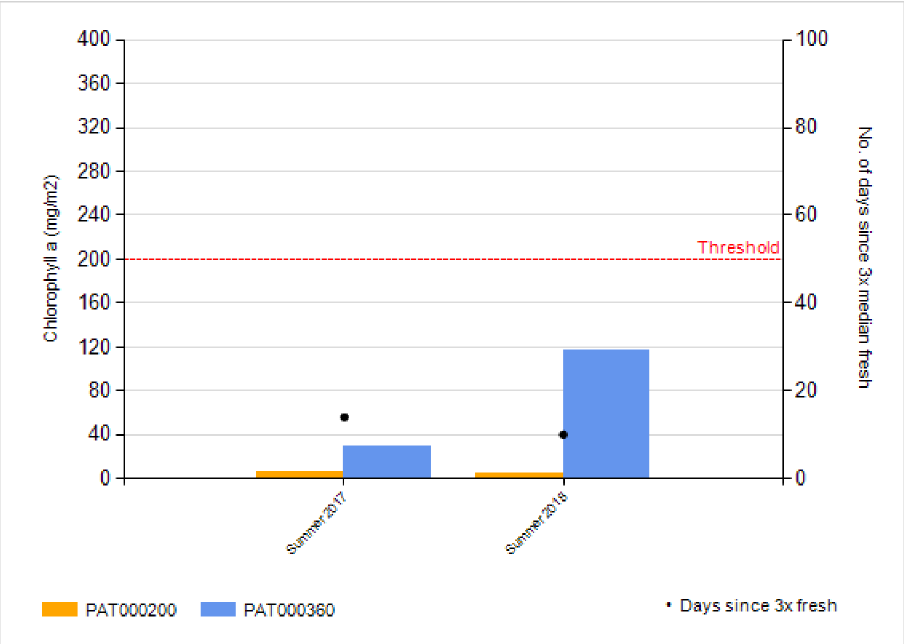


Figure 55 Periphyton biomass (chlorophyll *a*) on the Patea riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.6.5 Summary of 2002-2018 (16 year data set)

Over the entire period the Patea River had never breached thick algal mat periphyton guidelines (Figure 56). 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 2014-2016 monitoring period no nuisance periphyton was detected at the upper site but thick mats and long filaments were recorded at the bottom site. For the current monitoring period no nuisance periphyton was detected at the upper site but low levels of 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 16 year period of monitoring (particularly during the earlier monitoring years) (Figure 57). 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). There was a breach at the Skinner Road site in summer 2014 which corresponded with a long period without flushing flows. There were no breaches for the current reporting period.

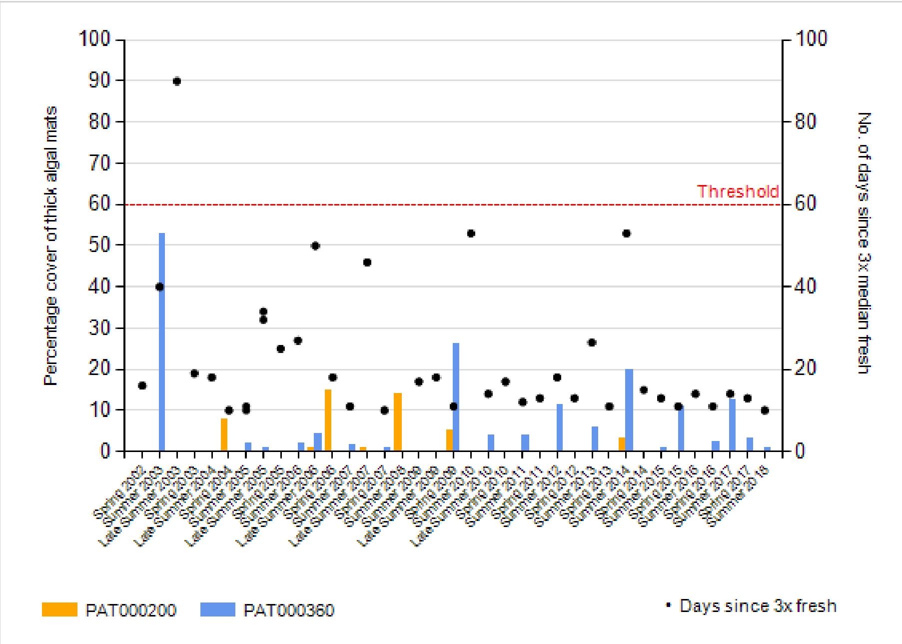


Figure 56 Percentage cover of thick mats of periphyton on the Patea riverbed in relation to the guidelines for recreational values over the 2002-2018 period

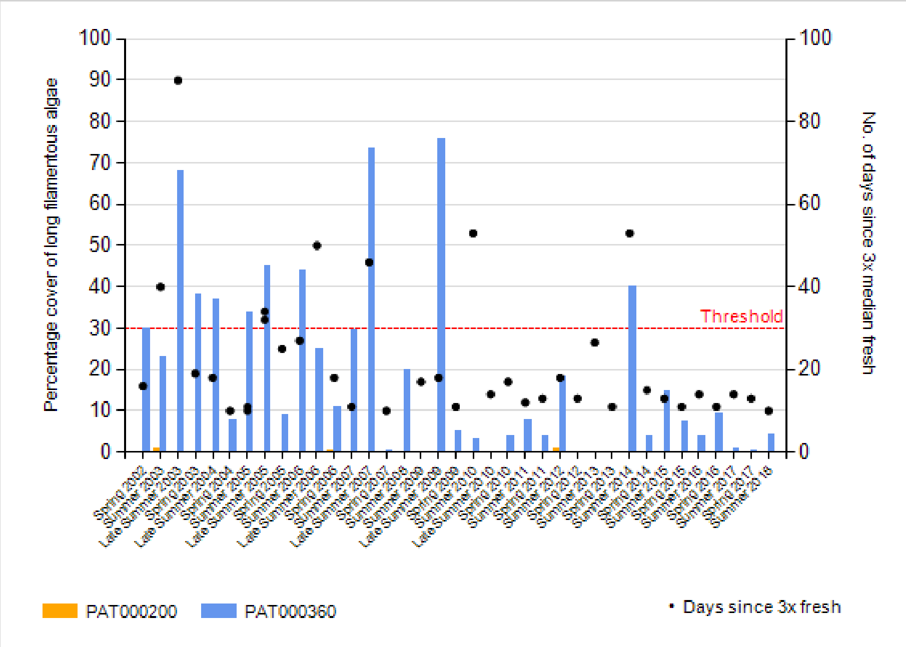
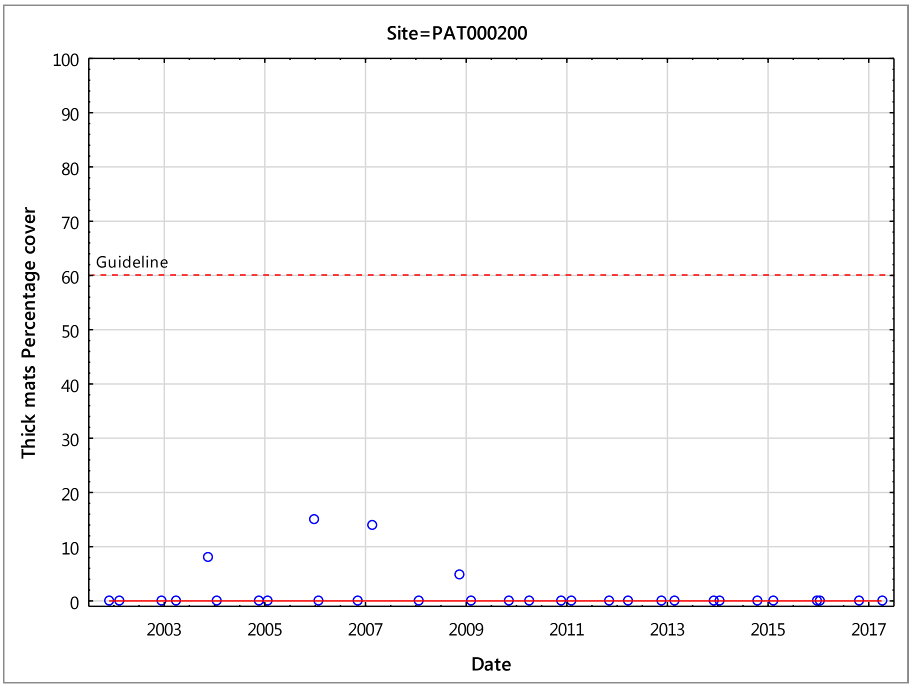


Figure 57 Percentage cover of long filamentous periphyton on the Patea River streambed in relation to the guideline for recreational values over the 2002-2018 period

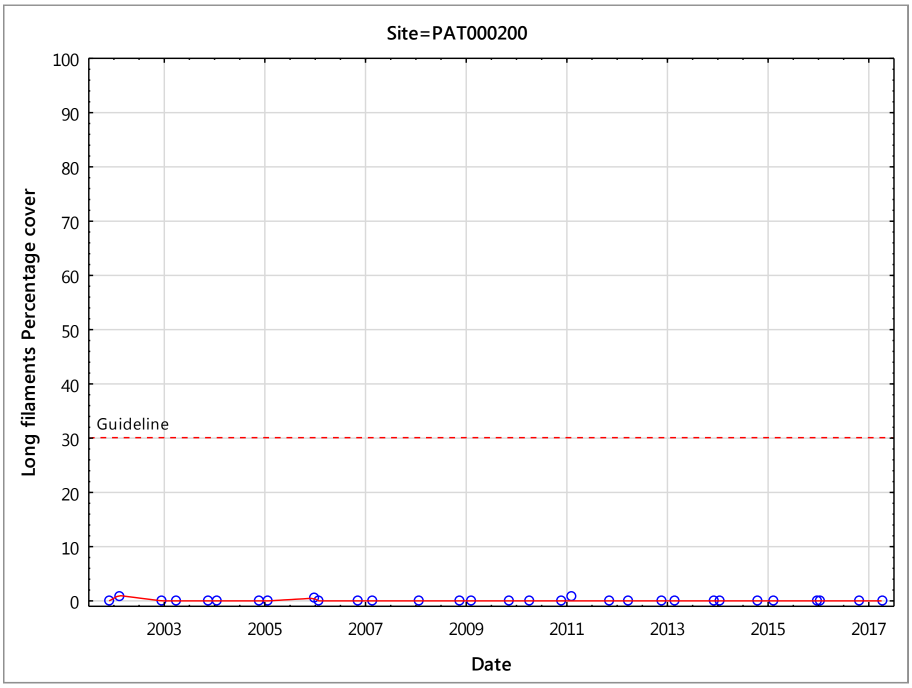
2.6.6 Long term trend analysis

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 Patea River, at Barclay Road, and Skinner Road over a 16 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 61).



n = 31
Kendal tau = -0.22
p-value = 0.09
FDR p-value = 0.20

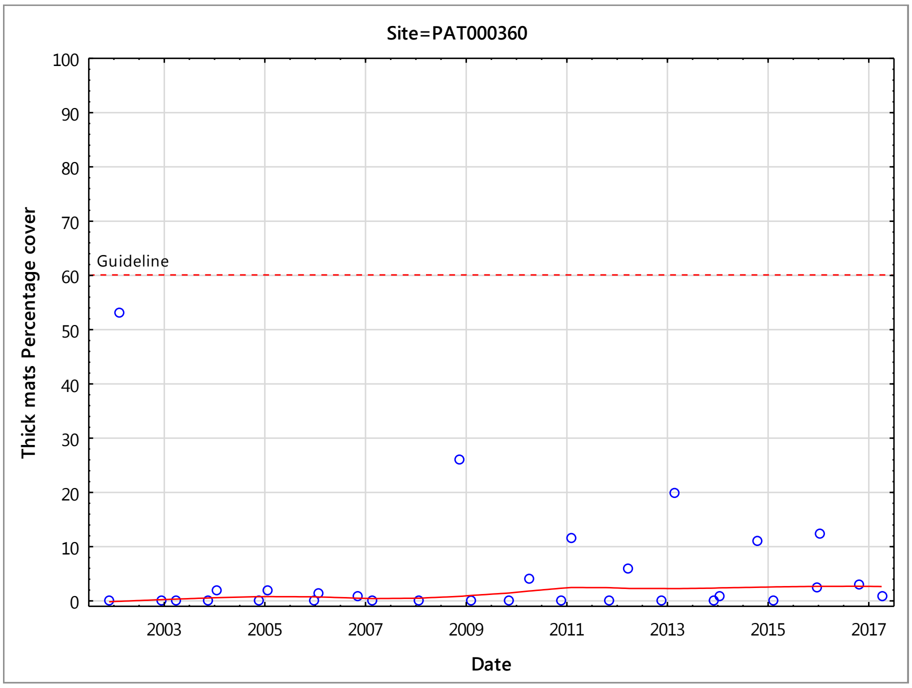
Figure 58 LOWESS trend analysis of percentage cover of thick mats at Patea River, Barclay Road (PAT000200)



n = 31
Kendal tau = -0.18
p-value = 0.16
FDR p-value = 0.32

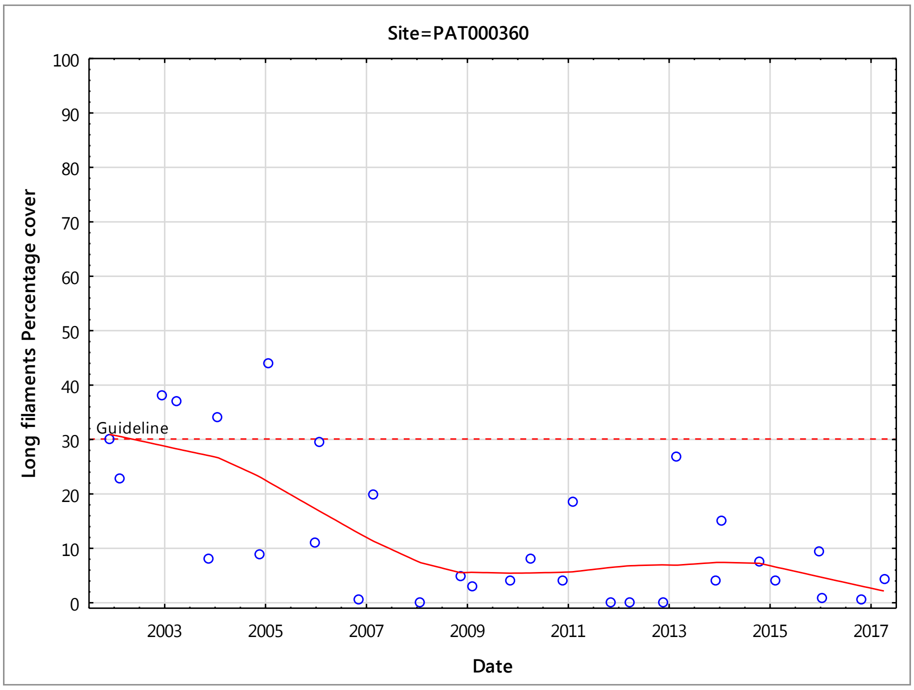
Figure 59 LOWESS trend analysis of percentage cover of long filaments at Patea River, Barclay Road (PAT000200)

At Barclay Road (PAT000200) over the 16 year monitored period there were no significant trends for thick mats (p=0.20) or long filaments (p=0.32) at the 5% level of significance after false discovery rate adjustment.



n = 31
Kendal tau = 0.19
p-value = 0.13
FDR p-value = 0.21

Figure 60 LOWESS trend analysis of percentage cover of thick mats at Patea River, Skinner Road (PAT000360)



n = 31
Kendal tau = -0.38
p-value < 0.01
FDR p-value = 0.03

Figure 61 LOWESS trend analysis of percentage cover of long filaments at Patea River, Skinner Road (PAT000360)

At Skinner Road (PAT000360) over the 16 year monitored period there was no significant trend for thick mats (p=0.21) at the 5% level of significance after false discovery rate adjustment. However, there was a significant (p<0.01) negative (tau=-0.38) 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.

2.7 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.

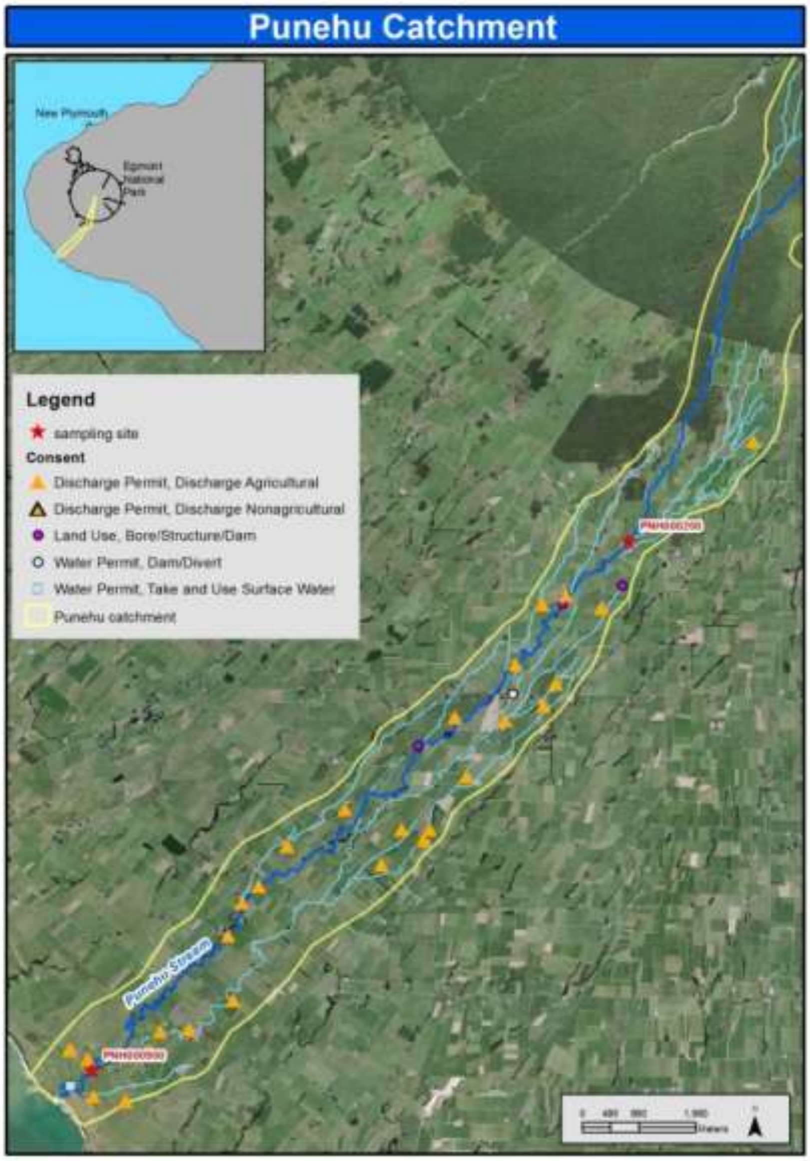


Figure 62 Monitoring site locations in relation to consents operating in the Punehu Stream

2.7.1 Flow and nutrient data and survey dates

Information regarding time of surveys and freshes are presented in Table 26.

Table 26 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	19/10/2016	10	10
Summer	02/03/2017	27	27
Spring	01/11/2017	20	23
Summer	15/02/2018	13	40

Nutrient data from the SEM physicochemical programme is collected at both sites. The site met the guideline for total nitrogen for an undisturbed (reference) upland site during 2016-2017 but not 2017-2018, and not for dissolved reactive phosphorus (DRP) for either year, and the lower site did not meet guidelines for DIN, total nitrogen, or DRP for an undisturbed (reference) lowland site (ANZECC 2000) (Table 27). 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.

Table 27 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Patea River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
Wiremu Road	270	0.021*	0.056	0.14	0.019*	0.080	0.30*
SH45	20	0.058*	1.465*	1.63*	0.042*	1.252*	1.98*

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

2.7.2 Periphyton cover

For the 2016-2017 monitoring period the upstream site had low levels of no nuisance periphyton recorded during the spring 2016 survey but during the summer 2017 survey thick mats were at moderate levels. The lower site had some thick mats and high levels of long filaments (31%) which breached the guideline value. The upper site had moderately low levels of thick mats and no filaments during the spring 2017 survey and extremely low levels of nuisance periphyton during the summer 2018 survey. The lower site had low levels of nuisance periphyton for both the spring 2017 and summer 2018 surveys (Figure 63 and Figure 64).

Typically, for the Punehu River, nuisance periphyton levels were higher at the downstream site compared with the upper site. The upper site had nutrient levels that would not promote excessive periphyton growth during the 2016-2017 period but both dissolved reactive phosphorus and total nitrogen were high enough to potentially cause issues during the 2017-2018 monitoring year while the lower site had elevated nutrients levels (Table 27). Partial shading of the riverbed by overhanging vegetation and steep banks would help limit periphyton growth at the lower site even though nutrient levels are at levels that will otherwise promote excessive growth.

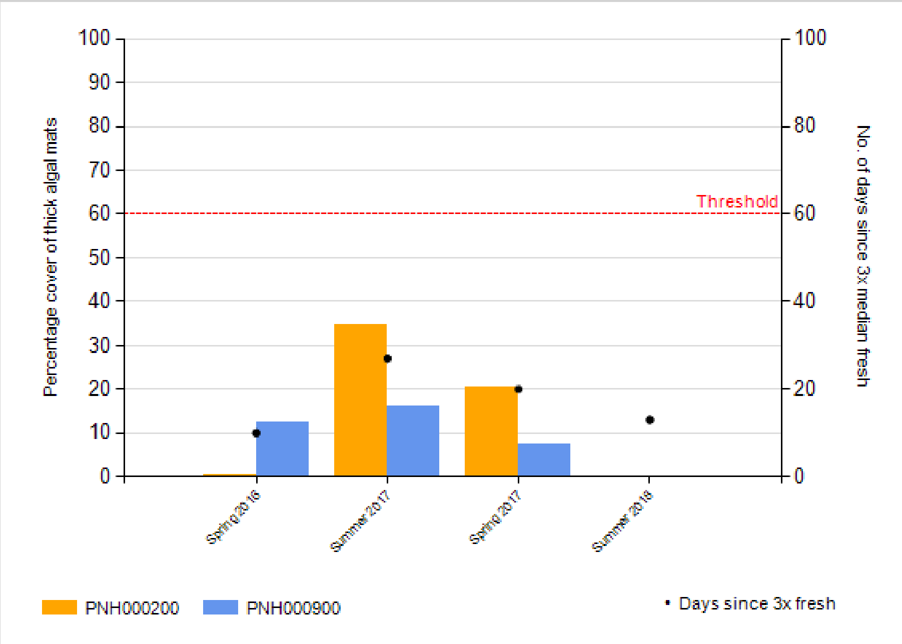


Figure 63 Percentage cover of thick mats of periphyton on the Punehu streambed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

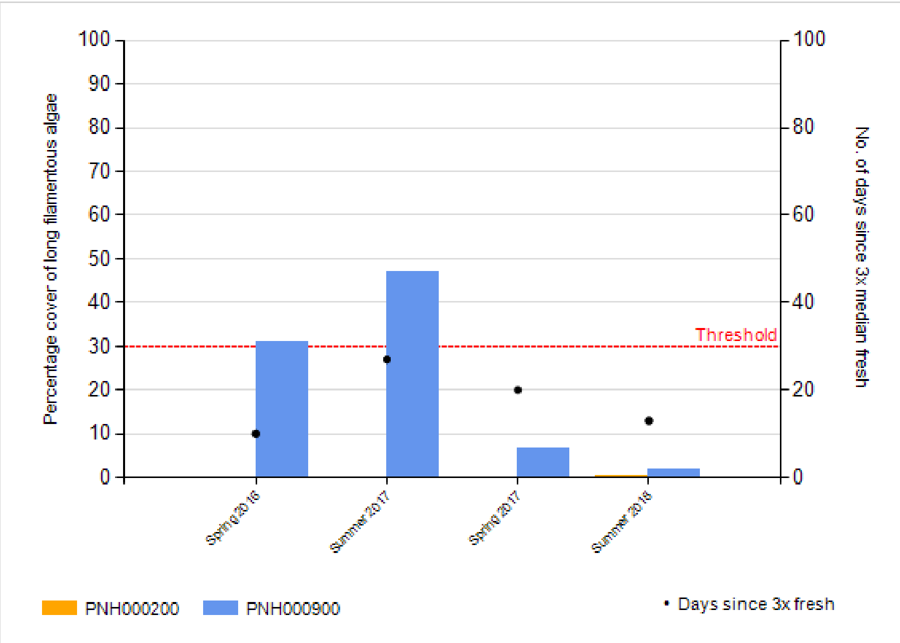


Figure 64 Percentage cover of long filamentous algae on the Punehu streambed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

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 28). During the reported period scores were equal to or slightly lower than historical medians, with the summer 2017 survey having a one unit decrease from the summer historical median.

The downstream site (PNH000900) had lower TRC PI scores than the upper site on all occasions but there was no noticeably trend between spring summer surveys which was typical for the site. Both 2016-2017 surveys were in the 'moderate' category and the 2017-2018 surveys in the 'very 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.

Table 28 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 2016	TRC PI Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
PNH000200	9.9	8.2	9.3	9.9	9.9	9.2
PNH000300	5.5	4.7	8.5	9.4	8.4	7.9
Difference	4.4	3.5	0.8	0.5	1.5	1.3

2.7.4 Periphyton biomass

The results for the 2016-2018 survey period for the upstream site showed that it had low chlorophyll *a* levels while the downstream site had a moderate value in the summer 2017 survey which exceeded the guideline limit to protect biodiversity (**Error! Reference source not found.**) and a low value for the summer 2018 survey (Figure 65). Chlorophyll *a* levels showed a deterioration between upstream and downstream sites for both surveys which was typical for the Punehu Stream.

The chlorophyll *a* levels were largely congruent with the TRC PI results that showed the upper Punehu Stream site had 'very good' periphyton communities. The lower site for the summer 2017 survey had high levels of filamentous algae and this was probably the cause of the higher than usual chlorophyll *a* result.

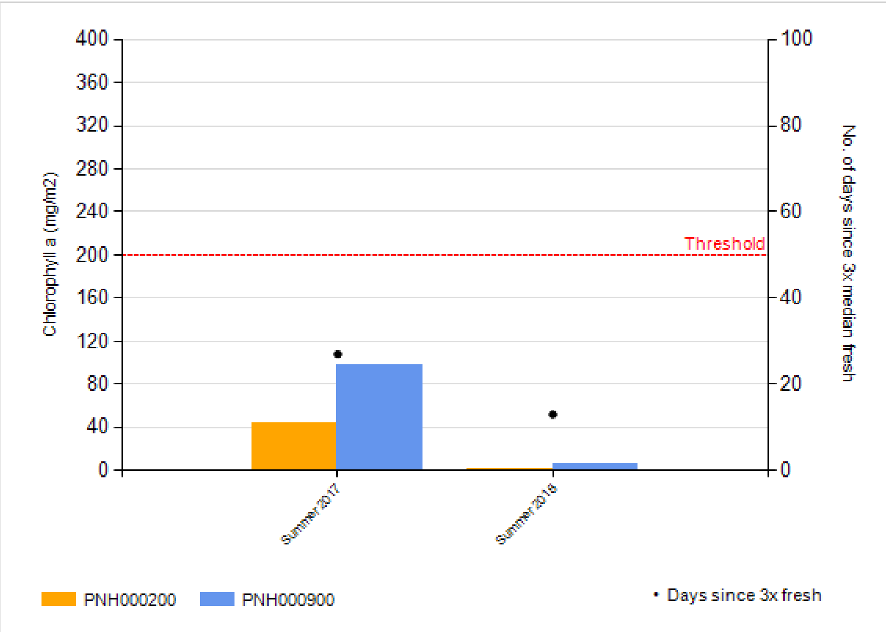


Figure 65 Periphyton biomass (chlorophyll *a*) on the Punehu riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.7.5 Summary of 2002-2018 (16 year data set)

No breaches in recreational guidelines for thick mats have been recorded at either site in the Punehu catchment over the past 16 year period (Figure 66). In the past there have been more frequent proliferations of thick mats at the downstream site although these have decreased in recent years (2006-2018).

The Punehu catchment has been subject to large proliferations of long filamentous algae over the 16 years of monitoring, especially at the downstream site (Figure 67). There have been a total of nine breaches of guidelines overall, two of which were recorded in the 2016-2018 period. During the 2002-2006 period there were much more frequent breaches in long filamentous periphyton at the downstream site. In the summer 2008, the largest amount recorded for a nuisance growth occurred with over 70% of the bed was covered in long filaments. These growths were not only restricted to summer months, and appeared throughout the 2002-2006 monitoring years, recording six breaches in total. There was also a breach at the upstream site after a long period of low flows in late summer 2005.

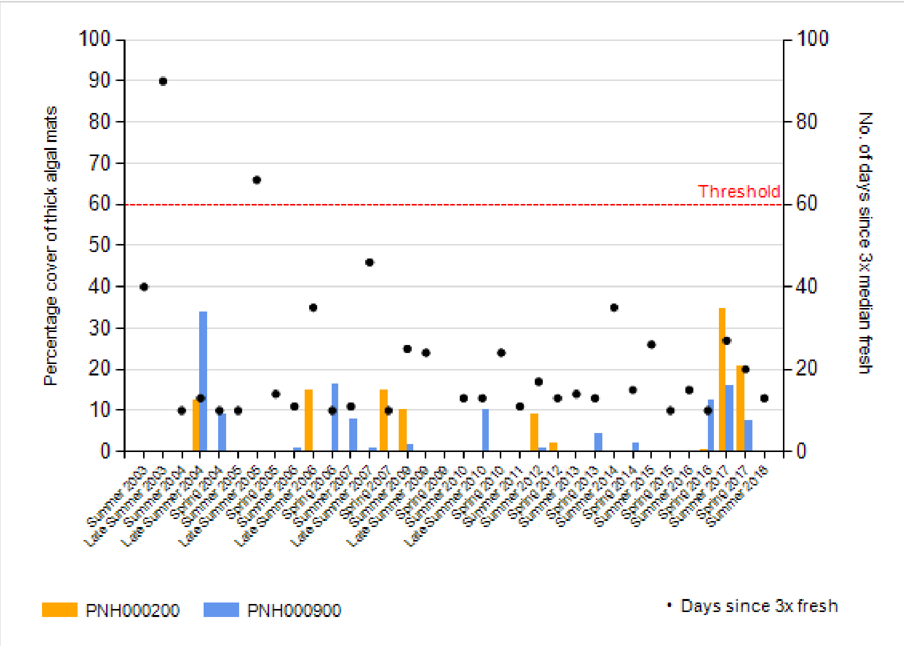


Figure 66 Percentage cover of thick mats of periphyton on the Punehu streambed in relation to the guidelines for recreational values over the 2002-2018 period

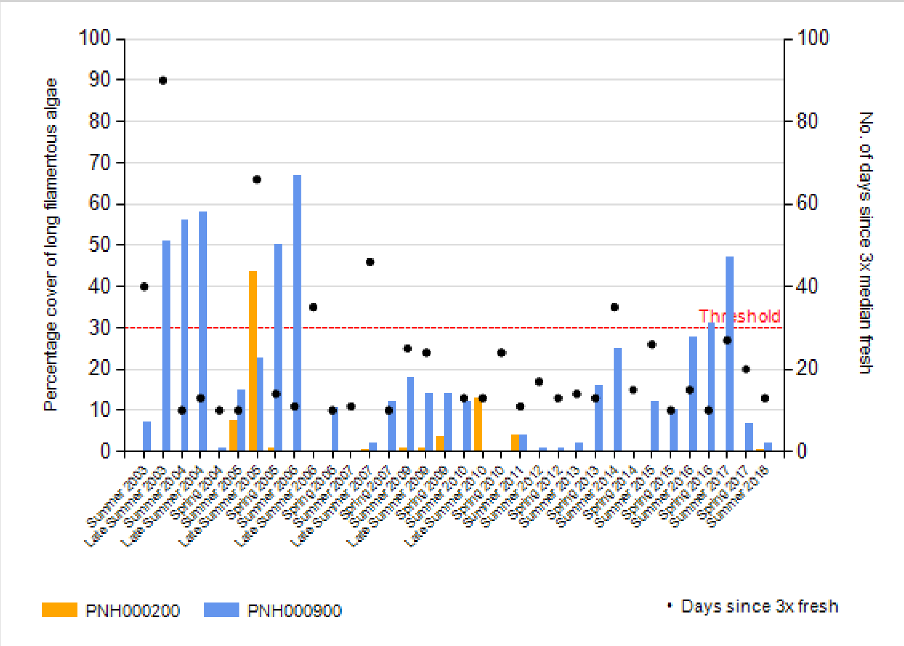
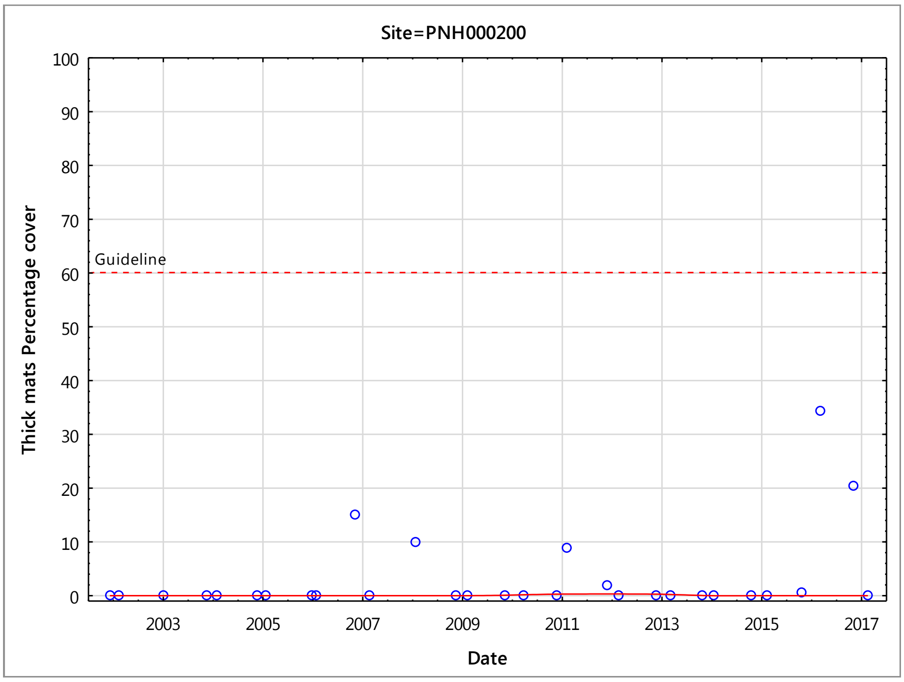


Figure 67 Percentage cover of long filamentous algae on the Punehu streambed in relation to the guidelines for recreational values over the 2002-2018 period

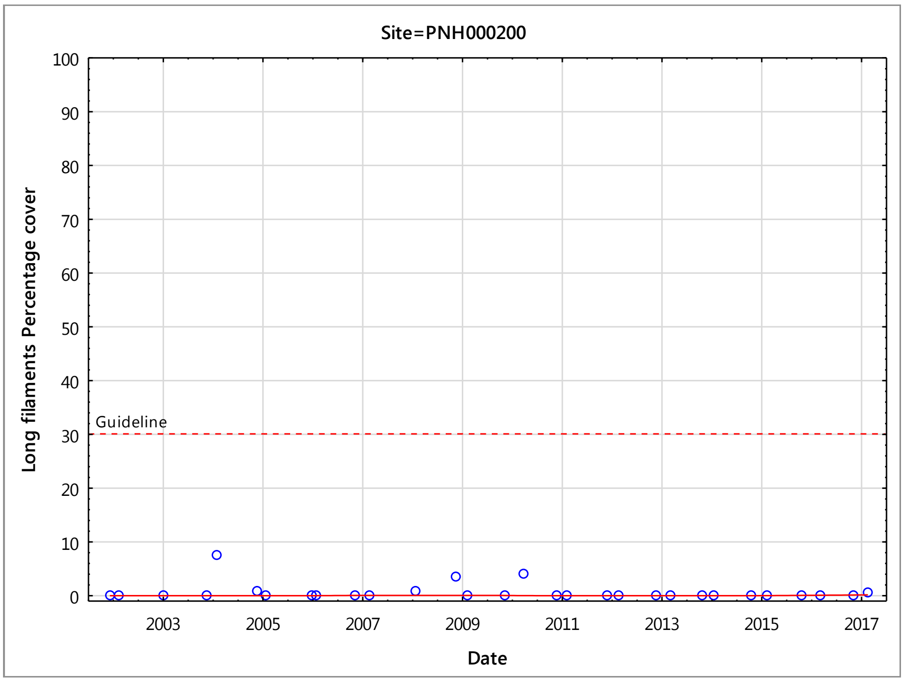
2.7.6 Long term trend analysis

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 16 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 68 to Figure 71).



n = 30
Kendal tau = 0.24
p-value = 0.06
FDR p-value = 0.20

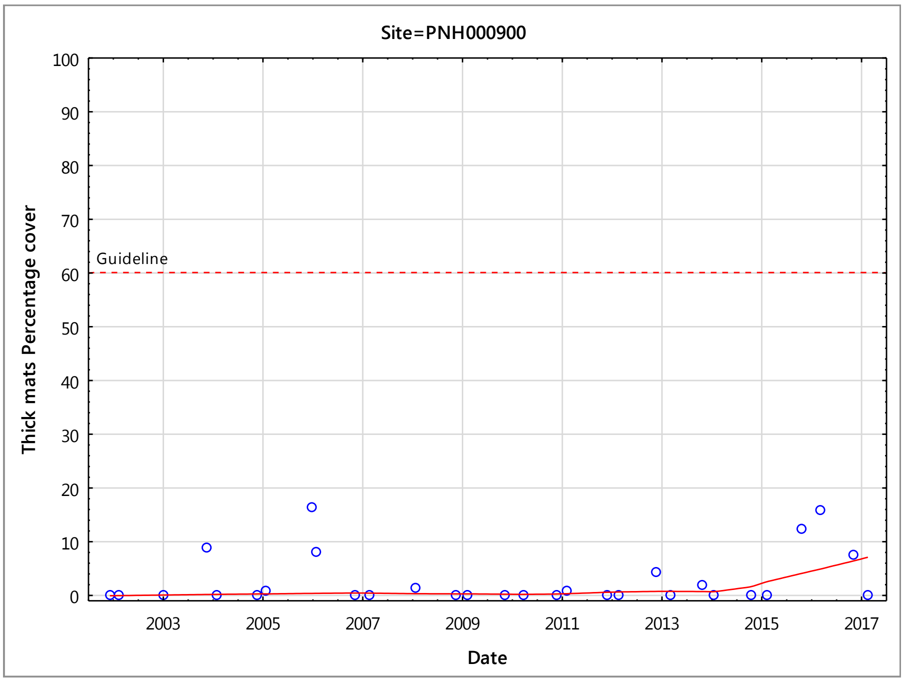
Figure 68 LOWESS trend analysis of percentage cover of thick mats at Punehu Stream, Wiremu Road (PNH000200)



n = 30
Kendal tau = -0.10
p-value = 0.44
FDR p-value = 0.55

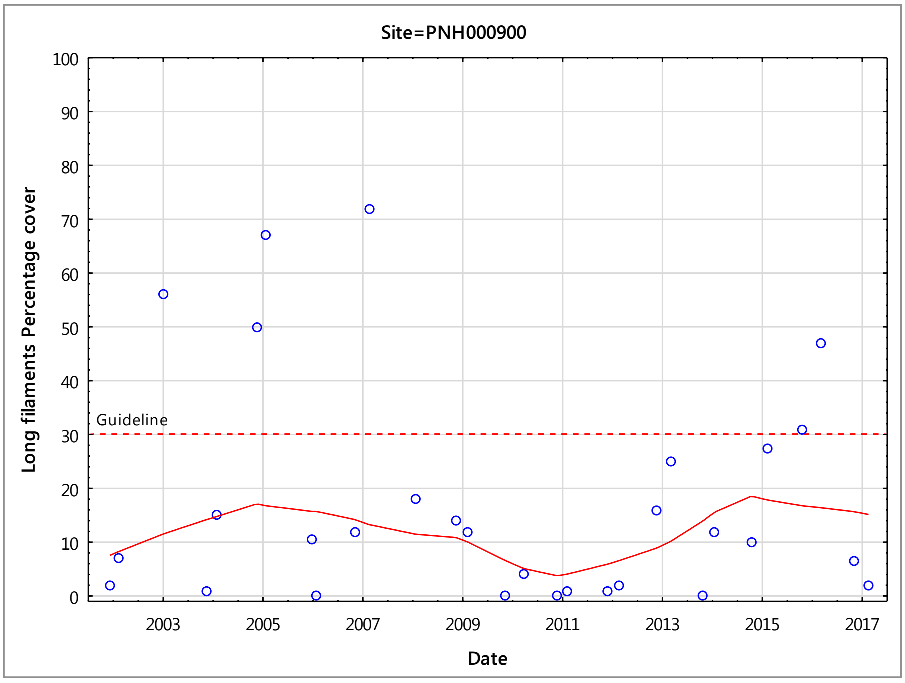
Figure 69 LOWESS trend analysis of percentage cover of long filaments at Punehu Stream, Wiremu Road (PNH000200)

At Wiremu Road (PNH000200) over the 16 year monitored period there were no significant trends for thick mats (p=0.20) or long filaments (p=0.55) at the 5% level of significance after false discovery rate adjustment.



n = 30
Kendal tau = 0.11
p-value = 0.40
FDR p-value = 0.46

Figure 70 LOWESS trend analysis of percentage cover of thick mats at Punehu Stream, SH45 (PNH000900)



n = 30
Kendal tau = -0.02
p-value = 0.89
FDR p-value = 0.89

Figure 71 LOWESS trend analysis of percentage cover of long filaments at Punehu Stream, SH45 (PNH000900)

At SH45 (PNH000900) over the 16 year monitored period there were no significant trends for thick mats (p=0.46) or long filaments (p=0.89) at the 5% level of significance after false discovery rate adjustment.

2.8 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 72). 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.

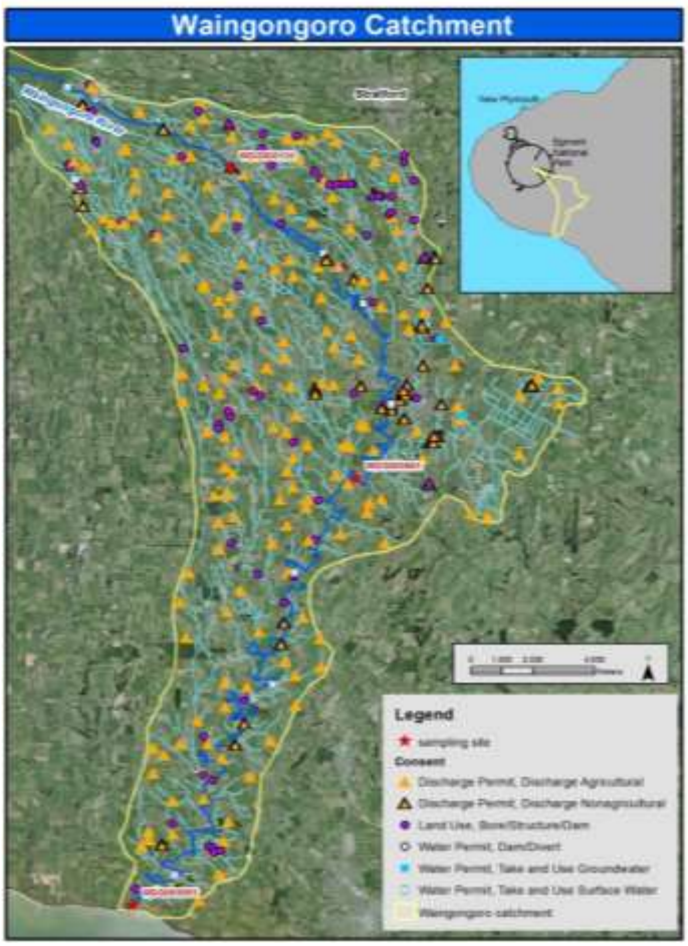


Figure 72 Monitoring site locations in relation to consents operating in the Waingongoro River catchment

2.8.1 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. Information regarding time of surveys and freshes are presented in Table 29.

Table 29 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	20/10/2016	11	18
Summer	10/01/2017	18	54
Spring	01/11/2017	21	23
Summer	06/03/2018	13	33

Nutrient data from the SEM physicochemical programme is collected at three sites on the Waingongoro River. The two sites where physicochemical data was collected were not at the same locations as the nuisance periphyton sites but they were close enough to provide a reliable guide as to the nutrient status of the periphyton sites. Both sites did not meet the guidelines for dissolved reactive phosphorus and total nitrogen at undisturbed (reference) sites (ANZECC 2000) (Table 30). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely to contribute to the exceedance in dissolved reactive phosphorus levels but point source inputs from industries and agricultural inputs would also contribute to the high DRP and were the likely cause of the exceedance in total nitrogen.

Table 30 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Stoney River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
Opunake Road	380	n/a	n/a	n/a	n/a	n/a	n/a
Stuart Road+	180	0.026*	1.50*	1.72*	0.031*	1.236*	1.17*
Ohawe Beach+	10	0.041*	1.857*	2.11*	0.048*	1.988*	2.62*

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

+Phys-chem site locations differ slightly from periphyton site locations

2.8.2 Periphyton cover

The bottom site breached the guideline limits for thick algal mats during the summer 2018 survey (Figure 73 and Figure 74).

In the 2016-2017 monitoring year, low levels of nuisance periphyton were recorded at the upper catchment site at Opunake Road and the middle site at Stuart Road. The bottom site at Ohawe Beach had moderate levels of long filaments in the spring 2016 and moderate levels of thick mats for the summer 2017 survey. In the 2017-2018 monitoring year the upper site again had very low levels of nuisance periphyton. The middle site had moderately low levels of thick mats during the summer 2018 survey and the bottom site had moderately low levels of thick during spring but high levels during summer with filamentous algae at low levels for both surveys.

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. 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.

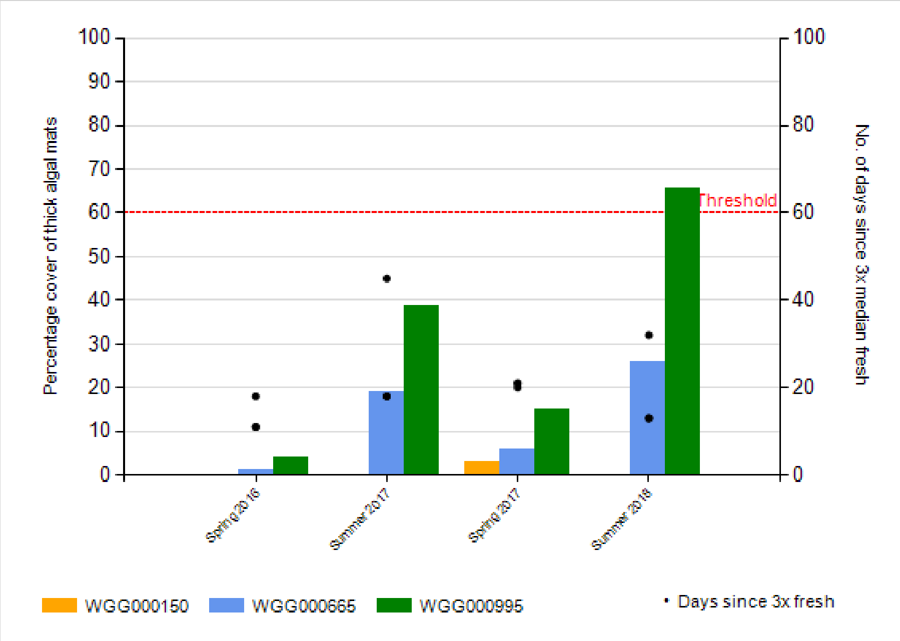


Figure 73 Percentage cover of thick mats of periphyton on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

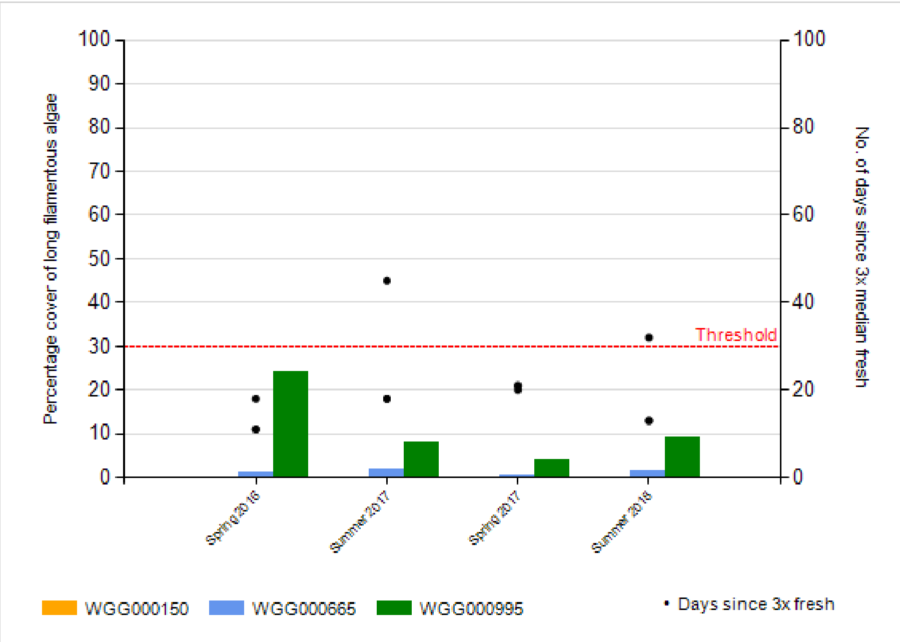


Figure 74 Percentage cover of long filamentous algae on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.8.3 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 31). At the middle site at Stuart Road TRC PI scores were lower but were still 'very good'. The bottom site at Ohawe Beach had 'good' scores during the 2017-2017 monitoring year and 'good' - 'moderate' scores for the 2017-2018 monitoring year. As expected, median scores show a decrease in TRC PI scores in a downstream direction for the period under review (Table 31).

Table 31 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 2016	TRC PI Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
WGG000150	9.0	10	9.7	9.7	9.3	9.4
WGG000650	9.5	8.4	9.5	8.0	8.5	7.7
WGG000950	6.5	7.5	7.6	5.6	9.0	7.0
Difference	2.5	2.5	2.1	4.1	0.3	2.4

2.8.4 Periphyton biomass

The results for the period 2016- 2018 indicate that the upstream site had very low levels of periphyton biomass and the middle and bottom sites both had moderately high levels (Figure 75). No samples breached the guideline thresholds for NOF standards (**Error! Reference source not found.**) but the middle site breached the level to protect benthic biodiversity on both occasions and the bottom site in summer 2017. Periphyton biomass levels did not match TRC PI scores particularly well for the lower sites as higher TRC PI scores and chlorophyll *a* levels were recorded at the middle site. 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 moderate to moderately high periphyton biomasses at the middle and lower sites suggests that significant nutrient enrichment occurred in the mid catchment, probably from agricultural inputs and possibly from industries located in the township of Eltham.

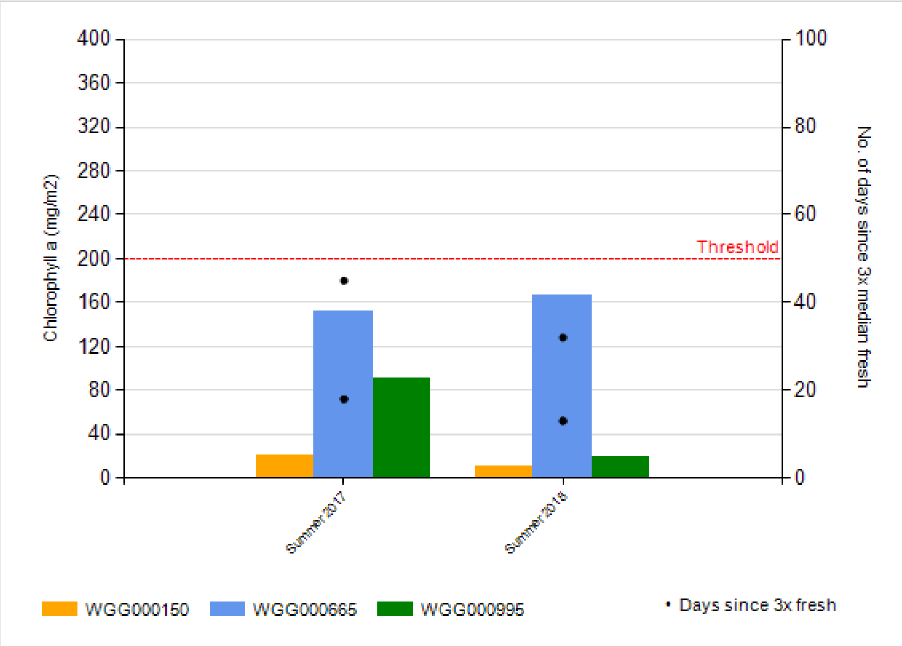


Figure 75 Periphyton biomass (chlorophyll *a*) on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.8.5 Summary of 2002-2018 (16 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 76 and Figure 77). 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 summer 2018 survey.

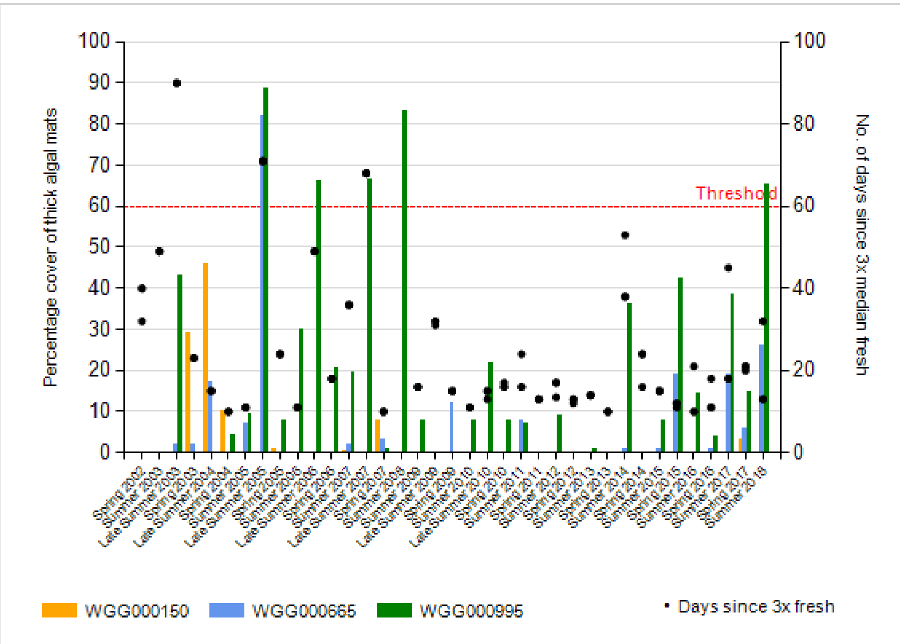


Figure 76 Percentage cover of thick mats of periphyton on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2002-2018 period

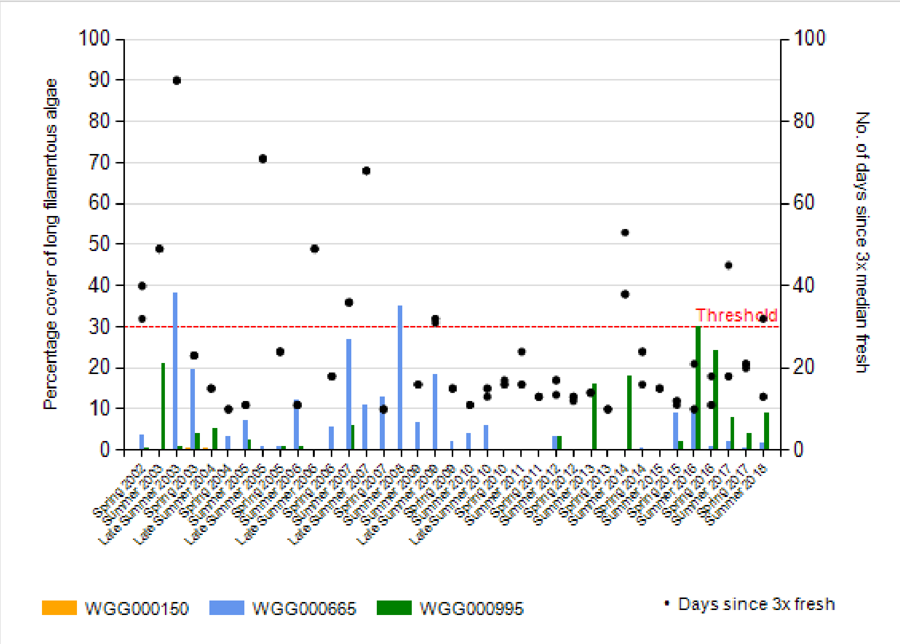
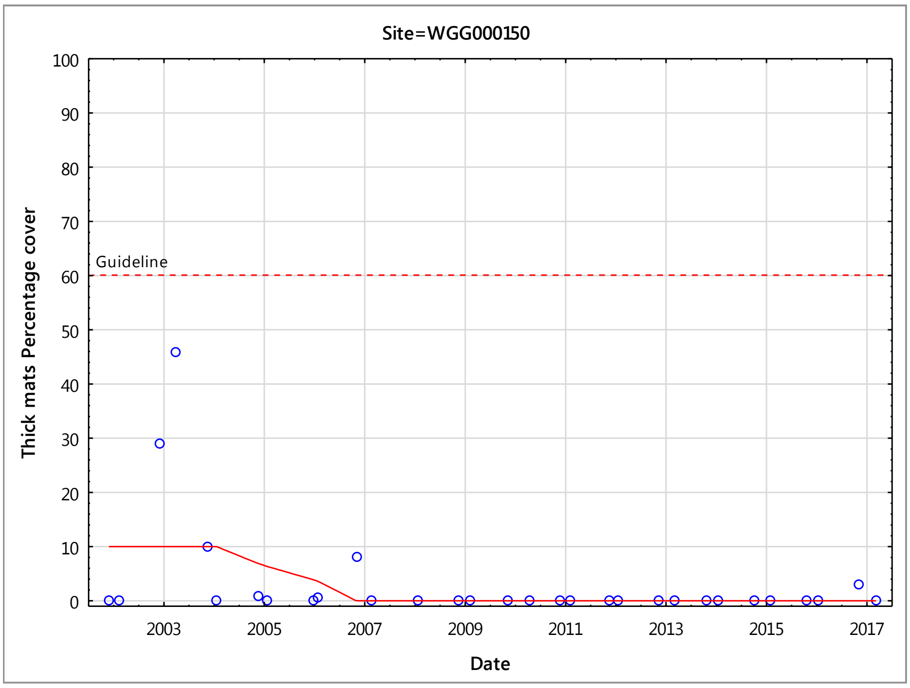


Figure 77 Percentage cover of long filamentous algae on the Waingongoro riverbed in relation to the guidelines for recreational values over the 2002-2018 period.

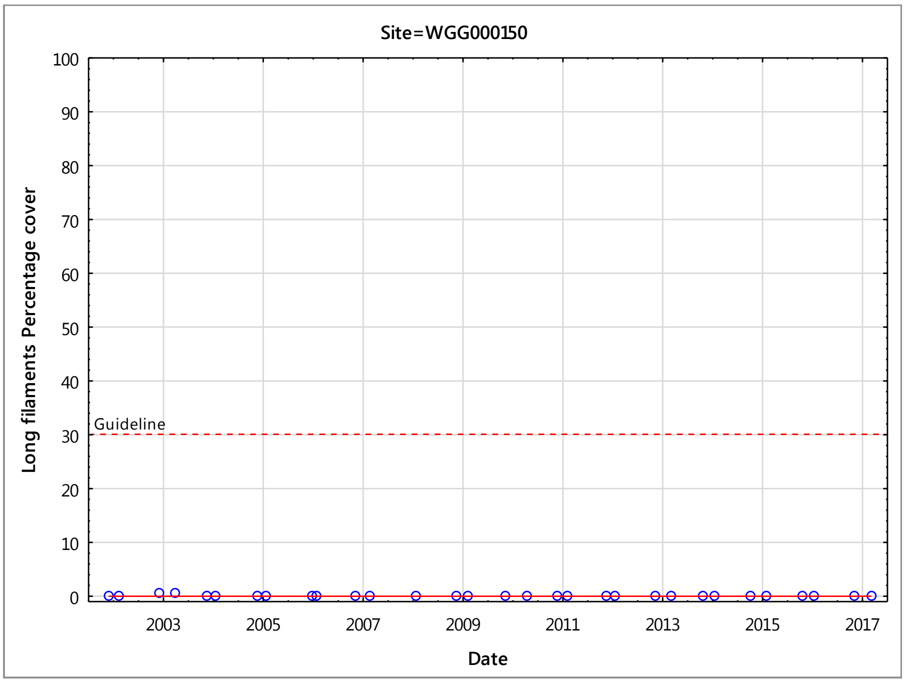
2.8.6 Long term trend analysis

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 the Waingongoro River, at Opunake Road, Stuart Road and Ohawe Beach, over a 16 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 78 to Figure 81).



n = 31
Kendal tau = -0.32
p-value = 0.01
FDR p-value = 0.11

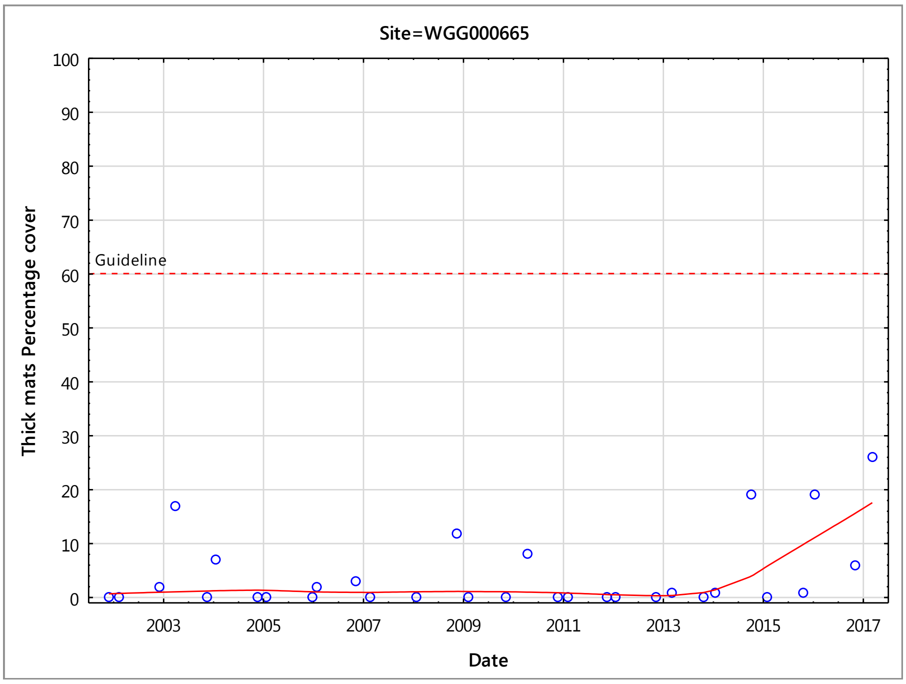
Figure 78 LOWESS trend analysis of percentage cover of thick mats at Waingongoro River, Opunake Road (WGG000150)



n = 31
Kendal tau = -0.30
p-value = 0.02
FDR p-value = 0.08

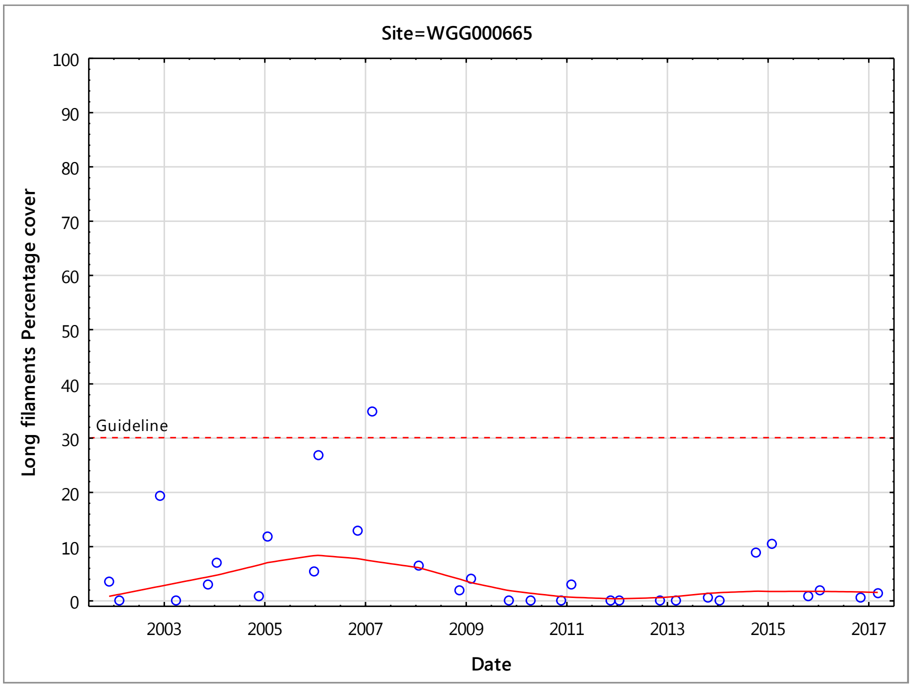
Figure 79 LOWESS trend analysis of percentage cover of long filaments at Waingongoro River, Opunake Road (WGG000150)

At Opunake Road (WGG000150) over the 16 year monitored period there was no significant trends for thick mats (p=0.11) or long filaments (p=0.08) at the 5% level of significance after false discovery rate adjustment.



n = 31
Kendal tau = 0.21
p-value = 0.10
FDR p-value = 0.20

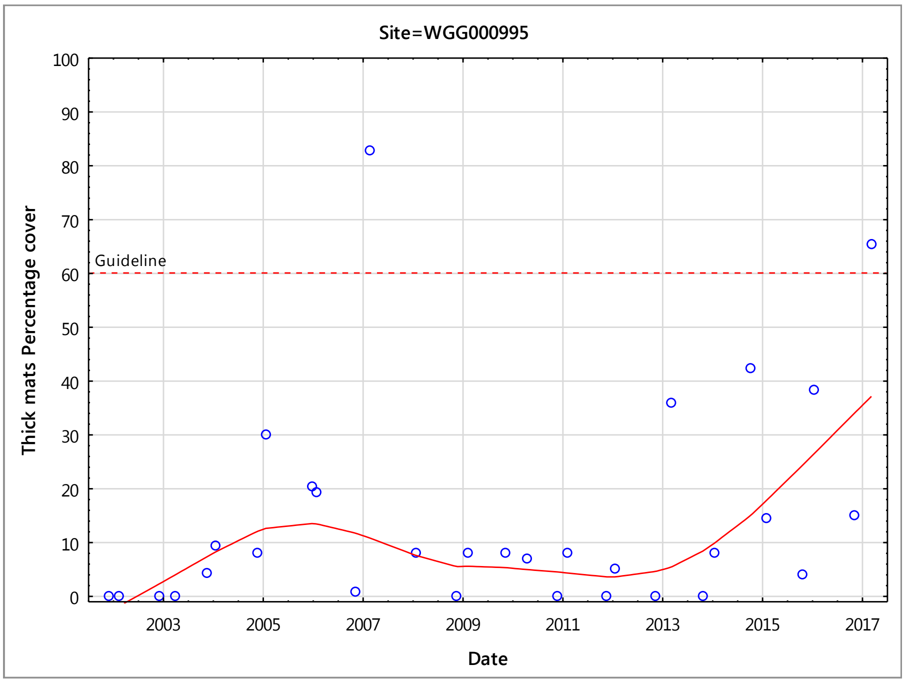
Figure 80 LOWESS trend analysis of percentage cover of thick mats at Waingongoro River, Stuart Road (WGG000665)



n = 31
Kendal tau = -0.18
p-value = 0.16
FDR p-value = 0.32

Figure 81 LOWESS trend analysis of percentage cover of long filaments at Waingongoro River, Stuart Road (WGG000665)

At Stuart Road (WGG000665) over the 16 year monitored period there were no significant trends for thick mats (p=0.20) or long filaments (p=0.32) at the 5% level of significance after false discovery rate adjustment.



n = 31
Kendal tau = 0.24
p-value = 0.06
FDR p-value = 0.20

Figure 82 LOWESS trend analysis of percentage cover of thick mats at Waingongoro River, Ohawe Beach (WGG000995)

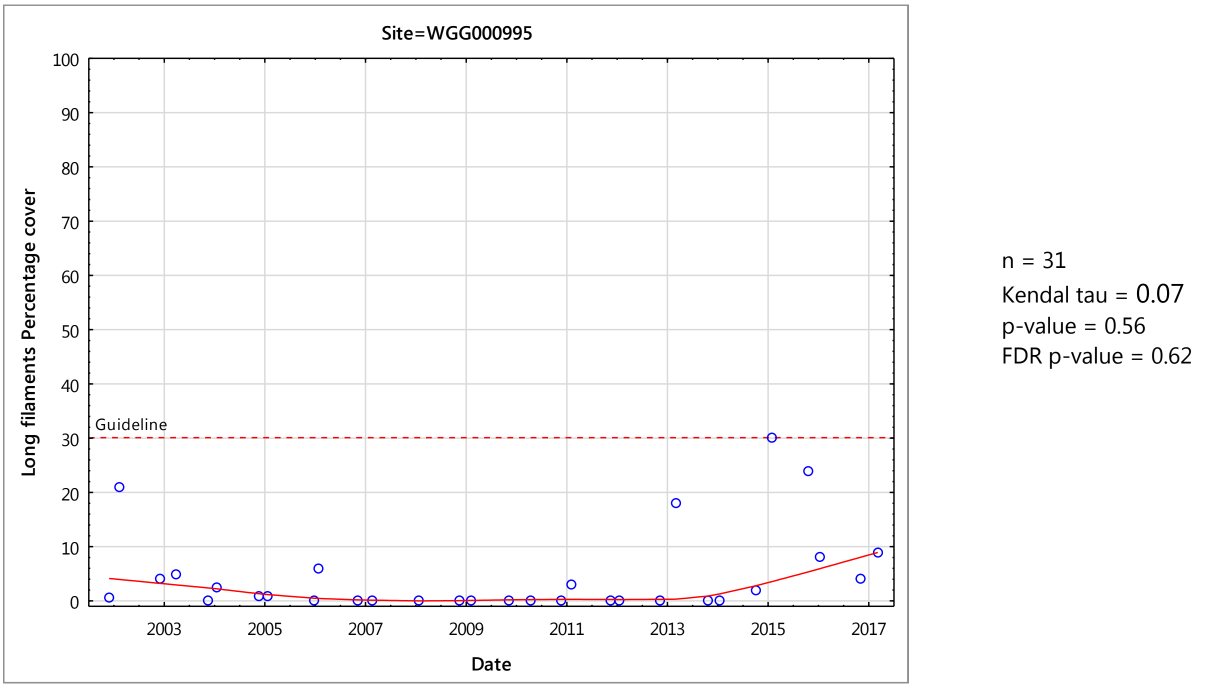


Figure 83 LOWESS trend analysis of percentage cover of long filaments at Waingongoro River, Ohawe Beach (WGG000995)

At Ohawe Beach (WGG000995) over the 16 year monitored period there were no significant trends for thick mats (p=0.20) or long filaments (p=0.62) 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 84). 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.

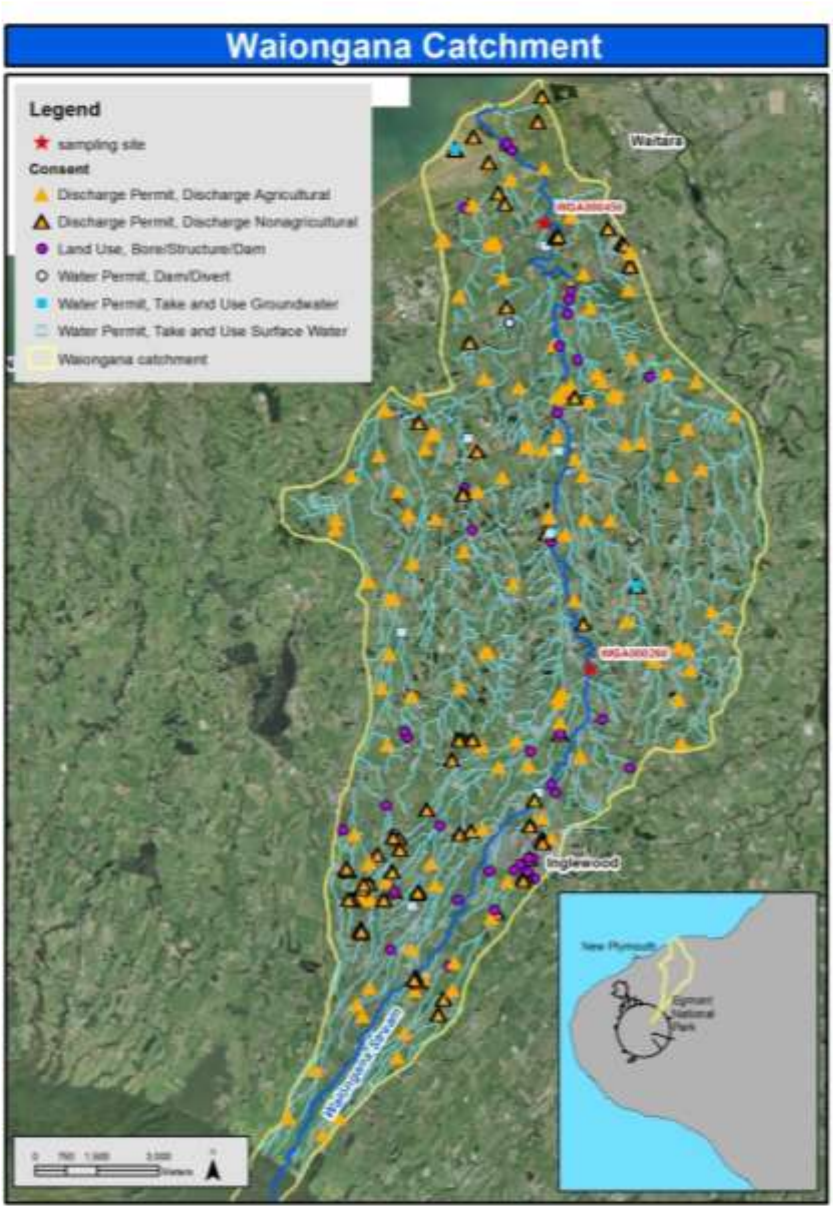


Figure 84 Monitoring site locations in relation to consents operating in the Waiongana Stream catchment

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). Information regarding time of surveys and freshes are presented in Table 32. The spring 2016 survey was not conducted due to persistently high spring flows.

Table 32 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	NA	NS	NS
Summer	15/02/2017	11	11
Spring	25/10/2017	11	11
Summer	09/04/2018	10	16

This site is not part of the SEM physicochemical monitoring programme, and so has no nutrient data.

2.9.2 Periphyton cover

There were two breaches in the periphyton guidelines in the 2016-2018 monitoring period (Figure 85 and Figure 86).

For the 2016-2017 monitoring period no spring samples were collected. There was one breach for long filamentous algae at the upper site (WGA000260) for long filamentous algae while the lower site also had moderately high long filamentous algae. Both sites also had minor levels of thick mats. For the 2016-2017 monitoring period both sites had moderate levels of long filamentous algae during the spring 2017 surveys. A breach occurred at the lower site (WGA000450) during the summer 2018 survey while the upper site only had very low levels of filamentous algae.

The high nuisance periphyton levels do not correspond with long periods without flushing flows (3x median flow) and presumably large freshes would be need to remove periphyton at this site.

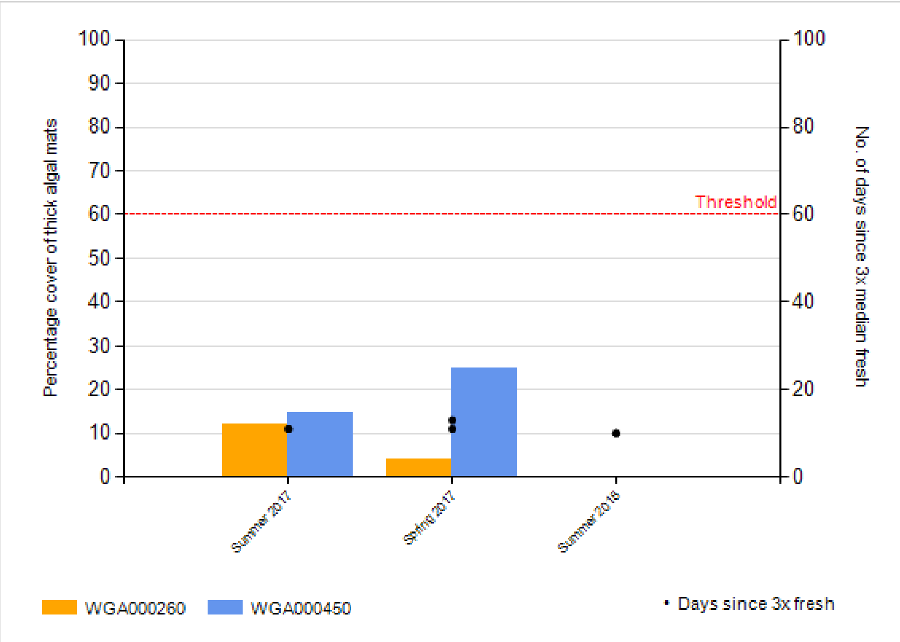


Figure 85 Percentage cover of thick mats of periphyton on the Waiongana riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

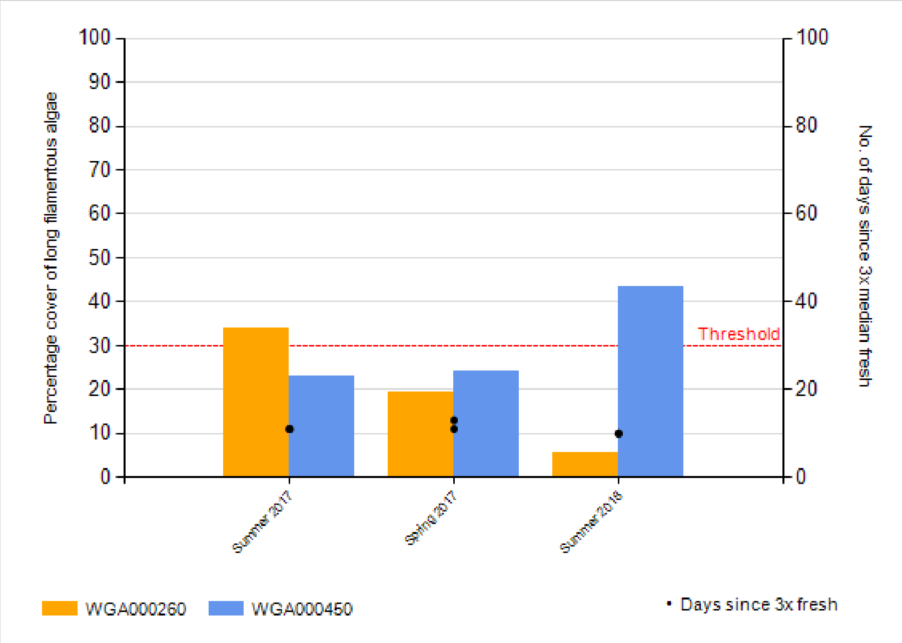


Figure 86 Percentage cover of long filamentous algae on the Waiongana riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

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 2016-2017 monitoring year the upstream site had a 'moderate' score for the summer 2017 survey and the bottom site had a 'very good' score (Table 33). For the 2017-2018 monitoring year the upstream site had a 'good' score for the spring 2017 survey and a 'moderate' score for the summer 2018 survey. The bottom site for the corresponding surveys had 'good' and 'moderate' scores. Scores were mostly above historical medians for both sites except for the summer 2016 survey for the lower site (Table 33).

For the summer survey the bottom site had a higher TRC PI score than the upper site. The increase in TRC PI score at the downstream site has 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, particularly in the upper site.

Table 33 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 Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
WGA000260	4.8	6.2	7.5	6.9	7.2
WGA000450	7.8	6.7	4.6	5.7	6.9
Difference	-3.0	-0.5	2.9	1.2	0.3

2.9.4 Periphyton biomass

The results for the 2017 summer for the mid catchment upstream site showed that it had moderately high chlorophyll *a* levels which came close to breaching the NOF standard for the summer 2017 survey (Figure 87). The bottom site had moderate chlorophyll *a* levels for the summer 2017 survey and a high chlorophyll *a* level for the summer 2018 survey which breached the NOF limit (Table 7). All surveys breached guidelines to protect benthic biodiversity values (**Error! Reference source not found.**)

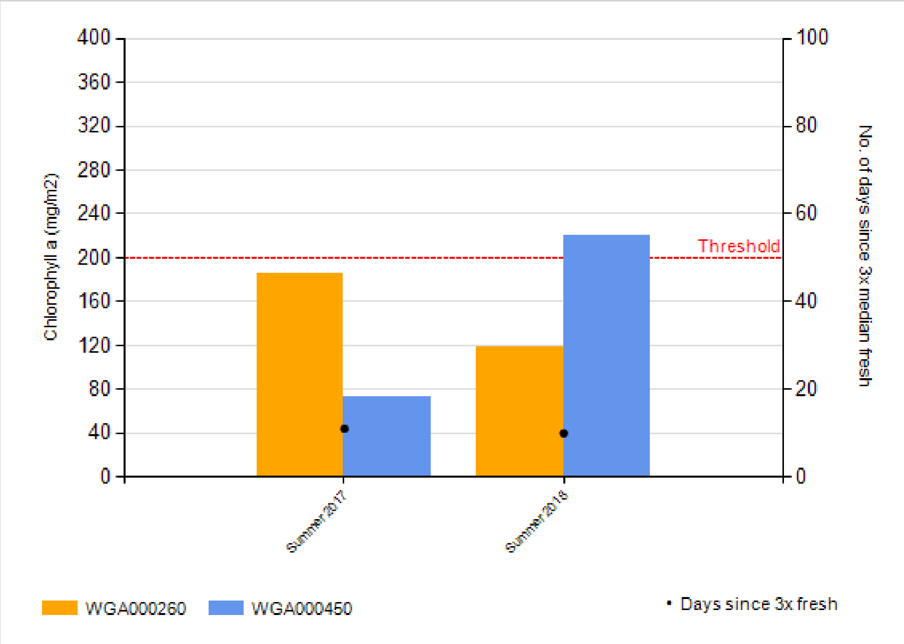


Figure 87 Periphyton biomass (chlorophyll *a*) on the Waiongana riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.9.5 Summary of 2002-2018 (16 year data set)

The Waiongana catchment over the 16 year data set has had no breaches in thick algal mats at either of the sites surveyed (Figure 88). There have been more significant growths of thick mats at the downstream site than the upstream site over more recent years (2016-2018). 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 89). 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 and two breaches occurred during the 2014-2016 survey. 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 close to breaching the guideline limit.

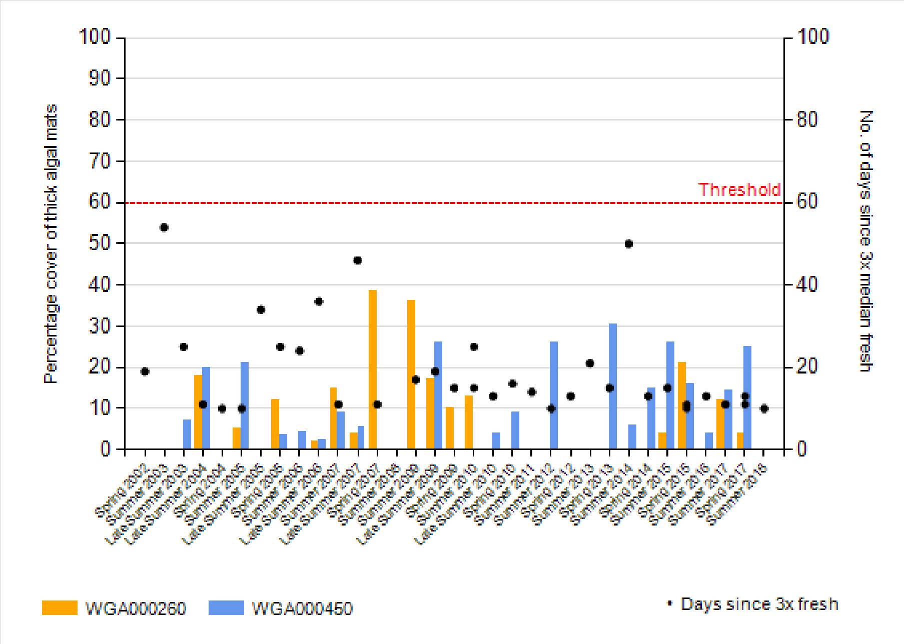


Figure 88 Percentage cover of thick mats of periphyton on the Waiongana riverbed in relation to the guidelines for recreational values over the 2002-2018 period

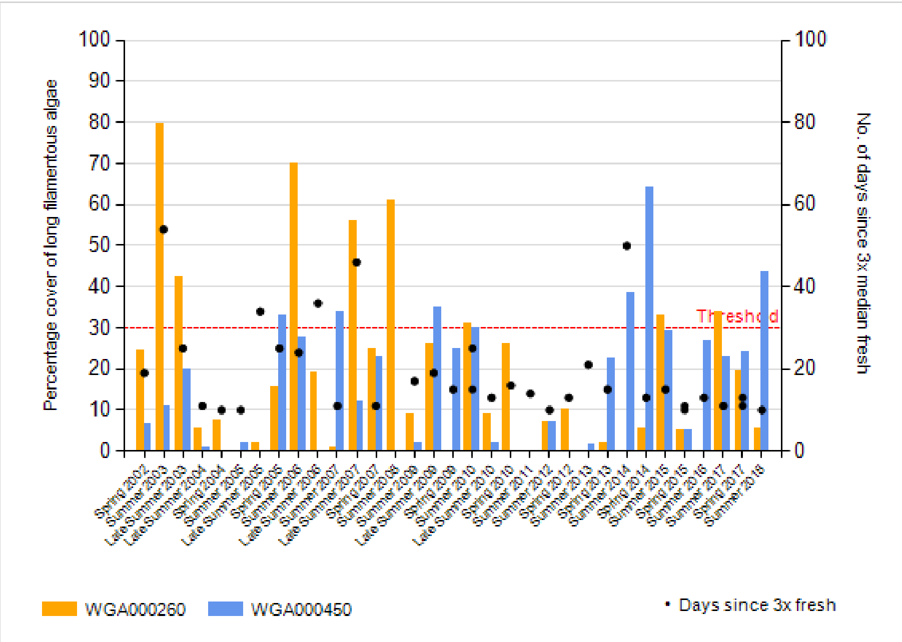
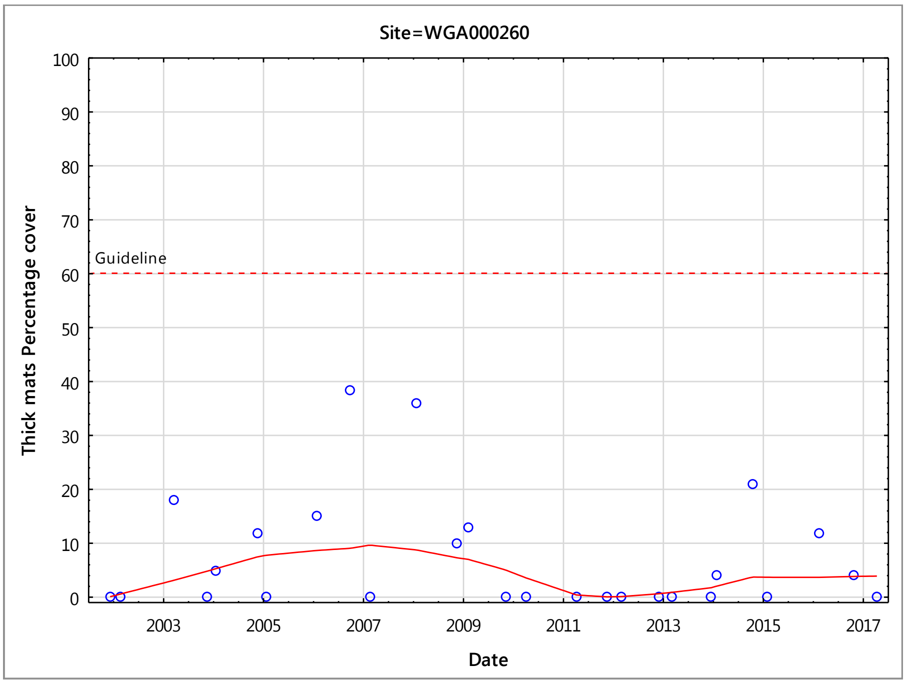


Figure 89 Percentage cover of long filamentous algae on the Waiongana riverbed in relation to the guidelines for recreational values over the 2002-2018 period

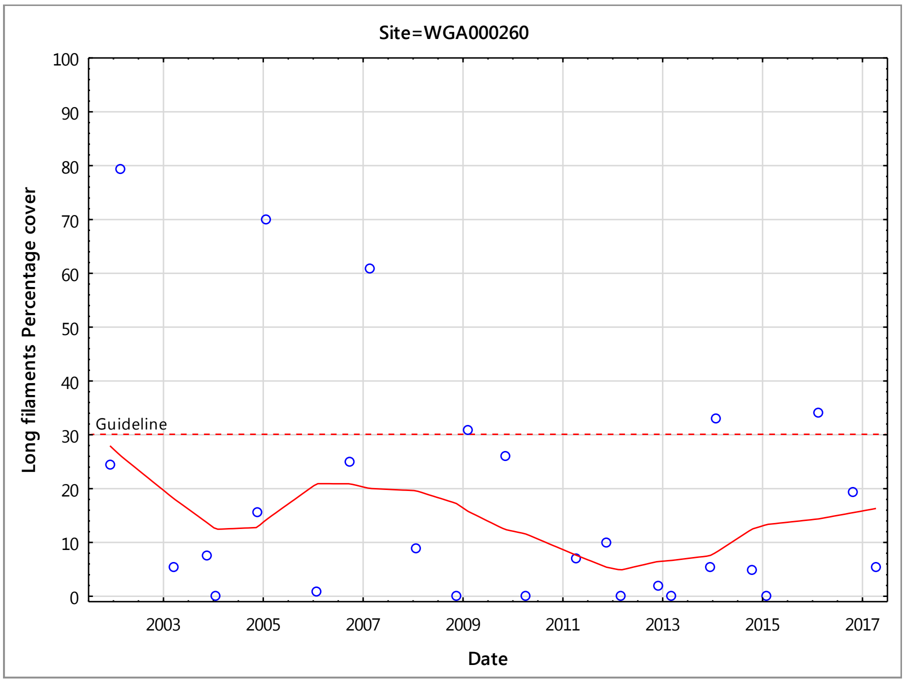
2.9.6 Long term trend analysis

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 16 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 90 to Figure 93).



n = 27
Kendal tau = -0.08
p-value = 0.55
FDR p-value = 0.61

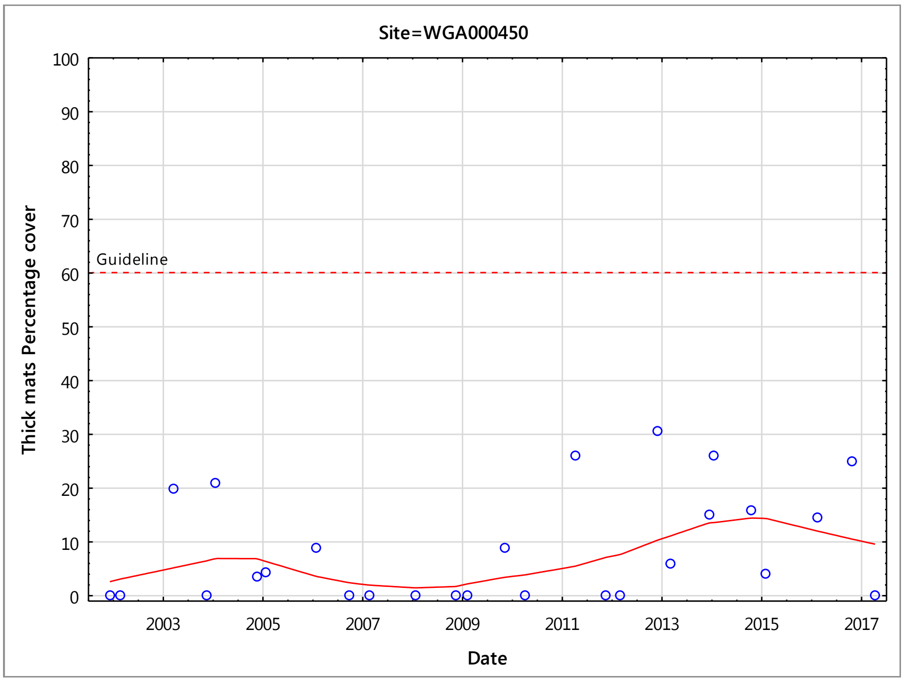
Figure 90 LOWESS trend analysis of percentage cover of thick mats at Waiongana River, SH3a (WGA000260)



n = 27
Kendal tau = -0.14
p-value = 0.29
FDR p-value = 0.45

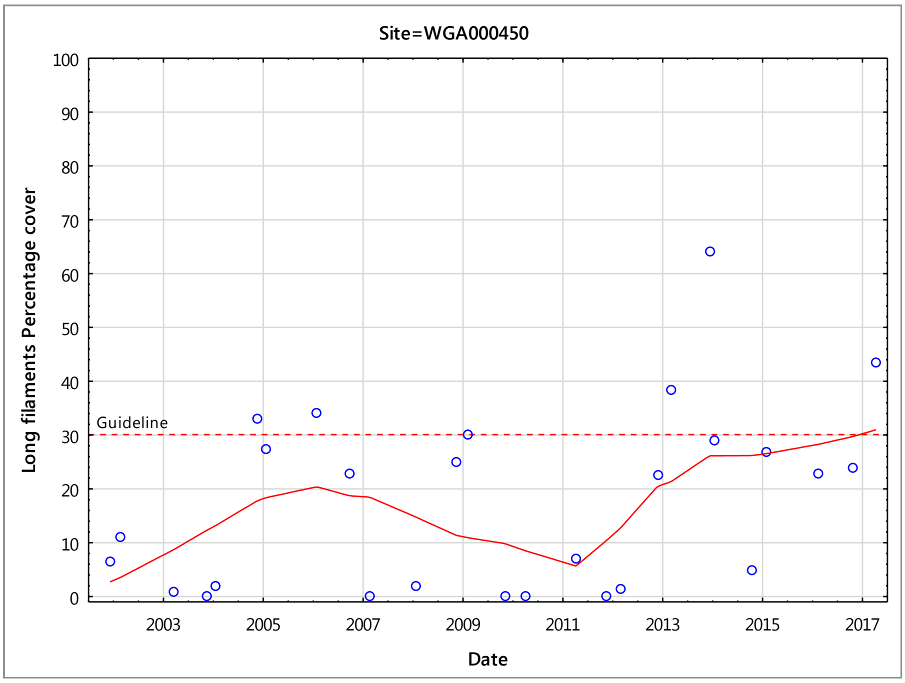
Figure 91 LOWESS trend analysis of percentage cover of long filaments at Waiongana River, SH3a (WGA000260)

At SH3a (WGA000260) over the 16 year monitored period there were no significant trends for thick mats (p=0.61) or long filaments (p=0.45) at the 5% level of significance after false discovery rate adjustment.



n = 27
Kendal tau = 0.23
p-value = 0.10
FDR p-value = 0.20

Figure 92 LOWESS trend analysis of percentage cover of thick mats at Waiongana River, Devon Road (WGA000450)



n = 27
Kendal tau = 0.22
p-value = 0.11
FDR p-value = 0.28

Figure 93 LOWESS trend analysis of percentage cover of long filaments at Waiongana River, Devon Road (WGA000450)

At Devon Road (WGA000450) over the 16 year monitored period there were no significant trends for thick mats (p=0.20) or long filaments (p=0.28) at the 5% level of significance after false discovery rate adjustment.

2.10 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.

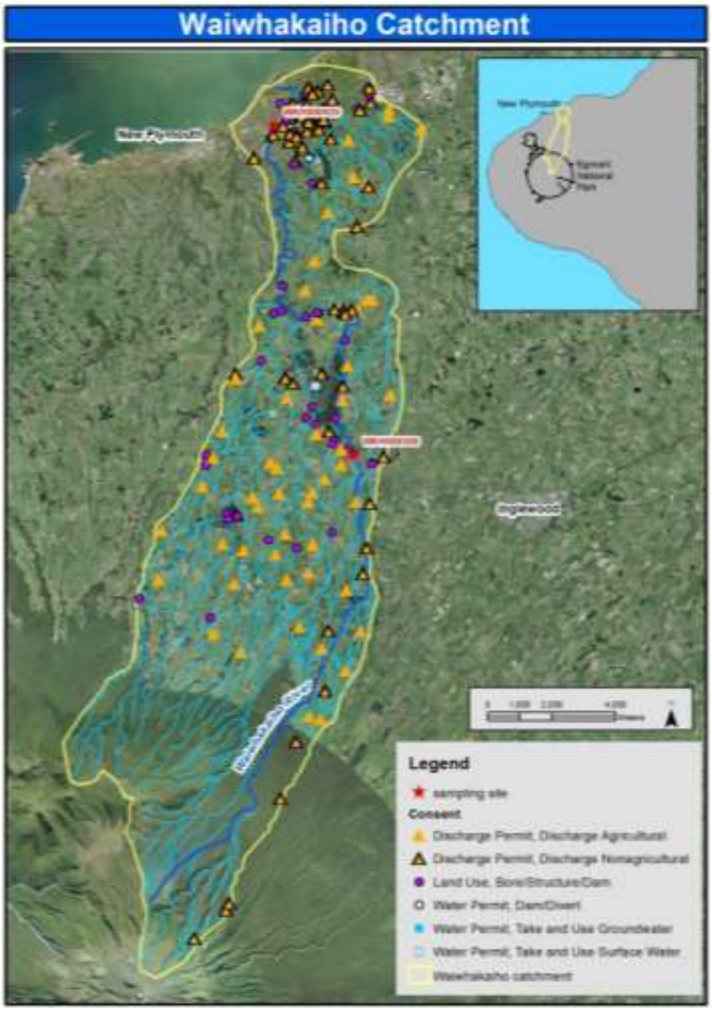


Figure 94 Monitoring site locations in relation to consents operating in the Waiwhakaiho River catchment

2.10.1 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).

Information regarding time of surveys and freshes are presented in Table 34. The spring 2016 survey was not conducted due to persistently high spring flows.

Table 34 Date, time since three and seven times median flow

Season	Date	3x	7x
Spring	NA	NA	NA
Summer	15/02/2017	12	12
Spring	11/12/2017	33	33
Summer	05/04/2018	12	12

Nutrient data from the SEM physicochemical programme was collected at site SH3 (WKH000500). The site did not meet the guideline for DRP for a undisturbed (reference) lowland site (ANZECC 2000) (Table 35). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was the likely cause of the exceedance in DRP levels, alongside diffuse pastoral runoff.

Table 35 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Waiwhakaiho River

Site	Altitude (m)	2016-2017			2017-2018		
		DRP	DIN	TN	DRP	DIN	TN
SH3 (Egmont Village)	175	0.030*	0.185*	0.23	0.029*	0.145*	0.23
Constance St, NP	20	n/a	n/a	n/a	n/a	n/a	n/a

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria

2.10.2 Periphyton cover

Nuisance periphyton at the upper SH3 site exceeded the guideline level for filamentous algae during the spring 2017 survey (Figure 95 and Figure 96).

In the 2016-2017 monitoring year no spring 2016 surveys were undertaken. The summer 2017 survey recorded moderately low levels of thick mats and low levels of long filaments at both sites. In the 2017-2018 monitoring year there was a breach in the guideline for long filaments at the upper site while the lower site came very close to breaching the long filaments guideline. The upper site also had minor levels of thick mats while the lower site had moderate levels of thick mats. During the 2018 summer survey both sites had low to moderate levels of thick mats and long filaments.

The presence of filamentous algae, seen in greater amounts at the upper site at SH3, was typical for the site and consistent with past monitoring. 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.

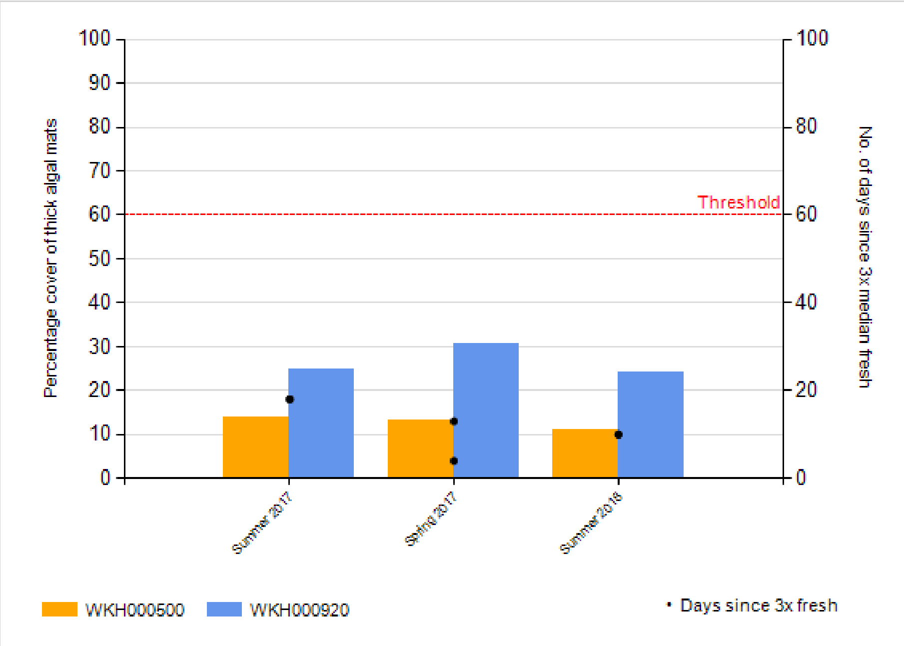


Figure 95 Percentage cover of thick mats of periphyton on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

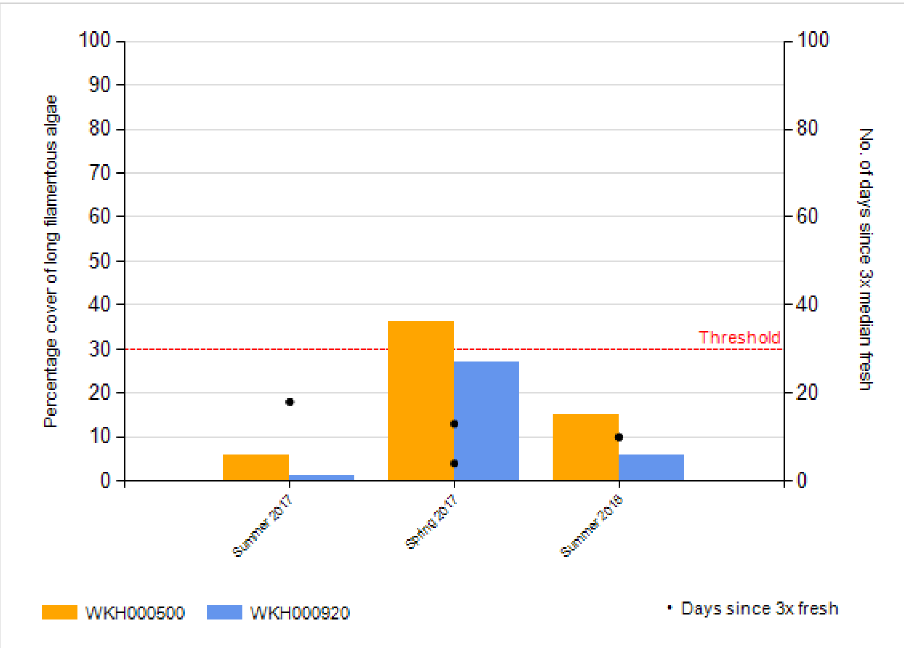


Figure 96 Percentage cover of long filamentous algae on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2016-2018 monitoring period and number of days since 3x median fresh

2.10.3 Periphyton Index Score

The Waiwhakaiho River, unlike other monitored rivers in Taranaki, normally shows a minor improvement in TRC PI score at the downstream site compared with the upstream site but in the current monitoring period there was a decline in TRC PI score for all three surveys (Table 36).

For the 2016-2017 monitoring year the upper and lower sites had a 'good' rating for the summer 2017 survey. Compared with historical medians the upper site had better than normal TRC PI scores while the lower site was similar to the historical median. For the 2017-2018 monitoring year the upper site had a 'moderate' rating for the spring 2017 survey and this increased to a 'good' rating for the subsequent summer 2018 survey. The bottom site had a 'moderate' rating for both the spring and summer surveys. Compared with historical medians the upper site was similar to the historic medians while the lower site was lower.

The low TRC PI scores for the spring 2017 survey may be related to the long period without a flushing flow. (33 days since a fresh of 3x median). The upper site receives runoff from primarily agricultural land (other than that from the National Park) but appears to have relatively low total nitrogen levels. 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 36 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 Summer 2017	TRC PI Spring 2017	TRC PI Summer 2018	TRC PI Historical spring median	TRC PI Historical summer median
WKH000500	7.8	5.1	7.4	7.2	6.7
WKH000920	6.6	4.6	5.5	7.9	6.7
Difference	1.2	0.5	1.9	-0.7	0

2.10.4 Periphyton biomass

The results for the period 2016-2018 showed that the upper site for the 2017 survey (chlorophyll *a* 186 mg/m^2) came close to breaching the NOF standard. The lower site breached the NOF standard (chlorophyll *a* 237 mg/m^2) for the summer 2018 survey and breached the guideline to protect benthic biodiversity for the summer 2017 survey (**Error! Reference source not found.**) (Figure 97).

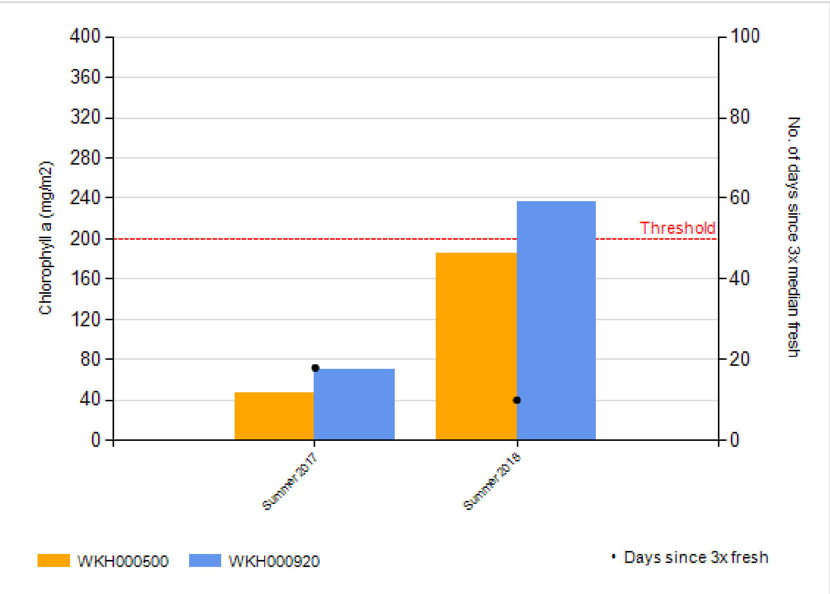


Figure 97 Periphyton biomass (chlorophyll *a*) on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2016-2018 period

2.10.5 Summary of 2002-2018 (16 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 nine occasions. In comparison, the lower site only breached guidelines on three occasions. The current period recorded a breach in long filamentous algae at the upper site (Figure 98 and Figure 99). 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.

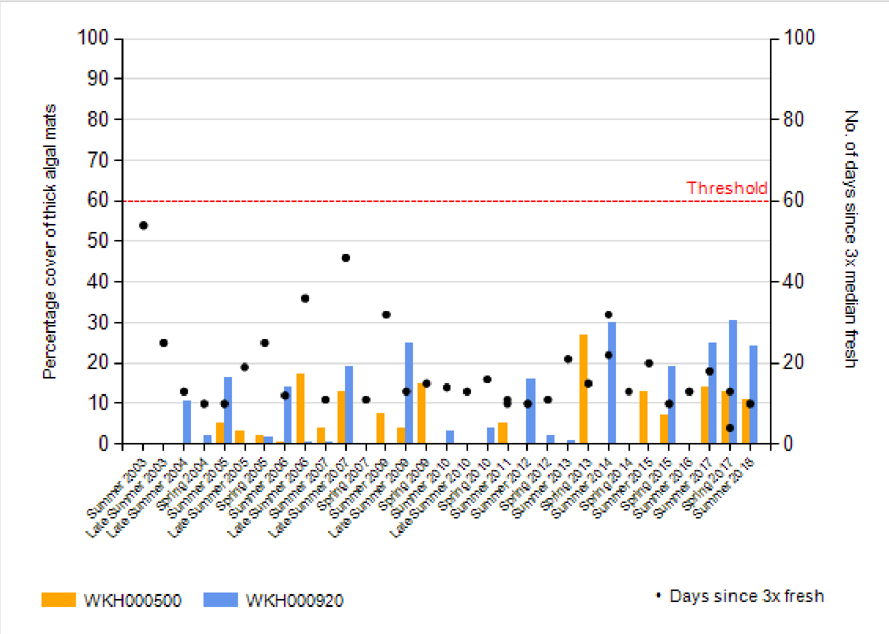


Figure 98 Percentage cover of thick mats of periphyton on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2002-2018 period

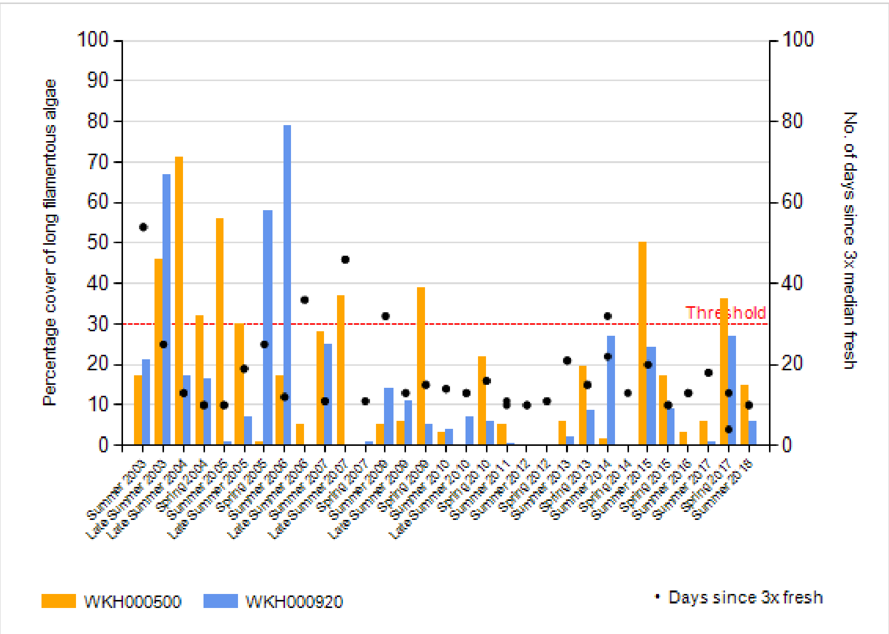
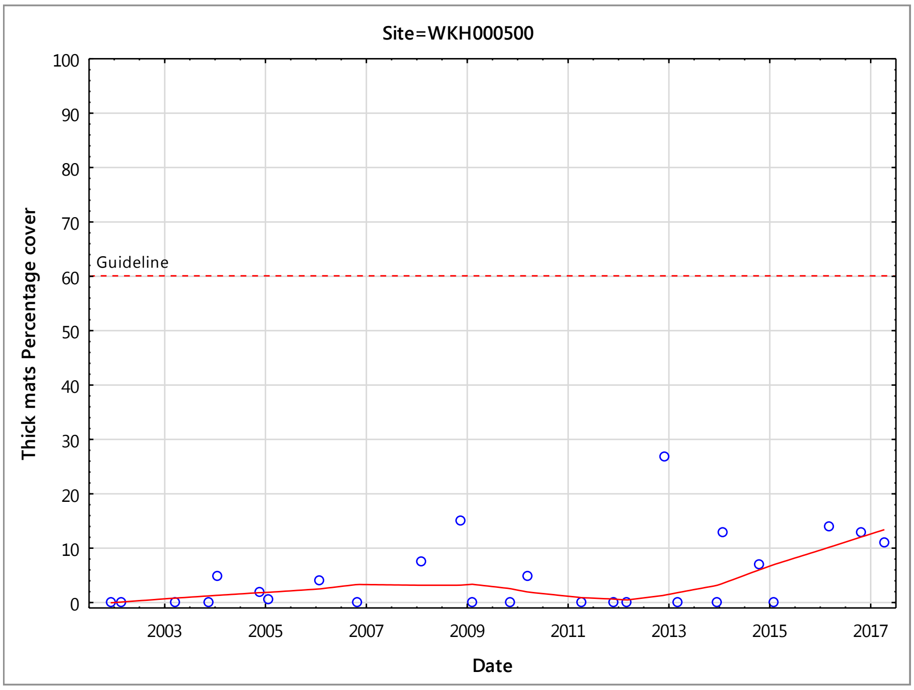


Figure 99 Percentage cover of long filamentous algae on the Waiwhakaiho riverbed in relation to the guidelines for recreational values over the 2002-2018 period

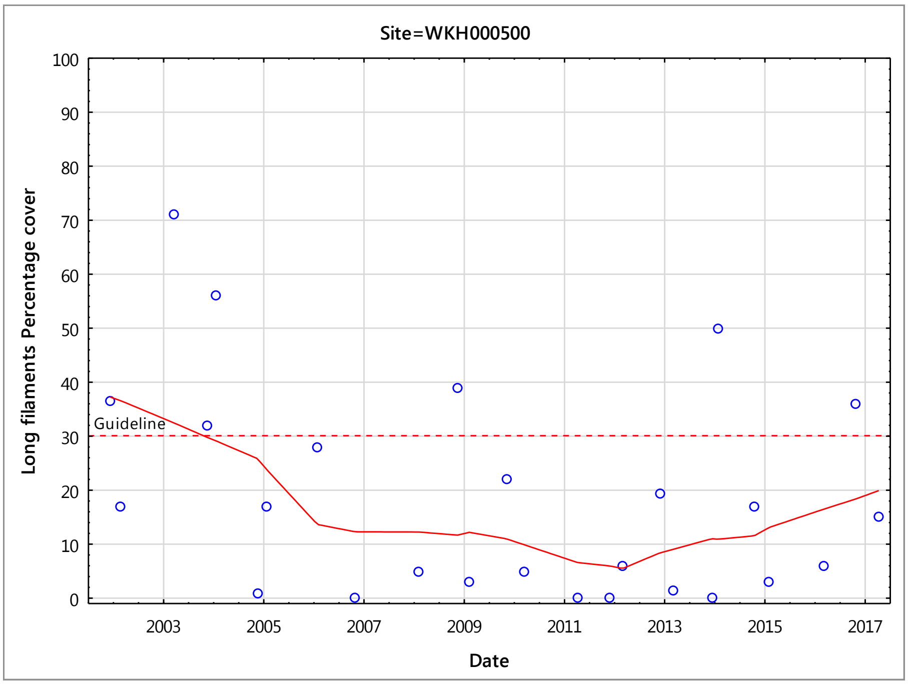
2.10.6 Long term trend analysis

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 Waiwhakaiho River, Constance Street and SH3 (Egmont Village), over a 16 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 100 to Figure 103).



n = 26
Kendal tau =0.27
p-value = 0.06
FDR p-value = 0.20

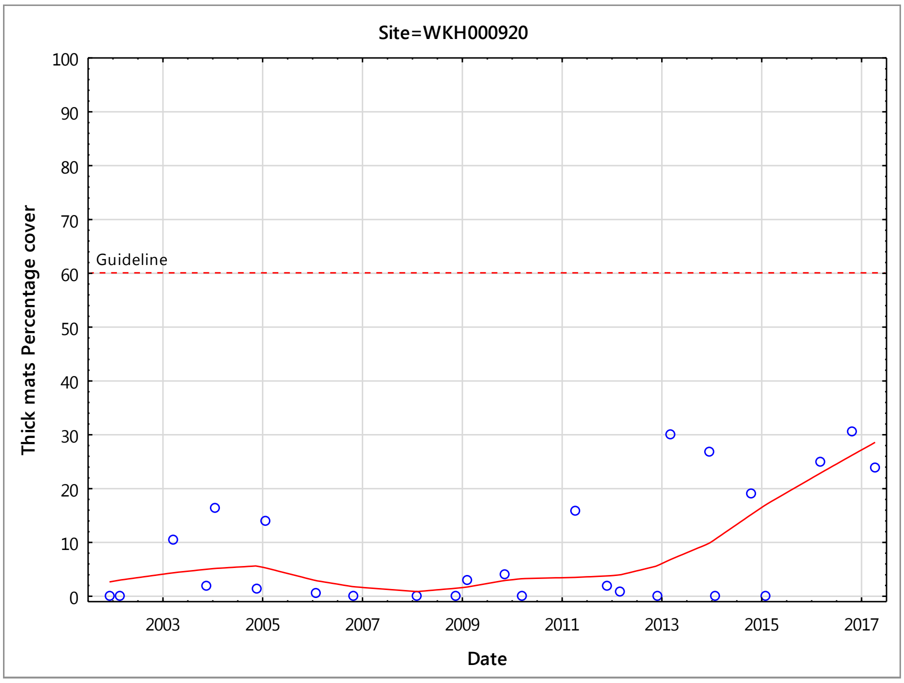
Figure 100 LOWESS trend analysis of percentage cover of thick mats at Waiwhakaiho River, SH3, Egmont Village (WKH000500)



n = 26
Kendal tau = -0.18
p-value = 0.19
FDR p-value = 0.34

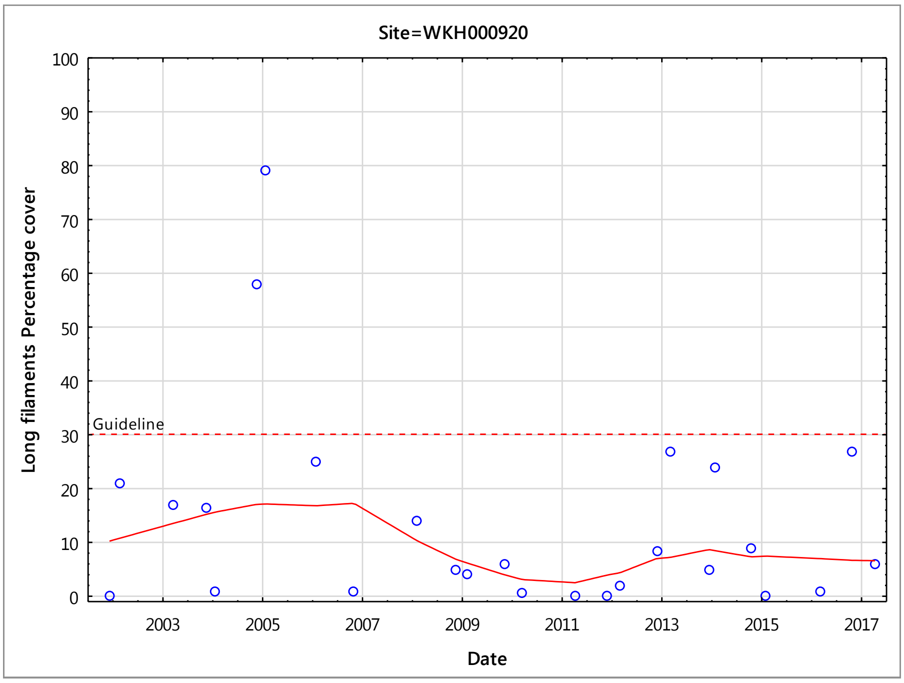
Figure 101 LOWESS trend analysis of percentage cover of long filaments at Waiwhakaiho River, SH3, Egmont Village (WKH000500)

At SH3 (Egmont Village) over the 16 year monitored period there were no significant trend for thick mats (p=0.20) or long filaments (p=0.34) at the 5% level of significance after false discovery rate adjustment.



n = 26
Kendal tau = 0.25
p-value = 0.07
FDR p-value = 0.20

Figure 102 LOWESS trend analysis of percentage cover of thick mats at Waiwhakaiho River, Constance Street, New Plymouth (WKH000920)



n = 26
Kendal tau = -0.09
p-value = 0.52
FDR p-value = 0.61

Figure 103 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 16 year monitored period there were no significant trends for thick mats (p=0.20) or long filaments (p=0.61) at the 5% level of significance after false discovery rate adjustment.

3 General summary

3.1 Periphyton cover

During the 2016-2018 monitoring period 21 sites were monitored for periphyton on four occasions; spring 2016, summer 2017, spring 2017 and summer 2018 (Table 37). For the spring 2016 period ten sites were not surveyed due to frequent flooding.

Table 37 Nuisance periphyton coverage at 21 sites over the 2016-2018 monitoring period

River/Stream	Site	Nuisance periphyton percentage cover							
		Spring 2016		Summer 2017		Spring 2017		Summer 2018	
		Mats	Filaments	Mats	Filaments	Mats	Filaments	Mats	Filaments
Hangatahua (Stony)	Mangatete Road	NS	NS	0	0	2	0	0	0
	SH45	NS	NS	0	0	0	0	0	0
Kapoaiaia	Wiremu Road	8	0	11	26	2	7	5	3
	Wataroa Road	17	12	18	70	15	0	0	67
	Cape Egmont	18	5	8	69	27	17	23	28
Maketawa	Derby Rd	NS	NS	0	0	1	2	0	2
	Tarata Road	NS	NS	2	1	0	2	4	2
Mangaehu	Raupuha Road	58	28	68	21	84	0	46	11
Manganui	SH3	NS	NS	0	0	0	0	11	10
	Bristol Road	NS	NS	0	6	0	1	0	0
Patea	Barclay Road	0	0	0	0	3	1	1	5
	Skinner Road	3	10	13	1	0	0	0	0
Punehu	Wiremu Road	1	0	35	0	21	0	0	1
	SH45	13	31	16	47	8	7	0	2
Waingongoro	Opunake Road	0	0	0	0	15	4	0	0
	Stuart Road	1	1	19	2	6	1	26	2
	Ohawe Beach	4	24	39	8	3	0	66	9
Waiongana	SH3a	NS	NS	12	34	4	20	0	6
	Devon Road	NS	NS	15	23	25	24	0	44
Waiwhakaiho	SH3 (Egmont Village)	NS	NS	14	6	13	36	24	6
	Constance St, NP	NS	NS	25	1	31	27	11	15
Average		11	10	14	15	12	7	10	10

*Exceeded guideline levels (MfE, 2000). NS = no survey

Over the 2016-2018 monitoring period there were three breaches in the thick algal mat guideline (greater than or equal to 60% coverage) and eight breaches in the long filamentous algae guideline (greater than or equal to 30% coverage). The eleven breaches occurred at eight sites (ie 62% of sites had no exceedances of any guidelines during the period). Only one breach, at SH45 site on the Punehu, occurred in the spring 2016 survey. Five breaches occurred during the summer 2017 survey. There were two breaches during the spring 2017 and three breaches during the summer 2018 survey. Three sites, Mangaehu River at Raupuha Road, Punehu at SH45, and the Kapoaiaia Stream at Wataroa Road had two breaches during the reported period (Table 37).

The overall compliance rate was 93% across all surveys undertaken.

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 cumulative cover of % thick algal mats +% long filamentous algae x 2, as long filamentous algae is considered to have twice the nuisance value of thick mats), then six additional surveys including one additional site would also have nuisance levels of periphyton. The discrepancy if mats and filaments are considered in isolation is highlighted by the spring 2016 survey of the Mangaehu River which passes both the thick mat and filaments criteria yet has a combined 86% nuisance periphyton streambed coverage. Taking into account such combined effects, the overall compliance rate was 89%.

Sites with higher levels of nuisance periphyton were located at the lower ends of their 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), but nitrogen levels are typically low and this would limit periphyton growth. Further away from the National Park nitrogen levels typically increase while phosphorus levels are variable depending on inputs from agriculture, meatworks, town sewerage schemes etc. 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 for undisturbed (reference) sites.

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 2017 had the highest combined levels of nuisance periphyton and in particular the highest long filamentous algae coverage, which is more problematic than thick mats, but the summer 2018 survey had nuisance periphyton levels comparable with the spring surveys, likely as a result of the relatively wet summer period.

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 38). For the spring 2016 survey 64% of sites were 'very good', 18% were 'good' and 18% had a 'moderate' rating (ten sites were not sampled due to frequent floods).

Table 38 TRC PI scores for 21 sites over the 2016-2018 monitoring period

River/ Stream	Site	TRC Periphyton Index Score								Median rating 2016-2018	
		Spring 2016		Summer 2017		Spring 2017		Summer 2018			
		TRC PI	Rating	TRC PI	Rating	TRC PI	Rating	TRC PI	Rating	TRC PI	Rating
Hangatahua	Mangatete Road	NA	NS	9.5	Very good	9.2	Very good	9.8	Very good	9.5	Very good
	SH45	NA	NS	8.6	Very good	8.1	Very good	10	Very good	8.6	Very good
Kapoaiaia	Wiremu Road	10	Very good	6.7	Very good	9.6	Very good	9.4	Very good	9.5	Very good
	Wataroa Road	8.1	Very good	3.0	Poor	8.8	Very good	3.5	Poor	5.8	Moderate
	Cape Egmont	8.1	Very good	4.0	Moderate	7.4	Good	5.7	Moderate	6.6	Good
Maketawa	Derby Rd	NA	NS	9.7	Very good	9.6	Very good	9.6	Very good	9.6	Very good
	Tarata Road	NA	NS	9.2	Very good	9.3	Very good	9.1	Very good	9.2	Very good
Mangaehu	Raupuha Road	4.0	Moderate	4.3	Moderate	4.9	Moderate	6.8	Good	4.6	Moderate
Manganui	SH3	NA	NS	10	Very good	10	Very good	10	Very good	10	Very good
	Bristol Road	NA	NS	8.3	Good	6.7	Good	7.1	Good	7.1	Good
Patea	Barclay Road	9.8	Very good	10	Very good	9.8	Very good	10	Very good	9.9	Very good
	Skinner Road	7.7	Good	8.4	Very good	9.5	Very good	8.0	Very good	8.2	Very good
Punehu	Wiremu Road	9.9	Very good	8.2	Very good	9.3	Very good	9.9	Very good	9.6	Very good
	SH45	5.5	Moderate	4.7	Moderate	8.5	Very good	9.4	Very good	7.0	Good
Waingongoro	Opunake Road	9.0	Very good	10	Very good	9.7	Very good	9.7	Very good	9.7	Very good
	Stuart Road	9.5	Very good	8.4	Very good	9.5	Very good	8.0	Very good	9.0	Very good
	Ohawe Beach	6.5	Good	7.5	Good	7.6	Good	5.6	Moderate	7.0	Good
Waiongana	SH3a	NA	NS	4.8	Moderate	7.8	Good	7.5	Good	7.5	Good
	Devon Road	NA	NS	6.2	Good	6.7	Good	4.6	Moderate	6.2	Good
Waiwhakaiho	SH3 (Egmont Village)	NA	NS	7.8	Good	5.1	Moderate	7.4	Good	7.4	Good
	Constance St, NP	NA	NS	6.6	Good	4.6	Moderate	5.5	Moderate	5.5	Moderate

For the summer 2017 survey 52% of sites were rated as 'very good', 23% were 'good', 19% 'moderate' and 5% 'poor'. For the spring 2017 survey 62% of sites were rated as 'very good', 23% were 'good' and 14% 'moderate'. For the summer 2018 survey 57% of sites were 'very good', 19% were 'good', and 19% 'moderate' and 5% 'poor' (Table 38).

No sites had a median score that would place it in the two lowest categories of 'poor' or 'very poor' and only three sites had median scores placing them in the 'moderate' category. However, some sites did have large fluctuations among surveys within the reported period and one site did receive a 'poor' rating for two surveys. 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 375 mg/m^2 over the reported period (Table 39). Four sites had values above the NOF guideline value (200 mg/m^2) and 13 sites had values above the guideline to protect benthic biodiversity (50 mg/m^2)). There were ten sites in summer 2017 that had values above 50 mg/m^2 and nine sites in summer 2018 that had values above 50 mg/m^2 (**Error! Reference source not found.**). Temporal trend analysis requires a minimum of ten years of data and therefore could not be applied to the complete monitoring dataset. Furthermore, 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 39 Periphyton biomass as estimated by chlorophyll *a* (mg/m^2) for 21 sites over the 2016-2018 monitoring period

River/Stream	Site name	Distance from Nat Park (km)	Periphyton biomass (chlorophyll *a* mg/m^2)	
			Summer 2017	Summer 2018
Hangatahua (Stony)	Mangatete Road	7.3	16	1
	SH45	12.5	33	7
Kapoaiaia	Wiremu Road	5.7	19	25
	Wataroa Road	13.5	237*	115
	Cape Egmont	25.2	133	17
Maketawa	Derby Rd	2.3	3	3
	Tarata Road	15.5	25	132
Mangaehu	Raupuha Road	NA	375*	89
Manganui	SH3	8.7	5	3
	Bristol Road	37.9	90	NR
Patea	Barclay Road	1.9	5	5
	Skinner Road	19.2	29	117
Punehu	Wiremu Road	4.4	45	1
	SH45	20.9	98	21
Waingongoro	Opunake Road	7.2	21	11
	Stuart Road	29.6	152	167
	Ohawe Beach	66.6	90	20
Waiongana	SH3a	16.1	185	119
	Devon Road	31.2	73	221*
Waiwhakaiho	SH3 (Egmont Village)	10.6	46	186
	Constance St, NP	26.6	70	237*
Average			83	75

*Exceeds NOF bottom line (D band), NS = no result

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. No sites within 10 km of the National Park boundary had values in exceedance of 50 mg/m^2. All ringplain sites further than 10 km from the National Park boundary, with the exemption of the Hangatahua River downstream site, had at least one value in exceedance of 50 mg/m^2. The Hangatahua River was selected for its outstanding water quality and it also has significant bed scouring from frequent freshes and high sediment loads.

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 analysis of time since 3x median flow and 7x median flow compared with chlorophyll *a* as the response variable shows a significant relationship for the summer 2017 survey results in response to time since a flow in excess of 3x median flow (N=21, F value = 7.52, p value 0.01) and 7x median flow (N=21, F value = 8.22, p value <0.01). There was also a significant positive relationship between distance from the National Park boundary and the summer 2018 TRC PI results (N=19, F value = 15.17, p value <0.01) but not the summer 2017 survey results.

The results do indicate that at times large freshes can reduce periphyton biomass by scouring periphyton off the streambed and sites further away from the National Park boundary have higher periphyton biomasses. 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. Interactive effects are also important and it should be noted that when flows had a significant effect in 2017, distance from the National Park was not significant, but when flows did not have a significant effect in 2018, distance from the National Park boundary was significant.

3.4 Long term trends

This programme was implemented to ascertain 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 fifth report written for this programme, and is the third to include analysis of trends. 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 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 16 year data set.

Table 40 Kendall Tau correlations for periphyton (thick mats) for data from 2002-2018. 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
STY000300	26	0.12	0.85	0.39	0.46
STY000400	26	-0.08	-0.56	0.58	0.61
KPA000250	28	-0.15	-1.12	0.26	0.35
KPA000700	28	-0.21	-1.55	0.12	0.21
KPA000950	28	-<.01	-0.02	0.98	0.98
MKW000200	29	0.15	1.17	0.24	0.35
MKW000300	29	-0.23	-1.77	0.08	0.20
MGH000950	29	0.33	2.50	0.01	0.11
MGN000195	29	-0.32	-2.43	0.02	0.11
MGN000427	29	0.15	1.14	0.26	0.35
PAT000200	31	-0.22	-1.72	0.09	0.20
PAT000360	31	0.19	1.52	0.13	0.21
PNH000200	30	0.24	1.88	0.06	0.20
PNH000900	30	0.11	0.85	0.40	0.46
WGG000150	31	-0.32	-2.53	0.01	0.11
WGG000665	31	0.21	1.63	0.10	0.20
WGG000995	31	0.24	1.91	0.06	0.20
WGA000260	27	-0.08	-0.60	0.55	0.61
WGA000450	27	0.23	1.65	0.10	0.20
WKH000500	26	0.27	1.90	0.06	0.20
WKH000920	26	0.25	1.83	0.07	0.20

Long term trend analysis of the 21 sites monitored for thick periphyton mats found three sites with significant trends before FDR adjustment and no sites had a significant p-value after FDR adjustment. The Mangaehu River, upper Manganui River and upper Waingongoro River sites were the sites with a significant p-value before FDR adjustment with the Mangaehu River having an increase in thick mats and the upper Manganui River and Waingongoro River sites having a reduction in thick mats (Table 40).

In total nine sites had a decreasing trend for thick mats and 12 sites had an increasing trend for thick periphyton mats.

Long term trend analysis of the 21 sites monitored for long filamentous algae found four sites with significant trends before FDR adjustment and two sites with a significant trends at the 5% level once p-values had the FDR adjustment applied to them (Table 41). The upper Waingongoro River and the upper Maketawa Stream sites had significant p-values before FDR adjustment with the upper Waingongoro River site having a reduction in long filamentous algae while the upper Maketawa Stream site had an increase in long filamentous algae. The upper Kapoaiaia River and lower Patea River sites both had significant trends after FDR adjustment which showed that filamentous algae had decreased at those sites.

In total 17 sites had a decreasing trend for long filamentous algae and three sites had an increasing trend while one site had no trend for filamentous algae.

Table 41 Kendall Tau correlations for periphyton (long filaments) for data from 2002-2018. 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
STY000300	26	-0.25	-1.76	0.08	0.28
STY000400	26	-0.23	-1.65	0.10	0.28
KPA000250	28	-0.43	-3.19	<0.01	0.03
KPA000700	28	-0.11	-0.84	0.40	0.54
KPA000950	28	-0.04	-0.28	0.78	0.82
MKW000200	29	0.33	2.54	0.01	0.07
MKW000300	29	-0.22	-1.65	0.10	0.28
MGH000950	29	-0.13	-0.97	0.33	0.47
MGN000195	29	NA	NA	NA	NA
MGN000427	29	-0.15	-1.14	0.26	0.43
PAT000200	31	-0.18	-1.42	0.15	0.32
PAT000360	31	-0.38	-3.02	<0.01	0.03
PNH000200	30	-0.10	-0.77	0.44	0.55
PNH000900	30	-0.02	-0.15	0.88	0.88
WGG000150	31	-0.30	-2.41	0.02	0.08
WGG000665	31	-0.18	-1.40	0.16	0.32
WGG000995	31	0.07	0.58	0.56	0.62
WGA000260	27	-0.14	-1.05	0.29	0.45
WGA000450	27	0.22	1.59	0.11	0.28
WKH000500	26	-0.18	-1.33	0.19	0.34
WKH000920	26	-0.09	-0.65	0.51	0.61

NA – no trend

There has been a significant amount of riparian vegetation and fencing implemented throughout the Taranaki region since periphyton monitoring began, but overall the majority of sites did not have a statistically significant trend, indicating little definite change in nuisance periphyton since monitoring began. However, 81% of sites had non-significant decreases in filamentous periphyton and further decreases in the future may result in more significant trends being defined. Furthermore, a number of sites had very little long filamentous algae and therefore there was little scope for improvement in any case.

4 Conclusions

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

- Generally, the monitored sites usually complied with established nuisance periphyton guidelines with 96% and 89% of surveys complying with the periphyton guideline for thick mats and long filaments respectively, equating to an overall compliance rate of 93% for nuisance periphyton surveys and with 62% of sites having no exceedances at any time.
- All rivers received a rating of at least 'moderate' for the TRC periphyton index score over all four surveys except for the Kapoaiaia River at Wataroa Rd which received two individual 'poor' ratings.
- Periphyton biomass results as measured by chlorophyll *a* were generally poorer than TRC PI results. The NOF limit (200 mg/m^2) was breached at two sites for the summer 2017 and summer 2018 surveys and the guideline to protect benthic biodiversity (50 mg/m^2) was breached at ten sites for the summer 2017 survey and nine sites for the summer 2018 survey.
- The data used for nuisance periphyton guidelines (thick algal mats and long filaments) correlates slightly with the periphyton index score but was potentially 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 effects 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 with some streams requiring relatively larger flows to dislodge nuisance periphyton.
- The time trend analyses for thick mats and long filaments reveals that the majority of sites did not have a statistically significant trend indicating little change in nuisance periphyton since monitoring began. However, 81% of sites had non-significant decreases in filamentous periphyton and further decreases in the future may result in more significant trends being determined.
- 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*. This diatom is also known as didymo, or 'rock snot'.

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 high country 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 geminata* covered rock

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

The sites in Table 42 and Figure 104 are popular freshwater recreational sites in Taranaki and are typically monitored during autumn 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 42 Sites monitored for *Didymosphenia geminate* and results of current surveys

River	Site Code	Site	2017	2018
Waiwhakaiho River	Constance Street	WKH000920	Absent	NS
Manganui River	Bristol Road	MGN000427	Absent	NS
Patea River	Skinner Road	PAT000360	Absent	NS
Waingongoro River	Ohawe Beach	WGG000995	Absent	NS
Kaupokonui River	Upper Glen Road	KPK000880	Absent	NS
Kapuni Stream	SH45	KPN000450	Absent	NS
Stony River	Mangatete Road	STY000300	Absent	NS
Mangaoraka Stream	Corbett Road	MRK000420	Absent	NS

*NS; no survey was able to be completed due to persistently high flows

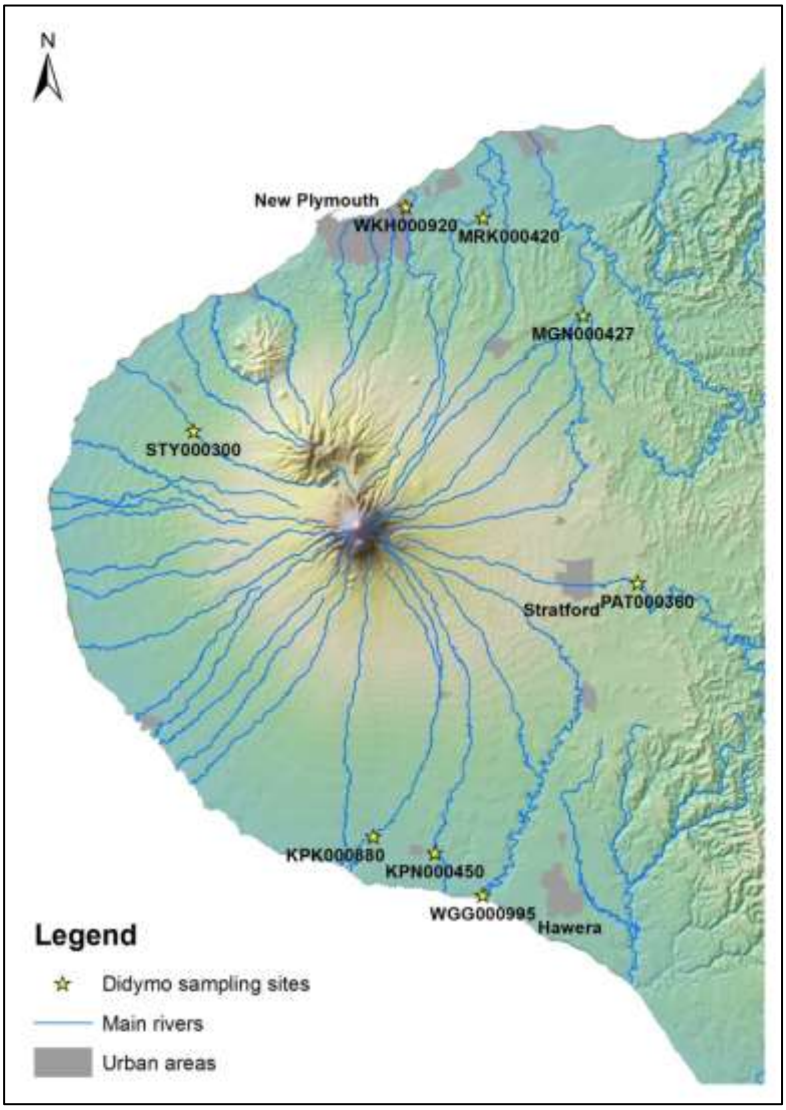


Figure 104 Sites monitored for *Didymosphenia geminata*

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 2018-2020 monitoring period, the Waiwhakaiho, Manganui, Patea, Waingongoro, Stony and Kaupokonui Rivers and Kapuni and Mangaoraka Streams are monitored for the invasive diatom *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.
5. That consideration be given to taking chlorophyll *a* samples for the spring surveys as well as the summer surveys as this is now the preferred technique to monitor benthic periphyton.

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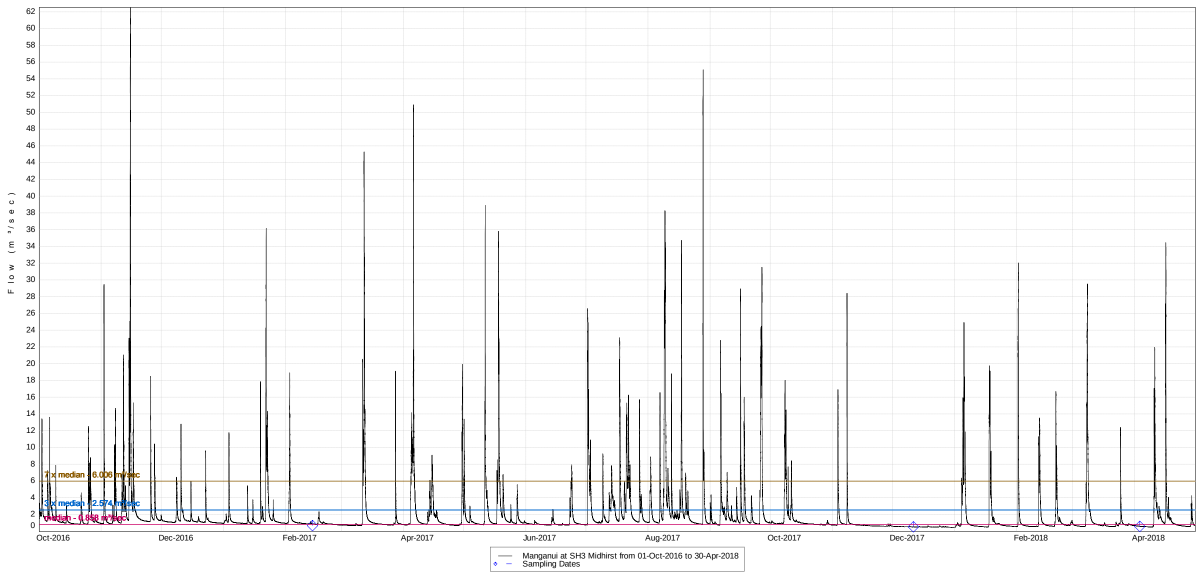
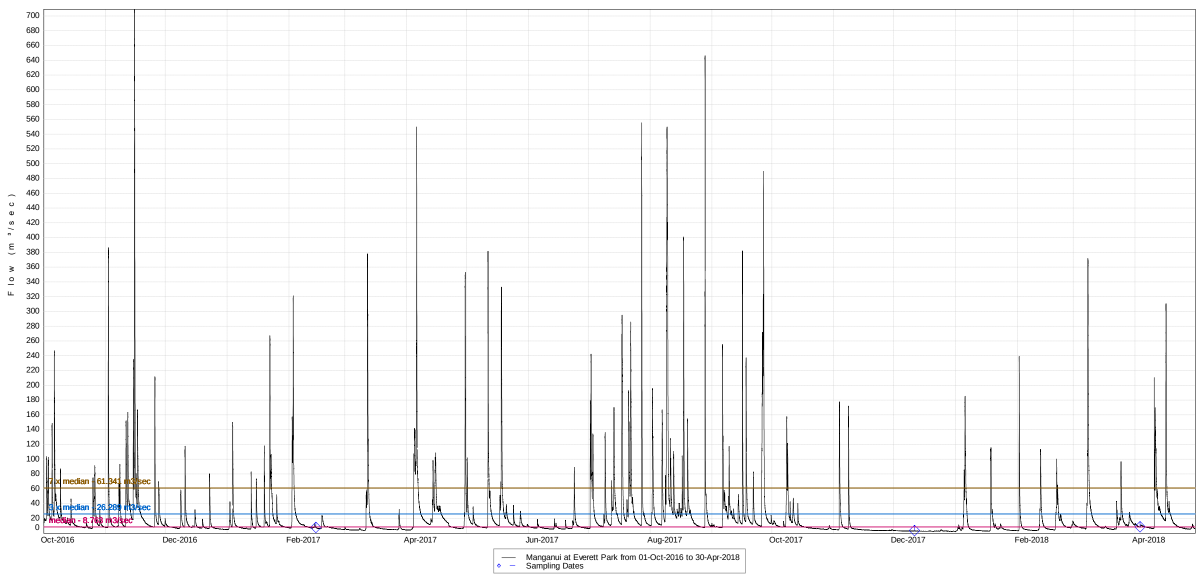
Appendix I

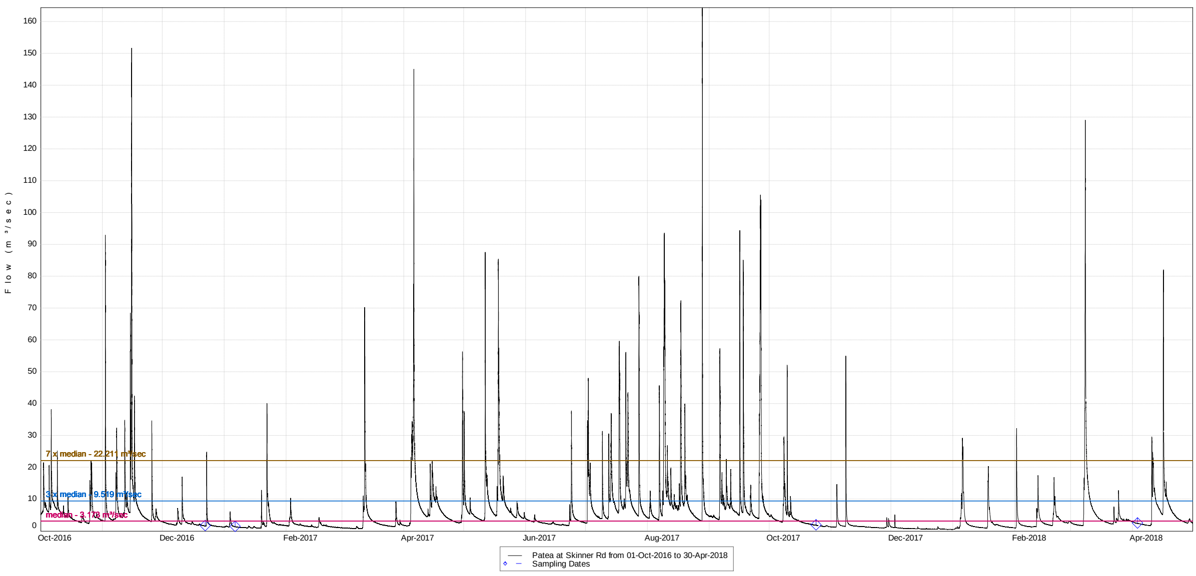
Flow data 2016-2018



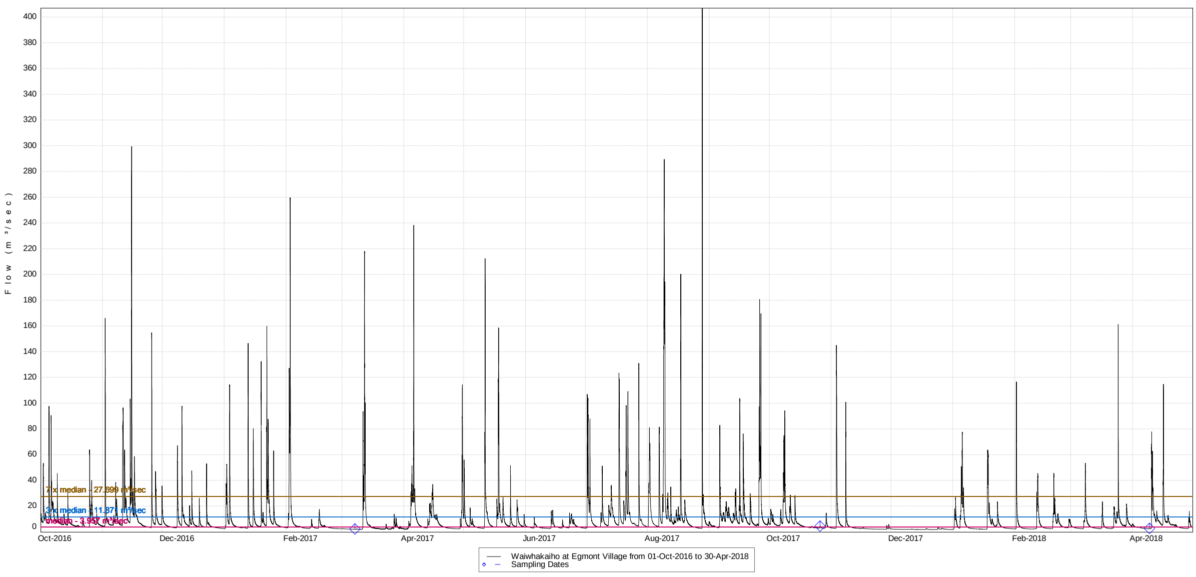
Flow in Manganui River at SH3 over the 2016-2018 sampling period



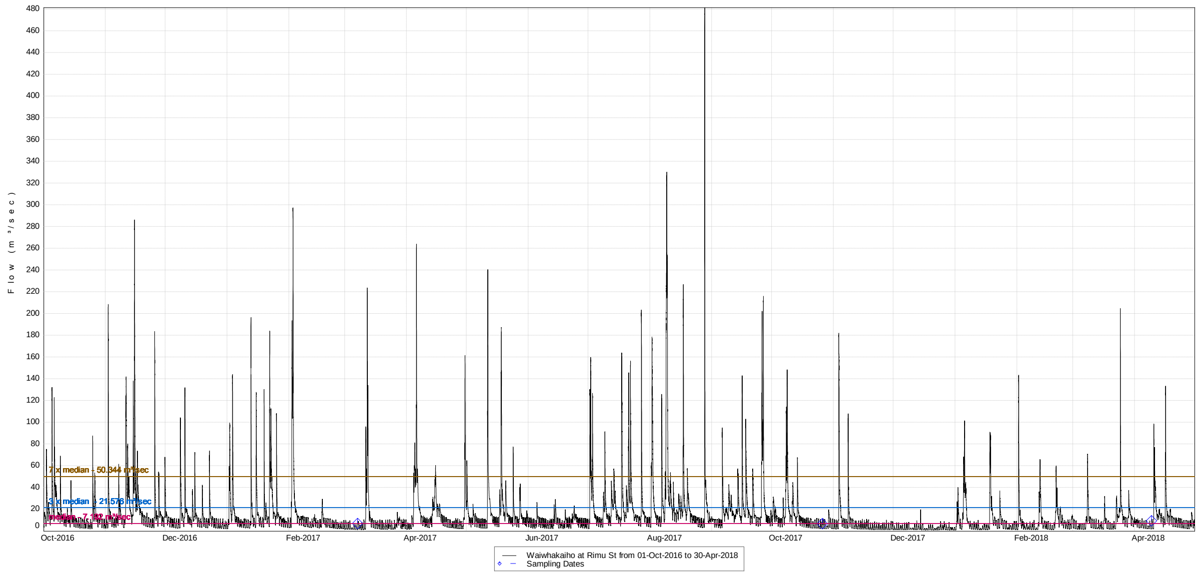
Flow in Manganui River at Everett Park over the 2016-2018 sampling period



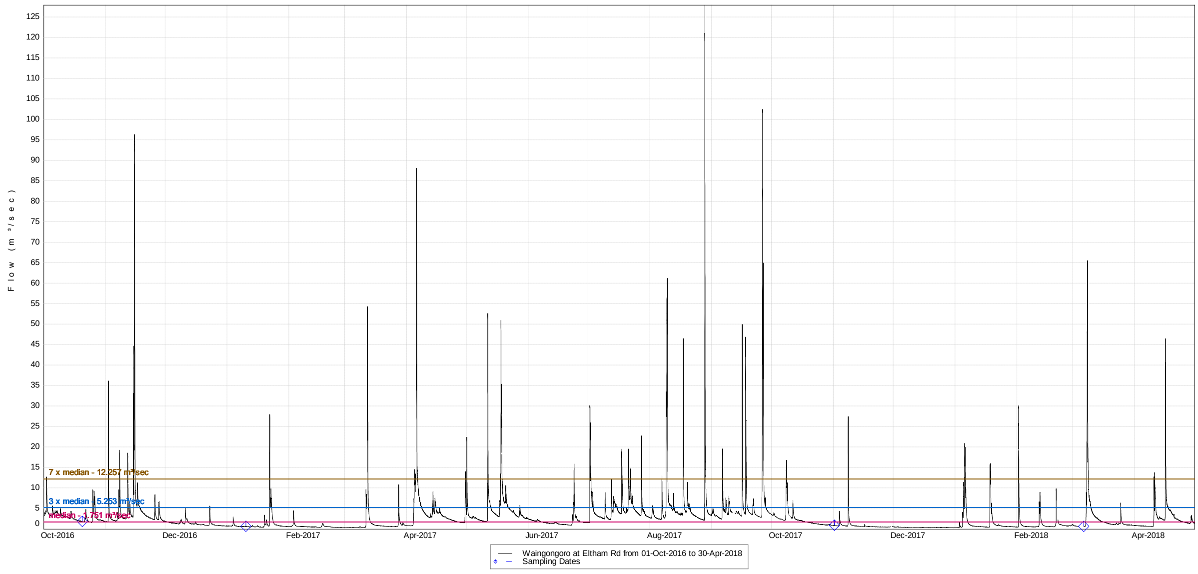
Flow in the Patea River over the 2016-2018 sampling period



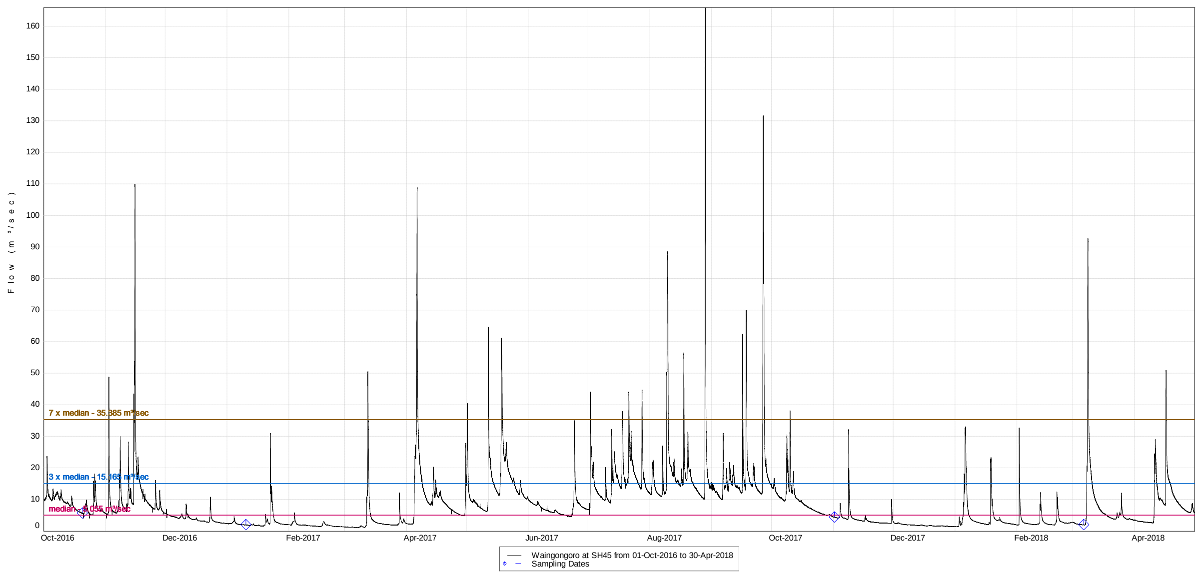
Flow in the Waiwhakaiho River at Egmont Village during the 2016-2018 sampling period



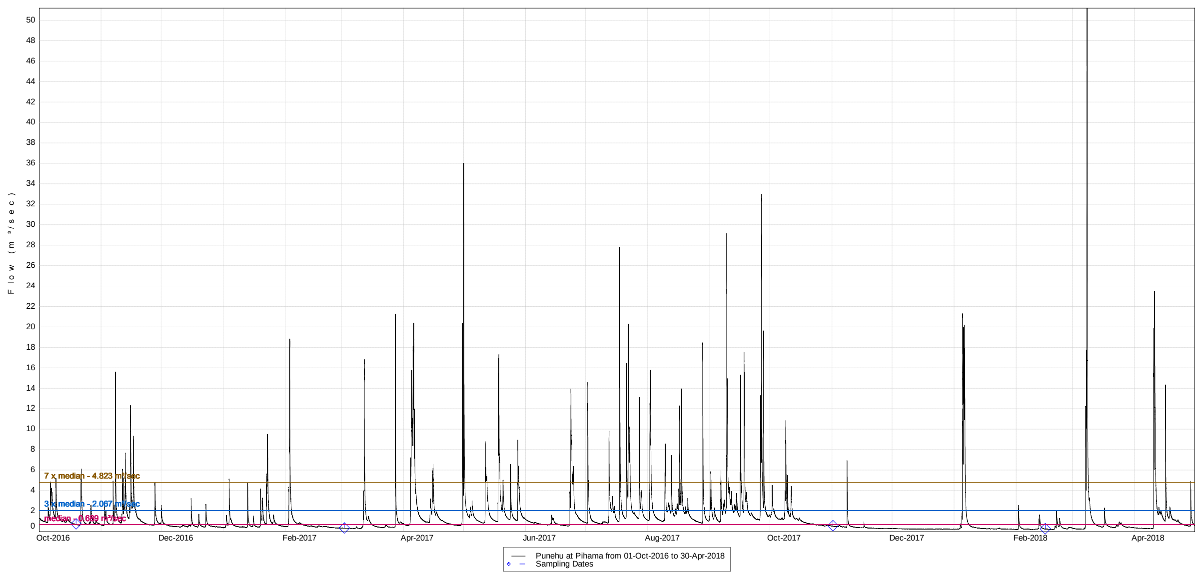
Flow in the Waiwhakaiho River at Rimu Street during the 2016-2018 sampling period



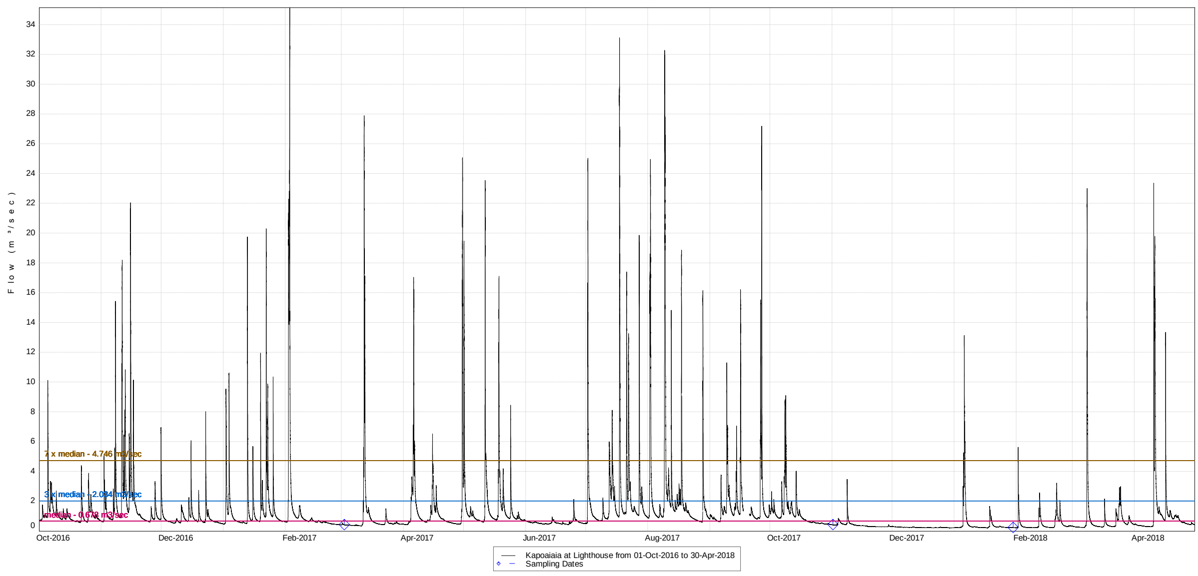
Flow in the Waingongoro River at Eltham Road during the 2016-2018 sampling period



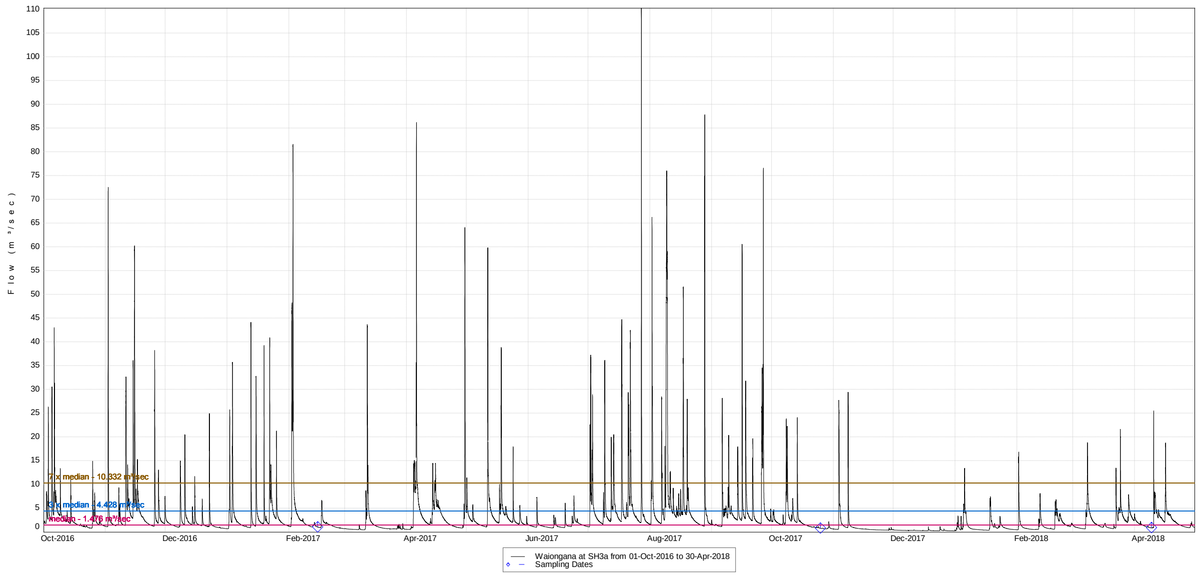
Flow in the Waingongoro River at SH45 during the 2016-2018 sampling period



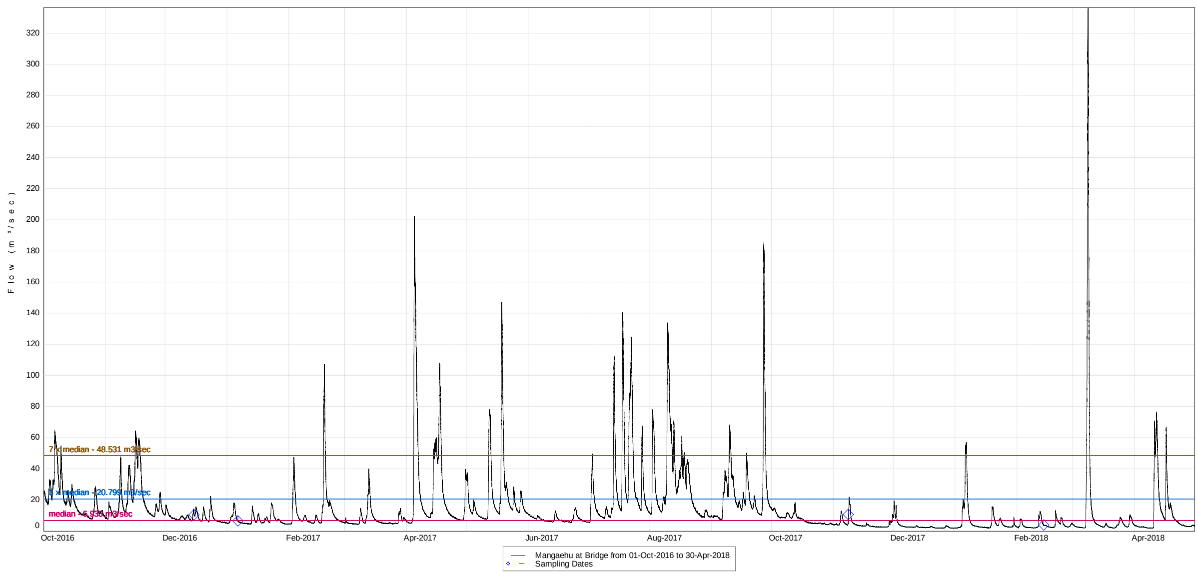
Flow in the Punehu Stream during the 2016-2018 sampling period



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



Flow in the Waiongana River at SH3a during the 2016-2018 monitoring period



Flow in the Mangaehu River during the 2016-2018 survey period

Appendix II

Nutrient data 2016-2018

Nutrient data showing median values for physiochemical samples for dissolved reactive phosphorus, dissolved inorganic nitrogen and total nitrogen for the preceding year. Prevention of undesirable growths for upland rivers (>150m) dissolved reactive phosphorus (DRP) <0.009 mg/L and total nitrogen (TN) <0.295 mg/L and for lowland rivers (≤150m) dissolved reactive 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	Distance from Nat Park (km)	Altitude (m)	2016-2017			2017-2018		
				DRP	DIN	TN	DRP	DIN	TN
Hangatahua (Stony)	Mangatete Road	7.3	160	0.023*	0.049	0.08	0.021*	0.026	0.025
	SH45	12.5	70	NA	NA	NA	NA	NA	NA
Kapoaiaia	Wiremu Road	5.7	240	NA	NA	NA	NA	NA	NA
	Wataroa Road	13.5	140	NA	NA	NA	NA	NA	NA
	Cape Egmont	25.2	20	NA	NA	NA	NA	NA	NA
Maketawa	Derby Rd	2.3	380	0.028*	0.450*	0.50*	0.037*	0.423*	0.47*
	Tarata Road	15.5	150	NA	NA	NA	NA	NA	NA
Mangaehu	Raupuha Road	NA	120	0.001	0.141*	0.31	0.007	0.176*	0.28
Manganui	SH3#	8.7	330	0.010*	0.161*	0.202	0.010*	0.118*	0.178
	Bristol Road	37.9	140	NA	NA	NA	NA	NA	NA
Patea	Barclay Road	1.9	500	0.020*	0.022	0.06	0.022*	0.022	0.06
	Skinner Road	19.2	240	0.035*	1.111*	1.22*	0.043*	0.920*	1.18*
Punehu	Wiremu Road	4.4	270	0.021*	0.056	0.14	0.019*	0.080	0.30*
	SH45	20.9	20	0.058*	1.465*	1.63*	0.042*	1.252*	1.98*
Waingongoro	Stuart Road+	7.2	180	0.026*	1.50*	1.72*	0.031*	1.236*	1.17*
	Ohawe Beach+	29.6	10	0.041*	1.857*	2.11*	0.048*	1.988*	2.62*
	Opunake Road	26.6	380	NA	NA	NA	NA	NA	NA
Waiongana	SH3a	66.6	140	NA	NA	NA	NA	NA	NA
	Devon Road	16.1	20	NA	NA	NA	NA	NA	NA
Waiwhakaiho	SH3 (Egmont Village)	31.2	175	0.030*	0.185*	0.23	0.029*	0.145*	0.21
	Constance St, NP	10.6	20	NA	NA	NA	NA	NA	NA

+ No nutrient data was available for the Waingongoro periphyton sites but sites located close to two periphyton sites on the Waingongoro River did have nutrient data and these are displayed.

NIWA water quality monitoring site

* Does not meet ANZECC 2000 guidelines or suggested NZFSS 2015 value to control cyanobacteria