Freshwater Periphyton

Monitoring Programme

(Periphyton monitoring in relation to amenity values)

State of Environment Monitoring Report

2018-2020

Technical Report 2020-24

Working with people | caring for Taranaki

Taranaki Regional Council

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Private Bag 713
Stratford

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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. Monitoring is timed for when river conditions are at their most conducive for promoting excessive periphyton growth. That is, by design the programme seeks to quantify 'worst-case' periphyton in the region's rivers. This report summarises the results of the State of the Environment periphyton programme for the monitoring period 2018-2020.

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 a stream's ecosystem, functioning by utilising sunlight via photosynthesis to absorb nutrients and organic compounds for growth. The periphyton subsequently becomes 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 instream values 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 e.g., tuna (eel), piharau (lamprey), kahawai, inanga and other whitebait species. These values would be adversely affected by excessive periphyton growth.

Twenty sites are surveyed in nine rivers/streams around the Taranaki Region. Sites have been chosen in order to be representative of different catchment types, such as high conservation, agriculture, riparian and major abstraction. Rivers or streams have one upper (mostly un-impacted) site, and one or two lower sites (with various degrees of land use impact).

Periphyton surveys are scheduled for two times per year; spring (15 September to 31 December) and summer (1 January to 15 April). Sampling is 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 are made across the stream using a periphyton viewer. Types of periphyton cover on the stream bed within each square are estimated visually as percentage coverage on the substrate. Periphyton types considered are thin, medium and thick films of mats and short and long filaments. The colour of the growth (brown, black, or green) is also recorded. Additionally, during the summer period periphyton samples are collected from ten rocks randomly selected at each site, and levels of chlorophyll *a* pigment are 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 more than 30% of the bed is covered by filamentous algae and/or more than 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) is also calculated from the periphyton cover data, and scores converted into one of five grades.

Chlorophyll *a* is 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, 2020) 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. The Council is now also conducting a NOF-aligned periphyton monitoring programme.

Long-term trends in periphyton cover have been analysed using a combination of the Mann-Kendall technique, a 5% significance level, and a Benjamini-Hochberg False Discovery Rate (FDR) analysis. A LOWESS curve is also fitted to the time series of cover data for each site, allowing a visual inspection of both short and long term trends.

The results for the SEM nuisance periphyton programme during the 2018-2019 monitoring year showed that on two occasions, at two sites, there was a breach of the thick mat guideline, and that on six occasions across four separate sites there was a breach of the long filaments guideline. For the 2019-2020 monitoring year there were no breaches of the thick mat guideline and five occasions, at five separate sites, where there was a breach of the long filaments guideline (Table 1).

For the TRC Periphyton Index, the median index value for 2018-2020 monitoring showed that ten sites (50%) recorded a 'very good' rating, eight sites (25%) recorded a 'good' rating, and two sites (10%) recorded a 'moderate' rating. All surveys received a rating of at least 'moderate' for the TRC periphyton index score except for three 'poor' scores and one 'very poor' score recorded out of a total of 80 surveys. That is, 95% of surveys found at least a 'moderate' periphyton condition.

Periphyton biomass did not exceed the NOF standard (200 mg/m^2) for the summer 2019 surveys but did exceed the NOF standard at three sites for the summer 2020 survey (but see further on the interpretation of NOF compliance below). Periphyton biomass exceeded the guideline to protect benthic biodiversity (50 mg/m^2) at six sites for the summer 2019 survey, and eight sites for the summer 2020 surveys.

Periphyton biomass results generally reflected nuisance periphyton percentage cover levels, and to a lesser extent TRC PI scores. There were three sites with chlorophyll *a* levels in exceedance of the NOF bottom line criterion, however for each of these three 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. These sites can therefore not be said to be compliant or non-compliant. Furthermore, the NOF protocol allows sites to have one sample per year (out of 12 surveys if the NOF procedure was used) for non-productive waterbodies above the 200 mg/m^2 standard without deeming the site's quality to be in non-compliance.

Table 1: Summary of SEM periphyton results for 2018-2020 monitoring period

River/Stream	Site	Distance from Nat Park (km)	Median TRC Periphyton Index	Long-Term Trend		Periphyton cover - compliance with national guideline		Periphyton biomass (chlorophyll a mg/m^2)	
				Thick mats	Long filaments	Thick mats	Long filaments	2019	2020
Hangatahua (Stony)	Mangatete Road	7.3	Very good	Indeterminate	Indeterminate	4/4	4/4	0	1
	SH45	12.5	Very good	Indeterminate	Indeterminate	4/4	4/4	1	4
Kapoaiaia	Wiremu Road	5.7	Very good	Indeterminate	**Decreasing***	4/4	4/4	10	81
	Wataroa Road	13.5	Good	Indeterminate	Indeterminate	4/4	$3/4^{+}$	17	42
	Cape Egmont	25.2	Good	Indeterminate	Indeterminate	4/4	$3/4^{+}$	36	66
Maketawa	Derby Rd	2.3	Very good	Indeterminate	Indeterminate	4/4	4/4	1	1
	Tarata Road	15.5	Very good	Indeterminate	Indeterminate	4/4	4/4	23	9
Manganui	SH3	8.7	Very good	**Decreasing***	Indeterminate	4/4	4/4	2	2
	Bristol Road	37.9	Good	Indeterminate	Indeterminate	4/4	$2/4^{+}$	88	48
Patea	Barclay Road	1.9	Very good	Indeterminate	Indeterminate	4/4	4/4	3	3
	Skinner Road	19.2	Moderate	Indeterminate	Indeterminate	4/4	$2/4^{+}$	142	621^{n}
Punehu	Wiremu Road	4.4	Very good	**Increasing***	Indeterminate	4/4	4/4	3	2
	SH45	20.9	Good	Indeterminate	Indeterminate	4/4	4/4	13	16
Waingongoro	Opunake Road	7.2	Very good	**Decreasing***	Indeterminate	4/4	4/4	44	64
	Stuart Road	29.6	Very good	Indeterminate	Indeterminate	4/4	4/4	75	92
	Ohawe Beach	66.6	Good	**Increasing***	Indeterminate	4/4	4/4	55	67
Waiongana	SH3a	16.1	Good	Indeterminate	Indeterminate	$3/4^{+}$	$3/4^{+}$	69	242^{n}
	Devon Road	31.2	Moderate	Indeterminate	Indeterminate	4/4	$1/4^{+}$	122	283^{n}
Waiwhakaiho	SH3 (Egmont Village)	10.6	Good	**Increasing***	Indeterminate	4/4	$3/4^{+}$	14	42
	Constance St, NP	26.6	Good	**Increasing***	Indeterminate	$3/4^{+}$	4/4	41	22

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

Long term periphyton trend analysis revealed that for the majority of sites neither thick mats nor long filamentous algae levels showed significant improvement or degredation.

The data used for nuisance periphyton guidelines (thick algal mats and long filaments) overlaps with the TRC periphyton index score but was potentially distinct from the periphyton biomass data. This is due to the rocks viewed for periphyton cover not necessarily, and probably unlikely, being the same ones as used to collect periphyton biomass. Therefore, even though ten replicates are 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 Te Papakura o Taranaki boundary had less periphyton than those further downstream. The majority of lowland sites, except for those on the Hangatahua, Punehu, and Maketawa Rivers had at least one survey with moderate to high levels of periphyton.

The difference between spring and summer surveys was typical, with average thick mat and long filamentous algae levels higher in summer by between 8-12 percent compared with spring. Furthermore, the majority of guideline breaches occurred during summer surveys (11 summer breaches vs two spring breaches) and the only notional breaches of the NOF guideline were all in a summer survey.

No *Didymosphenia geminata* was found for the monitoring period under review. Didymo, or 'rock snot', is a highly prolific and invasive diatom algae 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 97% and 86% of surveys complying with the periphyton guideline for thick mats and long filaments respectively, and 84% of sites being compliant with nuisance periphyton guidelines at all times.
2. 'Upstream sites' with little agriculture in their catchment had typically lower levels of periphyton compared with sites located further down the catchment, which had nuisance periphyton levels which occasionally breached guideline limits.
3. Due to the number of variables involved (e.g. nutrients, light level, temperature, shading, 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. 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.

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1. Introduction

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

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

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

The SEM Freshwater Nuisance Periphyton programme began in the 2002-2003 monitoring year. Five previous reports have been written, summarising the 2002-2006, 2006-2010, 2010-2012, 2012-2016 and 2016-2018 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 2018-2020 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 fourth 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, a draft document produced in 2019, and a new version produced in 2020. 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 separate NPS-FM compliant monitoring programme, but in the meantime is also 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 (site 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.

Nuisance periphyton can be defined as thick mats with a thickness greater than 3 mm and long filaments with a length greater than 2 cm long. It is considered to be at nuisance levels when thick mats cover 60% or more of the streambed and/or long filaments cover 30% or more of the streambed (Biggs, 2000). 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 occur in the absence 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

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

Table 2 New Zealand periphyton guidelines in gravel/cobble bed streams 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 the 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 1 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 (Table 3) for assessing the public health risk from cyanobacteria associated with contact recreation in lakes and rivers.

Table 3 Alert level framework for benthic cyanobacteria

Alert level[a]	Actions
Surveillance (green mode) Up to 20% coverage of potentially toxigenic cyanobacteria attached to substrate.	• Undertake fortnightly surveys between spring and autumn at representative locations in the water body where known mat proliferations occur and where there is recreational use. • Take scrapings every second survey for microscopic identification, to compare with visual assessments in order to ensure cyanobacteria is being recorded accurately, and to provide an indication of the species present.

Alert level[a]	Actions
Alert (amber mode) 20–50% coverage of potentially toxigenic cyanobacteria attached to substrate.	• Notify the public health unit. • Increase sampling to weekly. • Recommend erecting an information sign that provides the public with information on the appearance of mats and the potential risks. • Consider increasing the number of survey sites to enable risks to recreational users to be more accurately assessed. • If toxigenic cyanobacteria dominate the samples, testing for cyanotoxins is advised. If cyanotoxins are detected in mats or water samples, consult the testing laboratory to determine if levels are hazardous.
Action (red mode) *Situation 1:* Greater than 50% coverage of potentially toxigenic cyanobacteria attached to substrate; or *Situation 2:* up to 50% where potentially toxigenic cyanobacteria are visibly **detaching** from the substrate, accumulating as scums along the river's edge or becoming **exposed** on the river's edge as the river level drops.	• Immediately notify the public health unit. • If potentially toxic taxa are present then consider testing samples for cyanotoxins. • Notify the public of the potential risk to health.

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

Photo 2 Thick mat of cyanobacteria

1.1.3 Methodology

1.1.3.1 Periphyton surveys

Periphyton surveys are 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 are made across the stream using a periphyton viewer (110 cm^2). Periphyton cover on the streambed within each square is 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 the calculation)

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

Streams are 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 to 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 are sampled within a day or two of each other; sites within each individual stream catchment are always sampled on the same day.

1.1.3.2 Periphyton index

Percentage periphyton cover data 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 is assigned a score (Table 4). Scores are assigned according to the conditions in which each category is usually found to be dominating the cover of streambeds (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 the sampled community 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 Hangatahua 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, particularly when very small amounts of periphyton may give misleading results.

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, but includes all types of cover. However, there are some pitfalls to this type of interpretation, as illustrated in Table 5. It is possible that a site in breach of the recreational and aesthetic guidelines returns a very good PI. Therefore, interpretation of periphyton index 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: 1 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 create national standards for certain water quality parameters (Snelder et al., 2013).

Periphyton biomass surveys were initiated in the 2010-2011 monitoring year (for the summer 2011 survey). The surveys are undertaken at the same 21 sites, and in conjunction with the periphyton cover surveys. Periphyton biomass surveys are only undertaken during summer (January 1- April 15), as the time and cost involved in collecting and analysing the samples is significantly higher than surveying for periphyton cover. This report examines chlorophyll *a* data for two summers (2018-2020).

The method for collecting periphyton biomass is adapted from Biggs and Kilroy (2000). Ten rocks are randomly selected and a known area of periphyton (0.0196 m^2) is scraped off each rock. TRC employs a slightly different process to sample the periphyton than that suggested by Biggs and Kilroy (2000). A device has been 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 they are excluded. Prior to 2016 the strands would be included within the sample. 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, possibly giving rise to some large outlier measurements.

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

1.2 Trend analysis

For each site, the nuisance periphyton cover data (from 2002 to 2020) site is analysed for the presence of any long-term trends. It is intended that such analysis will aid in identifying the impact of activities along the river, such as riparian planting.

As a first step, the change in percentage cover of thick mats and long filaments over time is visually inspected, using a LOWESS (Locally Weighted Scatterplot) curve fitted to the data to create a smoothed trend line.

The periphyton cover data are then statistically analysed for trends over time using a Mann-Kendall test, followed by false discovery rate (FDR) analysis (Stark and Fowles, 2006). The significance of a site's trend (i.e. the strength of the trend) is assessed according to the statistical probability of occurrence (p-value), with comparisons between sites valid so long as similar numbers of samples have been collected for analysis at each site. A Kendall tau coefficient is also produced, which indicates whether the trend is positive or negative, and gives a measure of the magnitude of the trend.

It should be noted that while a trend may be statistically significant, it may have little ecological impact, or vice versa. The assessment of ecological importance may be made using the best professional judgment (BPJ) of a freshwater scientist who has knowledge of the region's rivers and streams. However, it is likely that the strongest trends (lowest p-values) also have the greatest ecological importance.

1.3 Site locations

For the 2018-2020 monitoring period, nuisance periphyton surveys were undertaken at twenty sites in nine 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.

It is noted that for the 2018-2020 monitoring period the Mangaehu River site was removed from the survey, due to health and safety issues. Unfortunately, a suitable replacement site has not been found, and no periphyton monitoring has been conducted in the river for the monitoring period under review.

Table 8 Summary of nuisance periphyton monitoring sites in the 2018-2020 SEM programme

Sites				
River/Stream	**Location**	**Site Code**	**Distance from National 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
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

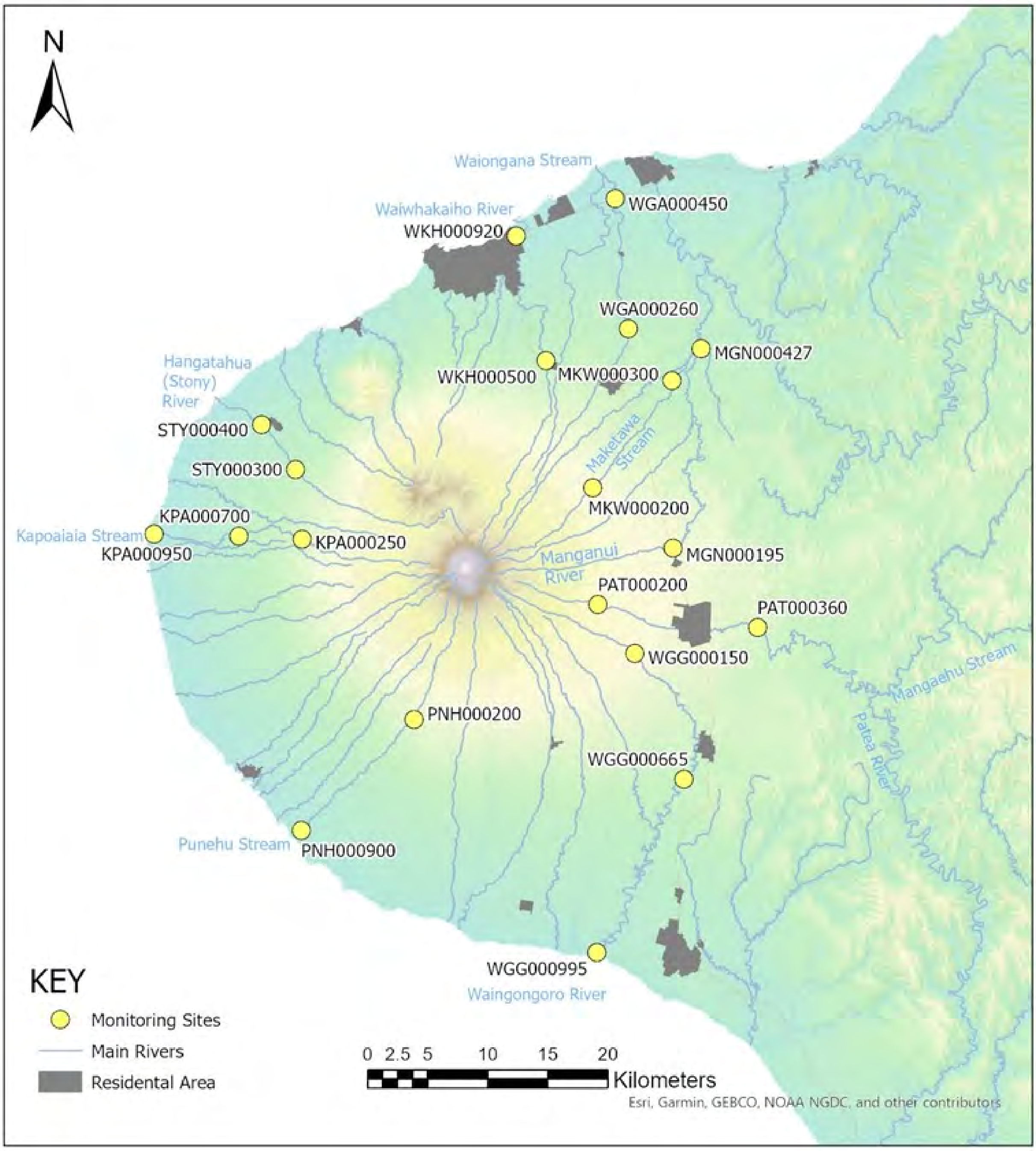


Figure 1 Location of nuisance periphyton monitoring sites within the Taranaki Region

2 Results

2.1 Hangatahua (Stony) River

The Hangatahua (Stony) River rises within the National Park boundary, on the north-western side of Taranaki Maunga. Upon leaving the National Park, it heads in a north-westerly direction for a distance of approximately 15 km 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 Hangatahua River is occasionally affected by significant natural erosion events in the headwaters, which can scour periphyton and limit proliferation, and which is a major source of sand for the Taranaki region.

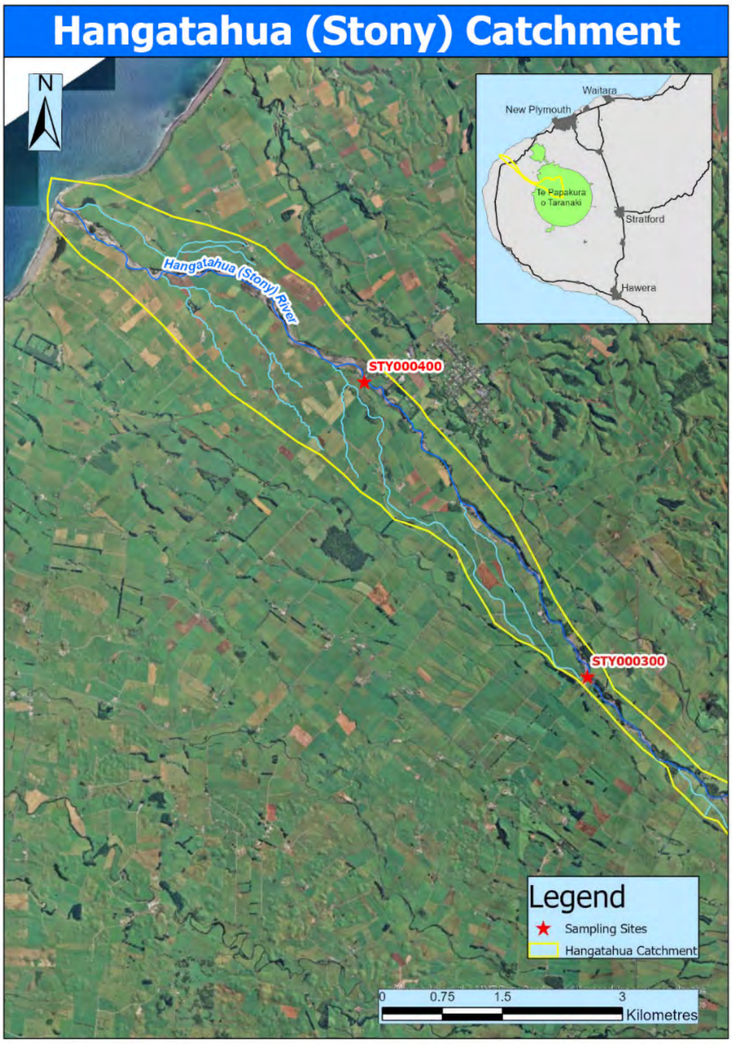


Figure 2 Monitoring site locations in the Hangatahua River catchment

The natural state of the river is protected 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 upper sampling site at Mangatete Rd (STY000300) is within seven km of the National Park boundary (as close as feasible for regular access), while the downstream site (STY000400) is just above SH45, 12 km 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 Hangatahua River at Mangatete Road, with flow data for this site available from 2004-2011. However, 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 days between freshes and sampling dates in the Hangatahua River catchment (Table 9).

Table 9 Date of samplings and days since three and seven times median flow. When samples were taken on different days, the second date is in brackets

Season	Date	3 x	7 x
Spring	25/10/2018	13	13
Summer	9/01/2019 (11/01/2019)	34 (36)	34 (36)
Spring	7/11/2019	15	27
Summer	24/01/2020	35	36

Nutrient data is collected at the Mangatete Rd site for the SEM physiochemical monitoring programme, for which a range of parameters are measured, including dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN) and total nitrogen (TN). Proposed limits for DRP and DIN, in order to prevent undesirable growths, are currently under review for the NPS-FM, (MfE, 2019). The Mangatete Rd site met the currently suggested guideline of a median of 1.0 mg/L for DIN but not that of 0.018 mg/L for DRP (Table 10). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels which was a possible cause of the exceedance in DRP levels.

Table 10 Medians for selected physicochemical water quality parameters for the Hangatahua River

Site	2018-2019			2019-2020		
	DRP	DIN	TN	DRP	DIN	TN
Mangatete Road	0.0189*	0.035	0.054	0.0197*	0.030	0.056

* Does not meet MfE (2019) draft guidelines

2.1.2 Periphyton cover

The Hangatahua River is generally characterised by a low periphyton biomass throughout its catchment. For 2018-2020 there was no nuisance periphyton recorded at the Mangatete Road site. In the 2018-2019 monitoring year, no nuisance periphyton was recorded during either survey of the lower SH45 site. During both surveys in 2019-2020 there were no long filaments found at the SH45 site, however there were low levels of thick mats (Table 11, Figure 3 and Figure 4).

The majority of the Hangatahua 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 are therefore expected to be low, and the periphyton results for the 2018-2020 monitoring period support this.

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 by reducing diffuse agricultural runoff, which is generally a significant nutrient source in intensively farmed areas.

Over 18 years of monitoring there has been very little periphyton proliferation at both sites monitored in the Hangatahua catchment (Figure 3 and Figure 4). There have been occasional spikes in periphyton levels, however no record has come close to breaching periphyton guidelines for mats or filaments.

Table 11 A comparison of historic survey results for the Hangatahua River with those for the current monitoring period

Site	Altitude (m)	SEM data (2002 to 2018)					Monitoring period			
							2018-2019		2019-2020	
		No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
Mangatete Rd	160	26	Thick mats	0-2	0	0	0	0	0	0
			Long filaments	0-1	0	0	0	0	0	0
SH45		26	Thick mats	0-18	0	1	0	0	2	5
			Long filaments	0-12	0	0	0	0	0	0

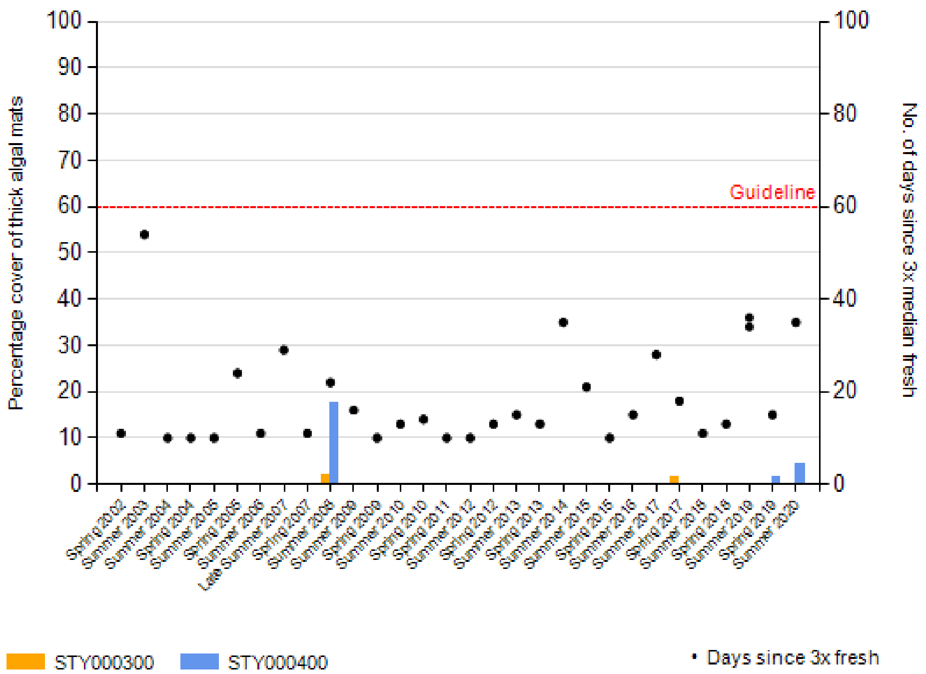


Figure 3 Percentage cover of thick mats of periphyton on the Hangatahua (Stony) riverbed in relation to the guidelines for recreational values and number of days since 3 x median fresh

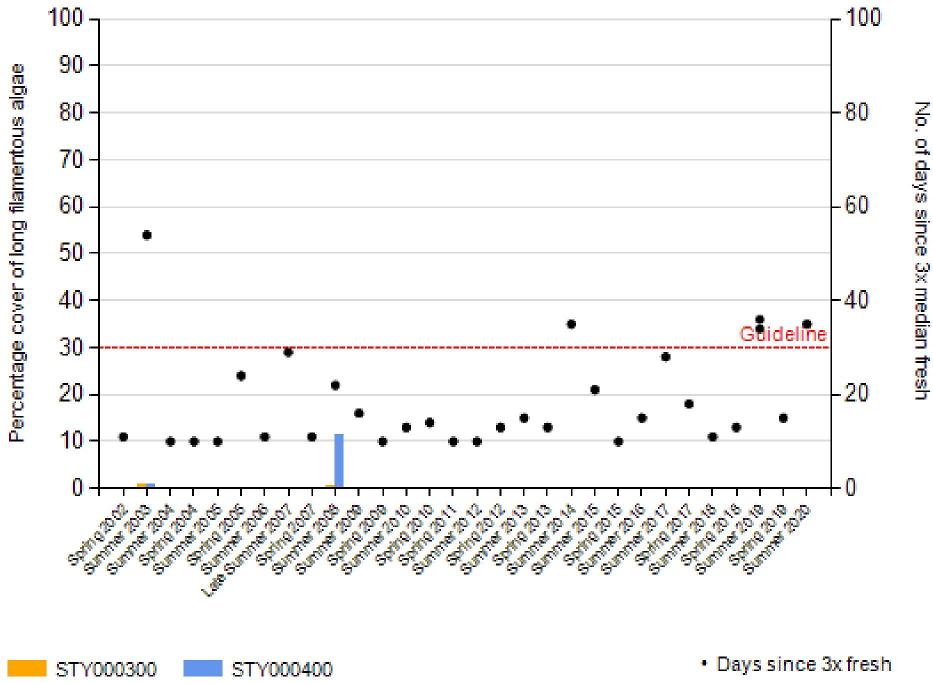


Figure 4 Percentage cover of long filamentous algae on the Hangatahua riverbed in relation to the guidelines for recreational values and number of days since 3 x median fresh

2.1.3 Periphyton Index Score

Over the 2018-2020 monitoring period the Hangatahua River had low levels of periphyton, with both sites consistently having a 'very good' TRC periphyton index score. A very slight decrease in TRC PI score was recorded between the upstream site and downstream site in the summer of the 2018-2019 monitoring year and in the spring of 2019-2020 (Table 12). In the 2019-2020 summer survey, a small decrease of 0.9 was noted between the upstream and downstream sites.

The results from the current monitoring period are in-line with historical results between the two Hangatahua River sites (Table 12). Both sites have an historical median TRC PI score of 10.0 for spring surveys, with the SH45 site having a slightly decreased median of 9.0 in summer surveys. This places both sites in the 'very good' category over the historical period of monitoring, and indicates that there is minimal difference between upstream and downstream condition (Table 12).

Table 12 Seasonal periphyton index scores for the Hangatahua River. The difference given is the TRC PI for the furthest upstream site minus the TRC PI for the furthest downstream site

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Spring Historic median	TRC PI Summer Historic median
Mangatete Rd	10	9.9	10	9.4	10	10
SH45	10	9.8	9.9	8.5	10	9.0
Difference	0	0.1	0.1	0.9	0	1.0

2.1.4 Periphyton biomass

During the summer of 2019 and 2020 very low cholorophyll *a* levels were recorded at both sites (0 - 4.1 mg/m^2) (Figure 5). These values are within the guidelines set to protect biodiversity, aesthetic and trout habitat/angling values (Table 2) and NOF guidelines (Snelder et al., 2013). The low chlorophyll *a* levels are congruent with the periphyton cover results and reinforce the findings that the Hangatahua River has good water quality.

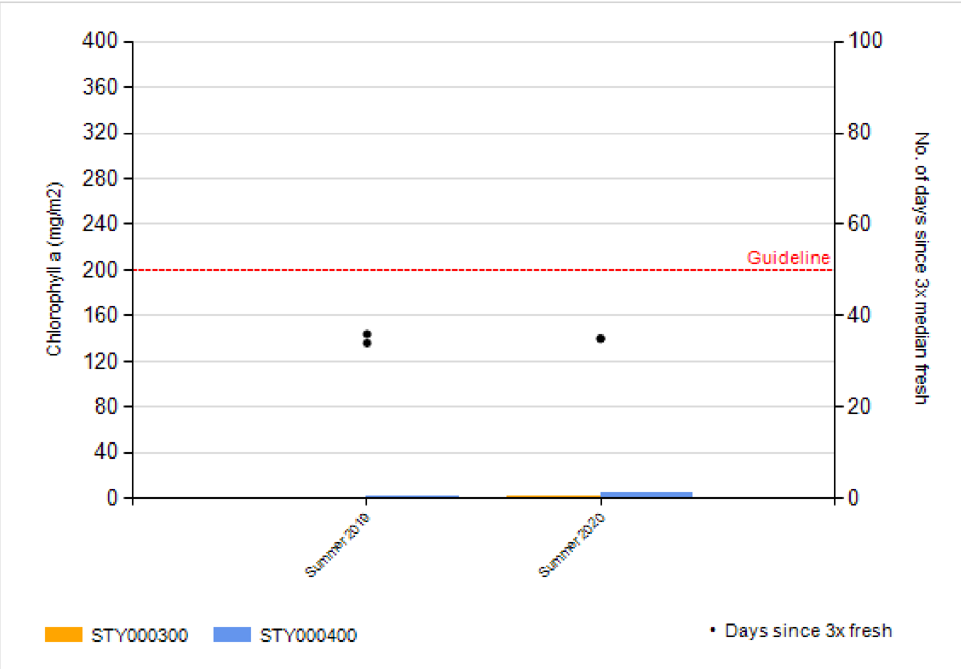
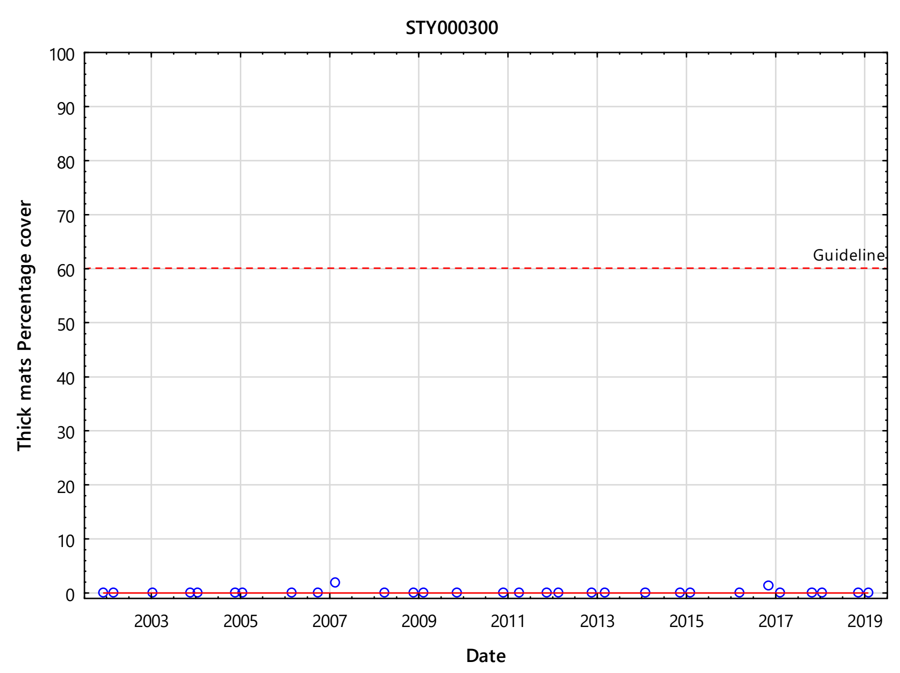


Figure 5 Periphyton biomass (chlorophyll a) on the Hangatahua riverbed over the 2018-2020 period, with respect to the NOF guideline

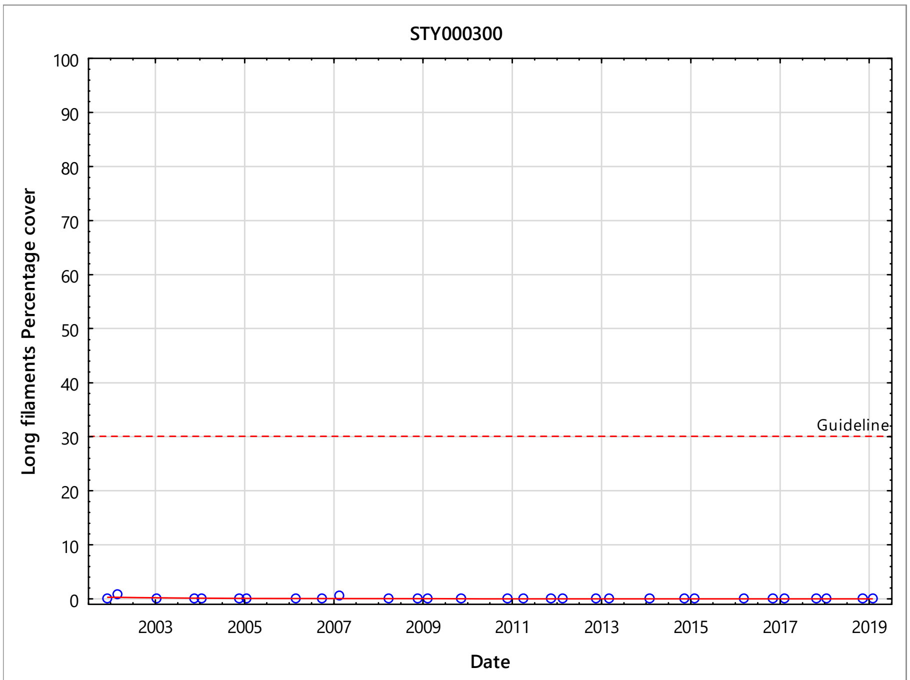
2.1.5 Long-term trend analysis

Long-term trend analysis of periphyton cover data from 2002-2020 is undertaken following the methods outlined in Section 1.2. At both sites in the Hangatahua River, there is no evidence of either an increasing or decreasing trend in thick mat or long filament cover over the 18 year monitored period (Figure 6 to Figure 9). This is unsurprising given the consistently minimal coverage of periphyton at both site.



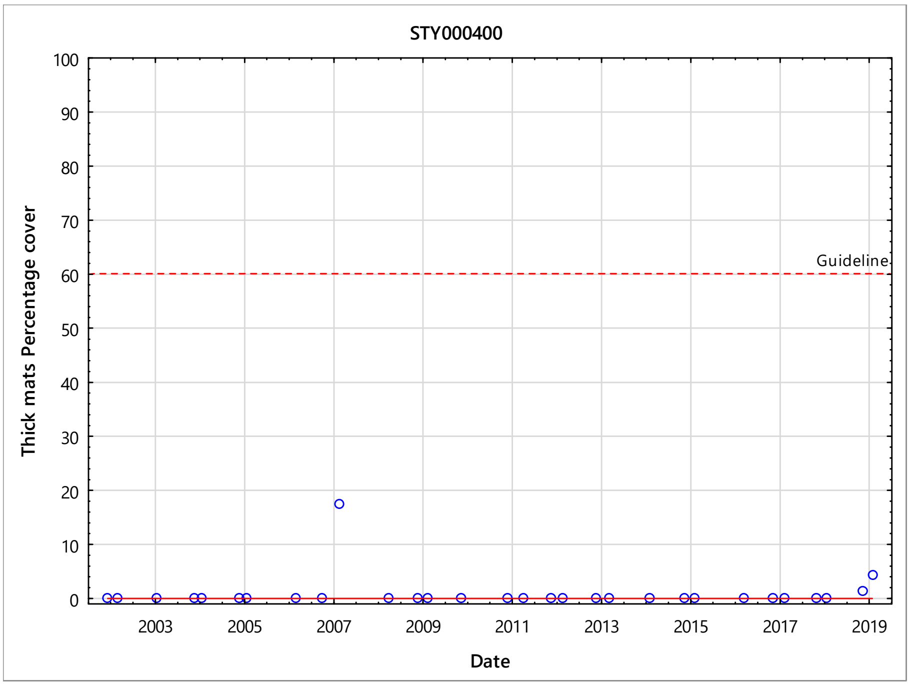
n = 30
Kendal tau = 0.044
p-value = 0.730
FDR p-value = 0.769

Figure 6 Time series of percentage cover of thick mats at Mangatete Road (STY000300). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



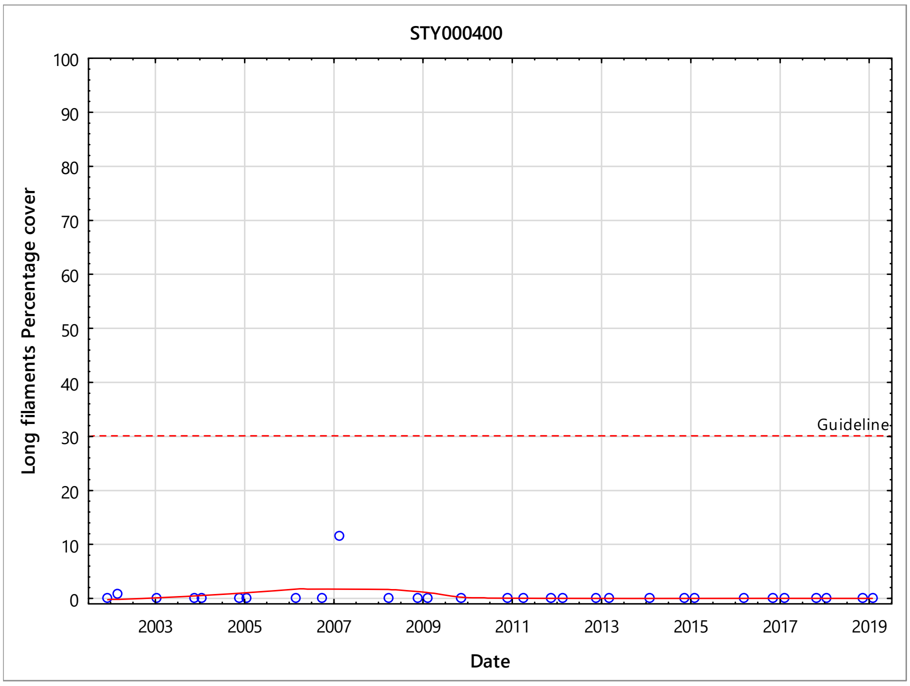
n = 30
Kendal tau = -0.248
p-value = 0.055
FDR p-value = 0.148

Figure 7 Long-term trend analysis of percentage cover of long filaments at Mangatete Road (STY000300



n = 30
Kendal tau = 0.230
p-value = 0.074
FDR p-value = 0.152

Figure 8 Long-term trend analysis percentage cover of thick mats at SH45 (STY000400)



n = 30
Kendal tau = -0.235
p-value = 0.068
FDR p-value = 0.162

Figure 9 Long-term trend analysis of percentage cover of long filaments at SH45 (STY000400)

2.2 Kapoaiaia Stream

The Kapoaiaia Stream arises in the National Park, heading west approximately 25 km to the coast, where it meets 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 that has relatively poor riparian vegetation. This catchment drains agricultural land throughout its entire catchment below the National Park boundary, and passes through Pungarehu township at SH45.

Monitoring is undertaken at 3 sites in the Kapoaiaia catchment (Figure 10). The upper site, located at Wiremu Road (KPA000250), is 5.5 km downstream of the National Park boundary. A second, mid-catchment site is located at Wataroa Road (KPA000700), while the lower site (KPA000950) is located at Cape Egmont, one kilometre upstream from the coast.

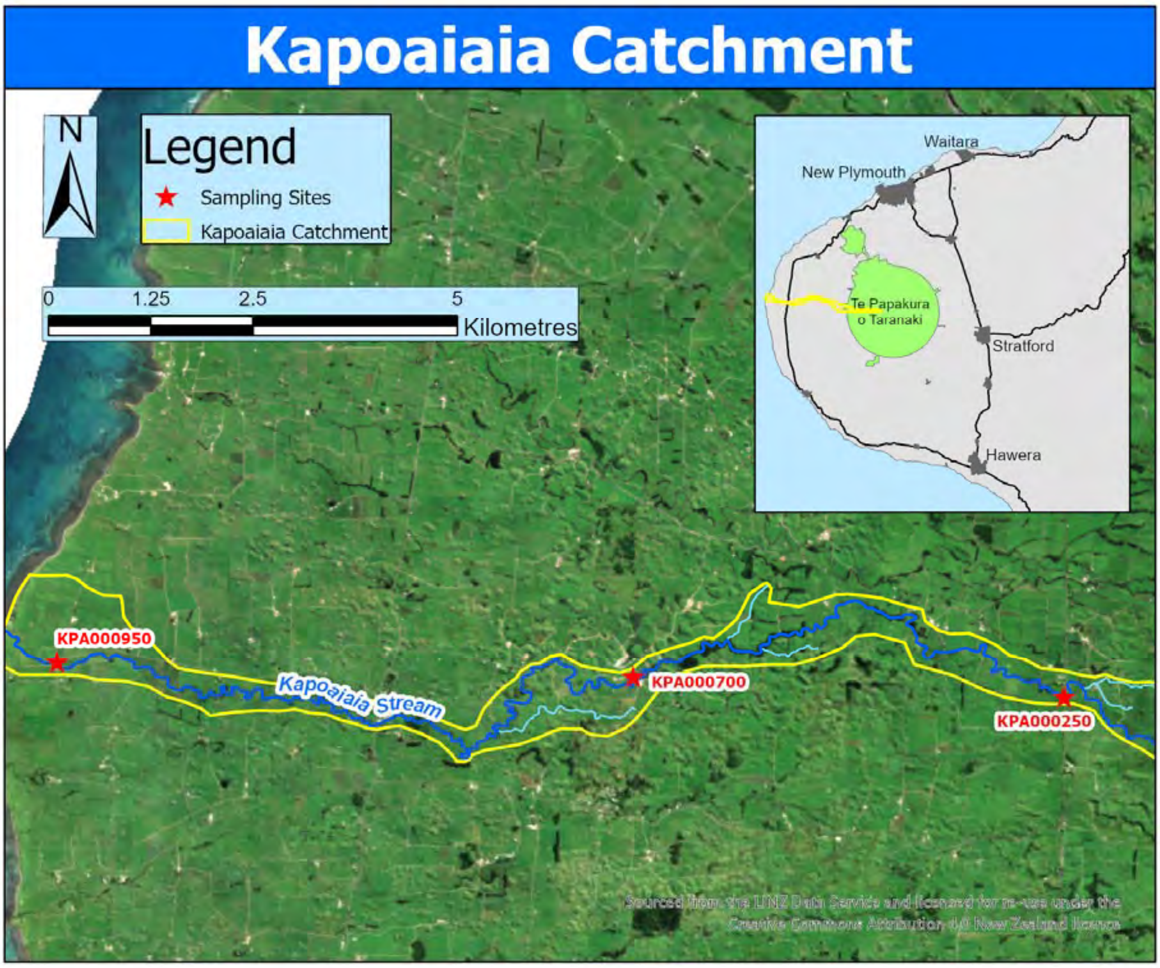


Figure 10 Monitoring site locations in the Kapoaiaia Stream catchment

2.2.1 Flow data, nutrient data and survey dates

The Kapoaiaia River has a telemetered hydrological monitoring station at the Cape Egmont lighthouse, located at the very bottom of the catchment. This telemetry station provides flow information for the catchment, in particular regarding the respective time of surveys and freshes in the catchment (Table 13).

Table 13 Date of sampling with reference to the number of days since three and seven times median flow

Season	Date	3 x	7 x
Spring	25/10/2018	12	12
Summer	31/01/2019	16	16
Spring	07/11/2019	15	19
Summer	24/01/2020	35	35

The Kapoaiaia River 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, with the exception of the summer survey in 2020, when thick algae mat levels were at half the 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, and a moderate level for the summer 2020 period. Unlike the upper site, however, filamentous algae levels were high and breached the guideline value at the Wiremu Road site in the 2020 summer survey. The lower site near Cape Egmont also had low levels of thick mats throughout the monitoring period except for the summer survey in 2020, when there were moderately high levels of thick algae mats. Filamentous algae levels breached the guideline value in the summer 2019 survey (Table 14, Figure 11 and Figure 12).

Table 14 Results of previous surveys performed in the Kapoaiaia River, together with the results for the current monitoring period

Site	SEM data (2002 to 2018)					Monitoring period			
						2018-2019		2019-2020	
	No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
Wiremu Road	28	Thick mats	0-56	0	8	5	0	1	30
		Long filaments	0-50	0	10	0	0	0	0
Wataroa Road	28	Thick mats	0-86	3	12	6	5	0	30
		Long filaments	0-79	10	21	1	3	18	59
Cape Egmont	28	Thick mats	0-75	8	17	3	0	3	50
		Long filaments	0-69	24	27	1	44	5	11

The Kapoaiaia Stream only has minor levels of riparian vegetation where it flows through farmland. The streambed is largely open, with high sunlight levels and relatively warm water temperatures. Furthermore, there is little buffering for nutrient inputs. All of these factors can contribute to periphyton growth. Consequently, nuisance periphyton levels at the lower sites can often be high. Summer results are often higher than spring results due to warmer temperatures and fewer flushing flows. In particular, large flushing flows are rare. The high summer 2020 results correspond with a period of 35 days without any significant (> 3 x median flow), or large (> 7 x median flow) flushing flows. However, a lack of flushing flows does not fully explain high summer periphyton levels, given that high nuisance periphyton levels were recorded at the lower site during the summer 2019 survey, when a large flushing flow (> 7 x median flow) occurred only 16 days before the survey.

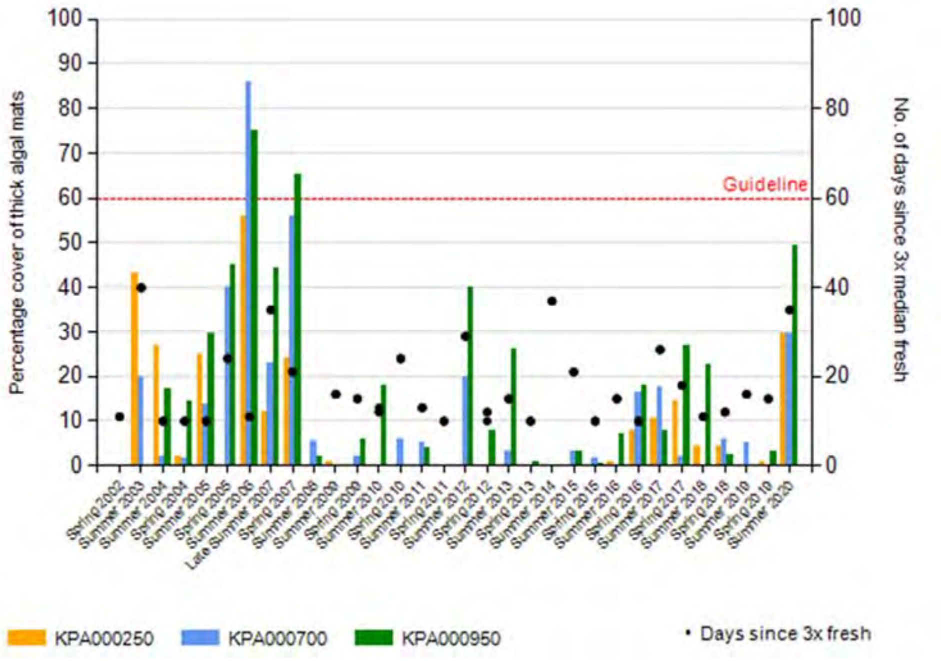


Figure 11 Percentage cover of thick mats of periphyton on the Kapoaiaia streambed compared to the number of days since 3 x median fresh. The NZ periphyton guideline is shown for reference

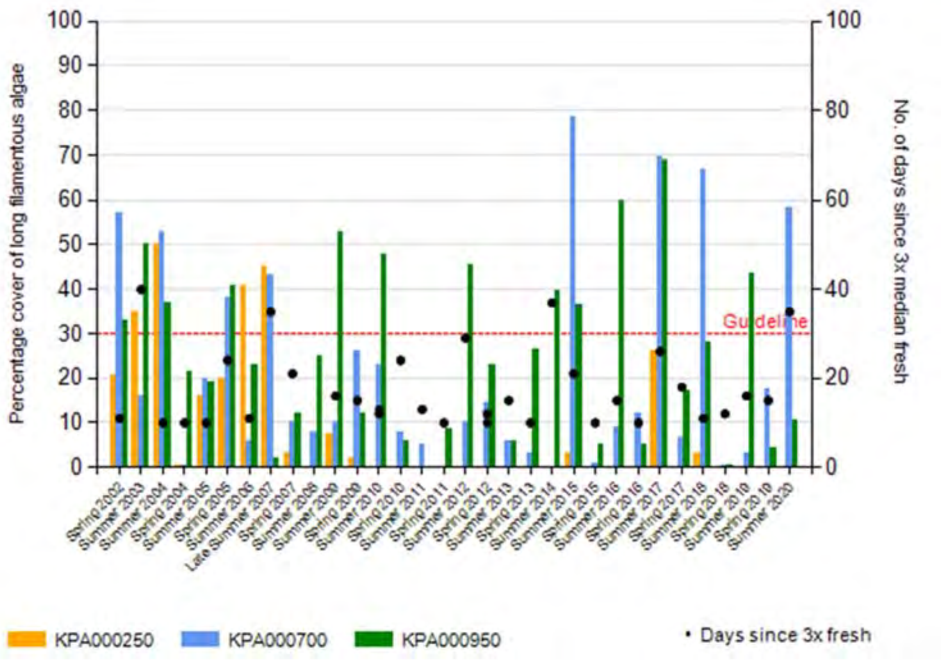


Figure 12 Percentage cover of long filamentous algae on the Kapoaiaia streambed in relation to the guidelines for recreational values over the 2002-2020 monitoring period and number of days since 3 x median fresh

The Kapoaiaia catchment has been monitored over an 18 year period. There have been three breaches in the guidelines in respect of thick algal mats over the three sites, none of which occurred in the 2018-2020 monitoring period (Figure 11).

The middle and lower sites breached thick mat guideline limits in earlier years of the monitoring programme. 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.

There have been a significant number of breaches over the 18-year monitoring period for long filamentous nuisance growths (33 in total) (Figure 12). 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 (2012-2020).

The Kapoaiaia Stream has the highest amount of nuisance growths for long filaments out of all the rivers and streams monitored over the 18-year period. There is still a significant level of work required in the Kapoaiaia catchment to reduce nutrient levels and increase riparian cover.

2.2.3 Periphyton Index Score

Over the 2018-2020 monitoring period the Kapoaiaia Stream showed a high level of variation in TRC PI scores between sites (Table 15). While the upstream site (Wiremu Rd) had 'very good' TRC PI, similar to historical medians, the other two sites had lower scores during summer surveys. The mid-catchment site (Wataroa Rd) had TRC PI scores corresponding with a 'good' and 'moderate' rating for the 2019 and 2020 summer surveys respectively. These lower scores were coincident with the high filamentous algae levels found at the site. The downstream site (Cape Egmont) had a similar pattern to the middle site with 'very good' scores in the spring and 'moderate' and 'good' ratings for the two respective summer surveys.

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

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

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
Wiremu Rd	9.8	9.5	9.9	8.1	9.6	8.8
Wataroa Rd	8.1	6.8	7.2	4.3	8.3	6.7
Cape Egmont	8.7	5.5	8.9	6.3	7.7	6.1
Difference	1.1	4.0	1.0	1.8	1.9	2.7

2.2.4 Periphyton biomass

All three sites in the Kapoaiaia Stream displayed low to moderately low chlorophyll *a* levels during the 2018-2020 monitoring period (Figure 13).

Chlorophyll *a* levels at Wiremu Rd and Cape Egmont during the summer 2020 survey breached guideline levels set to protect benthic biodiversity (50 mg/m^2), however, all recorded chlorophyll *a* levels for the 2018 – 2020 surveys were below the NOF limit of 200 mg/m^2.

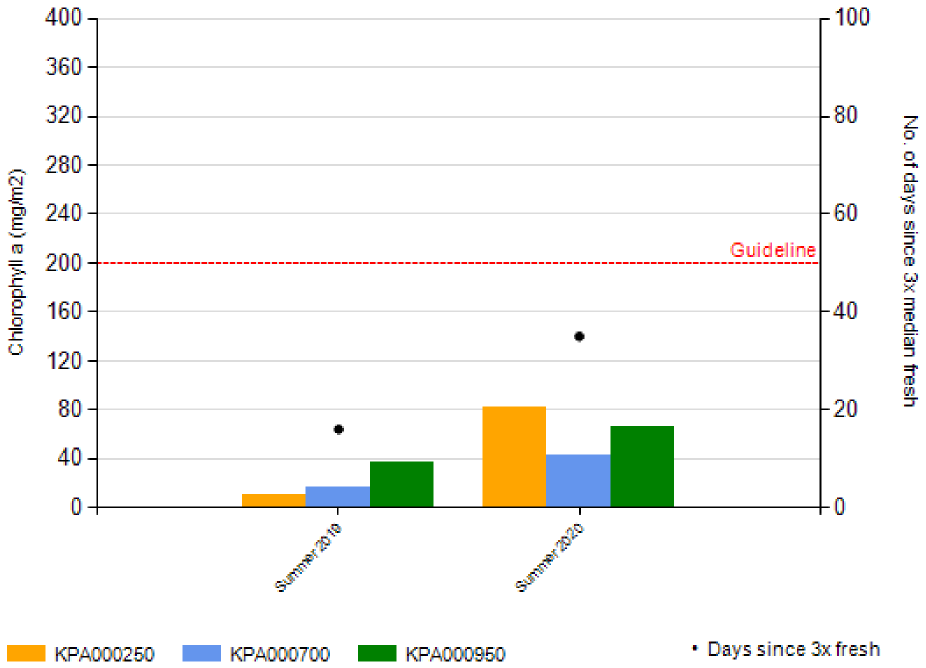
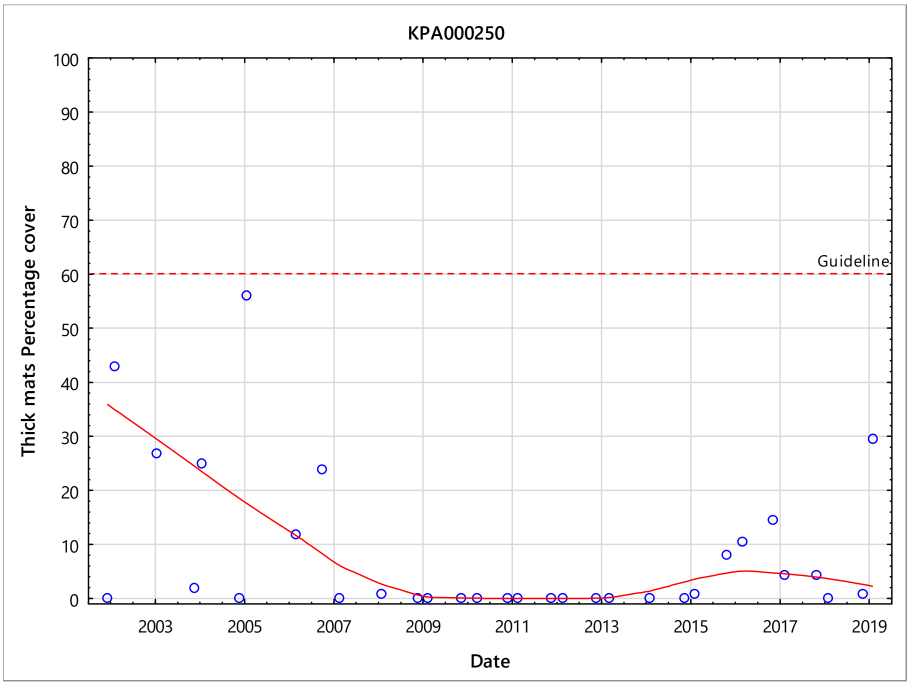


Figure 13 Periphyton biomass (chlorophyll *a*) on the Kapoaiaia riverbed over the 2018-2020 period, with respect to the NOF guideline. Number of days since 3x median fresh is shown for comparison

2.2.5 Long term trend analysis

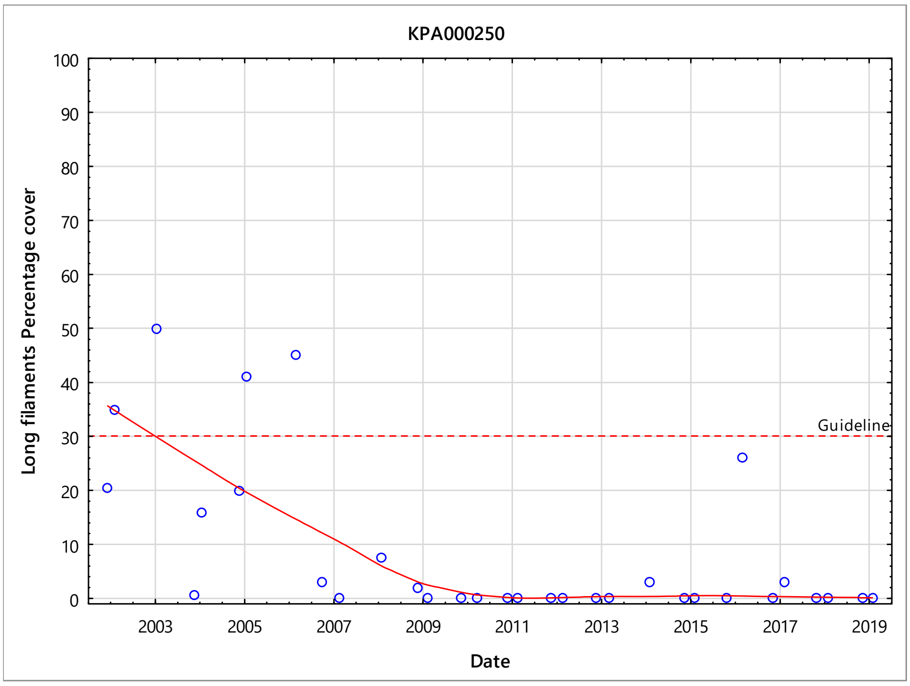
Following the methods outlined in Section 1.2, long-term trend analysis found evidence for a statistically significant decreasing trend in long filament cover at the Wiremu Road site (KPA000250) between 2002 and 2020 (Figure 15). There was no such statistically significant decreasing trend in thick mats (Figure 14), however, when the two datasets are compared, there are some striking similarities and differences. In particular, both thick mat and long filament cover at Wiremu Road appear to have declined between the start of monitoring and around 2008. This could be due to a number of reasons such as a reduction in nutrient inputs upstream of the site. While long filament cover at the site has since remained low, there have been increased levels of thick mat cover in recent years, resulting in the overall long-term trend being neither increasing nor decreasing. While there is not enough data to perform a thorough short-term trend analysis, the recent increase in thick mat cover at the Wiremu Road site should be noted, and attention paid as to whether this apparent trend is reinforced during the next monitoring period.

In contrast, no evidence was found for either a long-term increase or decrease in periphyton cover at either of the lower two Kapoaiaia Stream monitoring sites (Wataroa Rd, KPA000700 and Cape Egmont, KPA000950) (Figure 16 to Figure 19).



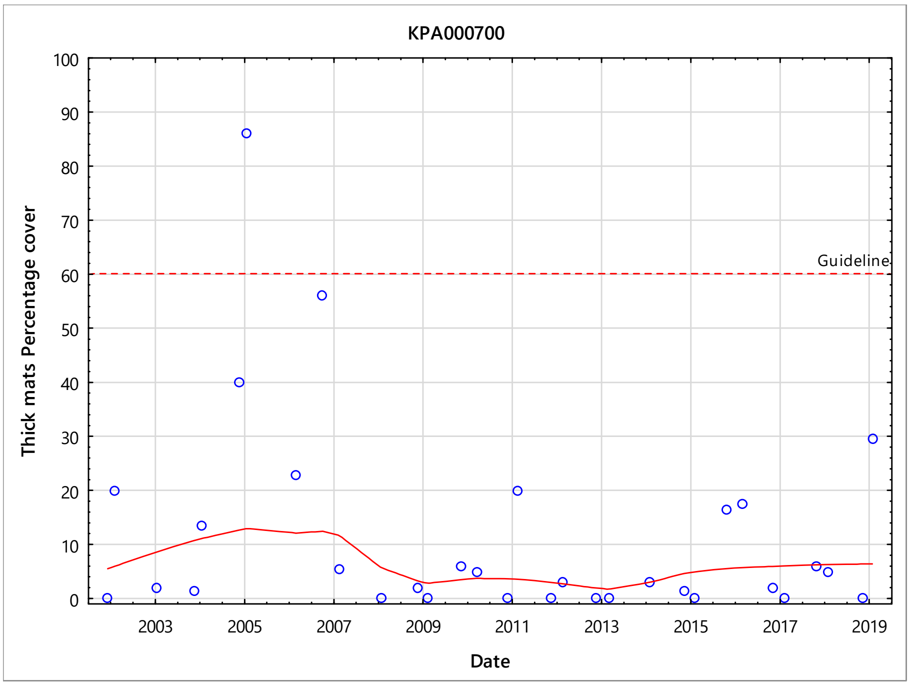
n = 32
Kendal tau = -0.015
p-value = 0.680
FDR p-value = 0.769

Figure 14 Time series of percentage cover of thick mats at Wiremu Road (KPA000250). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



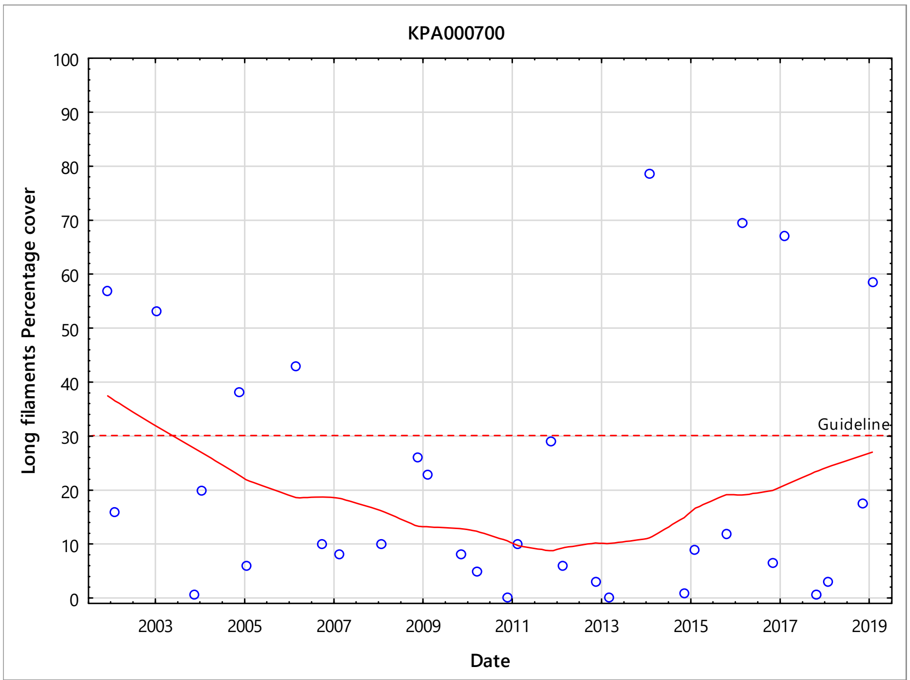
n = 32
Kendal tau = -0.477
p-value < 0.001
FDR p-value = 0.002

Figure 15 Long-term trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Wiremu Road (KPA000250)



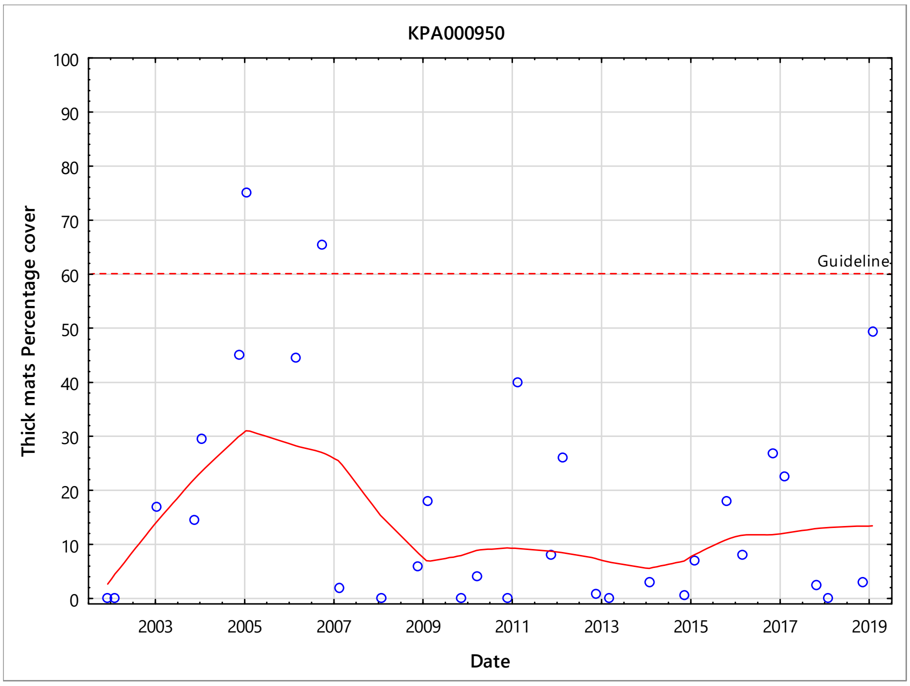
n = 32
Kendal tau = -0.122
p-value = 0.328
FDR p-value = 0.422

Figure 16 Long-term trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Wataroa Road (KPA000700)



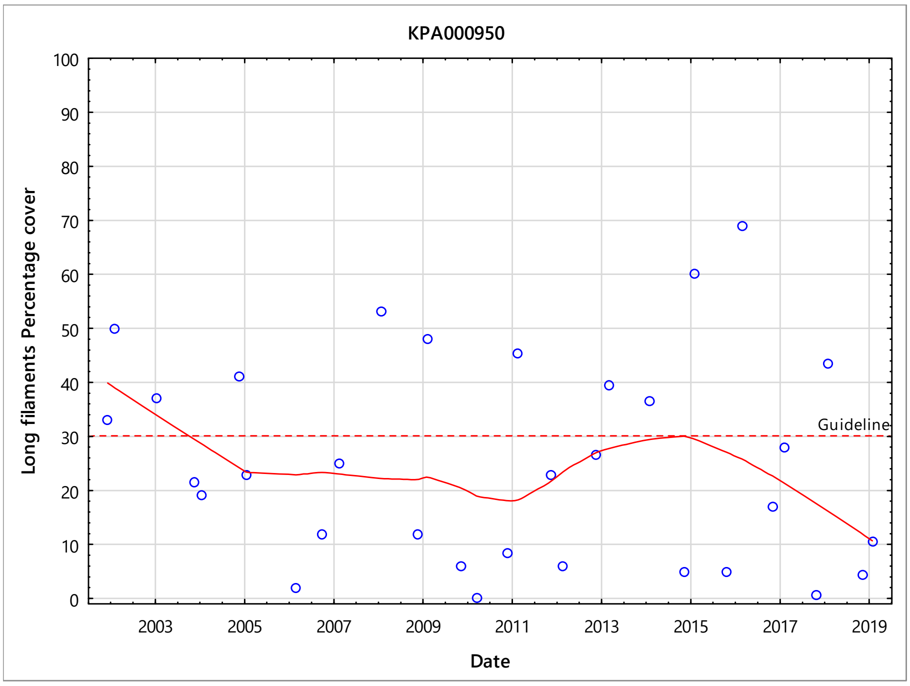
n = 32
Kendal tau = -0.102
p-value = 0.414
FDR p-value = 0.491

Figure 17 Long-term trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Wataroa Road (KPA000700)



n = 32
Kendal tau = -0.029
p-value = 0.816
FDR p-value = 0.816

Figure 18 Long-term trend analysis of percentage cover of thick mats at Kapoaiaia Stream, Cape Egmont (KPA000950)



n = 32
Kendal tau = -0.121
p-value = 0.329
FDR p-value = 0.418

Figure 19 Long-term trend analysis of percentage cover of long filaments at Kapoaiaia Stream, Cape Egmont (KPA000950)

2.3 Maketawa Stream

The Maketawa Stream originates in Egmont National Park, flowing approximately 25 km 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.

The Maketawa Stream has a catchment with high conservation status and is 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 20). The top site, Derby Road, (MKW000200) is 3.5 km from the National Park boundary. Upstream of this site the stream has good riparian cover over most of this length. The bottom site, Tarata Road, (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).

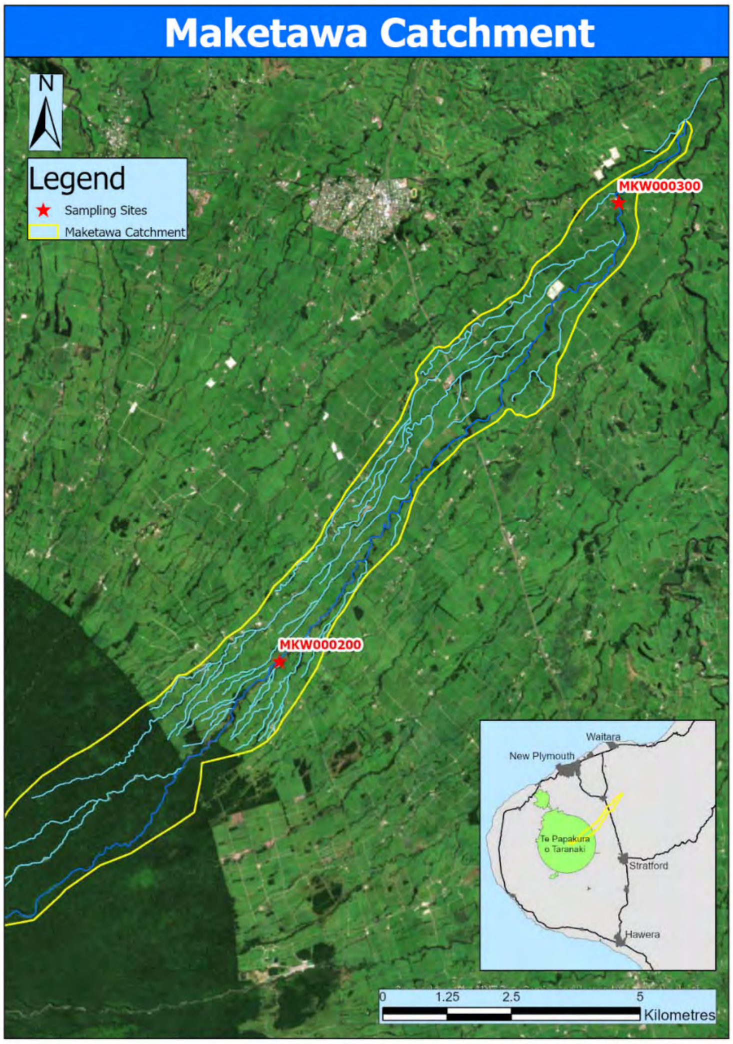


Figure 20 Monitoring site locations in the Maketawa Stream catchment

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 (Table 16).

Table 16 Date of sampling and corresponding time since three and seven times median flow

Season	Date	3 x	7 x
Spring	17/12/2018	11	13
Summer	11/01/2019	17	38
Spring	06/11/2019	13	13
Summer	05/02/2020	46	47

The TRC SEM physicochemical programme collects nutrient data at the Tarata Road site (MKW000300). Proposed limits for DRP and DIN, in order to prevent undesirable growths, are currently under review for the NPS-FM, (MfE, 2019). This site met the currently suggested guideline of a median of 1.0 mg/L for DIN but not that of 0.018 mg/L for DRP. The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels, which is a possible cause of the exceedance in DRP levels.

Table 17 Medians for selected physicochemical water quality parameters for the Maketawa Stream

Site	2018-2019			2019-2020		
	DRP	DIN	TN	DRP	DIN	TN
Derby Road	0.03*	0.305	0.40	0.029*	0.43	0.52

* Does not meet MfE (2019) guidelines (under review)

2.3.2 Periphyton cover

During the current monitoring period there were very low levels of nuisance periphyton detected at both sites. All values were well below guideline levels (Table 18, Figure 21 and Figure 22).

Table 18 Periphyton cover results of previous surveys performed in the Maketawa Stream together with the results for the current monitoring period

Site	Altitude (m)	SEM data (2002 to 2018)					Monitoring period			
							2018-2019		2019-2020	
		No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
Derby Road	380	26	Thick mats	0-8	0	0	1	0	0	0
			Long filaments	0-4	0	1	1	1	0	0
Tarata Road	150	28	Thick mats	0-23	0	4	8	5	6	3
			Long filaments	0-78	0	6	12	9	0	0

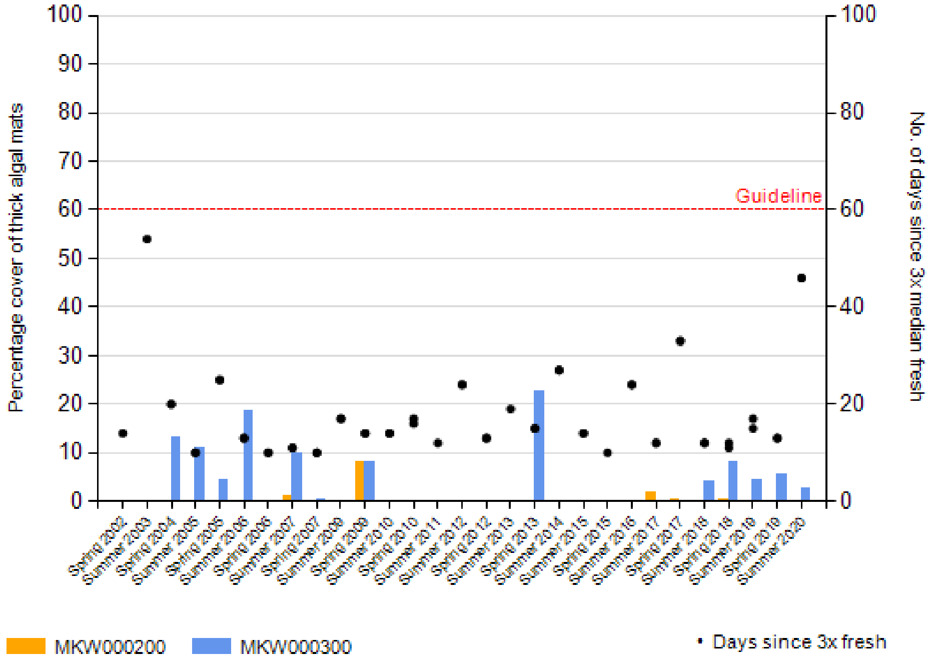


Figure 21 Percentage cover of thick mats of periphyton on the Maketawa streambed over the 2002-2020 monitoring period, with respect to the guidelines for recreational value. The number of days since the last 3 x median fresh is shown for comparison

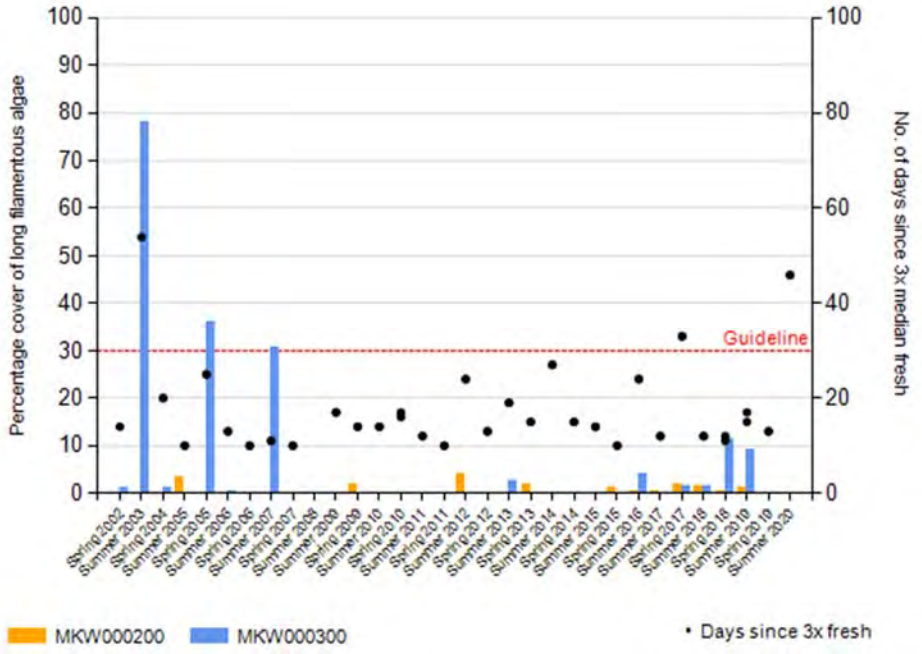


Figure 22 Percentage cover of long filamentous algae on the Maketawa streambed over the 2002-2020 monitoring period, with respect to the guidelines for recreational value. The number of days since the last 3 x median fresh is shown for comparison

Thick algal mats have never breached recreational guideline at the two Maketawa Stream sites (Figure 21). When thick algal mats have proliferated, it has typically been at the downstream Tarata Rd site, with only one occasion when thick mats have proliferated at the upstream Derby Rd site (spring 2009).

There have been three breaches in the long filamentous guidelines at the downstream site (Figure 22). Two of these breaches have coincided with longer than median periods of low flow. The upstream site has occasionally recorded some nuisance growths of filamentous algae between 2002-2010, but not to the same extent as the downstream site. Recently there have been relative proliferations of thick algal mats recorded at the downstream site, however these have been well below guideline levels.

2.3.3 Periphyton Index Score

The Maketawa Stream at both Derby Road and Tarata Road consistently had 'very good' TRC PI scores during the 2018-2020 monitoring period (Table 19). TRC PI scores were higher than historical medians for the upstream Derby Rd site, but were lower for the downstream Tarata Road site. Historically, the Tarata Rd site has had a consistently lower TRC PI rating than Derby Road, however the difference between the sites was larger in this monitoring period compared to previous years. The difference in scores between the two sites is likely a reflection of the increased nutrient inputs from agricultural land between the sites.

For the 2018-2020 monitoring period, the TRC PI scores show no obvious seasonal variation (Table 19). Historically, TRC PI scores have usually been lower during summer than spring at the Tarata Rd site. This is somewhat expected, due to longer sunlight hours and warmer temperatures leading to increased periphyton growth, combined with there being less scouring events over the summer period.

Table 19 Median seasonal periphyton index scores for Maketawa Stream.

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
Derby Road	9.9	9.8	9.9	10.0	9.6	9.6
Tarata Road	8.2	8.4	8.4	8.1	9.3	8.3
Difference	1.7	1.4	1.5	1.9	0.3	1.3

2.3.4 Periphyton biomass

The results for the current monitoring period found extremely low levels of chlorophyll *a* (0.5 and 1 chlorophyll *a* mg/m^2) at the upstream site. The downstream levels were higher (9.2 and 23 chlorophyll *a* mg/m^2), though still well below the NOF standard (Figure 23). The results are congruent with TRC PI scores, indicating that the Maketawa Stream generally has only low levels of periphyton, although the downstream site has higher levels than the upstream site.

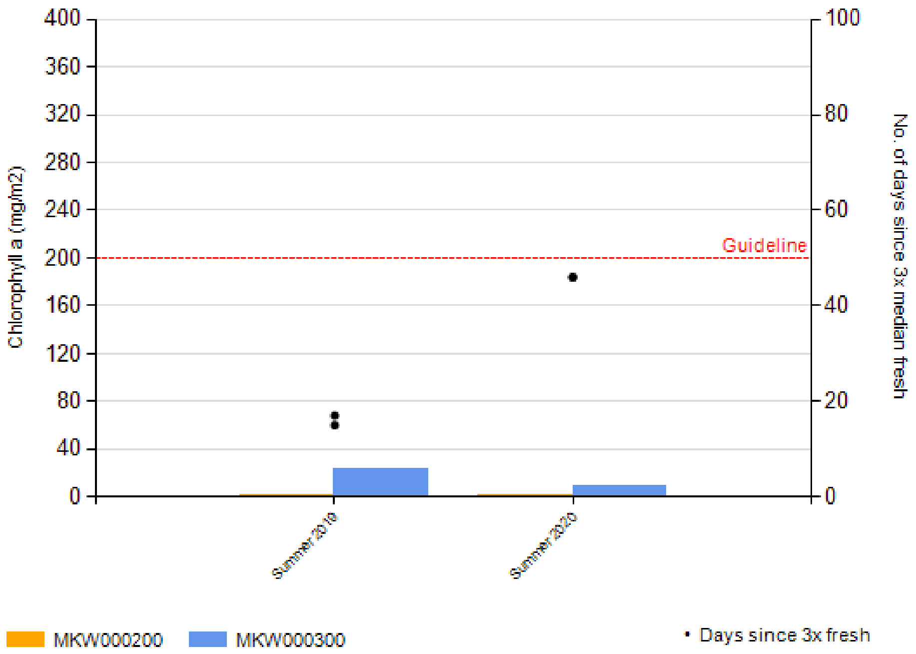
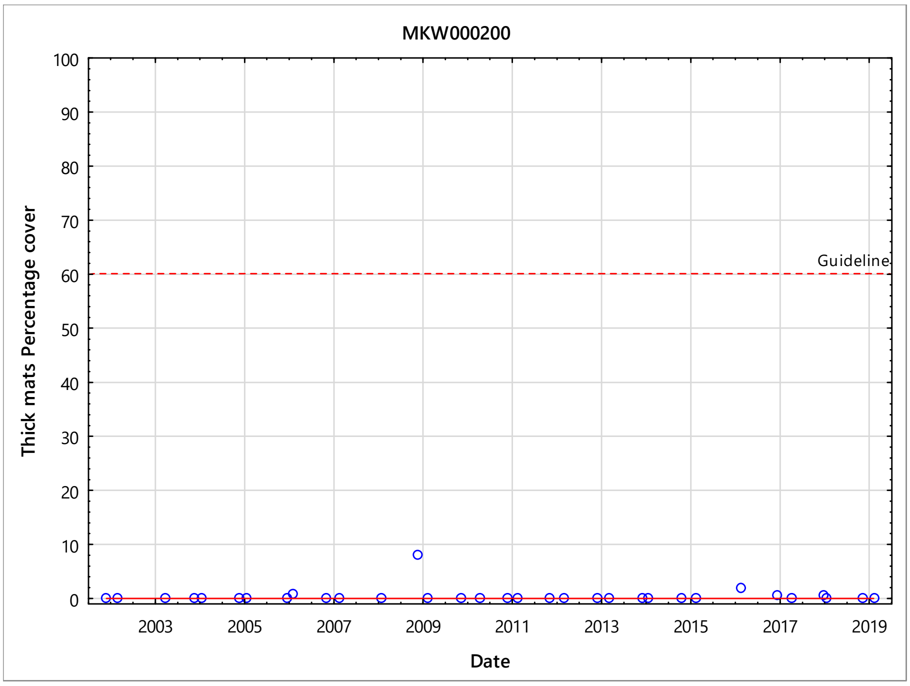


Figure 23 Periphyton biomass (chlorophyll *a*) on the Maketawa riverbed over the 2018-2020 period, with respect to the NOF guideline. The number of days since 3x median fresh is shown for comparison

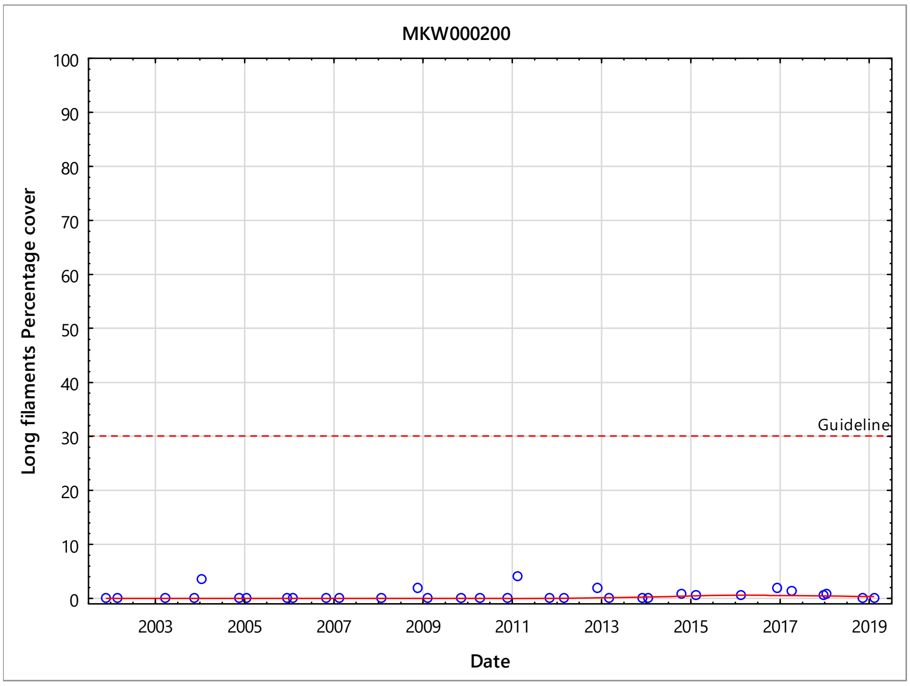
2.3.5 Long term trend analysis

Following the methods outlined in Section 1.2, long-term trend analysis found no evidence for either increasing or decreasing trends in periphyton cover at either of the Maketawa Stream monitoring sites. This is unsurprising given the extremely low cover levels found over the 2002-2020 period at the Derby Road (MKW000200) site. While in contrast there have been some fluctuations in periphyton cover at the Tarata Road site over the same period, no statistical evidence was found of either a significant increase or decrease in cover levels (Figure 24 through figure 27).



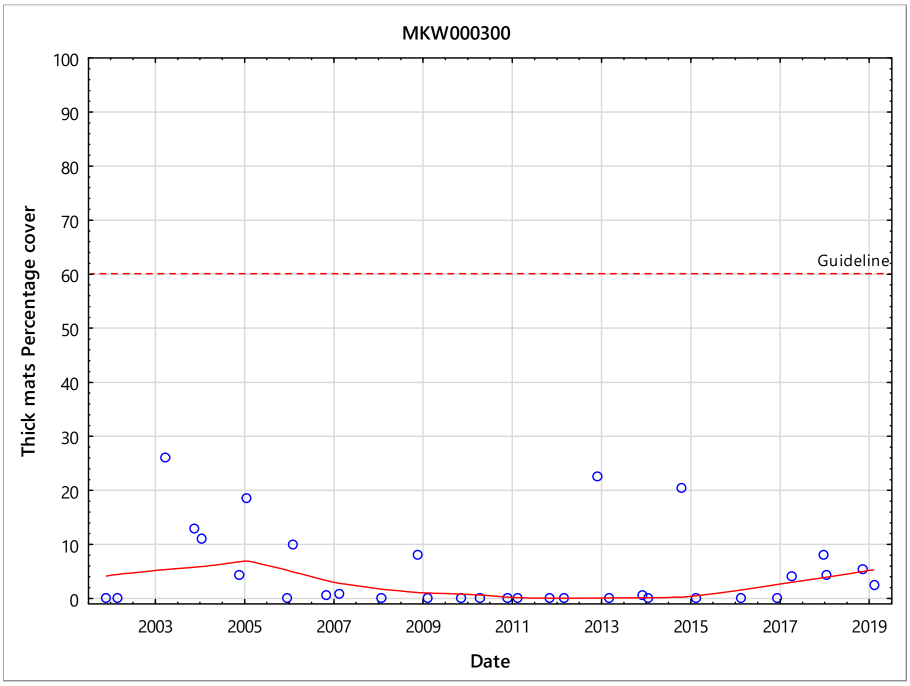
n = 33
Kendal tau = 0.139
p-value = 0.255
FDR p-value = 0.426

Figure 24 Time series of percentage cover of thick mats at Derby Road (MKW000200). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



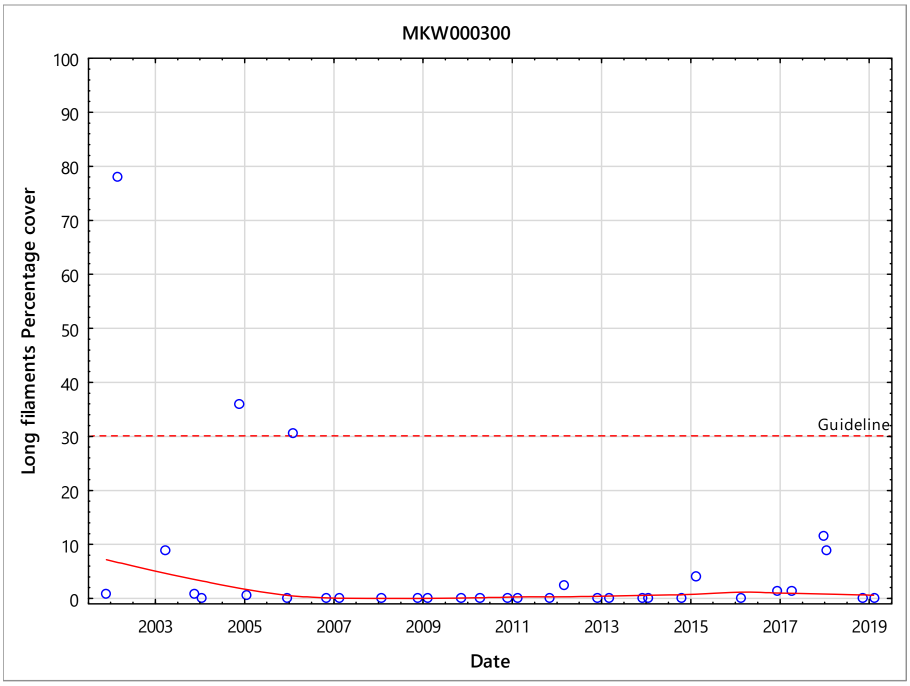
n = 33
Kendal tau = 0.271
p-value = 0.027
FDR p-value = 0.108

Figure 25 Long-term trend analysis of percentage cover of long filaments at Maketawa Stream, Derby Road (MKW000200)



n = 33
Kendal tau = -0.076
p-value = 0.536
FDR p-value = 0.670

Figure 26 Long-term trend analysis of percentage cover of thick mats at Maketawa Stream, Tarata Road (MKW000300)



n = 33
Kendal tau = -0.121
p-value = 0.321
FDR p-value = 0.418

Figure 27 Long-term trend analysis of percentage cover of long filaments at Maketawa Stream, Tarata Road (MKW000300)

2.4 Manganui River

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

The upstream monitoring site at SH3 (MGN000195) is located approximately 8 km downstream of the National Park boundary (Figure 28). The downstream monitoring site is located at Bristol Rd (MGN000427), 38 km downstream of the National Park boundary, where the river is draining a largely agricultural catchment.

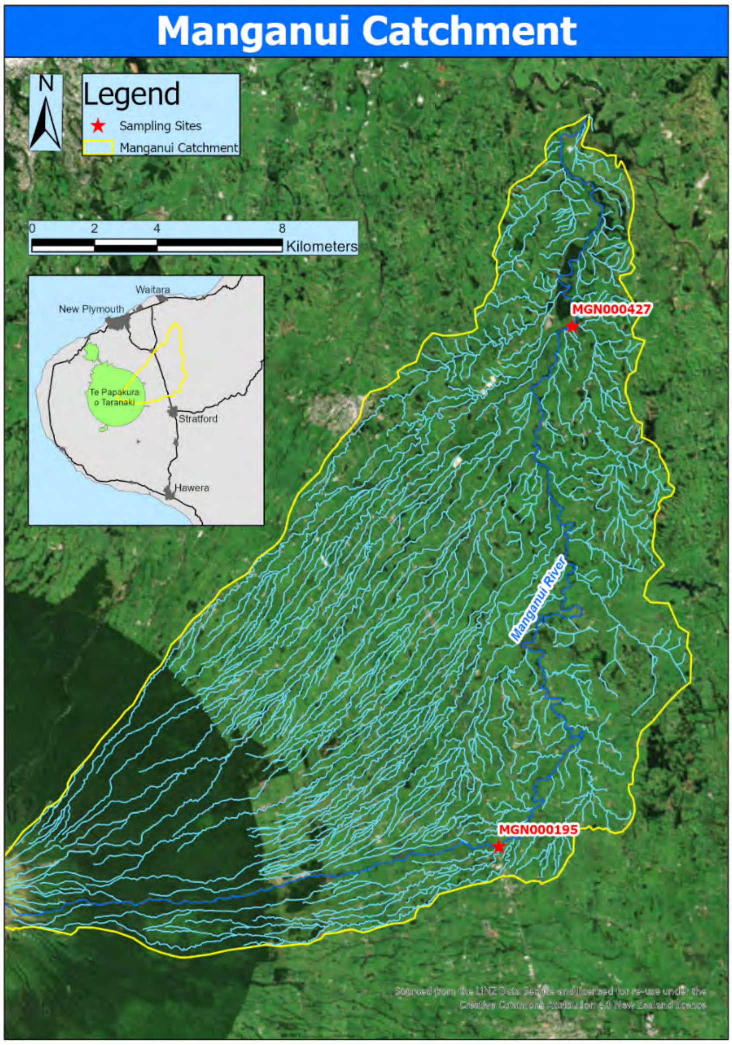


Figure 28 Monitoring site locations in the Manganui River catchment

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 into the Waitara River. Therefore, most of the water in the Manganui River at Bristol Road (which is 14 km downstream of this diversion) comes from tributaries such as the Mangamawhete, Waitepuke, Maketawa, and Ngatoro Streams. The exception to this is when the Tariki Rd weir is overtopping.

2.4.1 Flow and nutrient data and survey dates

There are two telemetered hydrological monitoring stations on the Manganui River, with continuous flow monitoring undertaken at both SH3 at Midhurst and at Everett Park (just downstream of the Bristol Road site). These two sites inform on flow conditions at the upstream and downstream periphyton monitoring sites respectively (Table 20).

Table 20 Date of sampling and corresponding time since three and seven times median flow. When dates vary, data for the downstream site is given in brackets

Season	Date	3 x	7 x
Spring	18/12/2018 (17/12/2018)	10 (11)	11 (13)
Summer	21/02/2019	37 (35)	59 (57)
Spring	06/11/2019	13 (14)	18
Summer	05/02/2020	46	47

As a part of their long-term national river networks program, NIWA collects physicochemical water quality data for the Manganui River at the SH3 site. NIWA measure a range of parameters at the site, including dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN). Proposed limits for DRP and DIN, in order to prevent undesirable growths, are currently under review for the NPS-FM, (MfE, 2019). The Manganui River at the SH3 site met the currently suggested guideline of 1.0 mg/L for DIN and that of 0.018 mg/L for DRP (Table 21).

Table 21 Medians for selected physicochemical water quality parameters for the Manganui River

Site	2018-2019			2019-2020		
	DRP	DIN	TN	DRP	DIN	TN
SH3#	0.0090	0.098	0.157	0.0107	0.155	0.254

NIWA data

2.4.2 Periphyton cover

While no nuisance periphyton was recorded at the upstream site at SH3 during the 2018-2020 period, variable levels were found at the downstream site at Bristol Road. Levels of nuisance periphyton here ranged from low through to exceeding guideline thresholds of (Table 22, Figure 29 and Figure 30).

In the 2018-2019 monitoring year the downstream Bristol Rd site had low-medium levels of thick mats and high levels of long filaments that exceeded the guideline threshold. However, in the 2019-2020 monitoring year surveys the site had low levels of both long filaments and thick mats.

Table 22 Periphyton cover results of previous surveys performed in the Manganui River together with the results for the current monitoring period

Site	Altitude (m)	SEM data (2002 to 2018)					Monitoring period			
							2018-2019		2019-2020	
		No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
SH3	330	29	Thick mats	0-29	0	2	0	0	0	0
			Long filaments	0-0	0	0	0	0	0	0
Bristol Rd	140	29	Thick mats	0-43	1	6	10	39	7	1
			Long filaments	0-75	9	15	43	48	8	4

The upstream SH3 site is well shaded by riparian vegetation. This shade, in conjunction with low nutrient levels, limits the growth of periphyton at this site. In contrast, the Bristol Road site has a much wider bed and is not shaded. The Manganui River runs through a substantial amount of agricultural area, and the combination of high sun exposure, water temperature and nutrient levels has caused significant nuisance periphyton growth at this site in the past.

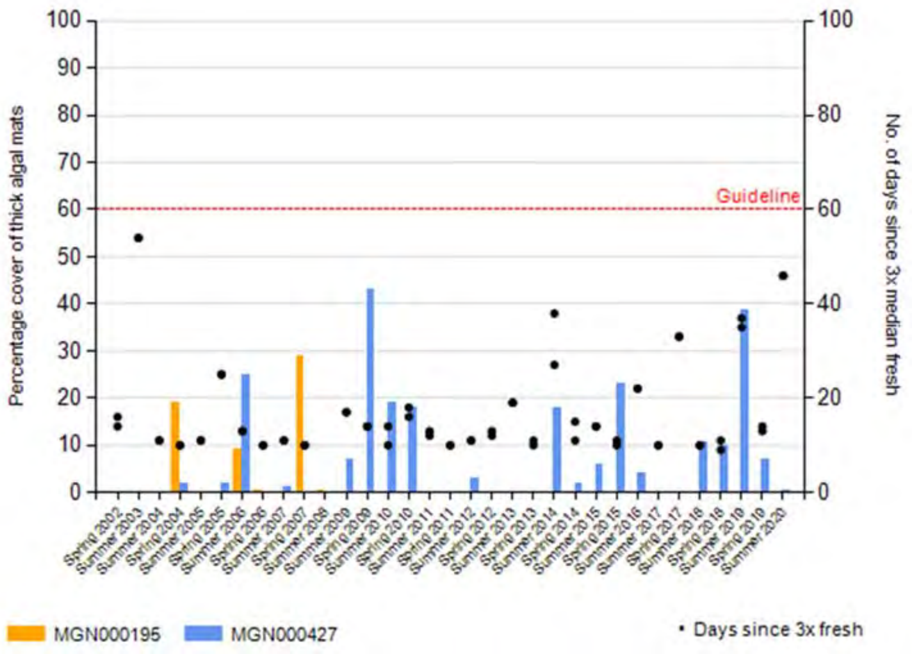


Figure 29 Percentage cover of thick mats of periphyton on the Manganui riverbed over the 2002-2020 monitoring period, with respect to the guidelines for recreational value. The number of days since the last 3 x median fresh is shown for comparison

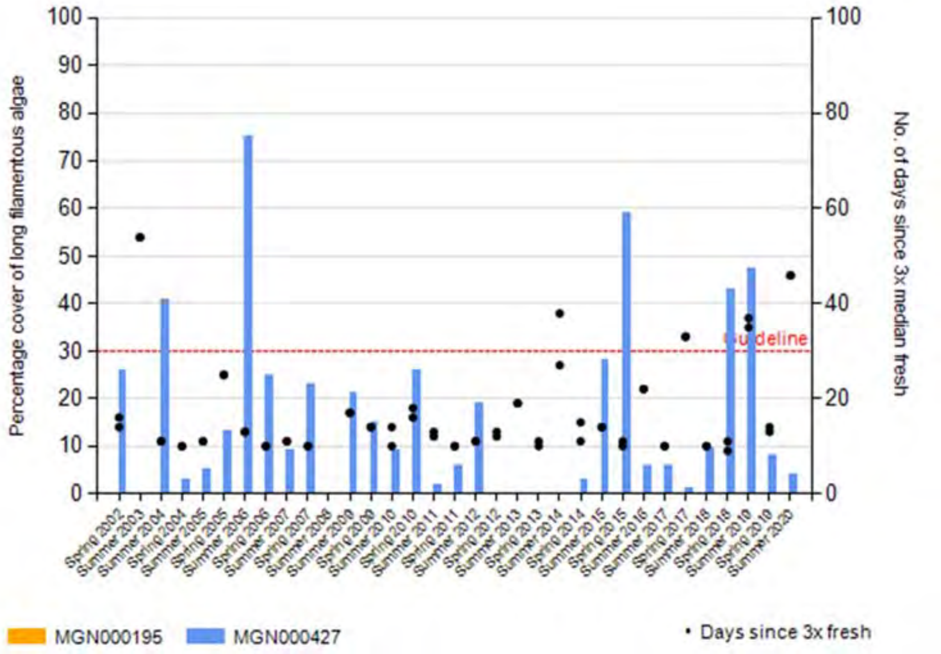


Figure 30 Percentage cover of long filamentous algae on the Manganui riverbed over the 2002-2020 monitoring period, with respect to the guidelines for recreational value. The number of days since the last 3 x median fresh is shown for comparison

While the upper site at SH3 displayed some thick algal mat growth over the 2005-2007 monitoring years, no growth of either thick mats or long filaments has been recorded at the site since summer 2008 (Figure 29 and Figure 30). The periphyton community at the downstream Bristol Road site, however, is more prolific, usually consisting of greater levels of long filamentous algae than thick algal mats.

While there have been no breaches in guidelines for thick algal mats at either site over the entire 18 years monitored, there have been breaches of long filamentous guidelines at the Bristol Road site on five occasions. This includes two breaches within the last monitoring period: in the spring of 2018 and the summer of 2019.

2.4.3 Periphyton Index Score

For the 2018-2020 period, the TRC PI scores at the SH3 site rank in the 'very good' band, while conditions at the Bristol Road vary between 'good' and 'poor'. This is relatively consistent with historical results (Table 23), although the Bristol Road site had slightly higher TRC PI values than historically typical during three surveys and a much lower score than typical during the spring 2018 survey.

The Manganui River periphyton surveys have typically recorded moderate differences in TRC PI between the SH3 and Bristol Road sites, a result reflected in this round of monitoring (Table 23). As discussed in the periphyton coverage section above, low nutrient input and good riparian shading contribute to the low levels of periphyton recorded at the upstream SH3 site, while the downstream Bristol Road site probably has issues with nutrient enrichment and a lack of shading.

Table 23 Median seasonal TRC periphyton index scores for Maketawa Stream

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
SH3	10.0	9.9	10.0	9.9	10.0	10.0
Bristol Road	3.9	7.3	7.3	7.5	6.9	6.2
Difference	6.1	2.6	2.7	2.4	3.1	3.8

2.4.4 Periphyton biomass

The results for the 2018-2020 monitoring period found extremely low levels of chlorophyll *a* at the SH3 site (1.6 and 2.0 mg/m^2) and a moderate level at the Bristol Road site (88 and 4 mg/m^2). During the summer 2019 survey, levels at Bristol Road breached the guideline for benthic biodiversity protection (Table 2, Figure 31). The results are largely congruent with the findings from the TRC periphyton index score.

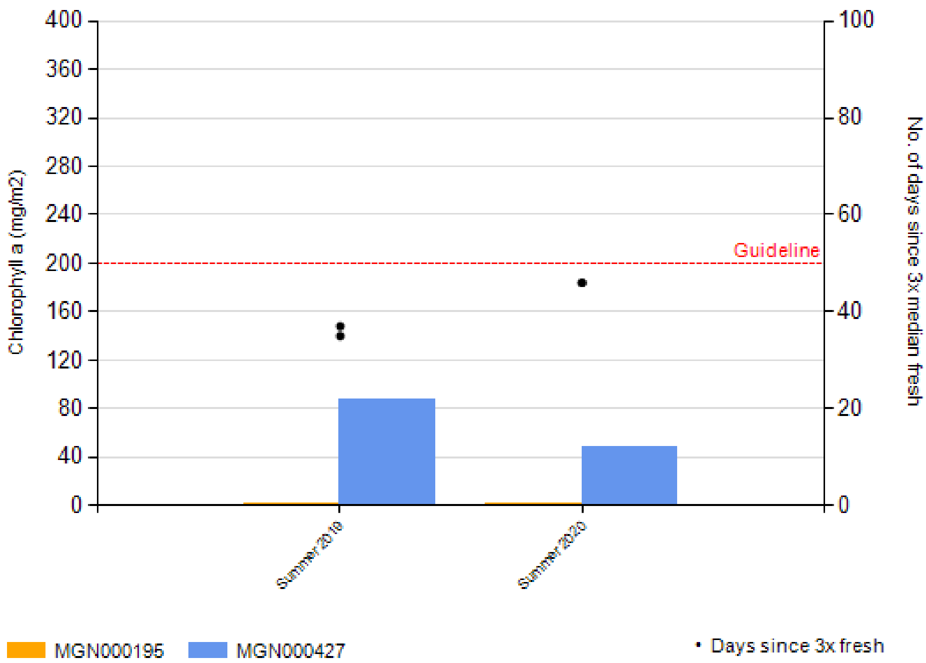
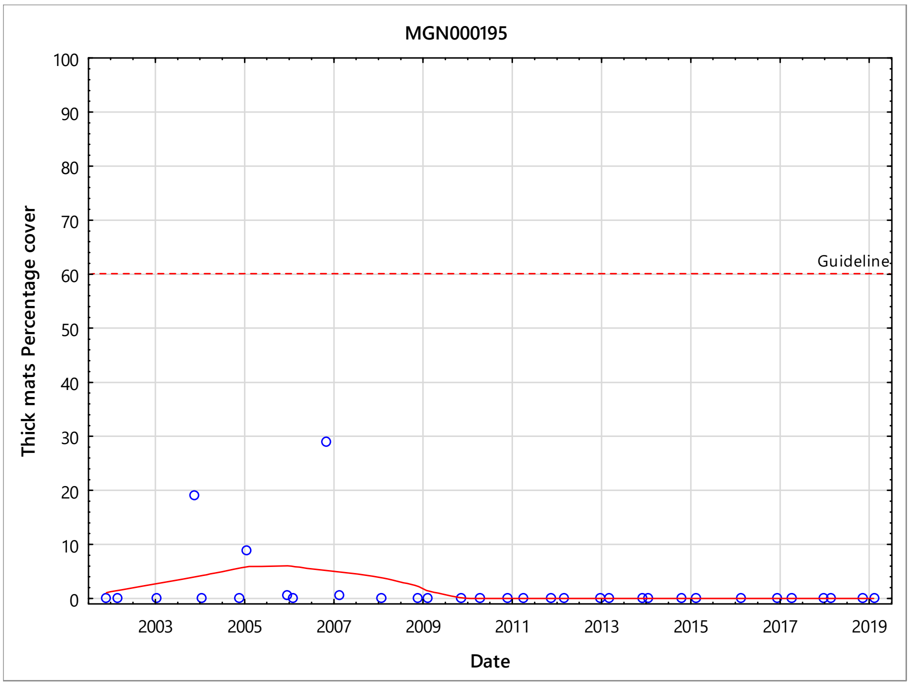


Figure 31 Periphyton biomass (chlorophyll *a*) on the Manganui riverbed over the 2018-2020 period with respect to the NOF guideline

2.4.5 Long term trend analysis

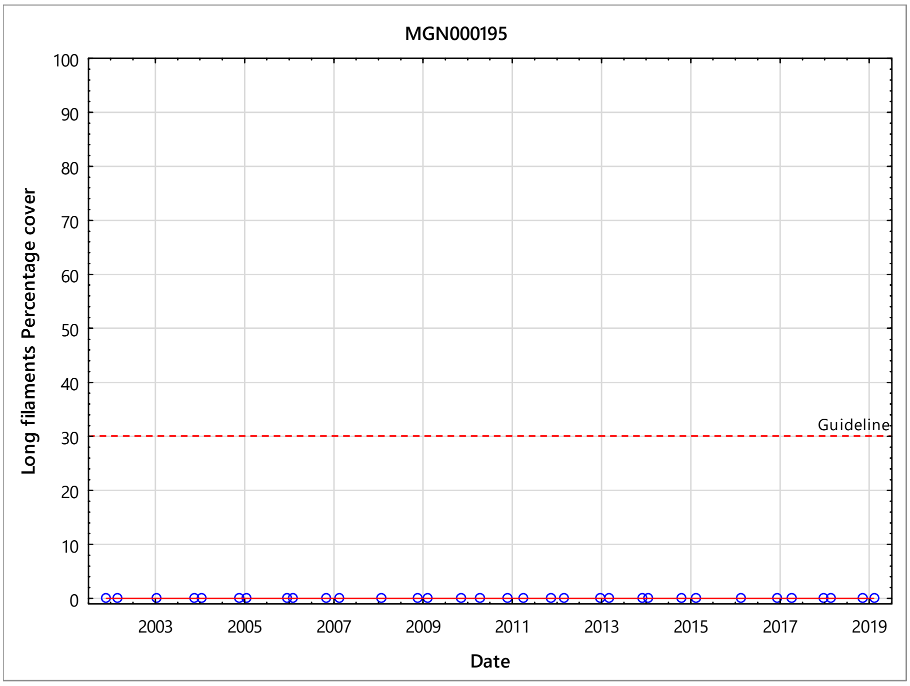
Following the methods outlined in Section 1.2, long-term trend analysis found evidence for a statistically significant decreasing trend in thick mat cover at the SH3 site (MGN000195). In reality, however, this result is entirely driven by the presence of thick mats at the site on four occasions prior to 2008. Since then, there has been no thick mat periphyton observed at the site. Similarly, no long filaments have been recorded at the site since the beginning of monitoring. It should be noted, however, that only spring and summer surveys have been included in this report, with late summer surveys, which occurred between 2002- 2012, excluded. Some of these surveys did have some very low levels of long filamentous algae present.

Meanwhile, at Bristol Road (MGN000427), there have been varying levels of both thick mat and long filament cover over the 18 year monitored period, however no statistically significant positive or negative trends was found.



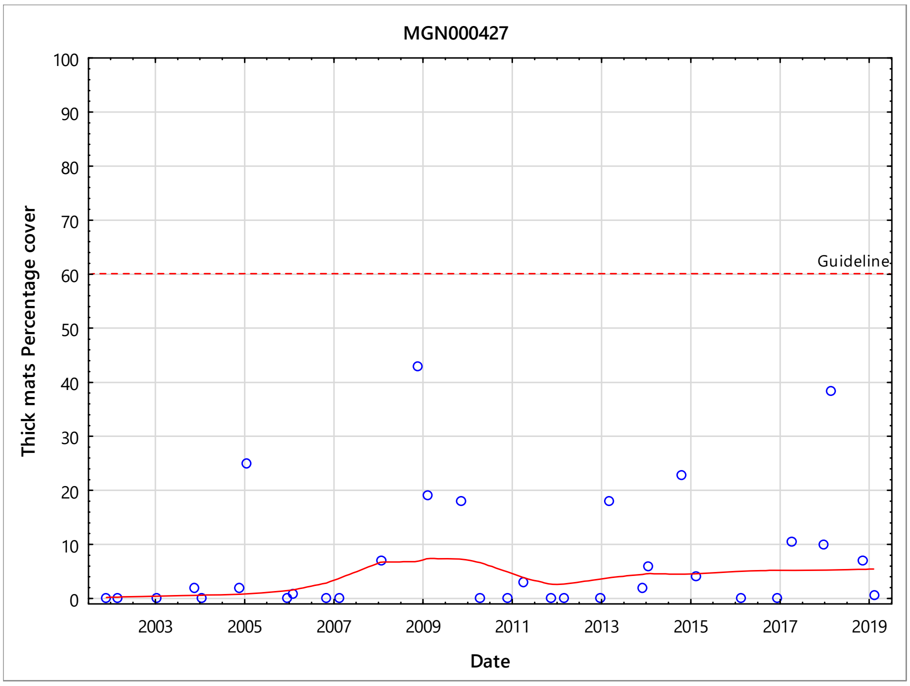
n = 33
Kendal tau = -0.332
p-value = 0.007
FDR p-value = 0.045

Figure 32 Long-term trend analysis of percentage cover of thick mats at Manganui River, SH3 (MGN000195). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



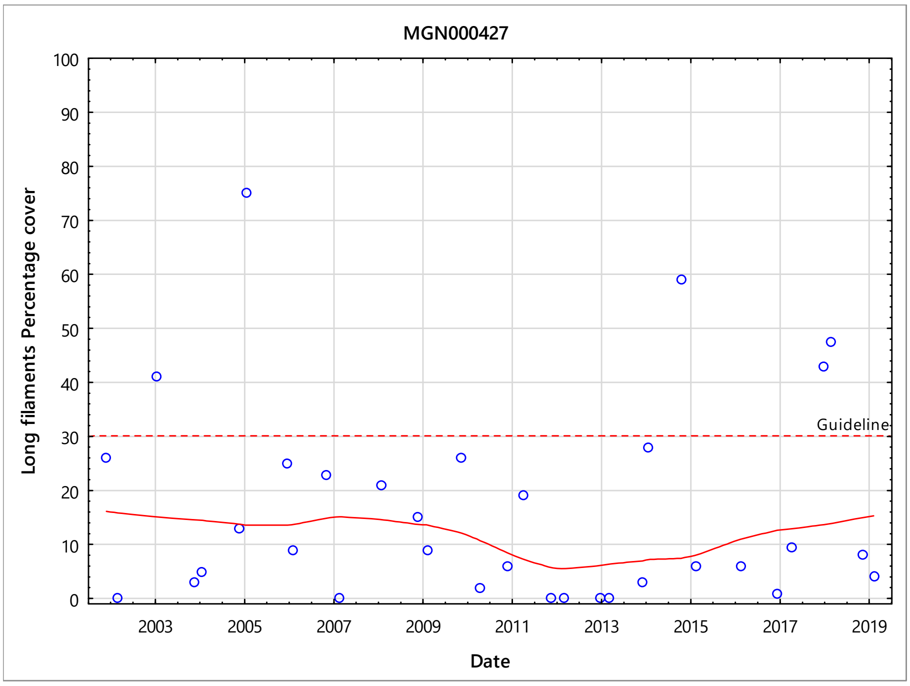
n = 33

Figure 33 Long-term trend analysis of percentage cover of long filaments at Manganui River, SH3 (MGN000195)



n = 33
Kendal tau = 0.218
p-value = 0.075
FDR p-value = 0.152

Figure 34 Long-term trend analysis of percentage cover of thick mats at Manganui River, Bristol Road (MGN000427)



n = 33
Kendal tau = -0.044
p-value = 0.716
FDR p-value = 0.756

Figure 35 Long-term trend analysis of percentage cover of long filaments at Manganui River, Bristol Road (MGN000427)

2.5 Patea River

The Patea River arises in the National Park and winds over 80 km, firstly east and then south, to the coast. Water quality is best in the upper reaches, and deteriorates in the lower reaches as the river travels through pasture, receiving wastes such as treated dairy effluent and the discharge from the Stratford oxidation pond system. Other rivers, such as Mangaehu River, converge with the Patea on its way to the coast (TRC, 1991).

The Patea has native forest in its headwaters, while the mid-low reaches comprise exotic forest and pasture. The top monitoring site (Barclay Road, PAT000200) is just below the boundary of the National Park, and as such has high water quality (Figure 36). The lower site, at Skinner Road (PAT000360) is mid-catchment and below several discharges. These include the Stratford municipal oxidation ponds, Stratford cycle power station discharge, and industrial discharges from the Kahouri Stream. The surrounding area is predominantly agricultural, and as such, the river tends to have lower water quality at the Skinner Road site, with a higher level of nutrients and lower clarity compared to the upper catchment site.

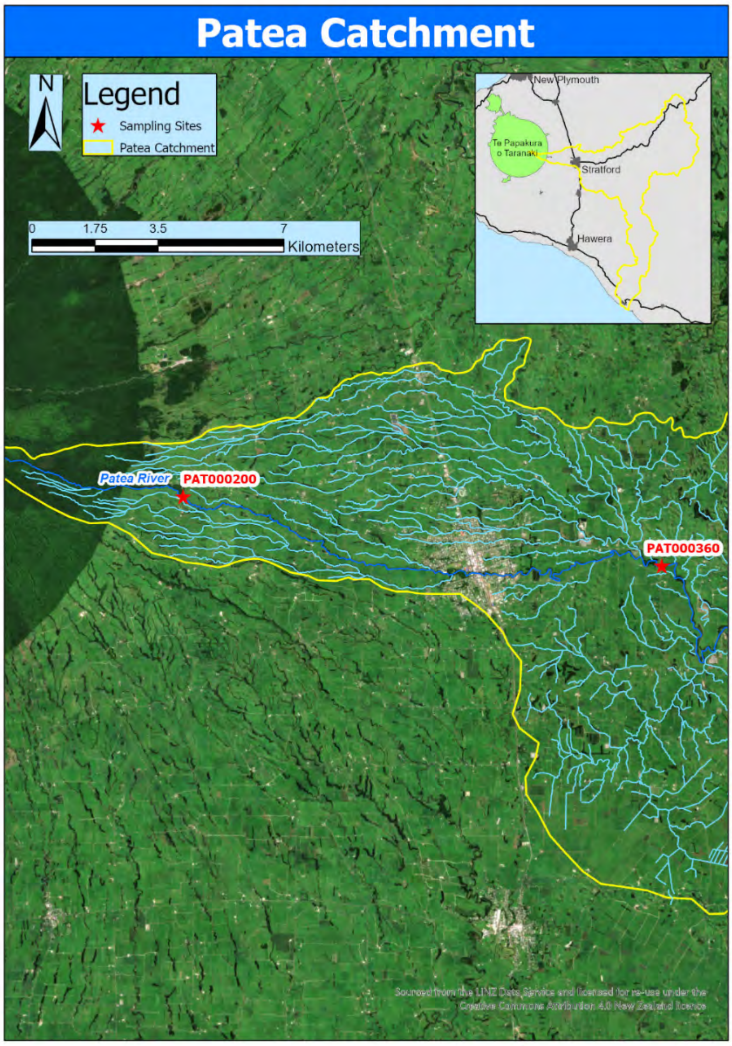


Figure 36 Monitoring site locations the Patea River catchment

2.5.1 Flow and nutrient data and survey dates

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

The Patea River has a telemetered hydrological monitoring station at Skinner Road, where the downstream periphyton-monitoring site is located. Records from this continuous monitoring station provide information on flow conditions in the river at the time of periphyton monitoring (Table 24).

Table 24 Date of sampling and corresponding time since three and seven times median flow

Season	Date	3 x	7 x
Spring	24/10/2018	11	36
Summer	29/01/2019	56	94
Spring	31/10/2019	12	12
Summer	15/01/2020	25	26

The TRC SEM physicochemical programme collects nutrient information at both the Barclay and Skinner Road sites. A range of parameters are measured, including DRP, DIN and TN. Proposed limits for DRP and DIN, in order to prevent undesirable growths, are currently under review for the NPS-FM (MfE, 2019), with the currently suggested guidelines being a median of 1.0 mg/L for DIN and 0.018 mg/L for DRP

For the 2018-2020 period, the Barclay Road monitoring site met the proposed guideline for DIN, but not for DRP. Meanwhile, the Skinner Road site failed to meet both DIN and DRP proposed guidelines (Table 25).

The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels, which are a possible cause of the exceedance in DRP levels at the upper site. However, the lower site displays both high DRP and nitrogen levels, which likely can be attributed to the combination of a point source discharge from the Stratford wastewater treatment plant, and agricultural inputs.

Table 25 Medians for selected physicochemical water quality parameters for the Patea River

Site	Altitude (m)	2018-2019			2019-2020		
		DRP	DIN	TN	DRP	DIN	TN
Barclay Road	500	0.0225*	0.036	0.06	0.0226*	0.023	0.072
Skinner Road	240	0.0460*	0.95	1.18*	0.0320*	1.04*	1.25*

* Does not meet MfE (2019) guidelines (under review)

2.5.2 Periphyton cover

For the 2018-2020 monitoring period, the upstream site at Barclay Road did not record any nuisance periphyton in any of the four surveys. The downstream site at Skinner Road had low levels of thick mats, which did not exceed guideline levels, over the reported period. Long filaments were present at the Skinner Road site for all four surveys, with levels fluctuating from moderate in spring surveys to very high in summer. Long filament coverage in both summer surveys greatly exceeded the guideline threshold (Table 26, Figure 37 and Figure 38).

Table 26 Periphyton cover results from previous surveys performed in the Patea River, together with the results for the current monitoring period

Site	SEM data (2002 to 2018)					Monitoring period			
						2018-2019		2019-2020	
	No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
Barclay Road	31	Thick mats	0-15	0	1	0	0	0	0
		Long filaments	0-1	0	0	0	0	0	0
Skinner Road	31	Thick mats	0-53	0	5	9	6	0	3
		Long filaments	0-44	8	13	2	77	4	88

Differences in algal coverage between the two sites may be due to the difference in shading and nutrient levels between the two sites. The Barclay Road site is completely shaded, with native riparian vegetation both at the site, and along most of the upstream reach, up to the nearby National Park. This shading, in conjunction with low nutrient levels, largely limits periphyton growth at the site to thin films. In contrast, the site at Skinner Road has far less shading, and has relatively high nutrient levels due to being located below the discharge from the Stratford wastewater treatment plant. The combination of high sunlight and nutrients levels promotes the proliferation of nuisance periphyton at the site.

The sites on the Patea River consistently have cooler water temperatures compared to the other nuisance periphyton monitoring sites in the region, which could slow the growth of periphyton at the sites. The cooler temperatures are likely a result of the higher elevations of the Patea River sites (500 and 240 masl) when compared to other monitoring sites.

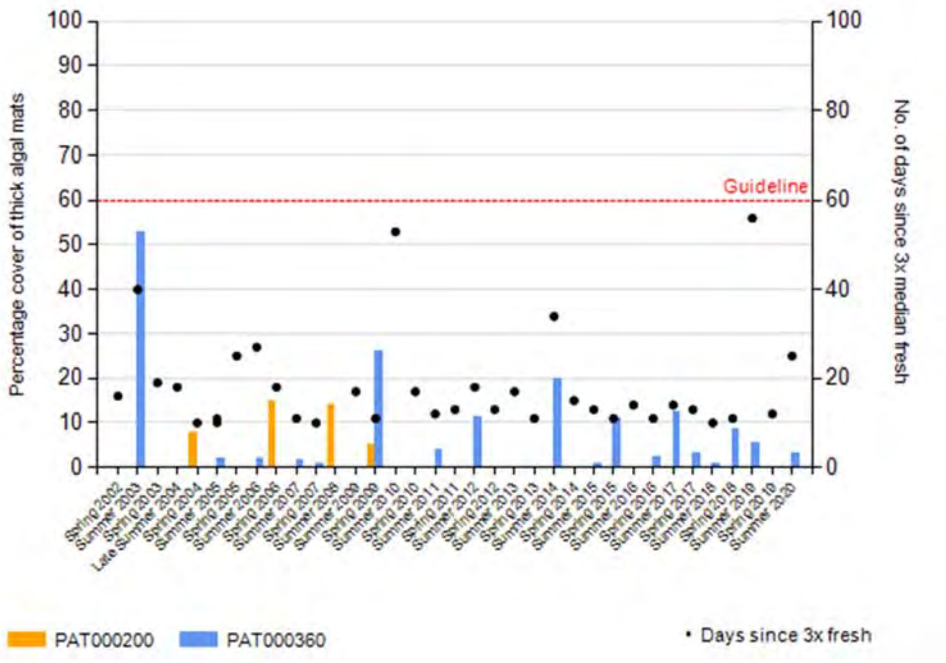


Figure 37 Percentage cover of thick mats of periphyton on the Patea riverbed over the 2002-2020 monitoring period, with respect to the guidelines for recreational values. The number of days since the last 3 x median fresh is shown for comparison

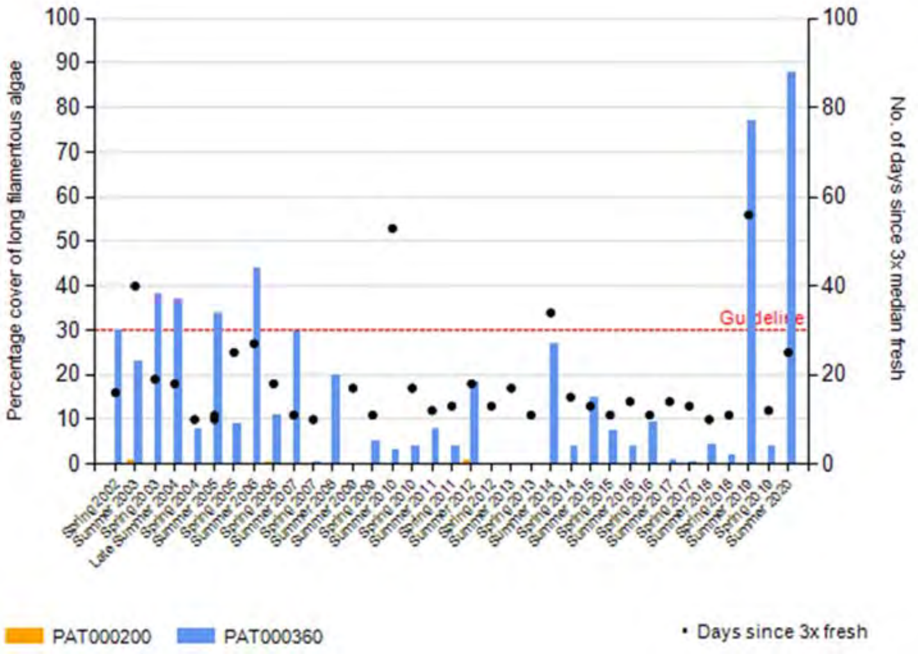


Figure 38 Percentage cover of long filamentous algae on the Patea riverbed over the 2002-2020 monitoring period, with respect to the guidelines for recreational value. The number of days since the last 3 x median fresh is shown for comparison

Thick algal mat periphyton guidelines haven't been breached at either of the Patea River sites since monitoring began in 2002 (Figure 37). As mentioned previously, proliferations of both thick mats and long filamentous algae are more frequent and prolific at the downstream site at Skinner Road. While thick algal mats have been recorded at Barclay Road on a small number of occasions, no thick mats have been recorded at the site since 2009.

At the downstream Skinner Road site, large proliferations of long filamentous algae have led to many breaches of guidelines throughout the 18-year period of monitoring. While a number of breaches occurred during the earlier monitoring years, the summer surveys of the current monitoring period recorded the highest levels at the site yet (Figure 38). Both of the most recent breaches correspond to periods of lower than usual flow, together with high river temperatures.

2.5.3 Periphyton Index Score

TRC PI scores for the upstream Barclay Road site consistently fell in the "very good" band for the 2018-2020 monitoring period, in line with historic medians for the site (Table 27). In contrast, the scores for the Skinner Road site rated as "good" during the spring surveys, but "poor" and "very poor" during the summer surveys. There has historically been a difference between the spring and summer results at the Skinner Road site, however, the summer results for this monitoring period were significantly worse than the historical median difference.

Table 27 Median seasonal periphyton index scores for the Patea River

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
Barclay Road	10.0	9.9	9.7	9.8	9.7	9.8
Skinner Road	7.6	2.1	7.7	1.6	7.7	6.1
Difference	2.4	7.8	2.0	8.2	2.0	3.7

2.5.4 Periphyton biomass

Surveys during the 2018-2020 monitoring period found very low levels of chlorophyll *a* (3.1 and 2.6 mg/m^2) at the Barclay Road site, and moderate to extremely high levels (141.8 and 621.4 mg/m^2) at the Skinner Road site. The chlorophyll *a* results from the Patea River sites reflect the sites' TRC periphyton index scores well (Table 27). The Barclay Rd site did not exceed the NOF standard for chlorophyll *a* of 200 mg/m^2 (Snelder et al., 2013), nor the guideline to protect benthic biodiversity of 50 mg/m^2 (Table 2). The Skinner Rd site, however, exceeded both the guideline to protect benthic biodiversity, and that for aesthetic values (120 mg/m^2) during both surveys. In the summer 2020 survey, the recorded chlorophyll *a* level was more than triple the NOF standard of 200 mg/m^2. Overall, results from the two sites suggest that periphyton biomass gain in the Patea River is driven by nutrients, likely received as runoff from agricultural pasture and as discharge from the Stratford wastewater treatment plant. As a result of these inputs, nutrient levels at the Skinner Road site are sufficiently high to promote excessive periphyton growth.

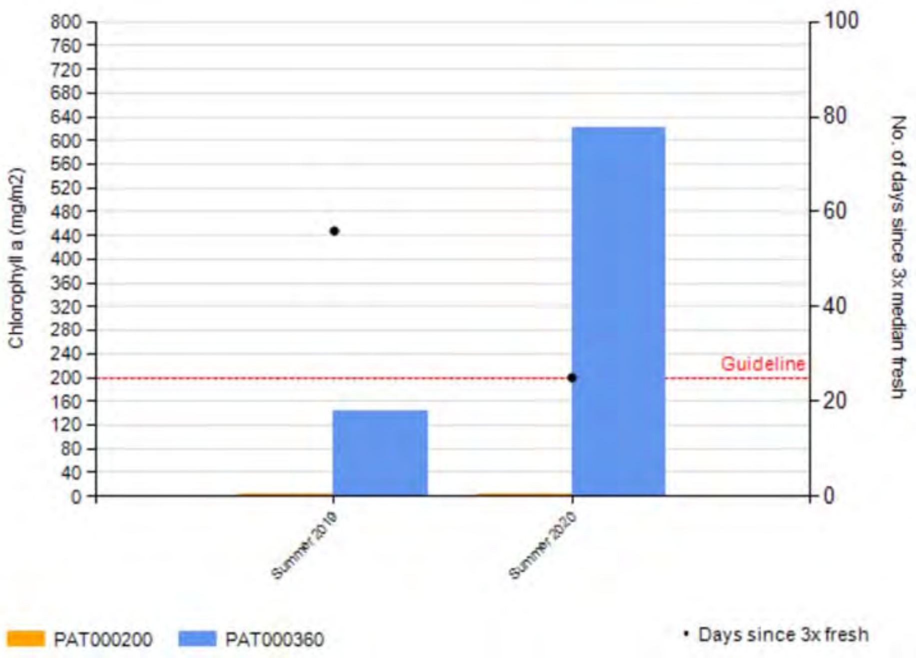


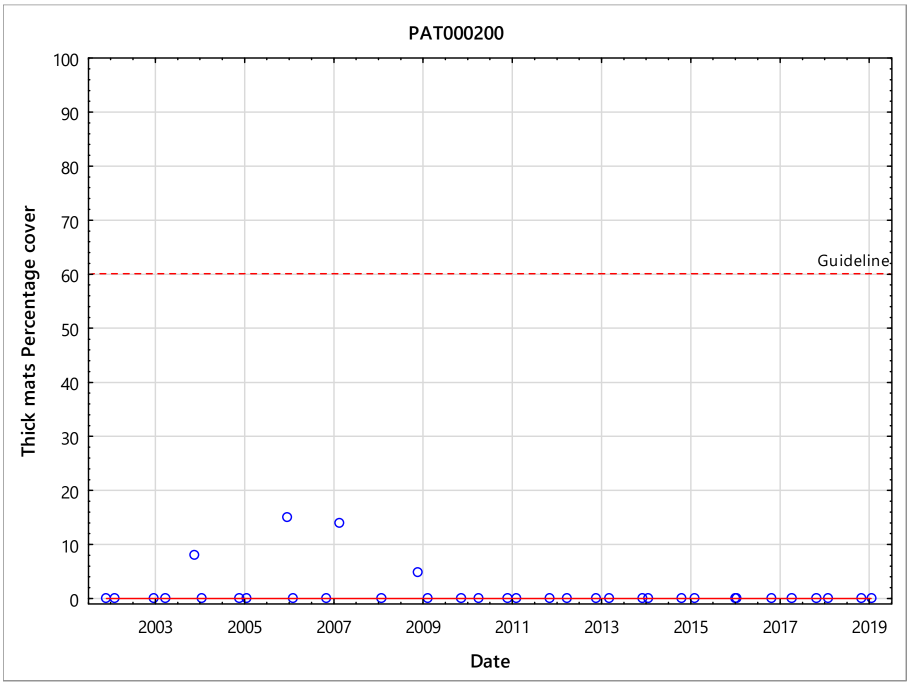
Figure 39 Periphyton biomass (chlorophyll *a*) on the Patea riverbed over the 2018-2020 period, in relation to the NOF guideline

2.5.5 Long term trend analysis

Long-term trend analysis was undertaken following the methods outlined in Section 1.2. At both sites in the Patea River, there was no significant increasing or decreasing trend in thick mat or long filament cover found over the 18 year monitored period (Figure 40 through Figure 43).

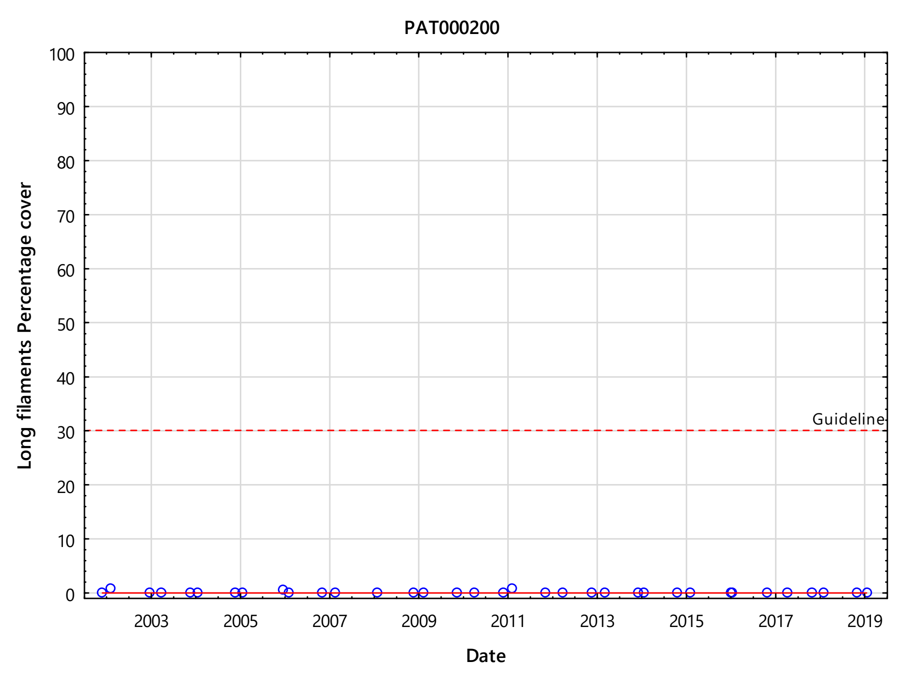
While initially a decreasing trend in thick mats was found at the Barclay Road site (PAT000200), this was found to not be significant after FDR analysis (Figure 40). In addition, on inspection, this result can be found to be due to the presence of thick mats at the site on only four occasions, all prior to 2009. Since then, no thick mats have been observed at the site.

Similarly, at the Skinner Road site (PAT000360), a decreasing trend in long filament cover was initially found over the 18 year monitored period (Figure 43). However, this trend was found to be not statistically significant following FDR analysis. This could be due to the unprecedented high level of long filament cover found at this site during the summer surveys of the current monitoring period. It is therefore worth keeping a close eye on the results of the next surveys at this site, to determine whether these most recent results were anomalous, or if they are potentially a sign of a change in conditions at the site.



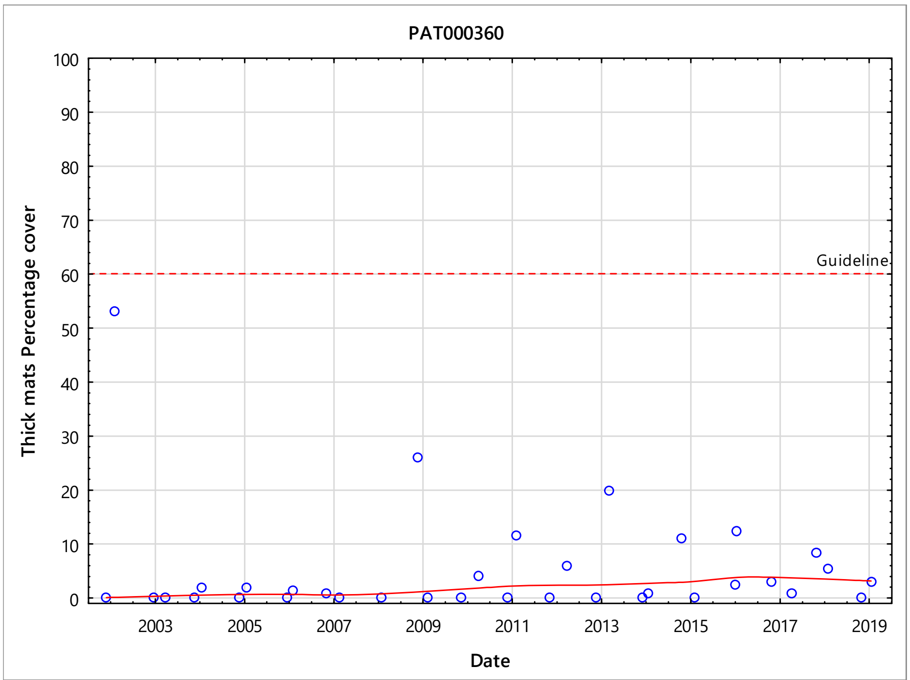
n = 35
Kendal tau = -0.237
p-value = 0.045
FDR p-value = 0.128

Figure 40 LOWESS trend analysis of percentage cover of thick mats at Patea River, Barclay Road (PAT000200)



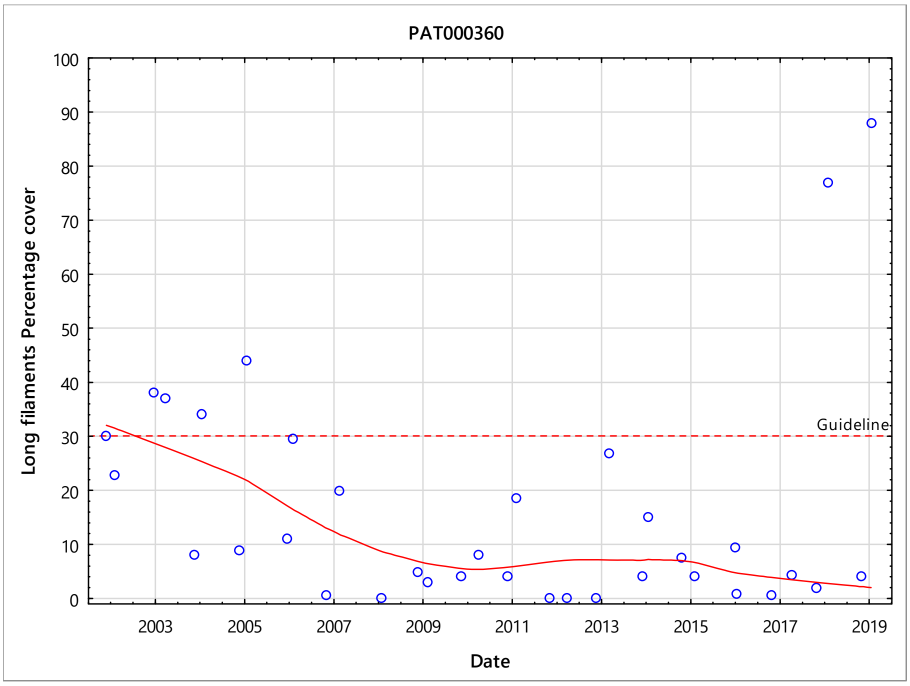
n = 35
Kendal tau = -0.199
p-value = 0.093
FDR p-value = 0.196

Figure 41 LOWESS trend analysis of percentage cover of long filaments at Patea River, Barclay Road (PAT000200)



n = 35
Kendal tau = 0.204
p-value = 0.084
FDR p-value = 0.153

Figure 42 LOWESS trend analysis of percentage cover of thick mats at Patea River, Skinner Road (PAT000360)



n = 35
Kendal tau = -0.234
p-value = 0.048
FDR p-value = 0.148

Figure 43 LOWESS trend analysis of percentage cover of long filaments at Patea River, Skinner Road (PAT000360)

2.6 Punehu Stream

The Punehu Stream arises in the National Park, heads approximately 25 km in a south westerly direction to the coast, and enters the sea just south of Opunake. The stream is representative of a south-western Taranaki catchment which is 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 is at Wiremu Road (PNH000200), and lies approximately 2 km below the National Park boundary. The site is thus representative of relatively un-impacted stream water quality (Figure 44). The lower catchment site, near the coast, is located at SH45 (PNH000900), and is approximately 20 km from the National Park.

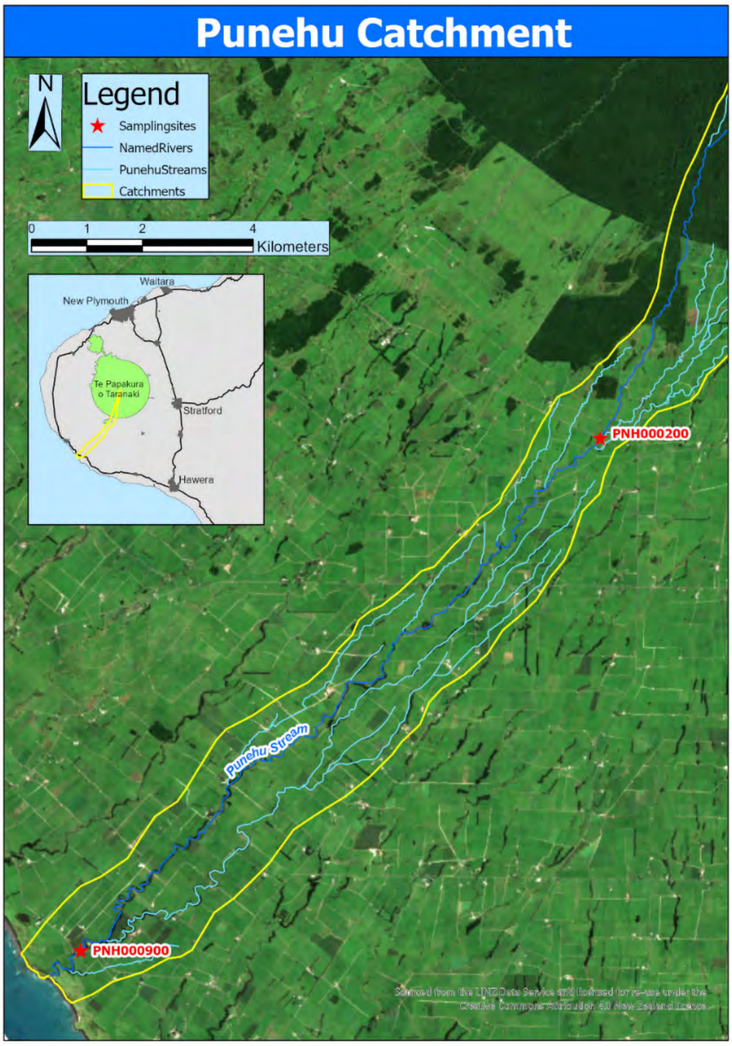


Figure 44 Monitoring site locations in the Punehu Stream

2.6.1 Flow and nutrient data and survey dates

The Puneho Stream has a telemetered hydrological monitoring station at Pihama, nearby where the downstream periphyton-monitoring site is located. Records from this continuous monitoring station provide information on flow conditions in the river at the time of periphyton monitoring (Table 28).

Table 28 Date of sampling and corresponding time since three and seven times median flow

Season	Date	3 x	7 x
Spring	25/10/2018	12	49
Summer	31/01/2019	16	16
Spring	07/11/2019	13	14
Summer	16/01/2020	26	27

The TRC SEM physicochemical program collects nutrient information at both the Wiremu Rd and SH45 sites. A range of parameters are measured, including DRP, DIN and TN. Proposed limits for DRP and DIN, in order to prevent undesirable growths, are currently under review for the NPS-FM (MfE, 2019), with the currently suggested guidelines being a median of 1.0 mg/L for DIN and 0.018 mg/L for DRP.

While the upstream Wiremu Road site met the proposed DIN guideline through the 2018-2020 period, it exceeded that for DRP. Similarly, DRP levels at the downstream SH45 site exceeded the proposed guideline during both 2018-2019 and 2019-2020 seasons, while the proposed guideline for DIN was exceeded during the 2019-2020 season. Total Nitrogen levels were also high (Table 29). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels, which may be the cause of the exceedance in DRP levels at the upstream Wiremu Road site. However, the increased levels of DRP recorded at the lower SH45 site are more likely caused by agricultural inputs.

Table 29 Medians for selected physicochemical water quality parameters for the Puneho Stream

Site	Altitude (m)	2018-2019			2019-2020		
		DRP	DIN	TN	DRP	DIN	TN
Wiremu Road	270	0.023*	0.059	0.146	0.020*	0.096	0.177
SH45	20	0.033*	0.90	1.13	0.038*	1.21*	1.35

* Does not meet MfE (2019) guidelines (under review)

2.6.2 Periphyton cover

During the 2018-2020 monitoring period, at the upstream Wiremu Road site, thick mats were recorded to be at moderate levels in summer 2019, and either at a low level or non-existent at the other sampling times. Long filament periphyton were not present at Wiremu Rd during any of the four surveys. Meanwhile, the SH45 site had low or non-existent levels of thick mats, and moderate levels of long filaments (Table 30, Figure 45 and Figure 46).

Table 30 Periphyton Cover results from previous surveys performed in the Punehu River, together with results for the current monitoring period

Site	SEM data (2002 to 2018)					Monitoring period			
						2018-2019		2019-2020	
	No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
Wiremu Rd	30	Thick mats	0-35	0	3	1	18	0	2
		Long filaments	0-8	0	1	0	0	0	0
SH45	30	Thick mats	0-17	0	3	5	1	1	0
		Long filaments	0-72	11	17	21	24	11	7

As typical for the Punehu Stream, nuisance periphyton levels during the 2018-2020 period were higher at the downstream SH45 site compared to the upper, Wiremu Road site. Partial shading of the riverbed by overhanging vegetation and steep banks likely helps limit periphyton growth at the SH45 site, even though nutrient levels are at levels that would otherwise promote excessive growth.

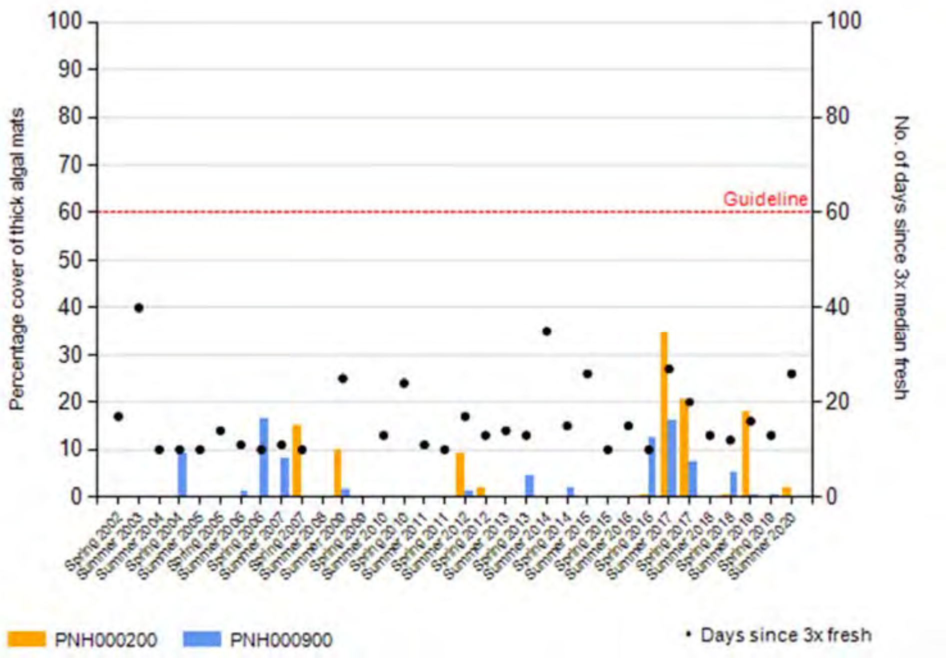


Figure 45 Percentage cover of thick mats of periphyton on the Puneho riverbed during the 2002-2020 monitoring period. The guideline for recreational values, and days since the last 3x median fresh, are shown for reference

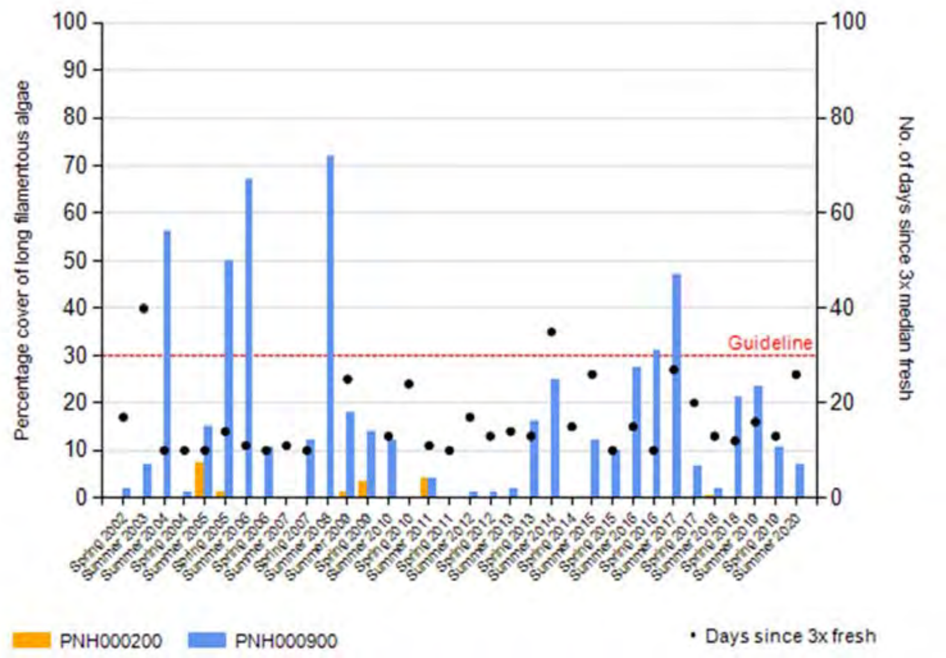


Figure 46 Percentage cover of long filamentous algae on the Puneho riverbed during the 2002-2020 monitoring period. The guideline for recreational values, and days since the last 3x median fresh, are shown for reference

Over the 18 years of monitoring in the Punehu catchment, there have been no recorded breaches in recreational guidelines for thick mats at either site (Figure 45). In the past few years, proliferations of thick mats have occurred more frequently at the upstream Wiremu Road site; however, these proliferations have remained below guideline values.

The Punehu catchment has been subject to large proliferations of long filamentous algae over the 18 years of monitoring, especially at the downstream SH45 site (Figure 46). There have been six breaches of guidelines since the start of monitoring, two of which occurred in the 2016-2018 period. Prior to this, a breach of guidelines had not been recorded since the summer of 2008, when over 70% of the river bed was covered in long filaments.

2.6.3 Periphyton Index Score

While the upstream site at Wiremu Road had a 'very good' TRC PI score for three surveys in the 2018-2020 period, the 'good' TRC PI score recorded in summer 2019 was significantly lower than the historic median summer score for the site (Table 31).

With the exception of the summer 2019 survey, the downstream site at SH45 had lower TRC PI scores than the Wiremu Road site. With all four surveys placing the TRC PI score at the SH45 site in the 'very good' category, there was no discernible difference in the state of the site between spring and summer surveys.

The Punehu Stream represents a catchment with dairy as its primary land use. There is, therefore, high potential for elevated nutrient inputs into the stream. The upstream site at Wiremu Road has no point source discharges in its headwaters, a fact reflected in the site's nutrient status and periphyton community. While the lower site has elevated nutrients levels, the heavily incised nature of the stream has resulted in steep, tall riverbanks. This, together with riparian vegetation, potentially limits periphyton growth from being as prolific as it could otherwise be considering such high nutrient levels.

Table 31 Seasonal periphyton index scores for the Punehu Stream

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
Wiremu Rd	9.9	6.7	9.9	9.7	9.9	9.5
SH45	7.3	7.5	8.1	9.0	9.9	8.7
Difference	2.6	-0.8	1.8	0.7	0.0	0.8

2.6.4 Periphyton biomass

During the 2018-2020 monitoring period, low chlorophyll *a* levels were recorded at both sites in the Puneho Stream (Figure 47), with neither site exceeding limits or guidelines (for recreational or aesthetic values, or biodiversity protection) (Table 2). Chlorophyll *a* levels showed a deterioration between upstream and downstream sites during both surveys, a result that has historically been typical for the Punehu Stream.

Measured chlorophyll *a* levels were largely congruent with the TRC PI results for both sites, and show that the Wiremu Road site generally has 'very good' periphyton communities. The lower PI score recorded during the summer 2019 survey was not associated with the flow regime or nutrient levels or any other obvious factor.

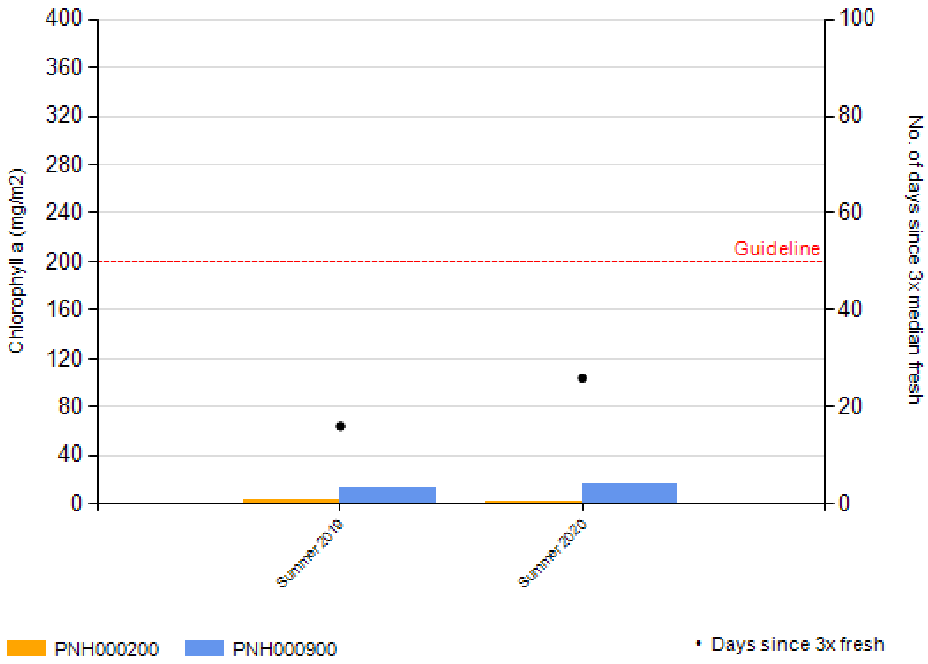
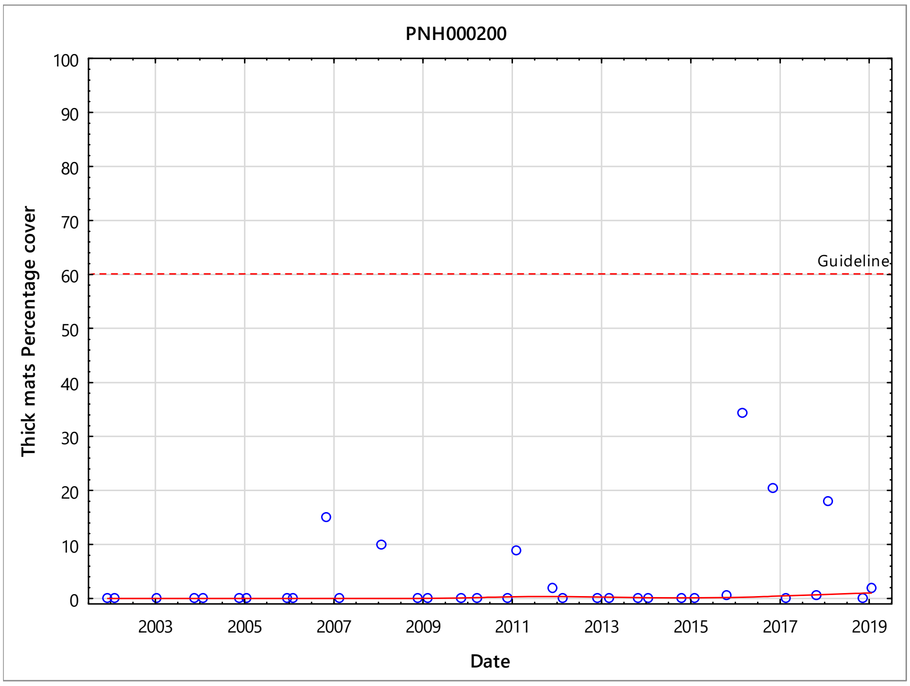


Figure 47 Periphyton biomass (chlorophyll *a*) on the Punehu riverbed over the 2018-2020 period. The guideline for recreational values is given for reference

2.6.5 Long term trend analysis

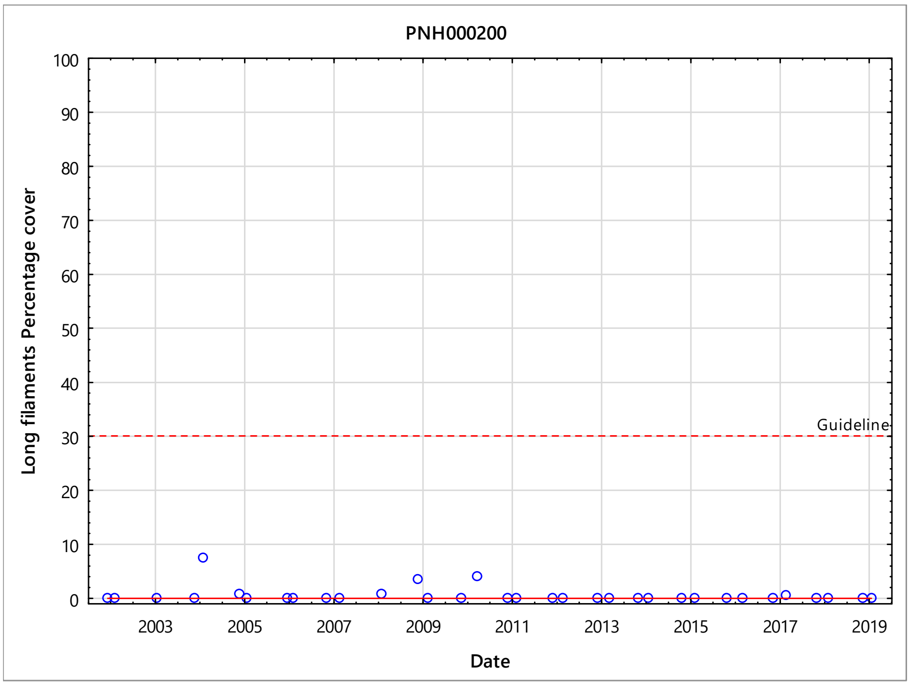
Long-term trend analysis was undertaken following the methods outlined in Section 1.2. A statistically significant increasing trend in thick mat cover was found at the Wiremu Road (PNH000200) site over the 2002-2020 period (Figure 48). It is noted, however, that thick mat cover at this site has never come close to breaching guidelines. While proliferations have been more frequent in recent years, their scale has not been of concern to date with the highest recorded thick mat coverage being 34.5% on the summer 2017 survey. This occurred after a period of stable flows (27 days after a 3x fresh).

No other statistically significant increasing or decreasing trends in periphyton cover were found at the Puneho Stream sites (Figure 49 through Figure 51).



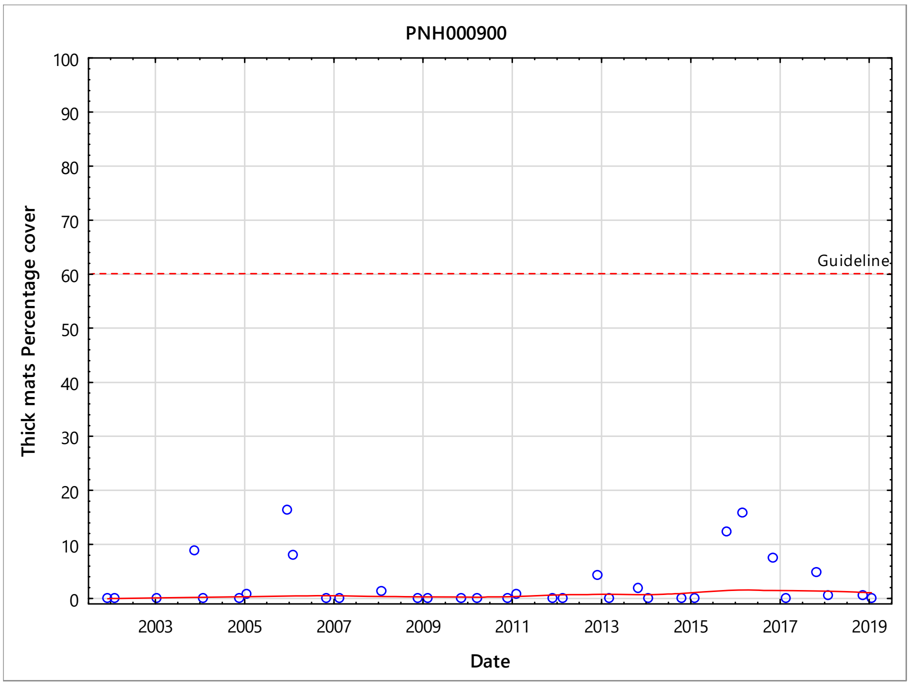
n = 34
Kendal tau = 0.309
p-value = 0.010
FDR p-value = 0.046

Figure 48 Long-term trend analysis of percentage cover of thick mats at Wiremu Road (PNH000200). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



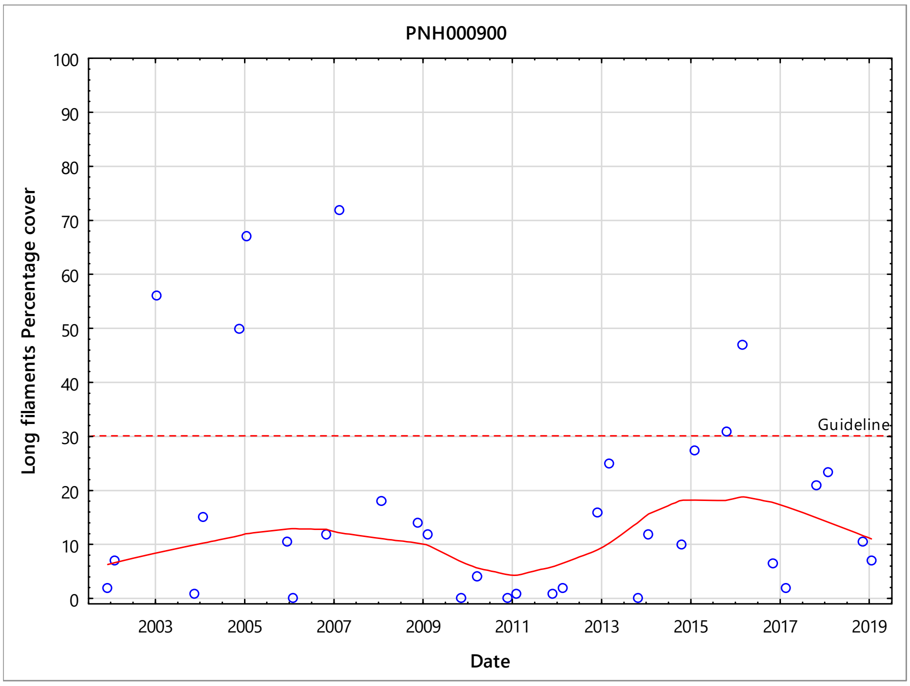
n = 34
Kendal tau = -0.156
p-value = 0.193
FDR p-value = 0.367

Figure 49 Long-term trend analysis of percentage cover of long filaments at Punehu Stream, Wiremu Road (PNH000200)



n = 34
Kendal tau = -0.121
p-value = 0.315
FDR p-value = 0.442

Figure 50 Long-term trend analysis of percentage cover of thick mats at Punehu Stream, SH45 (PNH000900)



n = 34
Kendal tau = 0.018
p-value = 0.880
FDR p-value = 0.880

Figure 51 Long-term trend analysis of percentage cover of long filaments at Punehu Stream, SH45 (PNH000900)

2.7 Waingongoro River

The Waingongoro River originates in the National Park and heads southeast towards Eltham. Here it turns southwest, and travels to its mouth at Ohawe. With a length of around 67 km from National Park boundary to coast, the Waingongoro is the region's longest river that is confined to the ring plain.

Characteristically, the upper reaches of the river have the best water quality, with quality declining in the middle and lower reaches. The Waingongoro River is a catchment with intensive usage, and highly rated for its recreational uses, and for its aesthetic and scenic values. As such, three sites are located in this catchment to monitor periphyton communities (Figure 52). The top site, at Opunake Road (WGG000150), is approximately six kilometres below the National Park, with a very high level of riparian cover present above the site. The mid catchment site is located at Stuart Road (WGG000665), and lies downstream of several industrial discharges, including an Eltham based meat works. Agricultural development is intense along the river, both above the Stuart Road site and between it and the lower catchment monitoring site, located at Ohawe Beach (WGG000995). This site lies just upstream of the river mouth.

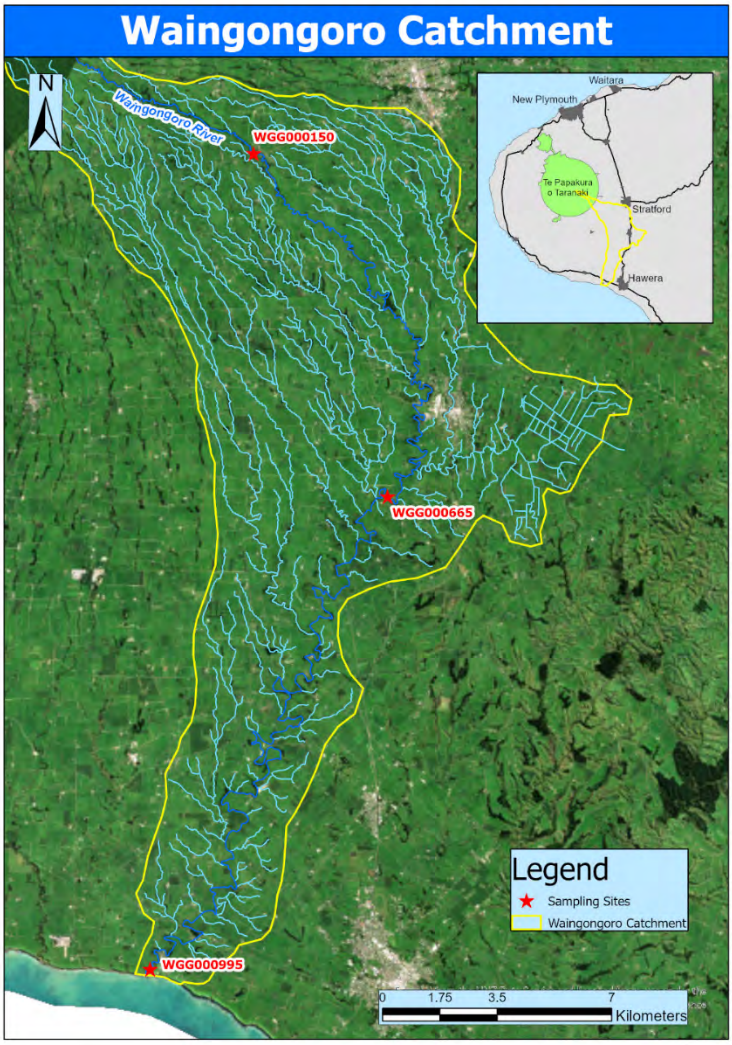


Figure 52 Monitoring site locations in the Waingongoro River catchment

2.7.1 Flow and nutrient data and survey dates

The Waingongoro River has two telemetered hydrological monitoring stations. The upper site, at Eltham Road, is used to provide information on flow conditions in the river for upper two periphyton-monitoring sites. The lower site is at SH45, and provides information of the flow conditions at the time of sampling at the Ohawe Beach site (Table 32).

Table 32 Date of sampling and corresponding time since three and seven times median flow. Values in brackets are for the Ohawe Beach site, when different to the upper two sites

Season	Date	3 x	7 x
Spring	24/10/2018	36 (35)	51
Summer	01/03/2019	112 (124)	180
Spring	07/11/2019	19 (18)	19
Summer	16/01/2020	27	38

The TRC SEM physicochemical program collects nutrient information at two sites along the Waingongoro River, one within the Eltham township and the other at SH45. While the two physicochemical monitoring sites are not the same locations as the nuisance periphyton sites, they provide a guide to the nutrient status near the lower two periphyton monitoring sites. A range of parameters is measured for the physicochemical program, including DRP, DIN and TN. The 2020 NPS limits for DRP and DIN, in order to prevent undesirable periphyton growths, remain currently under ongoing review for the NPS-FM and are considered interim by MfE (MfE, 2019). The proposed limits were a median of 1.0 mg/L for DIN and 0.018 mg/L for DRP.

Neither of the monitored sites would meet the prospective limit for DIN, while the lower site also failed to meet the proposed limit for DRP. While the volcanic soils around the Taranaki ringplain have naturally high phosphorus levels, source inputs from industries and agricultural inputs are likely cause of the exceedance in DRP at Ohawe Beach, and for the high levels of total nitrogen observed at both sites.

Table 33 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Waingongoro River

Site	2018-2019			2019-2020		
	DRP	DIN	TN	DRP	DIN	TN
Stuart Road⁺	0.015	1.28*	1.58	0.014	1.42*	1.59
Ohawe Beach⁺	0.039*	1.76*	2.10	0.037*	1.84*	2.19

* Does not meet MfE (2019) original proposals (still under review)

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

2.7.2 Periphyton cover

During the 2018-2020 monitoring period, no nuisance periphyton was recorded at the upper catchment site at Opunake Road, and only low levels of nuisance periphyton were recorded at the middle site at Stuart Road. The bottom site at Ohawe Beach had moderate levels of thick mats and long filaments in the summer 2019 and 2020 surveys (Table 34, Figure 53 and Figure 54).

Table 34 Periphyton results from previous surveys performed in the Waingongoro River, together with the results for the current monitoring period

Site	Altitude (m)	SEM data (2002 to 2018)					Monitoring period			
							2018-2019		2019-2020	
		No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
Opunake Rd	380	31	Thick mats	0-46	0	3	0	0	0	0
			Long filaments	0-1	0	0	0	0	0	0
Stuart Rd	180	31	Thick mats	0-26	0	4	0	1	8	4
			Long filaments	0-35	2	5	0	0	0	1
Ohawe Beach	10	31	Thick mats	0-83	8	14	6	40	16	41
			Long filaments	0-30	1	5	1	19	0	9

In line with historical results, the Ohawe Beach site displayed higher levels of nuisance periphyton than the other two sites in the 2018-2020 period. As is typical for the site, thick algal mats (mostly comprised of diatoms) occurred at greater levels than long filamentous algae. As the furthest site downstream in an agricultural catchment, the Ohawe beach site displays the cumulative effects of diffuse pollution from farms, which provide sufficient nutrients for excessive periphyton growth. While NOF limit levels were not breached during the 2018-2020 period, the levels of thick mats at Ohawe Beach site were higher than both the historic average and median.

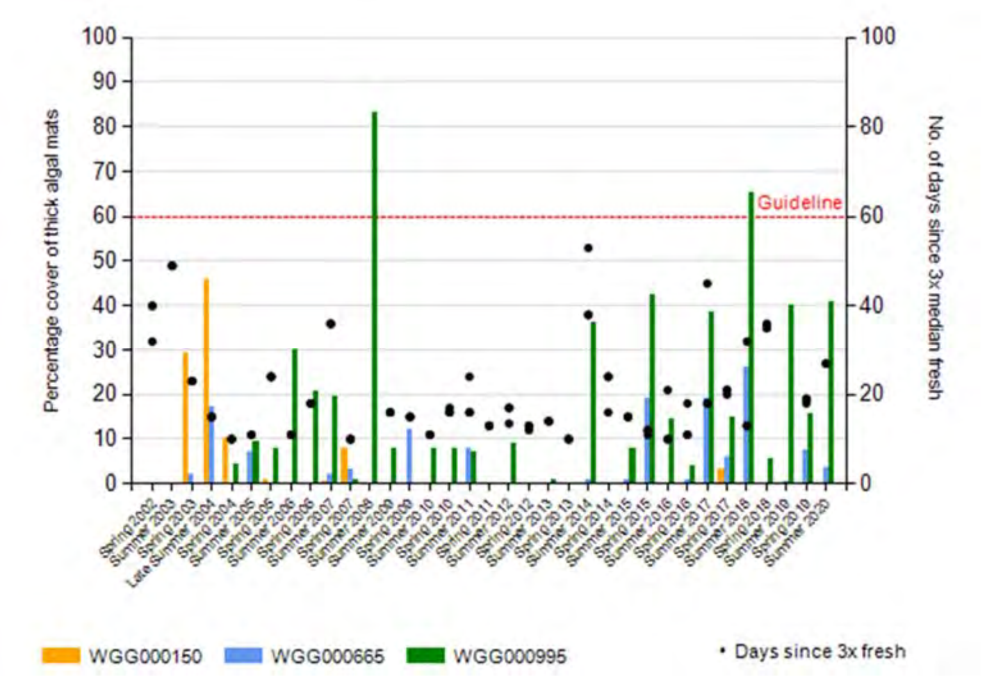


Figure 53 Percentage cover of thick mats of periphyton on the Waingongoro riverbed, in relation to the guideline for recreational values, over the 2002-2020 monitoring period. The number of days since 3 x median fresh is shown for reference

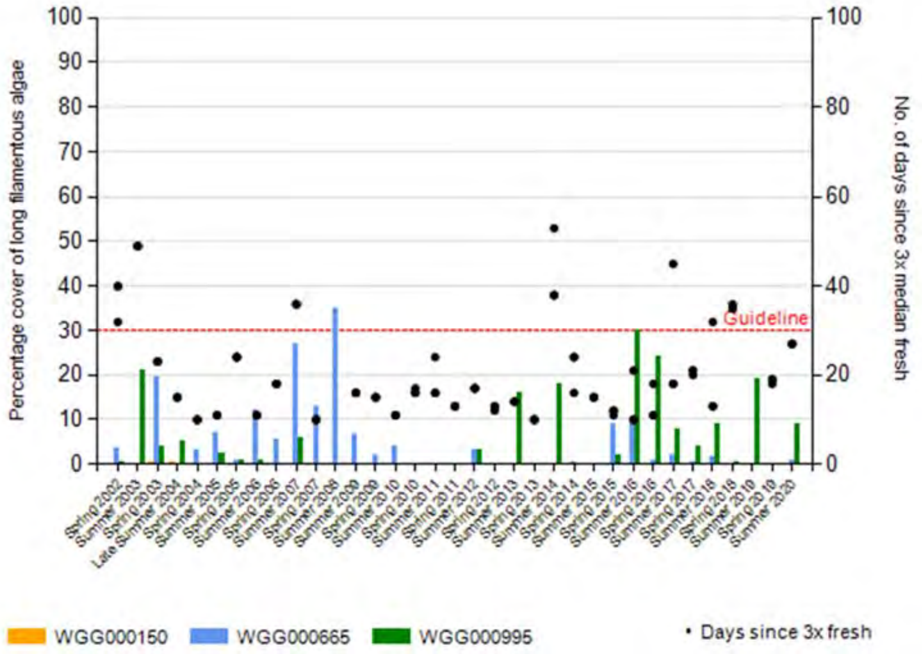


Figure 54 Percentage cover of long filamentous algae on the Waingongoro riverbed, with relation to the guidelines for recreational values, over the 2002-2020 monitoring period. The number of days since 3 x median fresh is shown for reference

2.7.3 Periphyton Index Score

During the 2018-2020 monitoring period, both the Opunake Road and Stuart road sites recorded TRC PI scores all falling in the 'very good' category (Table 35). However, it was the mid-catchment Stuart Road site had the highest TRC PI scores of the Waingongoro River sites, displaying little variation in scores between seasons. The furthest downstream site, at Ohawe Beach, had 'good' scores during both summer surveys and 'very good' scores during the spring surveys. As expected, historical median scores show a decrease in TRC PI scores in a downstream direction, however, interestingly, results from the 2018-2020 monitoring period do not reflect this pattern (Table 35).

Table 35 Seasonal periphyton index scores for Waingongoro River. The difference given is that between the furthest upstream site and the furthest downstream site

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
Opunake Rd	9.0	8.2	9.3	8.3	9.4	9.7
Stuart Rd	9.5	9.5	9.7	9.6	9.6	8.1
Ohawe Beach	8.8	6.3	8.9	6.7	9.8	7.2
Difference	0.2	1.9	0.4	1.6	0.4	2.5

2.7.4 Periphyton biomass

Moderate levels of periphyton biomass were recorded at all three sites for the 2018-2020 period, with the Stuart Road site having the highest level out of the three sites (Figure 55). No sites breached the guideline thresholds for recreational values (Table 2), however, during the monitoring period all sites breached the level to protect benthic biodiversity (50 mg/m^2). Periphyton biomass levels did not match TRC PI scores particularly well for the lower sites, as the Stuart Road site had both high TRC PI scores and chlorophyll *a* levels. This suggests that in this case, there is too much variability between periphyton cover and biomass as estimated by chlorophyll *a* to use periphyton cover as a surrogate for chlorophyll *a*.

The moderate periphyton biomasses recorded at the middle and lower sites suggest that significant nutrient enrichment occurs in the mid-catchment, likely from agricultural inputs, and possibly from industries located in the township of Eltham.

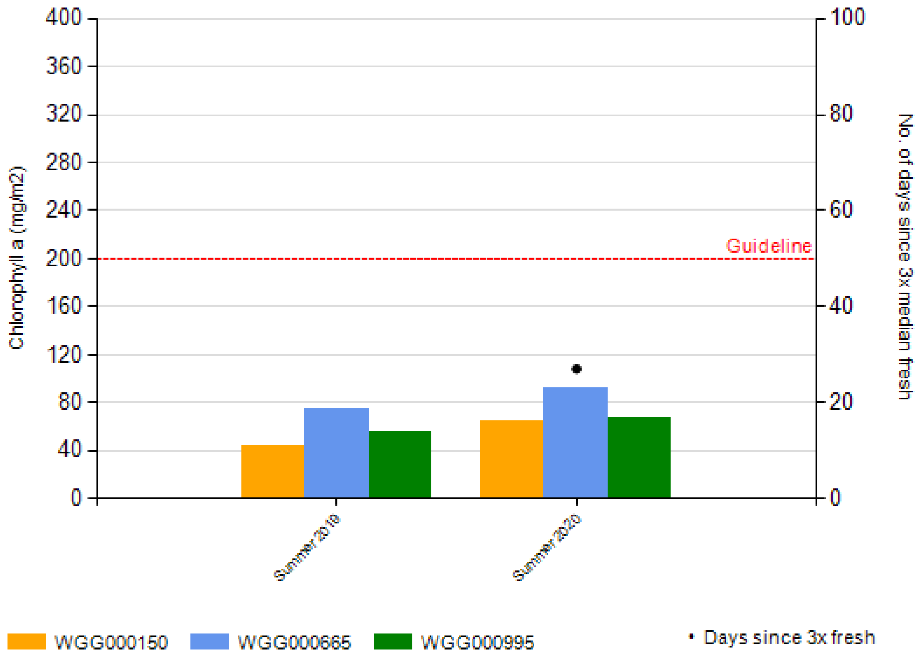


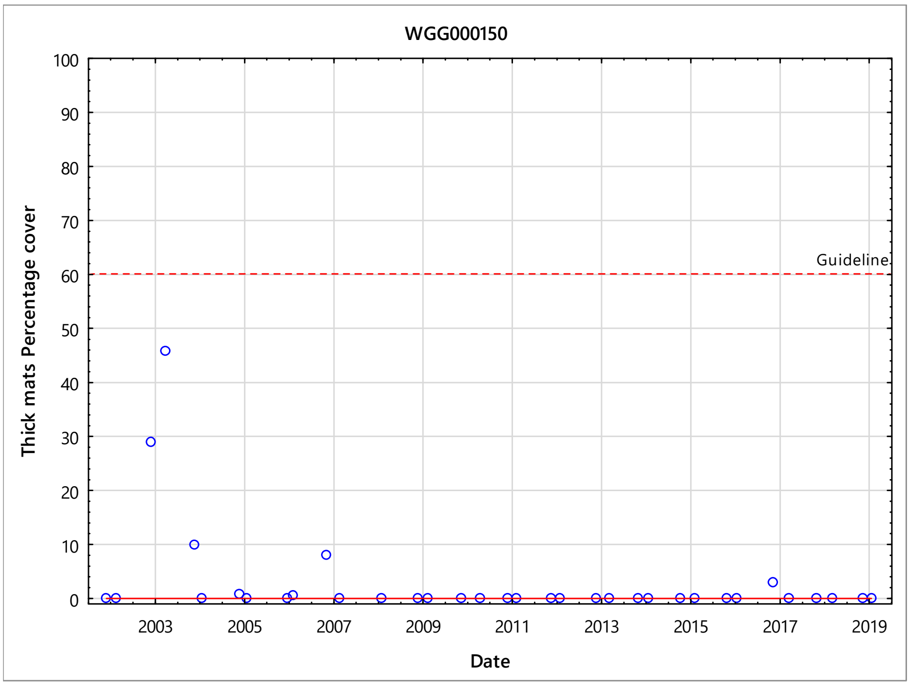
Figure 55 Periphyton biomass (chlorophyll *a*) on the Waingongoro riverbed, in relation to the guideline for recreational values, over the 2018-2020 period

2.7.5 Long term trend analysis

Long-term trend analysis was carried out following the methods outlined in Section 1.2. While evidence of a statistically significant decreasing trend was found in thick mat cover between 2002 and 2020 at the upstream Opunake Road site (WGG000150), this result is due to four observations of thick mat cover prior to 2007 (Figure 56). In the past 13 years, there has consistently been neither thick mat nor long filament cover at the site (Figure 57), with the exception of one observation of thick mat cover in Spring 2017.

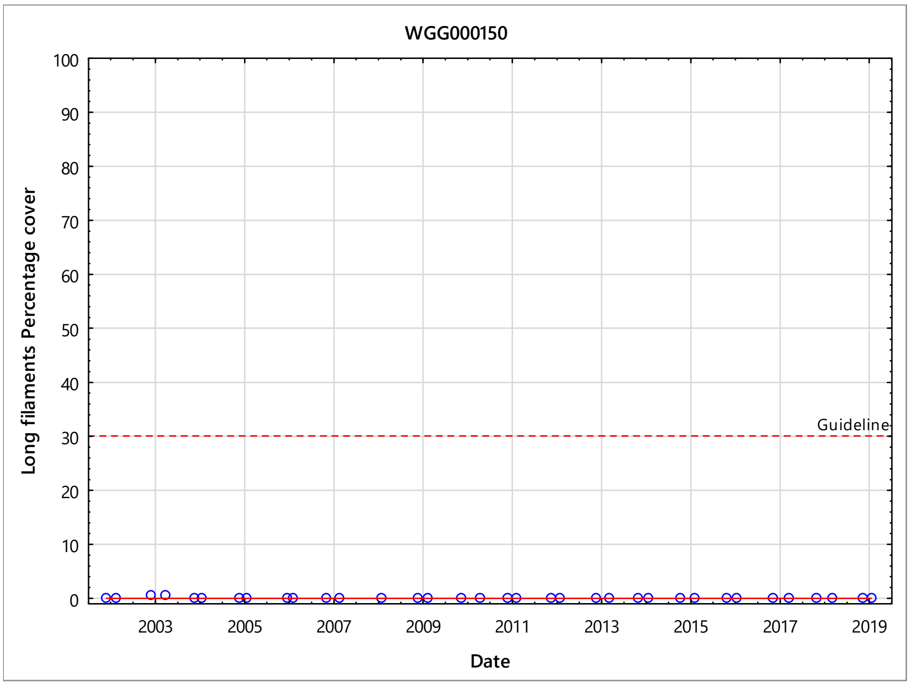
At the mid-catchment Stuart Road site (WGG000665) there is no evidence of either a significant increasing or decreasing trend in periphyton cover over the 18 year monitored period (Figure 59 and Figure 60). While initially a decreasing trend was found in long filament cover, this was determined to be non-significant following FDR analysis. On inspection, long filament cover was more frequent at this site prior to 2009, with only occasional small proliferations since.

At the low-catchment Ohawe Beach site (WGG000995), a statistically significant increasing trend for thick mat cover was found for the 2002-2020 period (Figure 61). On inspection, this appears to be driven by more frequent, and more extensive, thick mat proliferations over the last 10 years. While there is an apparent similar pattern of more frequent proliferations of long filaments over the last 10 years, no statistically significant increasing trend found (Figure 62). While there is not enough data to perform a robust short-term analysis, close attention should be paid to future results, as there may be an emerging increasing trend in long filament cover at this site.



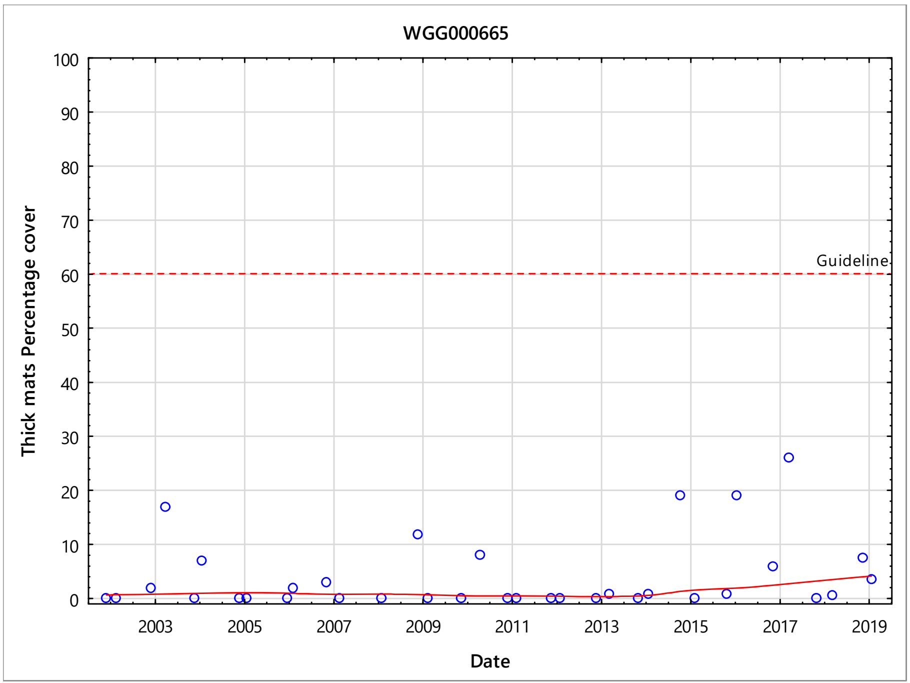
n = 35
Kendal tau = -0.342
p-value = 0.004
FDR p-value = 0.038

Figure 56 Long-term trend analysis of percentage cover of thick mats at Opunake Road (WGG000150). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



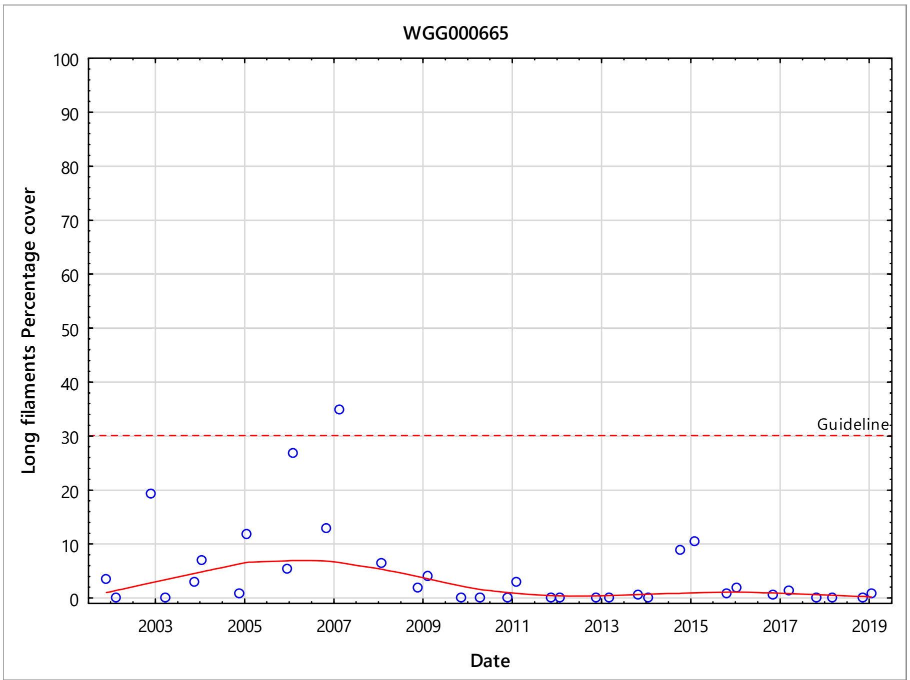
n = 35
Kendal tau = -0.293
p-value = 0.013
FDR p-value = 0.091

Figure 57 Long-term trend analysis of percentage cover of long filaments at Waingongoro River, Opunake Road (WGG000150)



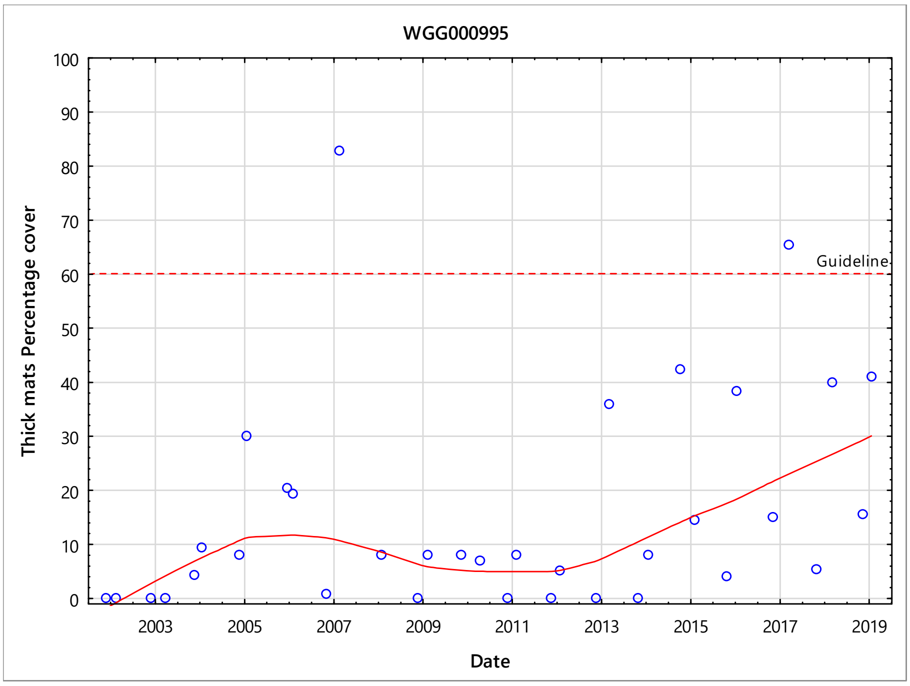
n = 35
Kendal tau = 0.210
p-value = 0.076
FDR p-value = 0.152

Figure 58 Long-term trend analysis of percentage cover of thick mats at Waingongoro River, Stuart Road (WGG000665)



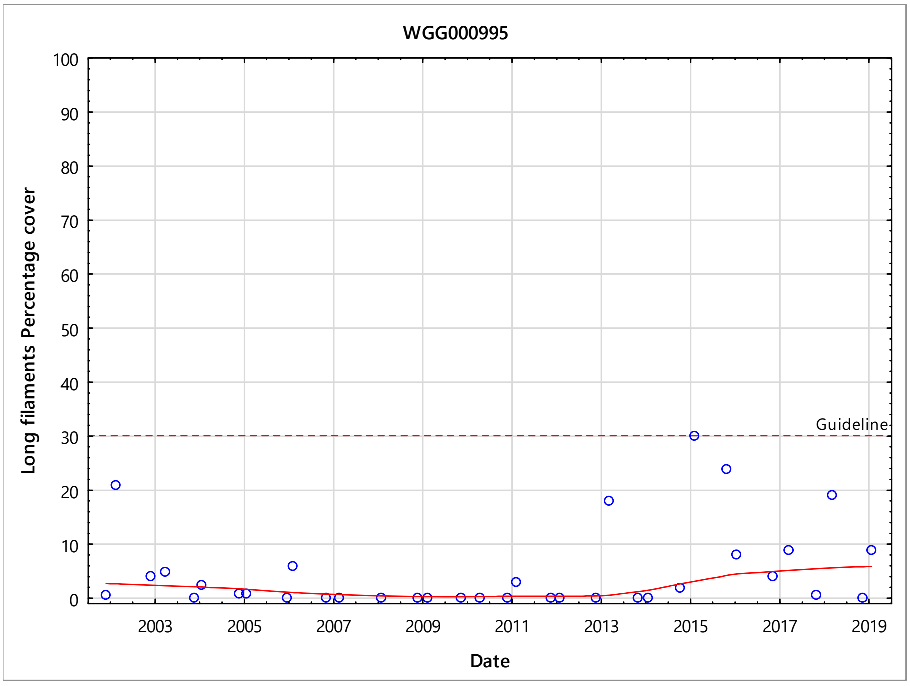
n = 35
Kendal tau = -0.259
p-value = 0.028
FDR p-value = 0.108

Figure 59 Long-term trend analysis of percentage cover of long filaments at Waingongoro River, Stuart Road (WGG000665)



n = 35
Kendal tau = 0.299
p-value = 0.012
FDR p-value = 0.046

Figure 60 Long-term trend analysis of percentage cover of thick mats at Waingongoro River, Ohawe Beach (WGG000995)



n = 35
Kendal tau = 0.115
p-value = 0.330
FDR p-value = 0.418

Figure 61 Long-term trend analysis of percentage cover of long filaments at Waingongoro River, Ohawe Beach (WGG000995)

2.8 Waiongana River

The Waiongana Stream arises in the National Park and tracks north east towards Inglewood before turning north to the coast, giving it a total length of approximately 35 km. The catchment covers a large area and includes numerous tributaries (Figure 62). The top periphyton-sampling site at SH3a (WGA000260) is mid-catchment and situated just north of Inglewood. The lower site at Devon Road (WGA000450) is located approximately 3 km from the mouth of the stream.

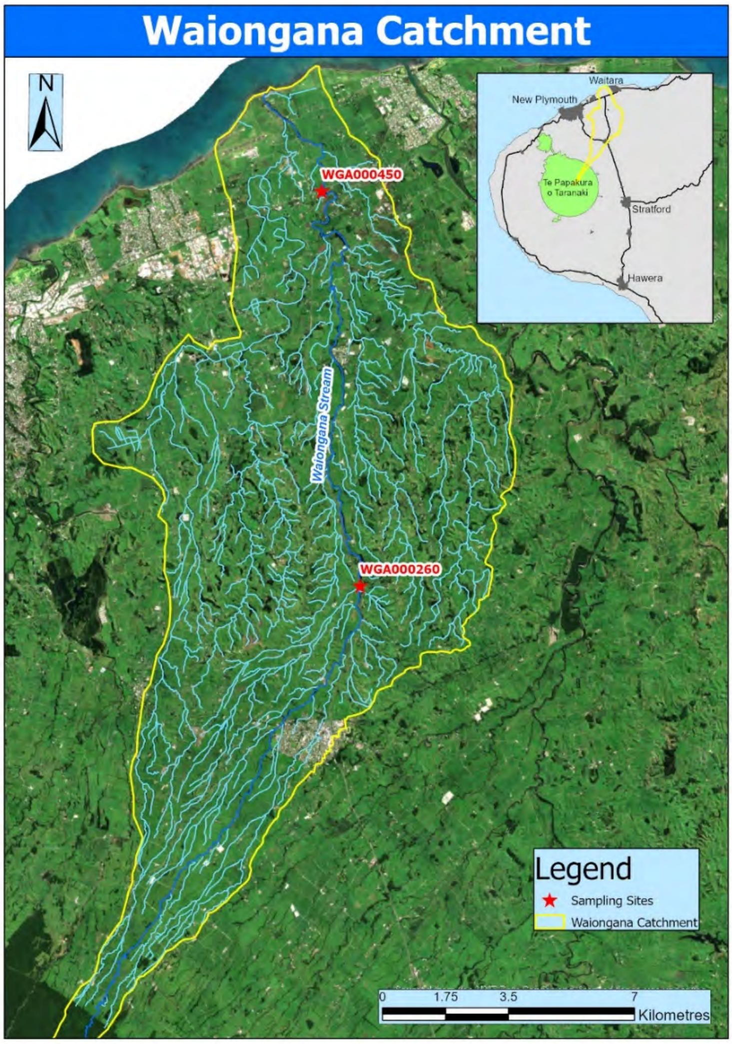


Figure 62 Monitoring site locations in the Waiongana Stream catchment

2.8.1 Flow and nutrient data and survey dates

There is a telemetered hydrological monitoring station on the Waiongana River at SH3a, near the upper periphyton site. This station provides information of the flow conditions at the time of sampling in the Waiongana River (Table 36).

Table 36 Date of sampling and corresponding time since three and seven times median flow

Season	Date	3 x	7 x
Spring	05/12/2018	10	26
Summer	01/02/2019	17	59
Spring	06/11/2019	13	18
Summer	20/01/2020	30	31

There are no corresponding SEM physicochemical monitoring sites within the Waiongana River, and so no relevant nutrient data is available for the periphyton sites in this catchment.

2.8.2 Periphyton cover

In the Waiongana River during the 2018-2020 monitoring period, there were five recorded breaches of periphyton guidelines (Figure 63 and Figure 64). One breach of long filamentous algae guidelines occurred at the upper site at SH3a, while three breaches were recorded at the lower site at Devon Road. The SH3a site also had one breach for levels of thick mats, recorded during the summer 2019 survey. Otherwise, low levels of thick mats were found at both sites during summer surveys, with no thick mats were recorded at either site during spring surveys.

The high nuisance periphyton levels found at the sites in 2018-2020 do not correspond directly with long periods without flushing flows (3 x median flow). It is thus probable that large freshes would be need to remove periphyton at these sites.

Table 37 Periphyton cover results of previous surveys performed in the Waiongana River, together with results from the current monitoring period

Site	SEM data (2002 to 2018)					Monitoring period			
						2018-2019		2019-2020	
	No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
SH3a	27	Thick mats	0-39	0	7	0	79	0	2
		Long filaments	0-80	8	18	2	1	4	32
Devon Road	27	Thick mats	0-31	4	9	0	15	0	3
		Long filaments	0-64	23	18	32	58	11	62

The summer 2019 breach in thick algal mat guidelines has been the only such breach at either of the sites in 18 years of periphyton monitoring in the Waiongana Catchment (Figure 63). Historically, thick mats have been at low to moderate levels at both sites.

In contrast, long filamentous algae levels have intermittently breached guidelines at both the upstream and downstream sites over the last 18 years (Figure 64). Breaches at the SH3a site have often, but not solely, been after long periods without flushing flows, while in recent years, levels at the Devon Road site have been moderate irrespective of flow conditions. Long filamentous algae levels at Devon Road have breached guidelines in four out of five of the most recent surveys.

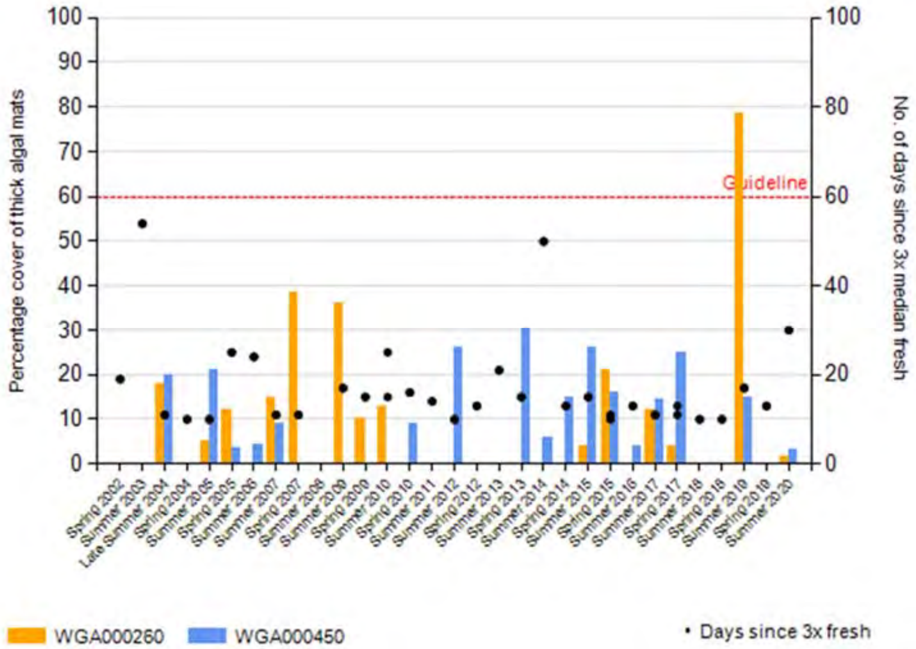


Figure 63 Percentage cover of thick mats of periphyton on the Waiongana riverbed. The guideline for recreational values, and number of days since 3 x median fresh, is shown for comparison

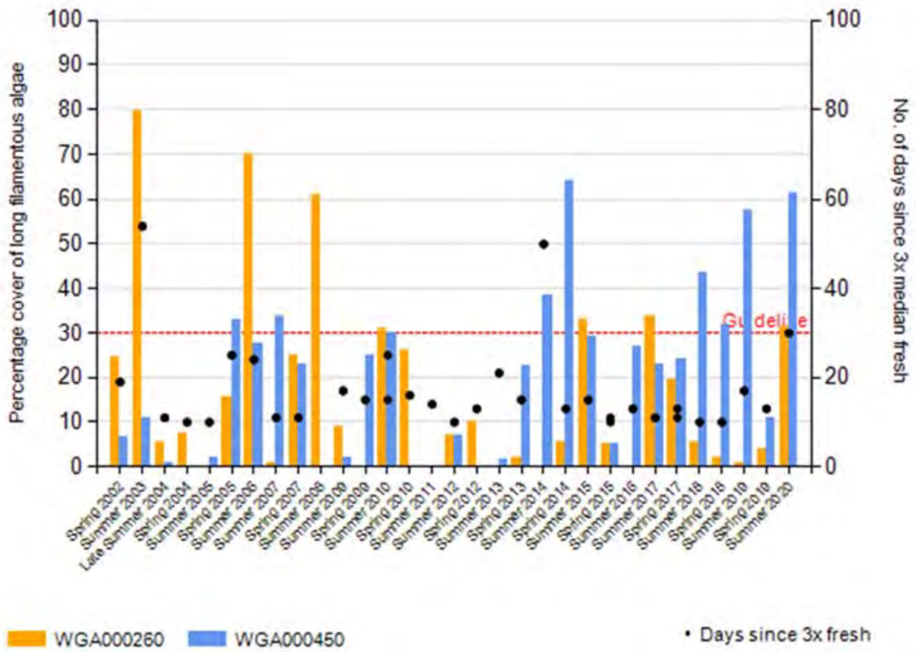


Figure 64 Percentage cover of long filamentous algae on the Waiongana riverbed in relation to the guidelines for recreational values

2.8.3 Periphyton Index Score

TRC PI scores for the Waiongana River sites were variable, both between the two reported monitoring years, and between the two sites surveyed. However, the scores generally reflected the levels of nuisance periphyton recorded (Table 38). Scores were above historical medians for both sites during the spring surveys, but below historical medians for the summer surveys (Table 38). While historically there has been a seasonal trend in TRC PI scores for the two sites, this pattern was thus more accentuated in the current monitoring period.

For the spring 2019 survey, the bottom site had a higher TRC PI score than the upper site which was unusual though the historic spring medians are only 0.6 units apart indicating that during spring there is not a large difference between the upper and lower sites in terms of TRC PI condition.

Table 38 Median seasonal periphyton index scores for the Waiongana River

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
SH3a	8.3	4.6	7.8	5.5	7.0	6.7
Devon Road	6.4	3.9	8.5	4.0	6.4	5.5
Difference	1.9	0.7	-0.7	1.5	0.6	1.2

2.8.4 Periphyton biomass

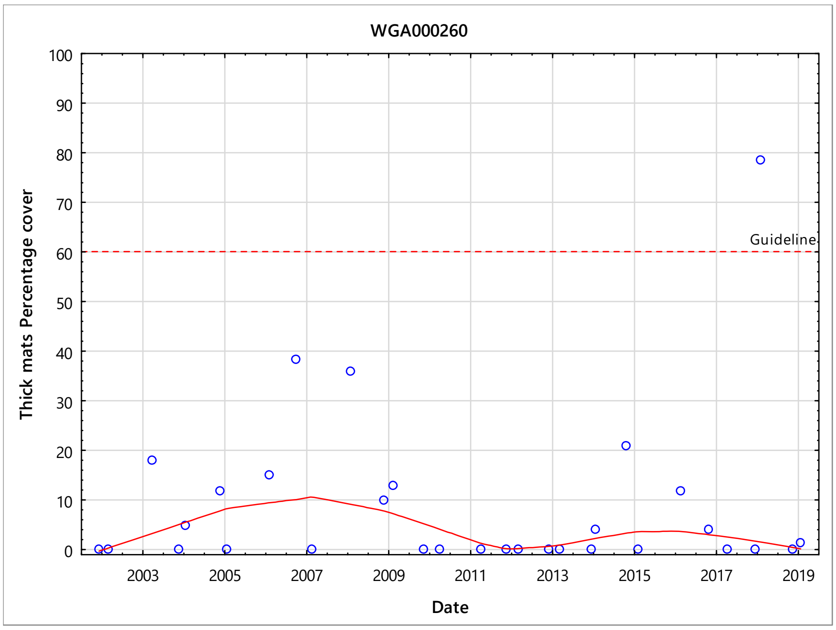
Both sites were found to have moderate chlorophyll *a* levels in summer 2019, and high chlorophyll *a* levels in the summer 2020. In the latter case, both sites breached the NOF standard for chlorophyll *a* (Figure 65, Table 7). Chlorophyll *a* levels found in all 4 surveys breached the guidelines set to protect benthic biodiversity values (Table 2).

Figure 65 Periphyton biomass (chlorophyll *a*) on the Waiongana riverbed, in relation to the guidelines for recreational values, over the 2018-2020 period

2.8.5 Long term trend analysis

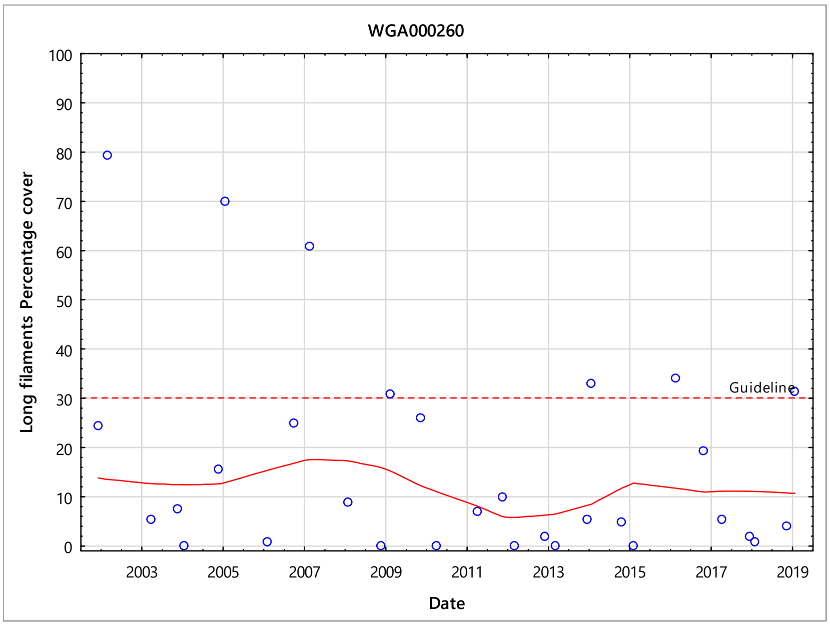
Following the methods outlined in Section 1.2, long-term trend analysis found no evidence for either increasing or decreasing trends in periphyton cover at either of the Waiongana River monitoring sites

(Figure 66 to Figure 69). A increasing trend in long filament cover was initially found at the Devon Road site, however this was not statistically significant following FDR. On inspection, there have been more frequent and extensive proliferations of long filaments at Devon Road in the last 7 years compared to prior (Figure 69), including four exceedances of guidelines within the last five surveys. A similar pattern was observed in thick mat coverage at this site, with frequent but not as extensive, proliferations from 2013 to 2018 (Figure 68). While the long-term trend is not statistically significant, and there is not frequent enough data to perform a robust short-term trend analysis, the increase in periphyton cover should be considered to be of ecologically significance. It is therefore recommended that future results at this site are carefully scrutinised, and some thought given to investigating the factors behind the increase.



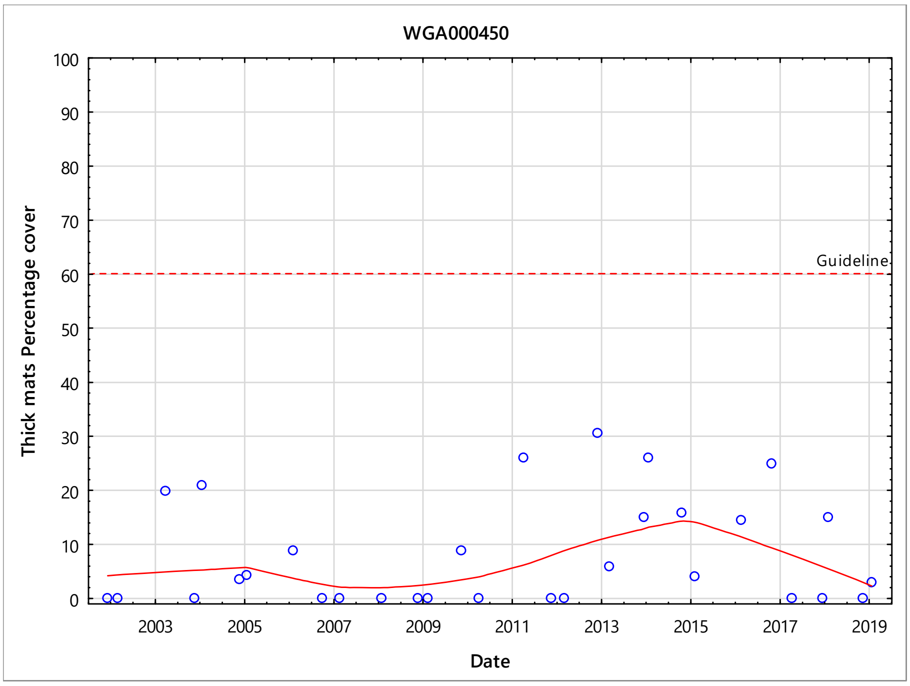
n = 31
Kendal tau = -0.044
p-value = 0.730
FDR p-value = 0.769

Figure 66 Long-term trend analysis of percentage cover of thick mats at SH3a (WGA000260). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



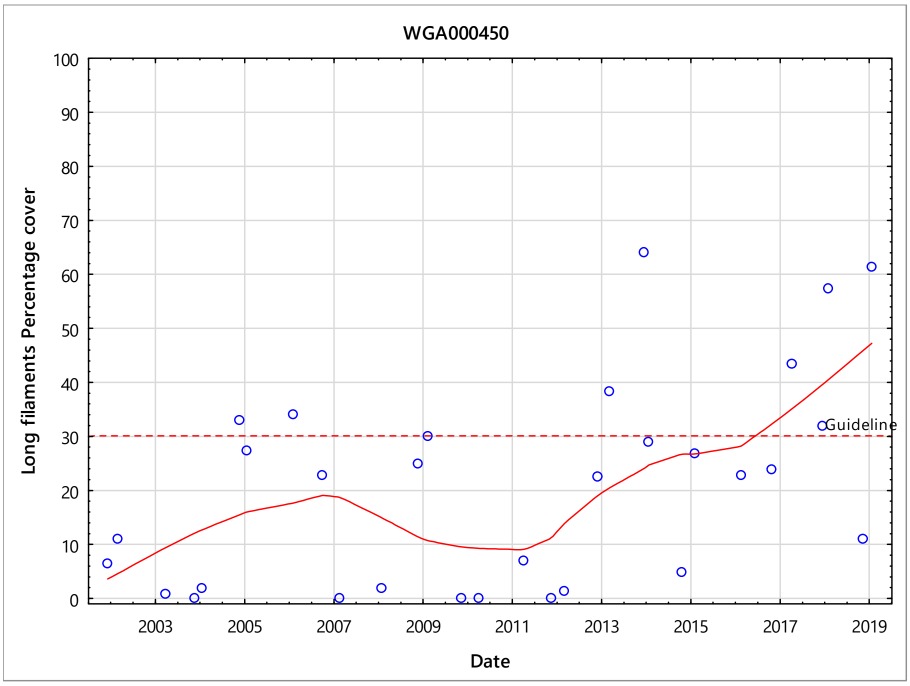
n = 31
Kendal tau = -0.143
p-value = 0.259
FDR p-value = 0.410

Figure 67 Long-term trend analysis of percentage cover of long filaments at Waiongana River, SH3a (WGA000260)



n = 31
Kendal tau = 0.123
p-value = 0.332
FDR p-value = 0.442

Figure 68 Long-term trend analysis of percentage cover of thick mats at Waiongana River, Devon Road (WGA000450)



n = 31
Kendal tau = 0.310
p-value = 0.014
FDR p-value = 0.091

Figure 69 Long-term trend analysis of percentage cover of long filaments at Waiongana River, Devon Road (WGA000450)

2.9 Waiwhakaiho River

The Waiwhakaiho River originates in the National Park, and winds approximately 30 km past Egmont Village, in a northeast direction to the coast. The mouth of the river is 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) is located at SH3, Egmont Village, and is representative of the mid catchment. Situated 9 km downstream of the National Park boundary, at this point the river drains developed farmland. Immediately downstream of the monitoring site is the major diversion point for the New Plymouth water supply and the Mangorei HEP scheme. The lower monitoring site (WKH000920) is located at Constance Street, approximately two kilometres from the mouth of the river. At this site the river is markedly influenced by changes in flow, due to hydroelectric generation releases from the upstream HEP scheme. In addition, the site displays various municipal and industrial impacts from the lower catchment area.

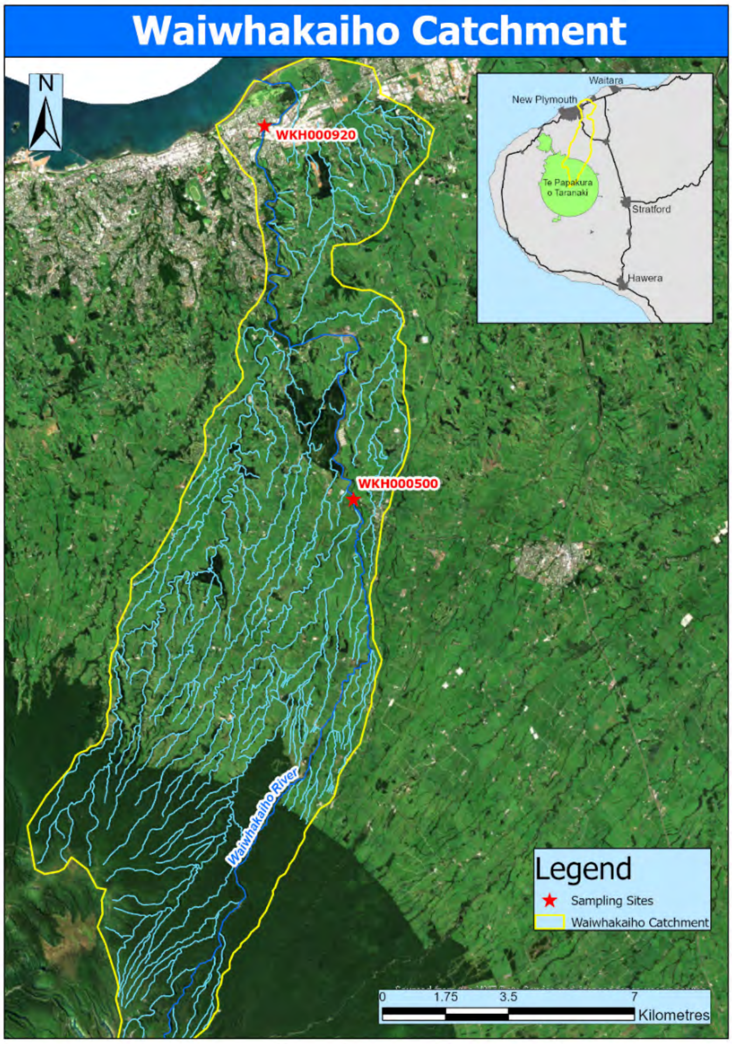


Figure 70 Monitoring site locations in the Waiwhakaiho River catchment

2.9.1 Flow and nutrient data and survey dates

The Waiwhakaiho River has a telemetered hydrological monitoring station at SH3, adjacent to the upper periphyton-monitoring site. A second telemetered hydrological monitoring station is located at Rimu St, in the bottom of the catchment and close to the periphyton site at Constance Street. These stations provide details of flow conditions during and prior to periphyton sampling (Table 39).

Table 39 Date of sampling and corresponding time since three and seven times median flow. Data in parentheses is for the lower site, when sites were not sampled on same date

Season	Date	3 x	7 x
Spring	17/12/2018	11	11
Summer	09-01-2019 (11/01/2019)	15 (17)	34 (36)
Spring	06/11/2019	13	13
Summer	20/01/2020	31	31

The TRC SEM physicochemical program collects nutrient information at the SH3 site. The site did not meet the limit of 0.018 mg/L that is set for DRP under the 2020 NPS-FM (MfE, 2020) (Table 40). The volcanic soils around the Taranaki ringplain have naturally high phosphorus levels, which is possibly a contributing factor to the exceedance in DRP levels, however diffuse pastoral runoff upstream of the site will also be a significant influence.

Table 40 Medians for dissolved reactive phosphorus (DRP), dissolved inorganic nitrogen (DIN), and total nitrogen (TN) for the Waiwhakaiho River

Site	2018-2019			2019-2020		
	DRP	DIN	TN	DRP	DIN	TN
SH3 (Egmont Village)	0.0325*	0.080	0.183	0.033*	0.149	0.22

* Does not meet MfE (2019) guidelines (under review)

2.9.2 Periphyton cover

Nuisance periphyton at the upper SH3 site exceeded the guideline level for filamentous algae during the summer 2020 survey, while at the lower Constance Street site; thick mats exceeded the guideline during the summer 2019 survey (Table 41, Figure 71 and Figure 72).

During the spring 2018 and 2019 surveys, low to moderate levels of nuisance periphyton were recorded at both sites. Results were more variable during summer surveys. While the summer 2019 survey recorded moderate levels of long filaments at both sites and low levels of thick mats at the SH3 site, the high thick mat coverage at the Constance street site exceeded guideline levels. In contrast, during the summer 2020 survey, the upper SH3 site exceeded the guideline for long filaments, compared to the low levels found at the Constance Street site. Both sites had moderate levels of thick mats in this instance.

Table 41 Periphyton cover results of previous surveys performed in the Waiwhakaiho River, together with the results for the current monitoring period

Site	Altitude (m)	SEM data (2002 to 2018)					Monitoring period			
							2018-2019		2019-2020	
		No.	Type	Range	Median	Mean	Spring	Summer	Spring	Summer
SH3 (Egmont Village)	175	26	Thick mats	0-27	0	5	1	2	12	23
			Long filaments	0-71	16	19	4	17	2	34
Constance St	20	26	Thick mats	0-31	2	9	6	66	28	34
			Long filaments	0-79	6	14	18	7	9	3

Prior to summer 2019 neither site has come close to breaching the guideline for thick algal mats (Figure 71). In contrast, the upper site has proven prone to long filamentous nuisance periphyton communities, which have breached guidelines on seven occasions in 18 years of monitoring. In comparison, the lower site has only breached guidelines on two occasions (Figure 72).

The greater coverage of filamentous algae observed at the SH3 site during 2018-2020, when compared to the Constance Street site, is typical for the river, and is consistent with the results of past monitoring. The reason for this is the significantly different substrates found at the two survey sites. At SH3, the substrate is dominated by large boulders, which provide a very stable substrate which is less susceptible to scouring during flood events. At Constance Street, the substrate has a greater proportion of cobbles and fine substrates such as sand and silt. These are more likely to move during floods, thus regulating the amount of filamentous algae by scouring the periphyton that would otherwise accumulate on more stable substrates.

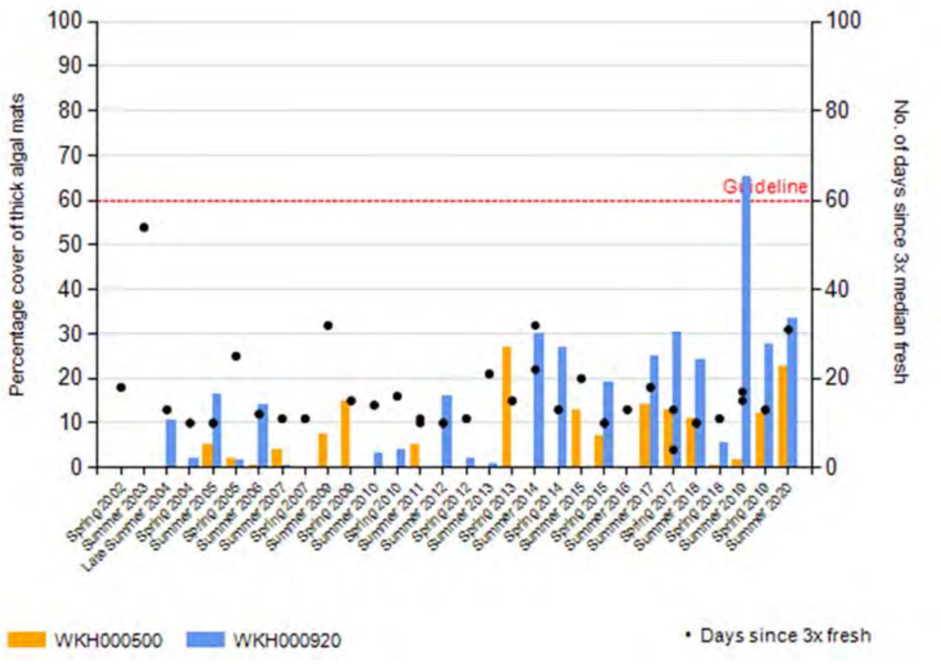


Figure 71 Percentage cover of thick mats of periphyton on the Waiwhakaiho riverbed over the 2002-2020 monitoring period. The guideline for recreational values, and number of days since 3 x median fresh, are shown for reference

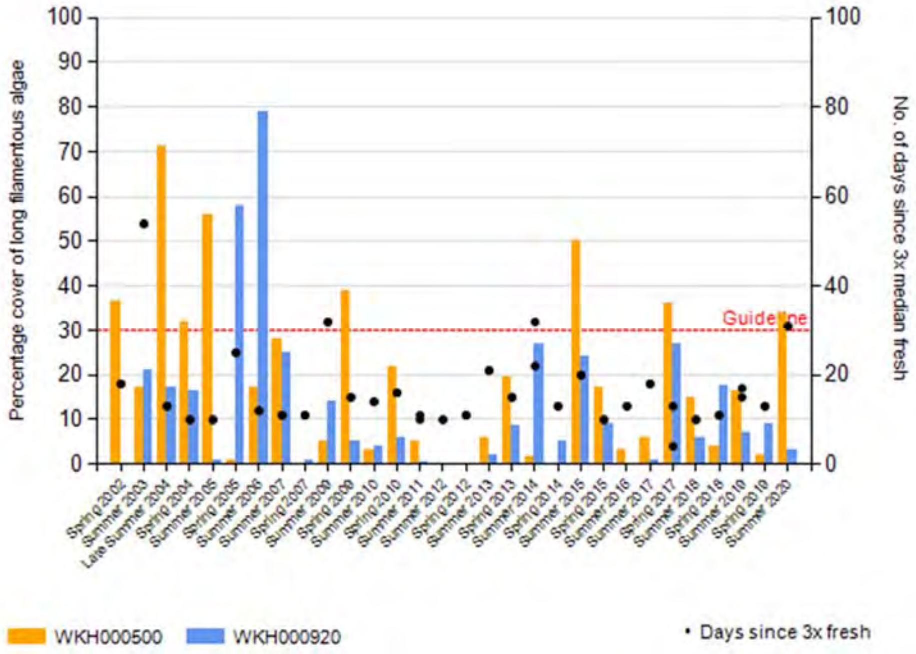


Figure 72 Percentage cover of long filamentous algae on the Waiwhakaiho riverbed over the 2002-2020 monitoring period. The guideline for recreational values, and number of days since 3 x median fresh, are shown for reference

2.9.3 Periphyton Index Score

The Waiwhakaiho River, unlike other monitored rivers in Taranaki, normally shows either a minor improvement or a similar TRC PI score at the downstream site compared with the upstream site. However, in the current monitoring period there was a downstream decline in TRC PI score for three of the four surveys (Table 42).

For the 2018-2020 monitoring period, the SH3 and Constance St sites, respectively, had “very good” and “good” TRC PI scores during spring surveys. During summer surveys, however, both sites had lower TRC PI scores, placing them within, or on the border, of the “moderate” ranking. Compared with historical medians, both sites generally had lower TRC PI scores during the 2018-2020 period, with the exception of spring surveys at the SH3 site.

While the upper site receives runoff from primarily agricultural land outside of the National Park boundary, nutrient data shows that it has relatively low total nitrogen levels. The lower site, however, is in an urban area, with bird colonies at various points along the river’s urban stretch. These could cause some nutrient enrichment. Riparian planting is negligible at both sites and therefore their periphyton growth should not be showing any limitation by seasonal changes in light.

Table 42 Seasonal periphyton index scores for the Waiwhakaiho River

Site	TRC PI Spring 2018	TRC PI Summer 2019	TRC PI Spring 2019	TRC PI Summer 2020	TRC PI Historical spring median	TRC PI Historical summer median
SH3	8.4	5.6	8.3	4.8	7.7	7.2
Constance St	7.0	4.4	6.7	6.0	7.9	6.7
Difference	1.4	1.2	1.5	-1.2	-0.2	0.5

2.9.4 Periphyton biomass

During the summer surveys over the period 2018-2020, low levels of chlorophyll *a* were found at both sites, and no guidelines were breached (Table 2) (Figure 73). The chlorophyll *a* results reflect the TRC PI scores, with the site with the higher periphyton biomass having the lower TRC PI score in both instances.

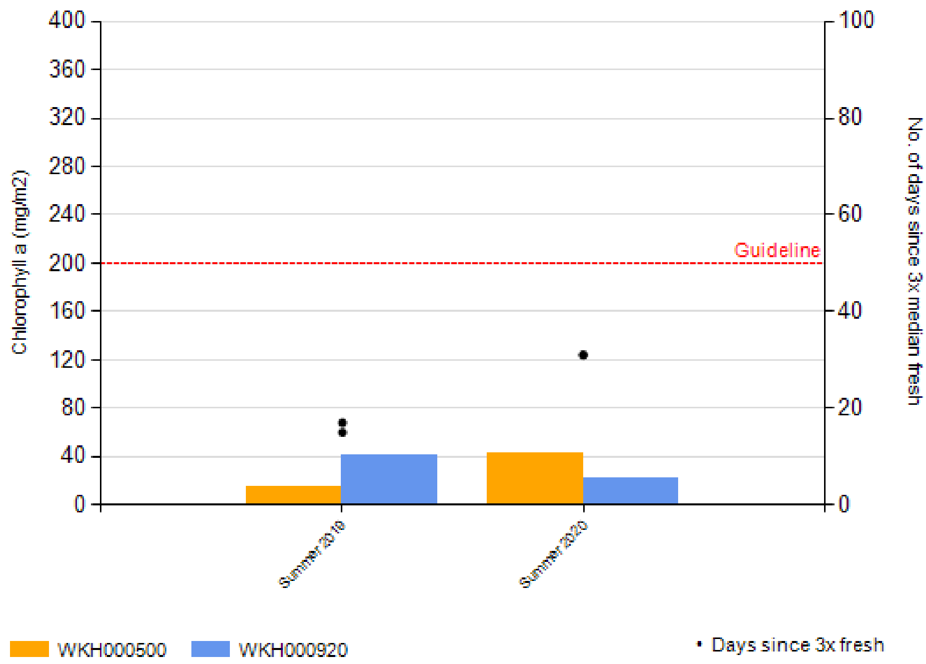
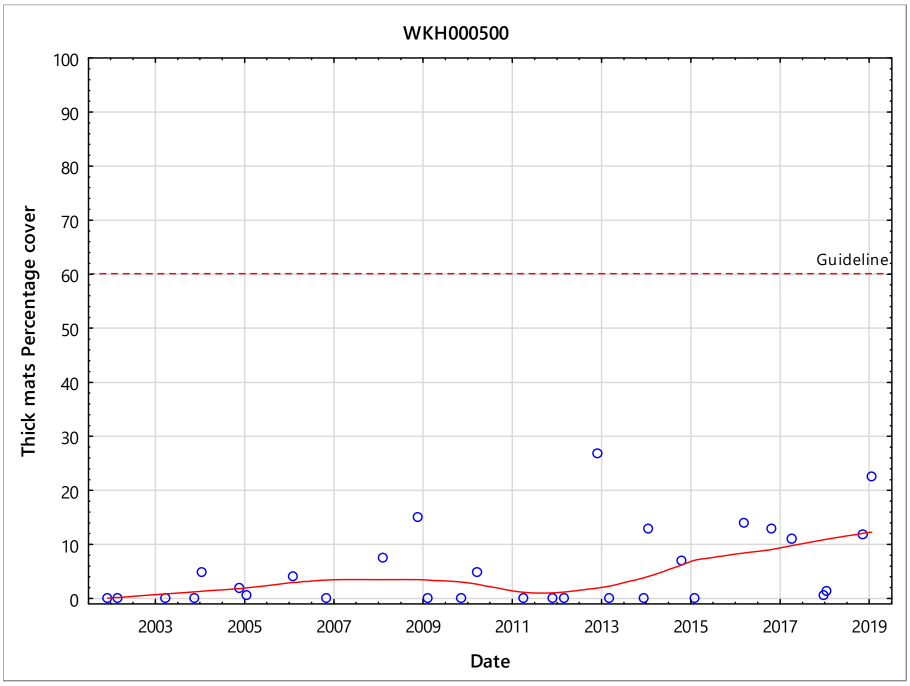


Figure 73 Periphyton biomass (chlorophyll *a*) on the Waiwhakaiho riverbed, in relation to the guidelines for recreational values, over the 2018-2020 period

2.9.5 Long term trend analysis

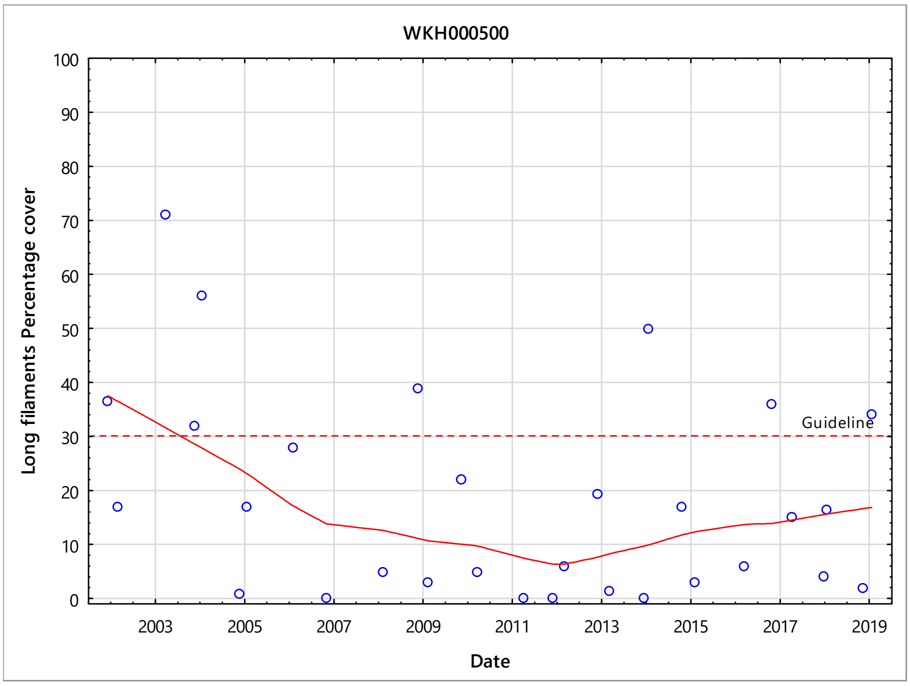
Following the methods outlined in Section 1.2, long-term trend analysis found evidence of a statistically significant increasing trend in thick mat cover at both the SH3 and Constance Street sites on the Waiwhakaiho River (Figure 74 and Figure 76). On inspection of the data and LOWESS curve fits, this increase has been most prominent in the most recent 7-8 years.

Similar increases in the LOWESS fits to long filament cover are observed from 2012 to present (Figure 75 and Figure 77). However, the wider variation seen in long filament cover at both sites results in there being no statistically significant increasing or decreasing long-term trends.



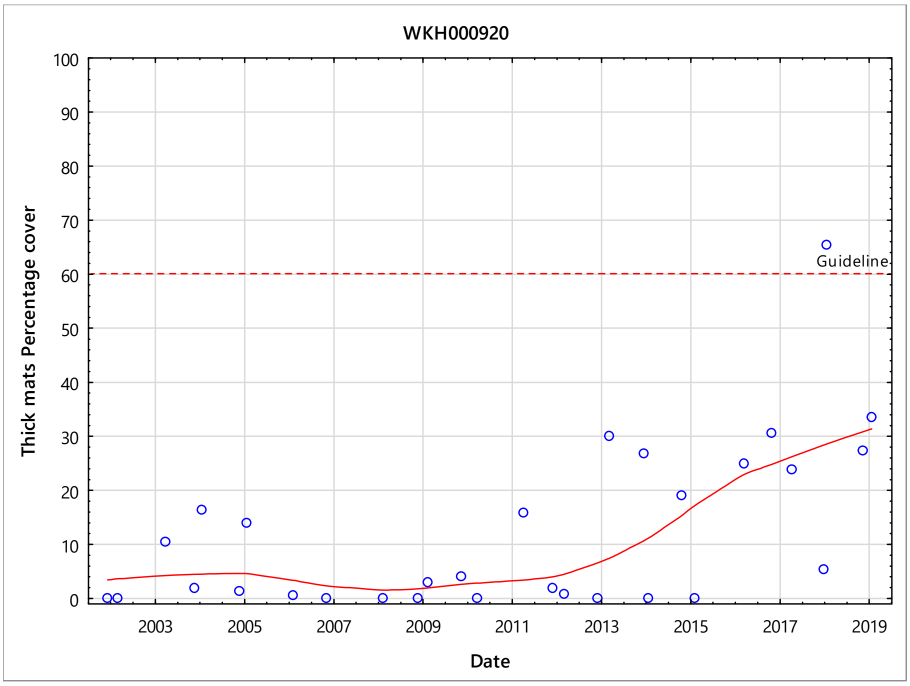
n = 30
Kendal tau =0.316
p-value = 0.014
FDR p-value = 0.047

Figure 74 Long-term trend analysis of percentage cover of thick mats at SH3, Egmont Village (WKH000500). A LOWESS curve (solid red line) is fitted to data, with Mann-Kendall analysis results given to the right of the plot



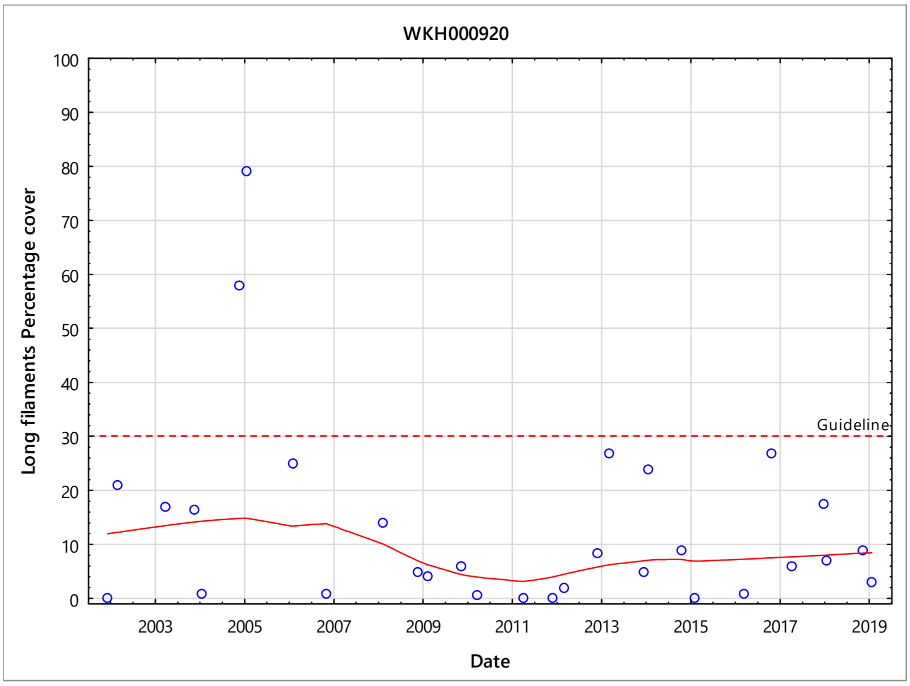
n = 30
Kendal tau = -0.156
p-value = 0.225
FDR p-value = 0.389

Figure 75 Long-term trend analysis of percentage cover of long filaments at Waiwhakaiho River, SH3, Egmont Village (WKH000500)



n = 30
Kendal tau = 0.385
p-value = 0.003
FDR p-value = 0.038

Figure 76 Long-term trend analysis of percentage cover of thick mats at Waiwhakaiho River, Constance Street, New Plymouth (WKH000920)



n = 30
Kendal tau = -0.051
p-value = 0.690
FDR p-value = 0.756

Figure 77 Long-term trend analysis of percentage cover of long filaments at Waiwhakaiho River, Constance Street, New Plymouth (WKH000920)

3 General summary

3.1 Periphyton cover

During the 2018-2020 monitoring period, nuisance periphyton was monitored at 20 sites around the region. Each site was surveyed on four occasions; spring 2018, summer 2019, spring 2019 and summer 2020 (Table 43). Among the sites there were two breaches in the thick algal mat guideline (greater than 60% coverage) and eleven breaches in the long filamentous algae guideline (greater than 30% coverage) during this period. The 13 breaches occurred at eight different sites. Six breaches occurred during the summer 2019 survey and five during the summer 2020 survey. Only two breaches occurred in spring; the Manganui River at Bristol Road and the Waiongana River at Devon Road, both in spring 2018. Four sites had two breaches during the reported period: The Manganui at Bristol Road, The Patea at Skinner Road, and the Waiongana at both SH3 and Devon Road.

Table 43 Nuisance periphyton coverage at 20 sites over the 2018-2020 monitoring period

River/Stream	Site	Nuisance periphyton percentage cover							
		Spring 2018		Summer 2019		Spring 2019		Summer 2020	
		Mats	Filaments	Mats	Filaments	Mats	Filaments	Mats	Filaments
Hangatahua (Stony)	Mangatete Road	0	0	0	0	2	0	0	0
	SH45	0	0	2	0	0	0	5	0
Kapoaiaia	Wiremu Road	5	0	0	0	1	0	30	0
	Wataroa Road	6	1	5	3	0	0	30	59
	Cape Egmont	3	1	0	44	3	5	50	11
Maketawa	Derby Rd	1	1	0	0	0	0	0	0
	Tarata Road	8	12	5	9	6	0	3	0
Manganui	SH3	0	0	0	0	0	0	0	0
	Bristol Road	10	43	39	48	7	8	1	4
Patea	Barclay Road	0	0	0	0	0	0	0	0
	Skinner Road	9	2	6	77	0	4	3	88
Punehu	Wiremu Road	1	0	18	0	0	0	2	0
	SH45	5	21	1	24	1	11	0	7
Waingongoro	Opunake Road	0	0	0	0	0	0	0	0
	Stuart Road	0	0	1	0	8	0	8	0
	Ohawe Beach	6	1	40	19	16	0	41	9
Waiongana	SH3a	0	2	79	1	0	4	2	32
	Devon Road	0	32	15	58	0	11	3	62
Waiwhakaiho	SH3 (Egmont Village)	1	4	2	17	12	2	23	34
	Constance St, NP	6	18	66	7	28	9	34	3
Average	-	3	7	14	15	4	3	12	15

Text highlighted in red exceeded guideline levels (MfE, 2000). Text highlighted in orange exceeded PeriWCC guideline (Matheson et al. 2012)

3.1.1 Weighted Composite Periphyton Cover

An alternative tool for assessing nuisance periphyton cover, called the periphyton weighted composite cover (PeriWCC), has been developed by Matheson et al. (2012). This alternative method resolves the discrepancy that can occur when there are high levels of both thick mats and long filaments at a site, but neither quite exceed MfE guidelines. In such a case, the combination of the two classes of periphyton represent significant coverage, but are not recorded as such, as the MfE guidelines consider mats and filaments in isolation to each other. The PeriWCC is calculated as:

$$\% \text{ filamentous algae} + (\% \text{ thick mats}/2).$$

With an aesthetic guideline for nuisance periphyton set to be ≥30% by Matheson et al. An example of the discrepancy that can be introduced using only MfE guidelines can be found in the spring 2016 survey of the historic Mangaehu River site. In this case, the site did not exceed the thick mat or long filament criteria, yet had a combined nuisance periphyton streambed coverage of 86%.

Based on the PeriWCC, two additional surveys in the 2018-2020 period would be non-compliant; the summer 2019 survey at the Waingangaoro River Ohawe Beach site, and the summer 2020 survey at the Kapoaiaia River Cape Egmont site.

3.1.2 Patterns in periphyton cover

In general, the 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 are likely to contribute to this situation, including nutrient levels, hydrology, shading, temperature, substrate composition and invertebrate grazing pressure. Of these factors, the strongest driver is likely to be nutrient levels. Taranaki waterbodies at higher altitudes around the ringplain have naturally high phosphorus levels, due to the area's volcanic geology. As a result, periphyton levels are unlikely to be limited by phosphorus levels (Biggs and Kilroy, 2004), a conclusion similar to that reported for other North Island regions with volcanic geology (Death, et al. 2007). However, nitrogen levels in the same high-altitude Taranaki waterbodies are typically low, which would limit periphyton growth. Further from the National Park, nitrogen levels typically increase, while phosphorus levels are variable depending on what other inputs influence the water body (e.g. agriculture, meat works, town sewerage schemes etc). Most of the surveyed streams and rivers flow through intensive agricultural areas, and as a result, at some of the lower catchment sites nutrient levels are high enough to cause excessive periphyton growths.

Other factors that may contribute to increased levels of nuisance periphyton at lower catchment sites include a lack of shading. This either can be due to limited riparian vegetation along the river (as is more common at lowland sites on the Taranaki ringplain) or due to the riverbed being wider and more open than further upstream, whereby shading from banks is reduced. Rivers and streams at higher altitudes are also more likely to have higher flood peaks when heavy rainfall occurs, with floods peaks becoming somewhat attenuated further downstream. High flood peaks promote scouring of the streambed, a process that reduces periphyton biomass. Finally, downstream sites have higher water temperatures than their upstream matched sites, a factor which promotes faster periphyton growth. Differences in invertebrate grazer abundances among sites would also affect periphyton biomass.

Results show that summer surveys usually have higher levels of nuisance periphyton than the spring surveys. This can be attributed to three main factors: higher water temperatures, which enables faster periphyton growth; longer daylight hours, which promote photosynthesis; and longer periods without freshes or floods to scour away periphyton. The monitoring period under review was typical in this regard, with average levels of thick mats and long filaments higher for both summer surveys compared with the two spring surveys. The spring 2018 survey had slightly higher levels of long filaments than the spring 2019 survey and there was little difference in periphyton levels between the two summer surveys.

3.2 TRC periphyton index

While there are no guidelines or limits for the TRC periphyton index score, the ratings give an indication of the level of nuisance periphyton at a site. Over the 2018-2020 period, TRC periphyton index scores ranged from 'poor' to 'very good' (Table 44).

Table 44 TRC PI scores for 20 sites over the 2018-2020 monitoring period

River/ Stream	Site	TRC Periphyton Index Score								Median rating 2018-2020	
		Spring 2018		Summer 2019		Spring 2019		Summer 2020			
		TRC PI	Rating	TRC PI	Rating	TRC PI	Rating	TRC PI	Rating	TRC PI	Rating
Hangatahua	Mangatete Road	10	Very good	9.9	Very good	10	Very good	9.4	Very good	10	Very good
	SH45	10	Very good	9.8	Very good	9.9	Very good	8.5	Very good	9.9	Very good
Kapoaiaia	Wiremu Road	9.8	Very good	9.5	Very good	9.9	Very good	8.1	Very good	9.7	Very good
	Wataroa Road	8.1	Very good	6.8	Good	7.2	Good	4.3	Moderate	7.0	Good
	Cape Egmont	8.7	Very good	5.5	Moderate	8.9	Very good	6.3	Good	7.0	Good
Maketawa	Derby Rd	9.9	Very good	9.8	Very good	9.9	Very good	10.0	Very good	9.9	Very good
	Tarata Road	8.2	Very good	8.4	Very good	8.4	Very good	8.1	Very good	8.3	Very good
Manganui	SH3	10.0	Very good	9.9	Very good	10.0	Very good	9.9	Very good	10	Very good
	Bristol Road	3.9	Poor	7.3	Good	7.3	Good	7.5	Good	7.3	Good
Patea	Barclay Road	10.0	Very good	9.9	Very good	9.7	Very good	9.8	Very good	9.9	Very good
	Skinner Road	7.6	Good	2.1	Poor	7.7	Good	1.6	Very poor	4.9	Moderate
Punehu	Wiremu Road	9.9	Very good	6.7	Good	9.9	Very good	9.7	Very good	9.8	Very good
	SH45	7.3	Good	7.5	Good	8.1	Good	9.0	Very good	7.8	Good
Waingongoro	Opunake Road	9.0	Very good	8.2	Very good	9.3	Very good	8.3	Very good	8.7	Very good
	Stuart Road	9.5	Very good	9.5	Very good	9.7	Very good	9.6	Very good	9.6	Very good
	Ohawe Beach	8.8	Very good	6.3	Moderate	8.9	Very good	6.7	Moderate	7.3	Good
Waiongana	SH3a	8.3	Very good	4.6	Moderate	7.8	Good	5.5	Moderate	6.7	Good
	Devon Road	6.4	Good	3.9	Poor	8.5	Very good	4.0	Moderate	5.2	Moderate
Waiwhakaiho	SH3 (Egmont Village)	8.4	Very good	5.6	Moderate	8.3	Very good	4.8	Moderate	7.0	Good
	Constance St, NP	7.0	Good	4.4	Moderate	6.7	Good	6.0	Good	6.4	Good

For the spring 2018 survey; 75% of sites were 'very good', 20% were 'good' and 5% had a 'poor' rating. For the summer 2019 survey 45% of sites were rated as 'very good', 20% were 'good', 25% 'moderate' and 10% 'poor'. For the spring 2019 survey 75% of sites were rated as 'very good' and 25% were 'good'. For the summer 2020 survey 60% of sites were 'very good', 10% were 'good', 25% 'moderate' and 5% 'very poor' (Table 44).

No sites had a median score that would place it in the two lowest categories of 'poor' or 'very poor' and only two sites had median scores placing them in the 'moderate' category. However, some sites did have large fluctuations among surveys within the reported period, including one site that received a 'poor' and a 'very poor' rating for two surveys (alongside two 'good' ratings). All sites along the two rivers selected for their high conservation values, (the Hangatahua (Stony) and Maketawa), and all sites located within 10 km of the National Park boundary, had 'very good' ratings.

3.3 Periphyton biomass (chlorophyll *a*)

Over the 2018-2020 monitoring period, periphyton biomass levels, as estimated by chlorophyll *a,* showed significant variation among sites, ranging from 0 to 621 mg/m^2 (Table 45). Three sites recorded levels above the NOF guideline value (200 mg/m^2), and nine sites had values above the guideline to protect benthic biodiversity (50 mg/m^2). Specifically, there were six sites in the summer 2019 monitoring period that had values above 50 mg/m^2 but none over 200 mg/m^2, while in the summer 2020 monitoring period eight sites had values above 50 mg/m^2 , three of which also exceeded 200 mg/m^2. Temporal trend analysis requires a minimum of ten years of data and therefore has not been carried out to this 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.

Table 45 Periphyton biomass, as estimated by chlorophyll *a* (mg/m^2), for 20 sites over the 2018-2020 monitoring period

River/Stream	Site name	Distance from Nat Park (km)	Periphyton biomass (chlorophyll *a* mg/m^2)	
			Summer 2019	Summer 2020
Hangatahua (Stony)	Mangatete Road	7.3	0	1
	SH45	12.5	1	4
Kapoaiaia	Wiremu Road	5.7	10	81
	Wataroa Road	13.5	17	42
	Cape Egmont	25.2	36	66
Maketawa	Derby Rd	2.3	1	1
	Tarata Road	15.5	23	9
Manganui	SH3	8.7	2	2
	Bristol Road	37.9	88	48
Patea	Barclay Road	1.9	3	3
	Skinner Road	19.2	142	621
Punehu	Wiremu Road	4.4	3	2
	SH45	20.9	13	16
Waingongoro	Opunake Road	7.2	44	64
	Stuart Road	29.6	75	92
	Ohawe Beach	66.6	55	67
Waiongana	SH3a	16.1	69	242
	Devon Road	31.2	122	283
Waiwhakaiho	SH3 (Egmont Village)	10.6	14	42
	Constance St, NP	26.6	41	22
Average	-	-	38	85

Text highlighted in orange exceeds Biggs, 2000 protection of benthic biodiversity value and text highlighted in red exceeds NOF bottom line

Chlorophyll *a* levels were generally congruent with other periphyton indices, with the lowest levels recorded at upstream sites or sites selected for their high conservation values. Interestingly, there were two upstream sites located within 10 km of the National Park boundary that had moderate levels of chlorophyll *a*. This indicates that even sites with limited disturbed upstream catchment can have elevated levels of periphyton.

3.4 Long-term trends

3.4.1 Thick periphyton mats

Long-term trend analysis of the 20 sites monitored for thick periphyton mats found seven sites with significant trends before FDR adjustment and six sites had a significant p-value after FDR adjustment. The upper Manganui River and upper Waingongoro River sites had a significant reduction in thick mats while the upper Punehu, lower Waingongaro River, and the two Waiwhakaiho sites had a significant increase in thick mats (Table 46).

Table 46 Kendall Tau correlations for periphyton (thick mats) for data from 2002-2020. A significant trend at $p<0.05$ is shown in orange text, and a highly significant trend at $p<0.01$ in red text

Site	No.	Kendall Tau	Z	p-value	FDR adjustment
STY000300	30	0.044	0.345	0.730	0.769
STY000400	30	0.230	1.786	0.074	0.152
KPA000250	32	-0.051	-0.412	0.680	0.769
KPA000700	32	-0.122	-0.978	0.328	0.442
KPA000950	32	-0.029	-0.233	0.816	0.816
MKW000200	33	0.139	1.138	0.255	0.426
MKW000300	33	-0.076	-0.619	0.536	0.670
MGN000195	33	-0.332	-2.713	0.007	0.045
MGN000427	33	0.218	1.781	0.075	0.152
PAT000200	35	-0.237	-2.005	0.045	0.128
PAT000360	35	0.204	1.726	0.084	0.153
PNH000200	34	0.309	2.567	0.010	0.046
PNH000900	34	0.121	1.005	0.315	0.442
WGG000150	35	-0.342	-2.892	0.004	0.038
WGG000665	35	0.210	1.773	0.076	0.152
WGG000995	35	0.299	2.525	0.012	0.046
WGA000260	31	-0.044	-0.345	0.730	0.769
WGA000450	31	0.123	0.970	0.332	0.442
WKH000500	30	0.316	2.452	0.014	0.047
WKH000920	30	0.385	2.984	0.003	0.038

3.4.2 Long filamentous algae

Long term trend analysis of the 20 sites monitored for long filamentous algae found six sites with significant trends before FDR adjustment and one site with a significant trend at the 5% level once p-values had the FDR adjustment applied to them (Table 47). The upper and middle Waingongoro River, lower Patea

River, upper Maketawa Stream, and lower Waiongana sites had significant p-values before FDR adjustment. Of these, the upper and middle Waingongoro River sites and lower Patea river site had a reduction in long filamentous algae, while the upper Maketawa Stream and lower Waiongana sites had an increase in long filamentous algae. The upper Kapoaiaia River site was the only site to have a significant trend after FDR adjustment, which showed that filamentous algae had decreased at the site.

Table 47 Kendall Tau correlations for periphyton (long filaments) for data from 2002-2020. A significant trend at $p<0.05$ is shown in orange text, and a highly significant trend at $p<0.01$ in red text

Site	Valid N	Kendall Tau	Z	p-value	FDR adjustment
STY000300	30	-0.248	-1.922	0.055	0.148
STY000400	30	-0.235	-1.824	0.068	0.162
KPA000250	32	-0.477	-3.839	<0.001	0.002
KPA000700	32	-0.102	-0.817	0.414	0.491
KPA000950	32	-0.121	-0.977	0.329	0.418
MKW000200	33	0.271	2.216	0.027	0.108
MKW000300	33	-0.121	-0.992	0.321	0.418
MGN000195	33	0	0	0	0
MGN000427	33	-0.044	-0.364	0.716	0.756
PAT000200	35	-0.199	-1.680	0.093	0.196
PAT000360	35	-0.234	-1.976	0.048	0.148
PNH000200	34	-0.156	-1.301	0.193	0.367
PNH000900	34	0.018	0.151	0.880	0.880
WGG000150	35	-0.293	-2.473	0.013	0.091
WGG000665	35	-0.259	-2.191	0.028	0.108
WGG000995	35	0.115	0.974	0.330	0.418
WGA000260	31	-0.143	-1.129	0.259	0.410
WGA000450	31	0.310	2.448	0.014	0.091
WKH000500	30	-0.156	-1.212	0.225	0.389
WKH000920	30	-0.051	-0.399	0.690	0.756

There has been a significant amount of riparian vegetation and fencing implemented throughout the Taranaki region since periphyton monitoring began. However, overall the majority of sites did not have a statistically significant trend, indicating little definite change in nuisance periphyton since monitoring began. It is noted, however, that 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 97% and 86% of surveys complying with the periphyton guideline for thick mats and long filaments respectively. 84% of sites remained compliant with both periphyton guidelines at all times.
- All rivers received a rating of at least 'moderate' for the TRC periphyton index score over all four surveys, except for three 'poor' scores and one 'very poor' score recorded out of a total of 80 surveys.
- Periphyton biomass results as measured by chlorophyll *a* showed the NOF limit (200 mg/m^2) was breached at three sites for summer 2020 surveys. The guideline to protect benthic biodiversity (50 mg/m^2) was breached at six sites for the summer 2019 survey and eight sites for the summer 2020 survey.
- The data used for nuisance periphyton guidelines (thick algal mats and long filaments) partially correlates with the TRC periphyton index score, but was potentially different from the periphyton biomass data. This is because the 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 are used in the surveys, results can 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.
- Generally, 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, occasionally breaching guidelines.
- Due to the number of variables involved (e.g. nutrients, sunlight, temperature, shading, substrate type, time since last significant fresh or flood, water clarity, level of invertebrate grazing etc), and the interaction between these 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. However, the degree of this effect is not consistent, with some streams requiring relatively larger flows to cause bed-moving events than others.
- The time trend analyses for thick mats show that two sites have had statistically significant reductions, and four sites have had significant increases in thick mats. Meanwhile, one site had a significant reduction in long filaments over the same period. No sites have had significant long-term increases in long filamentous algae.

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 surveillance monitoring programme undertaken by Council.

The sites in Table 48 and Figure 78 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 48 Sites monitored for *Didymosphenia geminate* and results of current surveys

River	Site Code	Site	2019	2020
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
Hangatahua River	Mangatete Road	STY000300	Absent	NS
Mangaoraka Stream	Corbett Road	MRK000420	Absent	NS

*NS; no survey was able to be completed due to the Covid-19 lockdown

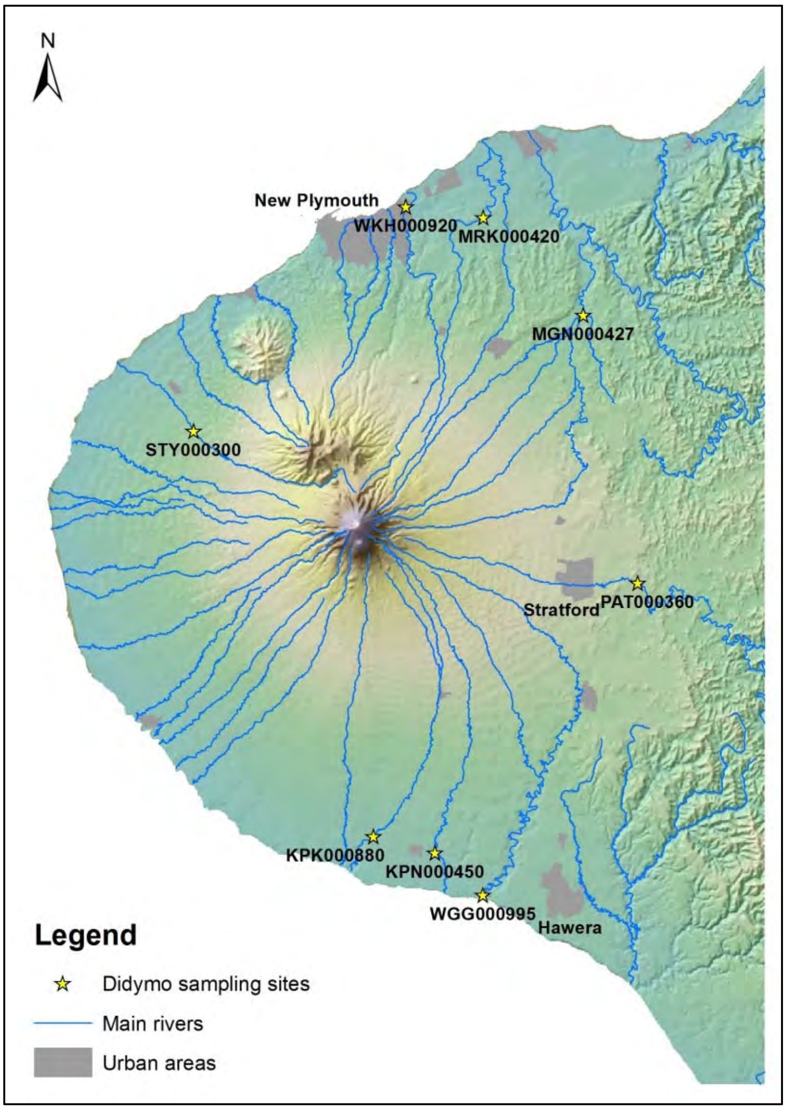


Figure 78 Sites monitored for *Didymosphenia geminata*

6 Recommendations

1. THAT monitoring of the periphyton communities in the Hangatahua, Maketawa, Manganui, Patea, Waiwhakaiho, Waingongoro, Punehu, Kapoaiaia, and Waiongana Rivers is continued.
2. THAT in the 2020-2022 monitoring period, the Waiwhakaiho, Manganui, Patea, Waingongoro, Hangatahua 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 the disposal of dairy shed effluent to land, in order to reduce periphyton levels in lowland streams and rivers in agriculturally dominated catchments.

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