

Periphyton and macrophytes in seven Hauraki-Coromandel rivers

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Periphyton and macrophytes in seven Hauraki-Coromandel rivers

Initial assessment of seasonal abundance, provisional attribute state and management options

Prepared for Waikato Regional Council

July 2017

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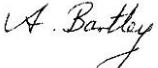
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Executive summary

The National Policy Statement for Freshwater Management (NPS-FM) identifies periphyton as the key attribute for assessing ecosystem health and trophic state in rivers. Waikato Regional Council (WRC) sought to gain a better understanding of periphyton and macrophyte abundance and seasonal dynamics in a selection of representative Hauraki-Coromandel rivers to inform an upcoming Plan Change (“Healthy Rivers #2”). WRC also wished to examine the applicability of periphyton cover to biomass conversion factors established for Canterbury rivers to the Hauraki-Coromandel system to ensure that current visual observation procedures would comply with NPS-FM requirements. There was also interest in the abundance of macrophytes, which are the primary attachment surface for periphyton in soft-bottom rivers which are common in the Hauraki-Coromandel system.

NIWA were engaged by WRC to undertake monthly monitoring of periphyton and macrophyte abundance for one year at the following river sites: Kauaeranga River at Smiths Cableway, Waiwawa at Rangihau Ford, Ohinemuri River at Karangahake, Waihou River at Te Aroha, Waitoa River at Mellon Road, Piako River at Kiwitahi and Piako River at Paeroa-Tahuna Road. Three of the sites were hard-bottom and four sites were soft-bottom. For periphyton, cover classes were assessed using the WRC protocol for wadeable streams and samples for biomass were collected and analysed in line with national protocols. For macrophytes the percentages of channel cross-sectional area or volume (CAV) and water surface area (WSA) occupied by individual species, and in total, were assessed. Monitoring at these sites also included assessments of channel width, water depth, dominant substrate type and shading. Flow records for the sites were also obtained and examined.

Our monitoring data indicate that two of the four soft-bottom river sites monitored (Piako – Kiwitahi and Waitoa) have a provisional NOF periphyton attribute state below the national bottom line. These two sites, and Piako River at Paeroa-Tahuna Road, also have nuisance macrophytes occupying more than 50% of the channel cross-sectional area or volume (and up to 90%) during the summer-autumn period which exceeds provisional guidelines to protect aesthetic, angling, ecological and flow conveyance values. The three hard-bottom river sites monitored (Kauaeranga, Ohinemuri and Waiwawa) and the fourth soft-bottom river site (Waihou) have provisional NOF periphyton attribute states in the A and B bands, indicating excellent and good condition, respectively.

The main drivers of periphyton and macrophyte abundance in rivers are flow, light, nutrients, grazing and temperature. Manipulation of channel lighting and temperature via riparian planting (to produce >60% shading across a large proportion of the river channel where it is < c. 14 m) is the most promising approach for reducing nuisance periphyton and macrophyte abundance in Hauraki-Coromandel soft-bottom rivers to comply with NOF requirements to implement remedial management actions at locations that fall below national bottom lines. Riparian planting also has a number of significant co-benefits. It is unlikely that the other main drivers of abundance (i.e., flow, nutrients and grazing) could be manipulated sufficiently to exert an influence in these rivers.

Waikato Regional Council’s State of Environment monitoring programme (for wadeable streams) currently assesses periphyton abundance as cover rather than biomass. The results of this investigation suggest that using conversion factors derived from Canterbury streams, or the overall cover metric to biomass regression equations derived using this Hauraki-Coromandel river data set, would likely provide only crude approximations of biomass at quite a coarse scale.

1 Introduction

The National Policy Statement for Freshwater Management (NPS-FM) identifies periphyton as the key attribute for assessing ecosystem health and trophic state in rivers. For example, regular and/or extended-duration nuisance blooms of periphyton (as chlorophyll *a* >200 mg/m²) are regarded as reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat. In soft-bottom rivers, macrophytes are a primary attachment surface for periphyton and usually contribute substantially to primary production. High levels of primary production (periphyton and/or macrophytes) can exert a strong influence on river dissolved oxygen levels and pH. Large diel fluctuations in these parameters are often associated with excessive primary production generating supersaturated oxygen and high pH levels during the day and very low levels of dissolved oxygen at night. Depleted dissolved oxygen levels are particularly harmful to fish and stream invertebrates.

Waikato Regional Council (WRC) sought to gain a better understanding of periphyton and macrophyte abundance and temporal dynamics in a selection of representative streams and rivers to inform the Hauraki-Coromandel Plan Change (“Healthy Rivers #2”). In addition, WRC wished to examine the applicability of the periphyton cover to biomass conversion factors established in Canterbury rivers (Kilroy et al. 2013) to the Hauraki-Coromandel system to ensure that procedures used from making visual observations will meet National Policy Statement requirements (as per Ministry for the Environment’s recent draft guidance for attributes, MfE 2015). NIWA were thus engaged by WRC to undertake monthly monitoring of periphyton and macrophyte abundance at the following river sites: Kauaeranga River at Smiths Cableway, Waiwawa at Rangihau Ford, Ohinemuri River at Karangahake, Waihou River at Te Aroha, Waitoa River at Mellon Road, Piako River at Kiwitahi and Piako River at Paeroa-Tahuna Road.

All sites selected for this study have matching flow and water quality data enabling examination of relationships between periphyton, flow and nutrients. Light availability is also a key driver of periphyton abundance, so measurements of shading were included in the monthly monitoring protocol. For future management of rivers based on the periphyton attribute, options to regulate biomass include: riparian planting and shading to limit light availability and reduce stream temperatures (most feasible for narrower channels), controls on point and diffuse source nutrient inputs and limits on water abstraction. Better understanding the relationships between periphyton and these drivers (particularly at regional and local scales) is critical for informing these management actions.

2 Methods

Monitoring was carried out monthly for 14 months as river flow conditions allowed. Monitoring of all sites except Waiwawa commenced in February 2016. Monitoring at Waiwawa began in April 2016.

To assess periphyton cover we used the NIWA RAM-2 protocol (Biggs and Kilroy 2000), as modified by Waikato Regional Council (Collier et al. 2014), which visually assesses cover of different periphyton categories (Table 2-1). We made assessments using an underwater viewer (or snorkelling mask in deeper water) at five equidistant points in each of five transects within a 100 m reach located in ‘run’ habitat. In total, 25 observations of periphyton cover are made at each site on each sampling date. Nuisance abundance is defined as >30% long filaments (LF) or >60% thick mats (TM) (MfE 2000), or a weighted composite cover >30% (i.e., PeriWCC = LF + (TM/2)) (Matheson et al. 2012a). We also calculated periphyton total cover as the sum of short and long filaments plus medium and thick mats.

Table 2-1: Periphyton cover categories used in the monitoring protocol.

Periphyton cover categories	
Mat	Filament
Thin film/mat	
Medium mat – green	Short filaments
Medium mat – light brown	Long filaments - green
Medium mat – black or dark brown	Long filaments – brown or red
Thick mat – green or light brown	
Thick mat – black or dark brown	

Thin film/mats are <0.5mm thick, medium mats are 0.5 to 3mm thick, thick mats are >3mm thick and long filaments are >2cm long.

At sites where macrophytes were present we assessed macrophyte abundance across the same transects as periphyton using a modified form of the Collier et al. (2014) protocol. At each transect point we recorded the percentage of the water surface area (%WSA) in a 0.5 m x 0.5 m quadrat occupied by each plant species. We also recorded the percentage of the channel wetted cross-sectional area or volume (%CAV) in this area occupied by each species. This enabled us to calculate %WSA and %CAV metrics by individual species and as a total (Matheson et al. 2012a, Davies-Colley et al. 2012).

At each transect point we measured water depth and recorded dominant substrate type (as boulder, cobble, gravel, sand, silt or clay). We also quantified % shade using a concave spherical densiometer (Forestry Suppliers®). A total of 25 observations of water depth, substrate and shade were made at each site on each visit.

Table 2-2: Substrate size categories used in the monitoring protocol.

Substrate size categories	
Boulder	>25.6 cm
Cobble	>6.4 to 25.6 cm
Gravel	>0.2 to 6.4 cm
Sand	<2 mm
Silt	<63 um
Clay	<3.9 um

To assess periphyton biomass (as chlorophyll *a*) we collected five samples at equidistant points across the central transect according to the quantitative defined area sampling protocols (1b and 3) of Biggs and Kilroy (2000). These samples were combined into a single sample for analysis. Where substrate was dominated by cobbles and/or gravels we collected whole rocks with a combined surface area of at least 10 x 10 cm at each sampling point. Where substrate was boulder (or, rarely, bedrock) we carefully selected an adjacent cobble with comparable periphyton cover. Boulders were most frequently encountered in the Ohinemuri River with snorkelling generally required to collect samples. This precluded use of the Biggs and Kilroy (2000) boulder sampler device. Where substrate was fine sediment (sand and/or silt), in either shallow or deeper water, samples to c. 2 cm depth were scooped up in a 7.5 cm x 7.5 cm fine mesh net. Where macrophytes were present at the sampling point we collected a circular defined area (10 cm diameter) on the uppermost surface of the macrophyte bed.

In the laboratory we carefully removed periphyton from the substrates in each of our samples. To remove periphyton from cobbles and gravels we used a small scrubbing brush. We carefully dislodged periphyton adhering to macrophytes and fine sediments by hand, by wiping leaf blades clean and agitating sediment, respectively. Periphyton samples with substrate removed were homogenised in a blender. Duplicate subsamples were filtered for analysis of chlorophyll *a* by acetone pigment extraction and spectrophotometry (APHA 1998). We measured the *a*, *b* and *c* axes of all gravels and cobbles. Chlorophyll *a* content was converted to areal units (mg/m²) by dividing by solar-exposed surface area of the stones according to Dall (1979) and/or the defined surface area sampled for fine sediments and macrophytes. Using the conversion factors in Kilroy et al. (2013) we calculated an estimate of periphyton chlorophyll *a* from the percentage cover data for comparison with our direct measurements of chlorophyll *a*.

For each site we obtained the entire flow record (5 min intervals) from 1 January 2015 to 23 March 2017 from WRC. We calculated the median flow for each site, including Waiwawa, for the 2-year period 1 February 2015 to 31 January 2017. In general, a flood of three times the median flow or greater is considered likely to scour periphyton from the river bed (Clausen and Biggs 1997). For each site and sampling date we examined the flow record to calculate the number of days since a flushing event that was greater than or equal to three times the median flow. Relationships between plant abundance and the number of days since an event that was greater than or equal to three times the median flow were examined using linear regression.

3 Results

3.1 Kauaeranga River

The monitoring site was located c. 20 m downstream of the Regional Council's flow monitoring tower (Figure 3-1). This site was monitored 13 times between 1 February 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed (Figure 3-2), by wading. The only month not sampled was May.



Figure 3-1: **Kauaeranga River site.** View looking upstream from true left bank of most downstream transect. Photo taken in February 2016 (Photo: T. Burton).

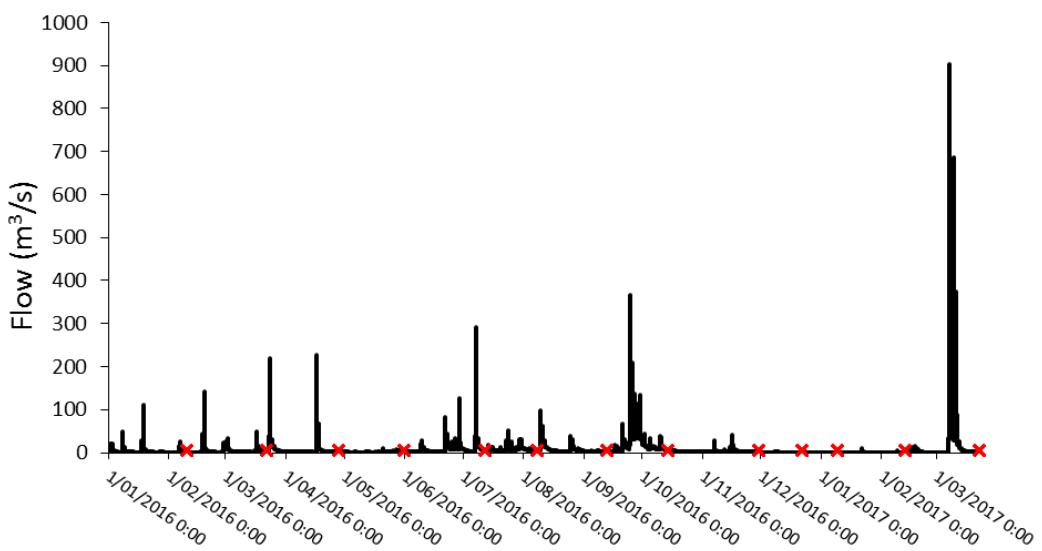


Figure 3-2: **Kauaeranga River flow from 1 January 2016 to 23 March 2017.** Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

At this site river wetted width was c. 30 m. Average water depth on sampling dates ranged from 0.29 m in January to 0.62 m in October with an overall range of 0.03 m to 0.97 m (See Table 3-1 on following page). Substrate was predominantly cobble intermixed with boulders and gravel, occasional patches of sand and, rarely, silt. Average shading of the site from riparian vegetation ranged from a low of 7% in August to a high of 28% in March 2016.

Periphyton cover only once reached nuisance levels at this site (Figure 3-3), namely in December. Thin films, short filaments and medium mats (light brown) were usually most prevalent at this site. At the peak of periphyton abundance in December, thick mats (green/light brown) and long filaments (green and brown/red) presented a combined nuisance cover (i.e., LF + TM) of 58% and a weighted composite nuisance cover (i.e., LF + (TM/2)) of 34%.

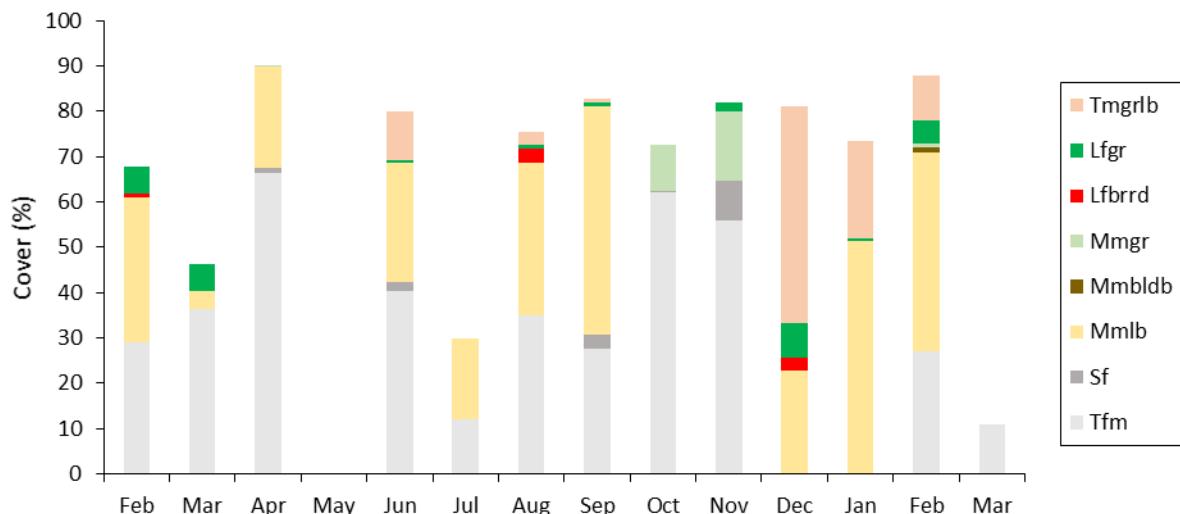


Figure 3-3: Kauaeranga River periphyton cover on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in May 2016. Tfm = Thin film, Sf = Short filaments, Mmlb = Medium mat light brown, Mmbldb = Medium black dark brown, Mmgr = Medium mat green, Lfbrdd = Long filaments brown/red, Lfgr = Long filaments green, Tmgrib = Thick mat green/light brown. See Appendix A for underlying data including standard error values.

Measured periphyton biomass (chlorophyll *a*) at this site was consistently low, with no obvious seasonal pattern, ranging from a minimum of 2 mg/m² in November and March (2017), to a maximum of 26 mg/m² in February 2017 (Table 3-1). We found that measured chlorophyll *a* was significantly correlated with chlorophyll *a* derived from periphyton cover using Kilroy et al. (2013) conversion factors (Figure 3-4).

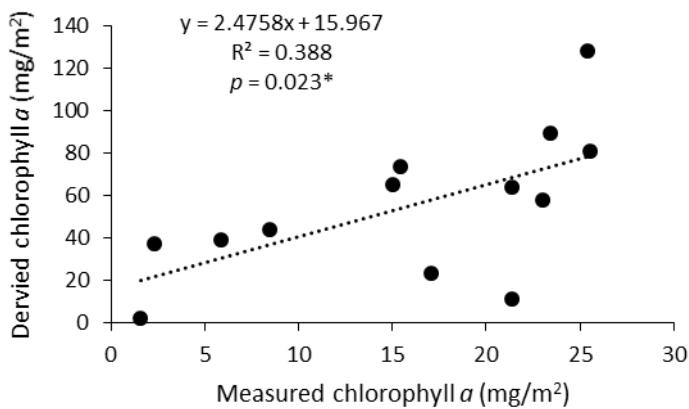


Figure 3-4: Derived versus measured derived chlorophyll *a* values for Kauaeranga River site. Derived chlorophyll *a* values calculated from periphyton cover for the chlorophyll *a* sampled transect using conversion factors of Kilroy et al. (2013).

We also found that measured periphyton biomass was positively correlated to cover metrics but this relationship was only statistically significant with total periphyton cover (i.e., combined cover of short and long filaments plus medium and thick mats) (Figure 3-5).

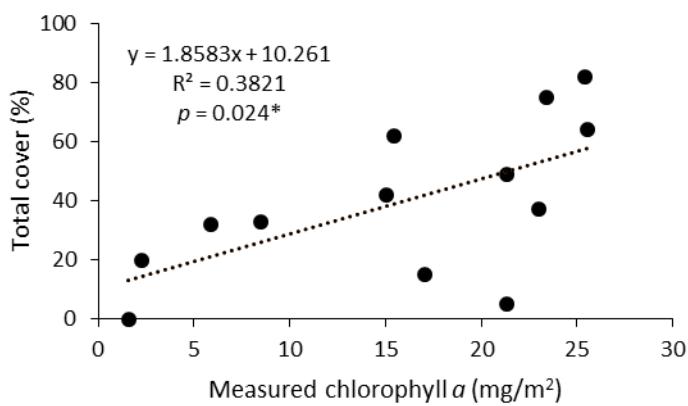


Figure 3-5: Periphyton total cover versus measured periphyton biomass as chlorophyll *a* at Kauaeranga River site. Periphyton total cover = cover of long and short filaments plus medium and thick mats.

The native charophyte, *Nitella* aff. *cristata* was periodically observed in low abundance adjacent to one or two inshore transect points on the true right bank. No other macrophytes were recorded in, or adjacent to, transects.

Table 3-1: Kauaeranga River monthly summary data for shade, water depth, substrate, chlorophyll α and the number of days since an event greater than or equal to three times the median flow. Values are means with range in parentheses where applicable.

Parameter	Month													
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	18 (0-77)	28 (9-50)	22 (0-67)	-	22 (4-47)	12 (0-51)	7 (0-40)	9 (0-53)	8 (0-33)	13 (0-55)	13 (0-63)	13 (0-71)	13 (0-55)	11 (0-54)
Water depth (m)	0.40 (0.05-0.95)	0.53 (0.16-0.91)	0.36 (0.05-0.67)	-	0.51 (0.16-0.90)	0.55 (0.24-0.97)	0.55 (0.19-0.95)	0.43 (0.10-0.82)	0.62 (0.29-0.92)	0.40 (0.11-0.80)	0.35 (0.14-0.73)	0.31 (0.03-0.72)	0.29 (0.10-0.62)	0.46 (0.06-0.68)
Substrate	C (G-B)	C (C-B)	C (G-B)	-	C (C-B)	C (S-B)	C (S-B)	C (S-B)	C (S-B)	C (T-B)	C (S-B)	C (S-B)	C (G-B)	C (S-B)
Measured chl α (mg/m ²)	15	21	8	-	23	6	21	23	17	2	25	15	26	2
Derived chl α (mg/m ²)	66	11	44	-	58	39	64	89	24	37	128	74	81	2
Ratio of derived to measured chl α	4.4	0.5	5.5	-	2.5	6.5	3.1	3.9	1.4	18.5	5.1	4.9	3.1	1.0
Days since 3Xmedian flow event	3	1	9	-	3	0	1	14	1	12	34	52	24	9

'-' = missing data.

B=Boulder, C=Cobble, G=Gravel, S=Sand, T=Silt.

Examining the dataset derived from individual transect points we found that nuisance cover of long filaments ($>30\%$) and thick mats ($>60\%$) occurred exclusively where there were low to moderate levels of shade (i.e., $\leq 55\%$) (Figure 3-6).

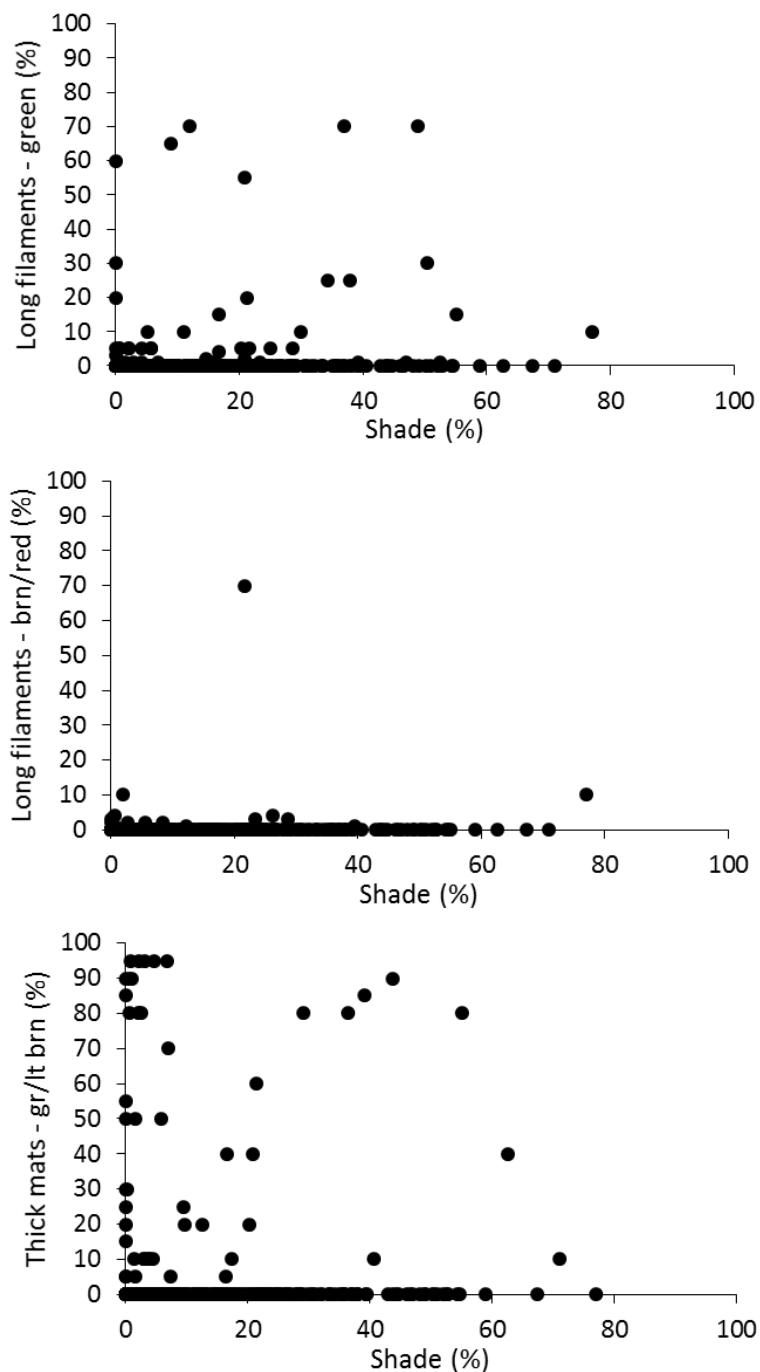


Figure 3-6: Periphyton cover versus shade at the Kauaeranga River site. Data shown are for individual transect points from February 2016 to March 2017. Nuisance covers of long filaments and thick mats are $>30\%$ and $>60\%$, respectively.

For the two-year period from 1 February 2015 to 31 January 2017 median flow in the Kauaeranga river was $2.19 \text{ m}^3/\text{s}$ and thus three times the median flow was $6.57 \text{ m}^3/\text{s}$. We found a significant relationship between the number of days since flow event greater than or equal to three times the median flow and periphyton total cover (Figure 3-7), weighted composite cover (not shown) and cover of thick mats (not shown). We did not find a significant relationship with biomass as chlorophyll *a* or with cover of long filaments.

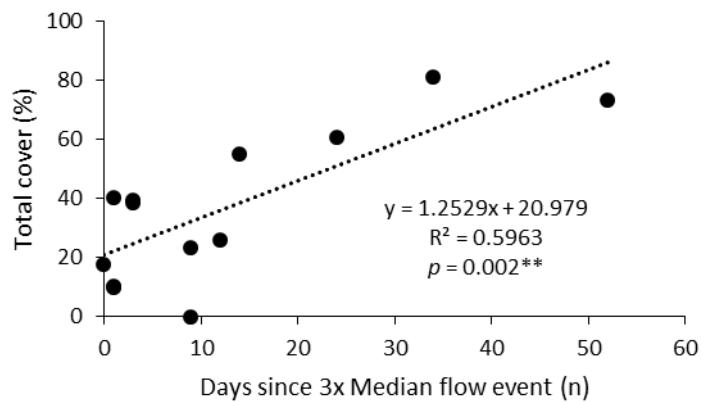


Figure 3-7: Periphyton total cover versus days since an event greater than or equal to three times the median flow at the Kauaeranga River site. Data shown corresponds to each monthly sampling event. “Total cover” refers to cover of short and long filaments plus medium and thick mats.

3.2 Ohinemuri River

The Ohinemuri monitoring site was located c. 50 m downstream of the Regional Council's flow monitoring tower (Figure 3-8).



Figure 3-8: Ohinemuri River site. View looking downstream across the lower transects in February 2016 (Photo: F Matheson).

This site was monitored 11 times between 1 February 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed, usually by snorkelling from a small inflatable boat (Figure 3-9). Months not sampled were June, August and January. A rare error with fieldwork scheduling was the cause of the missed sampling in January, rather than unsafe river flow conditions.

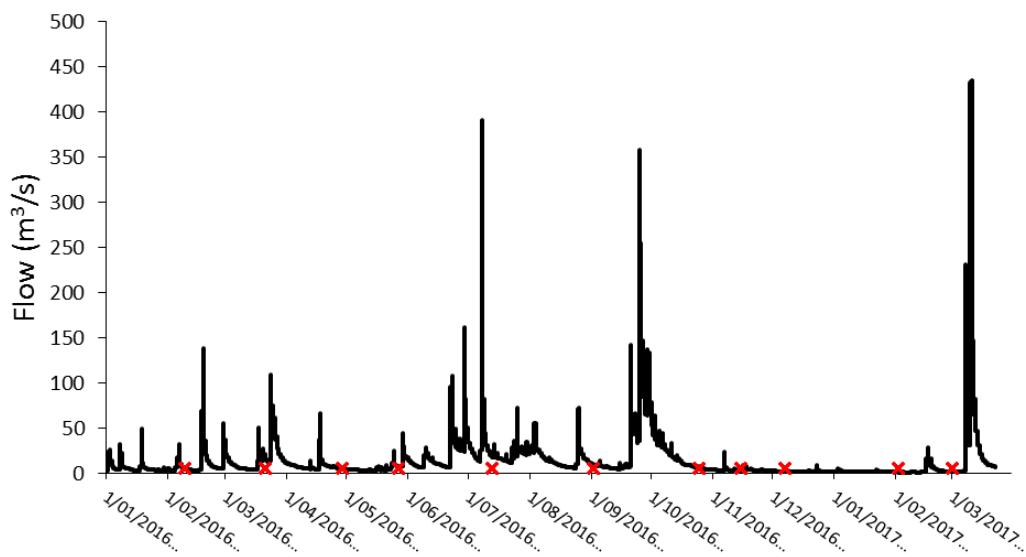


Figure 3-9: Ohinemuri River flow from 1 January 2016 to 23 March 2017. Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

River wetted width at this site was c. 36 m. Average water depth on sampling dates ranged from 0.90 m in February 2017 to 1.68 m in July with an overall range of 0.54 m to 2.35 m (See Table 3-2 on following page). Substrate was predominantly cobble or boulder. There were frequently areas of sand or gravel on the margins. Average shading of the site from riparian vegetation ranged from a low of 9% in July and September to a high of 38% in February 2016.

Periphyton cover did not reach nuisance levels at this site (Figure 3-10). Thin films were dominant at all times. Long green filaments were present at covers >10% in late summer and early autumn. Thick mats were rarely observed, although medium green mats (up to 14% cover) were recorded periodically in spring, summer and early autumn.

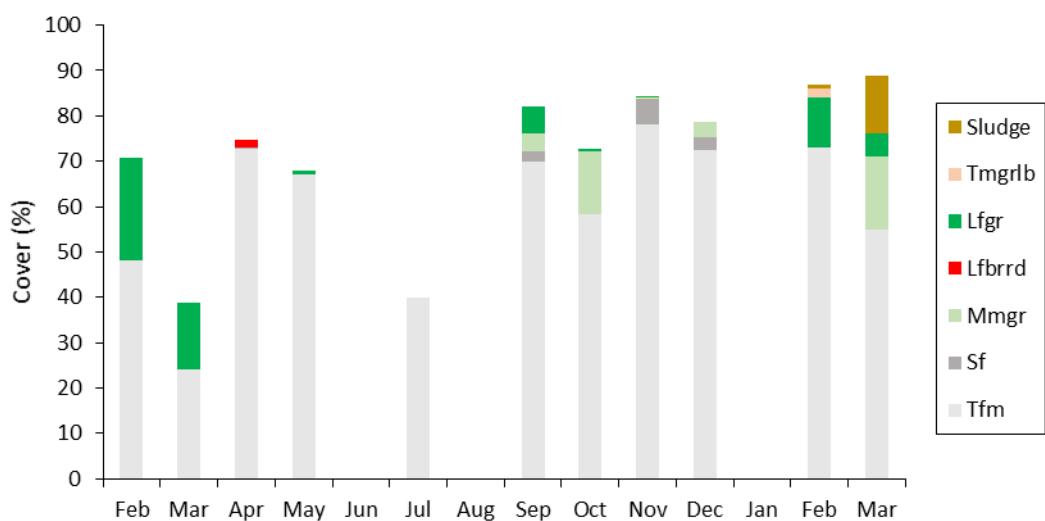


Figure 3-10: Ohinemuri River periphyton cover on monthly sampling dates from February 2016 to January 2017. Note that sampling did not occur in June, 2016, August 2016 and January 2017. Tfm = Thin film, Sf = Short filaments, Mmgr = Medium mat green, Lfbrrd = Long filaments brown/red, Lfgr = Long filaments green, Tmgrlb = Thick mats green light brown. See Appendix A for underlying data including standard error values.

Measured periphyton biomass (chlorophyll *a*) at this site was low to moderate (i.e., <100 mg/m²) with some evidence of seasonality. Minimum levels were encountered during winter and early spring (1 and 7 mg/m², respectively) while highest values were recorded in early autumn (84 and 275 mg/m², respectively) (Table 3-2).

Measured chlorophyll *a* was not significantly correlated with chlorophyll *a* derived from periphyton cover information using Kilroy et al. (2013) conversion factors. At this site, we also found that periphyton biomass and cover metrics were not significantly correlated.

The native charophyte, *Nitella* aff. *cristata* and the introduced (but relatively innocuous) oxygen weed, *Elodea canadensis*, were periodically recorded along the channel margins. At peak abundance in May, *Elodea* and *Nitella* occupied 4% and 1% of channel cross-sectional area or volume (CAV), respectively.

Table 3-2: Ohinemuri River monthly summary data for shade, water depth, substrate, chlorophyll *a* and number of days since an event greater than or equal to three times the median flow. Values are means with range in parentheses where applicable.

Parameter	Month													
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	38 (6-93)	34 (8-90)	21 (5-68)	10 (1-33)	-	9 (4-20)	-	9 (3-21)	31 (3-96)	35 (2-74)	32 (3-71)	-	24 (0-88)	27 (3-75)
Water depth (m)	1.13 (0.75- 1.60)	1.45 (0.80- 1.90)	1.10 (0.65- 1.55)	1.17 (0.69- 1.72)	-	1.68 (1.05- 2.35)	-	1.20 (0.78- 1.96)	1.21 (0.83- 1.70)	1.00 (0.54- 1.56)	1.01 (0.60- 1.50)	-	0.90 (0.55- 1.38)	1.04 (0.64- 1.50)
Substrate	C (S-B)	C (S-B)	B (G-B)	C (S-B)	-	C (G-B)	-	C (S-B)	C (S-B)	C (S-B)	C (S-B)	-	C (S-B)	C (S-B)
Measured Chl <i>a</i> (mg/m ²)	30	84	50	45	-	1	-	7	36	27	78	-	67	275
Derived Chl <i>a</i> (mg/m ²)	85	57	8	6	-	4	-	29	25	35	16	-	48	27
Ratio of derived to measured Chl <i>a</i>	2.8	0.68	0.16	0.13	-	4.0	-	4.1	0.69	1.3	0.21	-	0.72	0.10
Days since 3Xmedian flow event	3	0	11	2	-	0	-	3	11	8	30	-	87	12

'-' = missing data.

B=Boulder, C=Cobble, G=Gravel, S=Sand, T=Silt.

We found that nuisance cover of long green filaments (>30%) was associated with shading less than 60% (Figure 3-11). Long brown or red filaments and thick mats were detected only where shading was less than 20%.

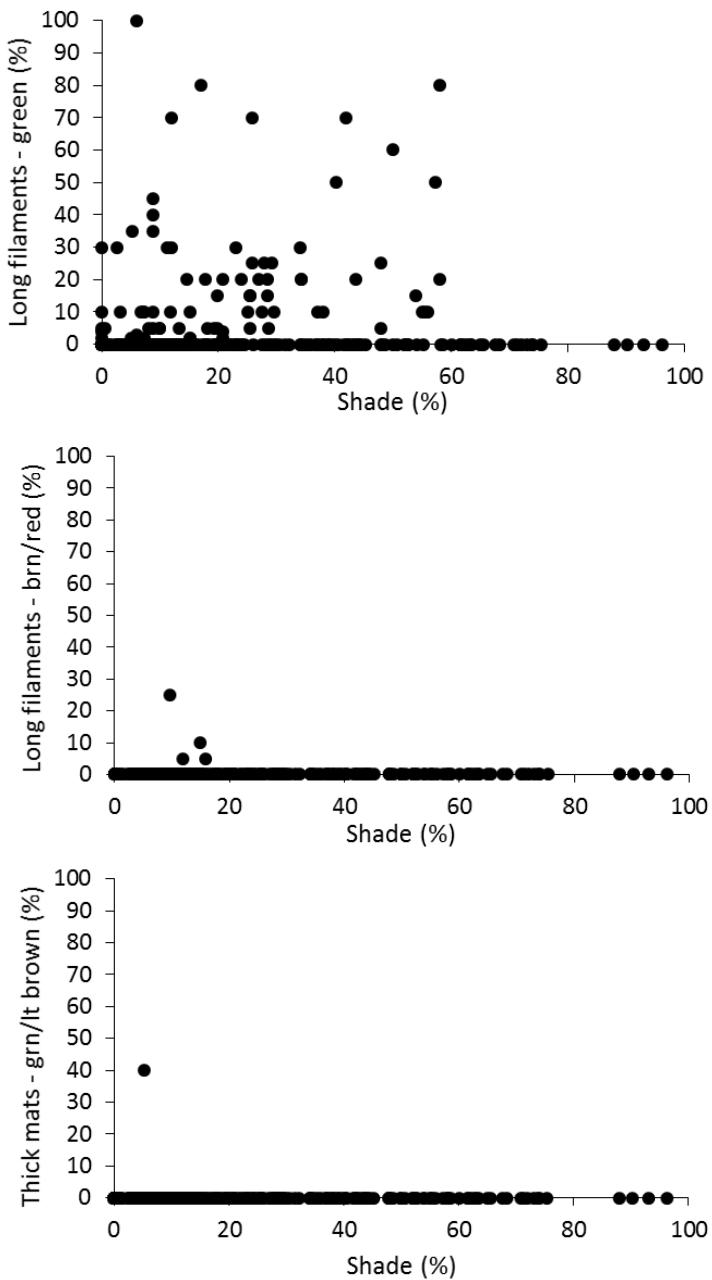


Figure 3-11: Periphyton cover versus shade at the Ohinemuri River site. Data shown are for individual transect points from February 2016 to March 2017. Nuisance cover of long filaments is >30%.

For the period from 1 February 2015 to 31 January 2017 median flow in the river was $5.71 \text{ m}^3/\text{s}$ and thus three times the median flow was $17.1 \text{ m}^3/\text{s}$. In the Ohinemuri River we did not find a significant relationship between the number of days that had elapsed since an event three times the median flow or higher and periphyton cover or biomass.

3.3 Waiwawa River

The Waiwawa monitoring site was located 20 m upstream of the Rangihau Rd Ford (Figure 3-12). The Regional Council's flow monitoring tower was located adjacent to the sampling reach on the true right bank.



Figure 3-12: Waiwawa River site. View looking upstream from the Ford. Photo taken in April 2016 (Photo: F. Matheson).

This site was monitored 11 times between 1 April 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed (Figure 3-13), by wading. The only month not sampled was May.

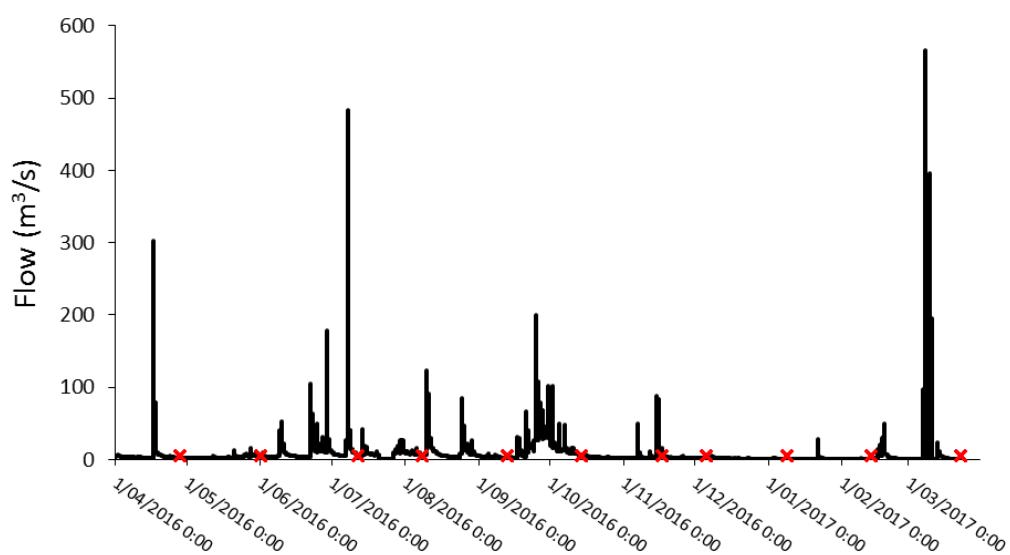


Figure 3-13: Waiwawa River flow from 1 April 2016 to 23 March 2017. Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

River wetted width at this site was c. 35 m. Average water depth on sampling dates ranged from 0.65 m in April to 1.00 m in November with an overall range of 0.18 m to 1.40 m (Table 3-3). Cobble was the dominant substrate with patches of sand and gravel, and boulders were also encountered.

Average shading of the site from riparian vegetation ranged from a low of 19% in October to a high of 38% in April.

Periphyton cover did not reach nuisance levels at this site (Figure 3-14). The periphyton community was usually dominated by thin films or medium mats. Low to moderate abundance of long filaments was occasionally observed with the highest total cover (15%) in late spring (November). In early spring (September) there was a 35% cover of thick green mats. All periphyton mats and filaments were apparently scoured from the bed during the large flood that preceded sampling in late March 2017.

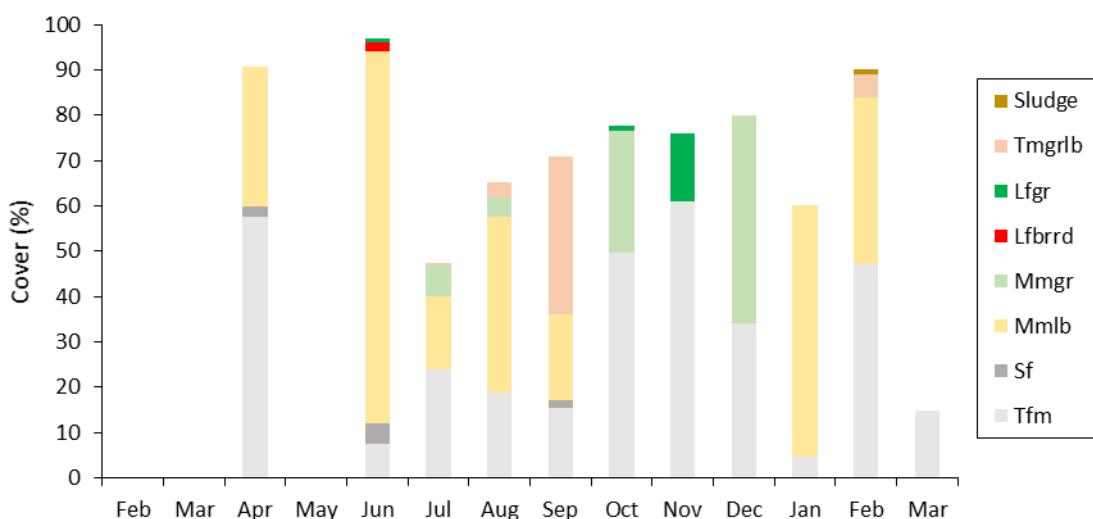


Figure 3-14: Waiwawa River periphyton cover on monthly sampling dates from April 2016 to March 2017.
Note that sampling did not occur in May 2016. Tfm = Thin film, Sf = Short filaments, Mmlb = Medium mat light brown, Mmgr = Medium mat green, Lfbrrd = Long filaments brown/red, Lfgr = Long filaments green, Tmgrlb = Thick mat green/light brown. See Appendix A for underlying data including standard error values.

Measured periphyton biomass (chlorophyll *a*) at this site ranged from a minimum of 6 mg/m² in July to a maximum of 56 mg/m² in January, with no obvious seasonal pattern (Table 3-3). Measured chlorophyll *a* was not significantly correlated with chlorophyll *a* derived from periphyton cover information using Kilroy et al. (2013) conversion factors. At this site, we found that periphyton biomass and cover metrics were not significantly correlated. No macrophytes were encountered on the Waiwawa transects during this study.

Table 3-3: Waiwawa River monthly summary data for shade, water depth, substrate, chlorophyll *a* and days since an event greater than or equal to three times the median flow. Values are means with range in parentheses where applicable.

Parameter	Month											
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	38 (10-73)	-	36 (4-79)	33 (2-71)	26 (1-71)	27 (3-68)	19 (0-61)	24 (0-73)	21 (1-82)	27 (0-82)	26 (0-66)	24 (1-86)
Water depth (m)	0.65 (0.15-1.00)	-	0.75 (0.33-1.01)	0.89 (0.35-1.32)	0.88 (0.36-1.20)	0.78 (0.30-1.20)	0.87 (0.47-1.21)	1.00 (0.55-1.40)	0.74 (0.30-1.10)	0.67 (0.19-1.01)	0.67 (0.24-1.00)	0.69 (0.18-1.07)
Substrate	C (G-B)	-	C (G-B)	C (S-B)								
Measured Chl <i>a</i> (mg/m ²)	10	-	17	6	46	17	15	19	15	56	49	1
Derived Chl <i>a</i> (mg/m ²)	43	-	119	23	66	49	36	27	32	62	47	1
Ratio of derived to measured Chl <i>a</i>	4.3	-	7.0	3.8	1.4	2.9	2.4	1.4	2.1	1.1	1.0	1.0
Days since 3Xmedian flow event	9	3	1	1	14	2	0	19	53	22	9	9

'-' = missing data.

B=Boulder, C=Cobble, G=Gravel, S=Sand.

At this site, we found that nuisance (>60%) and non-nuisance covers of thick mats were associated with riparian shading less than 35-40% (Figure 3-15). Cover of long filaments >5% was rare but only occurred where shading was \leq 10%.

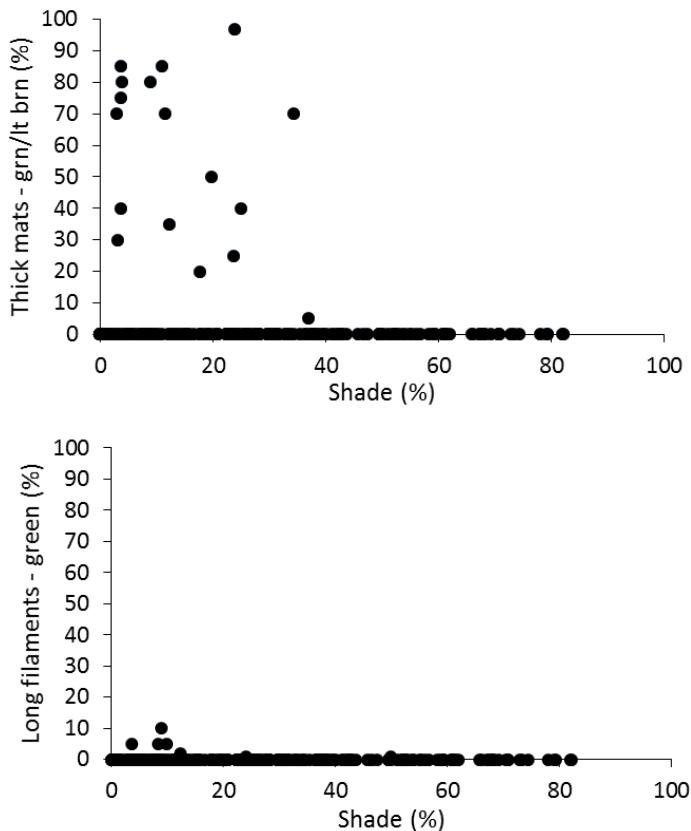


Figure 3-15: Periphyton cover versus shade at the Waiwawa River site. Data shown are for individual transect points from April 2016 to March 2017. Nuisance cover of long filaments is >30%.

For the period from 1 February 2015 to 31 January 2017 median flow in the river was $2.84 \text{ m}^3/\text{s}$ and thus three times the median flow was $8.53 \text{ m}^3/\text{s}$. At this site we found a significant relationship between the number of days since an event greater than or equal to three times the median flow and periphyton biomass (Figure 3-16), but not periphyton cover.

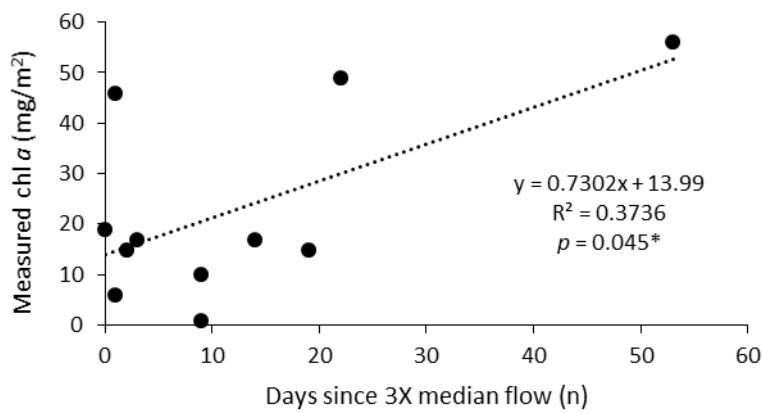


Figure 3-16: Periphyton biomass as chlorophyll *a* versus number of days since an event greater than or equal to three times the median flow at the Waiwawa River site. Data shown corresponds to each monthly sampling event.

3.4 Piako River – Kiwitahi

The Kiwitahi monitoring site was located upstream of the Regional Council monitoring station (Figure 3-17). The most downstream transect was c. 20 m upstream of the station.



Figure 3-17: Piako River - Kiwitahi site. View looking upstream over lower-mid transects from true left bank. Photo taken in December 2016 (Photo: F. Matheson).

The Kiwitahi site was monitored 12 times between 1 February 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed (Figure 3-18), usually by wading, occasionally by snorkelling. The two months not sampled were April and July.

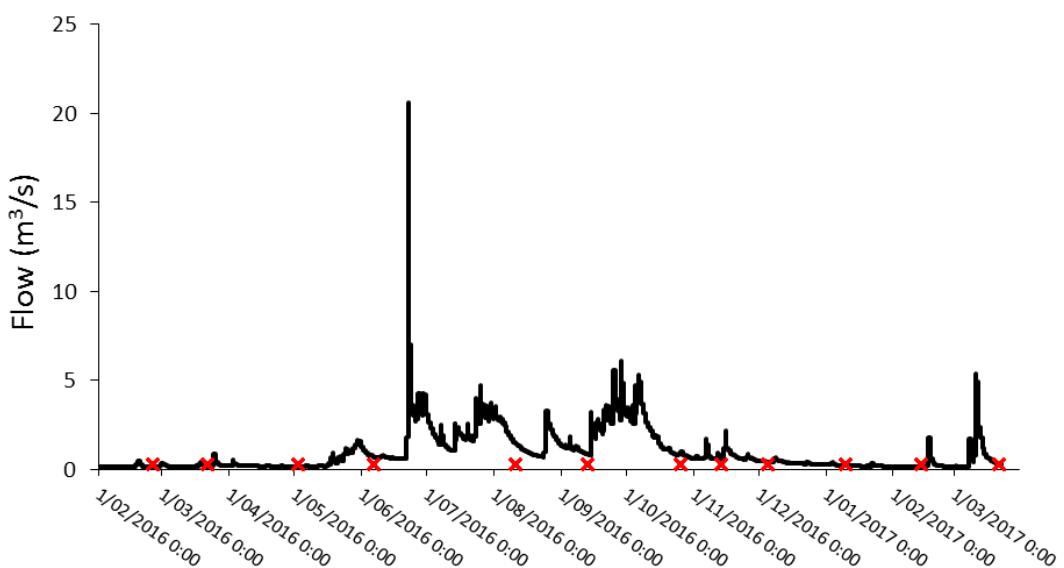


Figure 3-18: Piako River - Kiwitahi flow from 1 February 2016 to 23 March 2017. Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

River wetted width at this site was c. 10 m. Average water depth on sampling dates ranged from 0.71 m in January to 1.25 m in August with an overall range of 0.14 m to 1.94 m (Table 3-4). The substrate at the Kiwitahi site was highly variable. Sand was frequently encountered particularly towards the centre of the channel with silt on the margins. However, following high flow events it was clear that these fine sediments were removed with scouring exposing hard compact clay, and occasional boulders. Average shading of the site from banks and riparian vegetation was minimal and ranged from 0% in August and October to 9% in March 2016.

At this site periphyton was frequently attached to macrophytes and, occasionally, during periods of stable flow, adhering to fine bottom sediments. Nuisance cover of periphyton as long filaments (i.e., >30%) was observed in May (green), September (red), February 2017 (red) and March 2017 (red), covering at least half of the available attachment surface (Figure 3-19). Periphyton mats (green or light brown) were found only in December and January and not at nuisance levels.

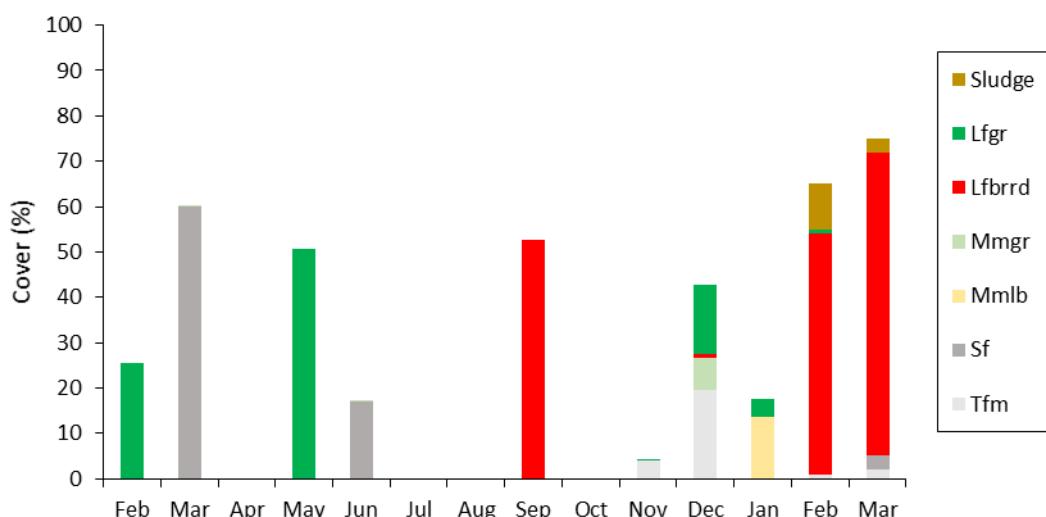


Figure 3-19: Piako River - Kiwitahi periphyton cover on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in April and July 2016. No periphyton cover was observed in August and October. Tfm = Thin film, Sf = Short filaments, Mmlb = Medium mat light brown, Lfbrdd = Long filaments brown/red, Lfgr = Long filaments green. See Appendix A for underlying data including standard error values.

Measured periphyton biomass (chlorophyll *a*) at this site ranged from a minimum of 6 mg/m² in August to a maximum of 486 mg/m² in February 2017, which is regarded as a nuisance level (i.e., >200 mg/m²). There was evidence of a seasonal pattern at this site with low abundance during winter and peak abundances in late summer and autumn. Measured chlorophyll *a* was not significantly correlated with chlorophyll *a* derived from periphyton cover information using Kilroy et al. (2013) conversion factors. At this site, we did not find significant relationships between periphyton biomass and cover metrics.

Table 3-4: Piako River - Kiwitahi monthly summary data for shade, water depth, substrate, chlorophyll *a* and number of days since an event greater than or equal to three times median flow. Values are means with range in parentheses where applicable.

Parameter	Month													
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	6 (0-46)	9 (0-32)	-	2 (0-12)	3 (0-14)	-	0 (0-2)	-	0 (0-3)	2 (0-16)	2 (0-8)	3 (0-18)	1 (0-7)	2 (0-13)
Water depth (m)	0.92 (0.14-1.94)	0.85 (0.19-1.29)	-	0.87 (0.26-1.55)	0.83 (0.42-1.30)	-	1.25 (0.55-1.70)	1.05 (0.48-1.55)	1.14 (0.60-1.65)	0.89 (0.49-1.40)	0.84 (0.42-1.25)	0.71 (0.23-1.10)	0.71 (0.23-1.14)	0.85 (0.45-1.30)
Substrate	S (T-C)	S (T-B)	-	S (T-C)	S (T-B)	-	S (L-B)	T (L-G)	S (T-B)	G (T-B)	G (T-B)	T (L-B)	S (L-B)	S (L-B)
Measured Chl <i>a</i> (mg/m ²)	50	283	-	191	12	-	6	45	7	35	32	44	64	189
Derived Chl <i>a</i> (mg/m ²)	219	249	-	198	19	-	1	238	1	2	6	82	486	295
Ratio of derived to measured Chl <i>a</i>	4.4	0.88	-	1.0	1.6	-	0.2	5.3	0.1	0.1	0.2	1.9	7.6	1.6
Days since 3Xmedian flow event	146	171	-	212	247	-	2	14	13	32	54	90	125	9

'-' = missing data.

B=Boulder, C=Cobble, G=Gravel, S=Sand, T=Silt, L=Clay.

Aquatic macrophytes occupied 50% or more of the channel cross-sectional area or volume (CAV) from February to June 2016 after which a scouring flow removed a large proportion of the biomass (Figure 3-20). At their peak in February they occupied nearly 90% of the watercolumn. After being flushed out in winter there was a steady increase in macrophyte occupation of the channel from August through to February. A flow event in early March 2017 reduced CAV in the final month of sampling. The dominant species present was the exotic submerged oxygen-weed, *Egeria densa*. A second submerged species, the curly-leaved pondweed, *Potamogeton crispus*, was also frequently present in low to moderate abundance. Emergent sprawling species, swamp willow weed (*Persicaria* spp.) and mercer grass (*Paspalum dischitum*) encroached from the margins from February to June.

Macrophytes occupied more than 50% of the channel water surface area (WSA) in February 2016 only (Figure 3-21). In February 2017 WSA was c. 30%. In other months during the main summer season (i.e., December to March) the percentage of the water surface occupied was usually c. 20-25%. From June to November this was reduced to $\leq 5\%$. Dominant species occupying the water surface were *Egeria densa*, *Azolla* spp., and/or *Persicaria* spp.

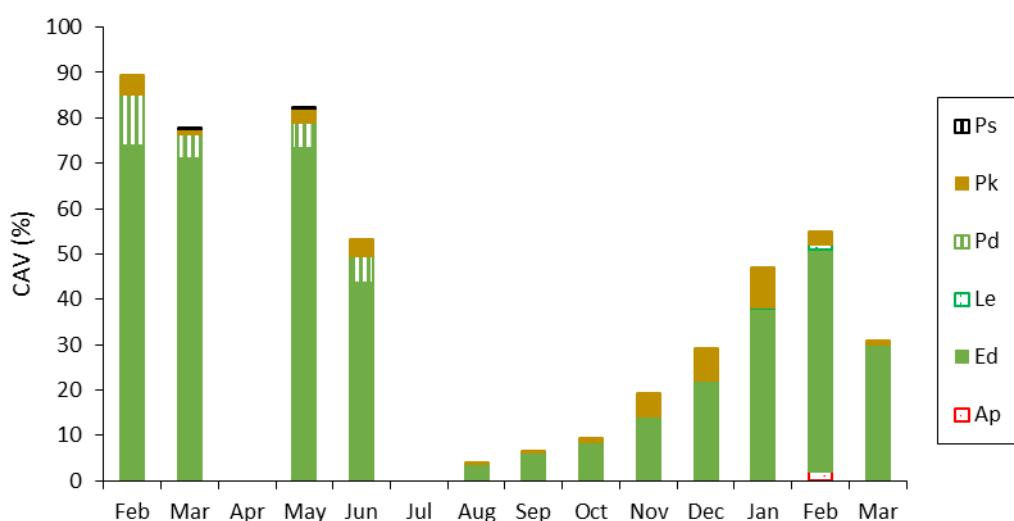


Figure 3-20: Piako River - Kiwitahi percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in April and July 2016. Solid bars indicate submerged species, striped bars show emergent species and dotted bars indicate floating species. Ed = *Egeria densa*, Le = *Lemna* spp., Pd = *Persicaria* spp., Pk = *Potamogeton crispus*. See Appendix A for underlying data including standard error values.

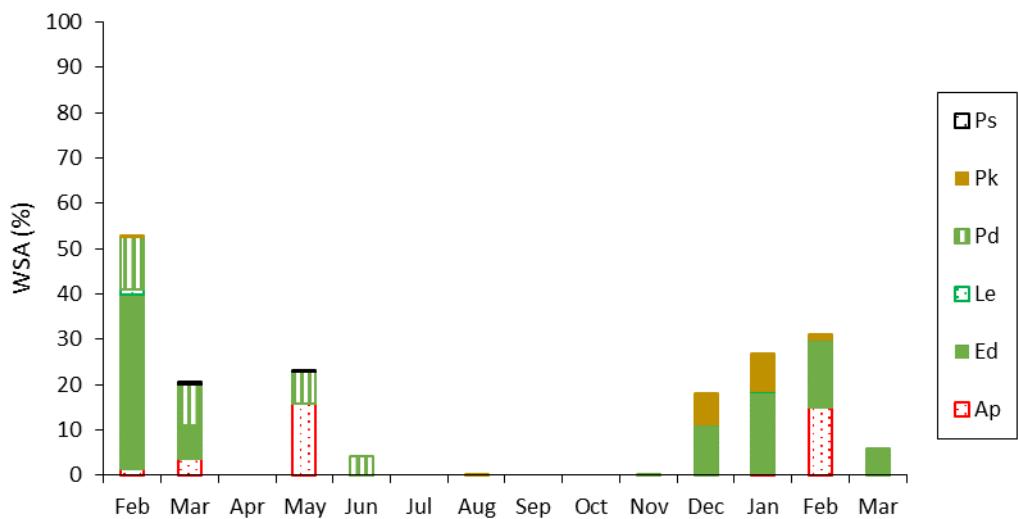


Figure 3-21: Piako River - Kiwitahi macrophyte percentage of channel water surface area (WSA) occupied by macrophytes on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in April and July 2016. Solid bars indicate surface-reaching submerged species, striped bars show emergent species and dotted bars indicate floating species. Ap = *Azolla* spp., Ed = *Egeria densa*, Le = *Lemna* spp., Pd = *Persicaria* spp., Pk = *Potamogeton crispus*, Ps = *Paspalum distichum*. See Appendix A for underlying data including standard error values.

We did not examine periphyton and macrophyte relationships with shade at this site as shade levels were negligible.

For the period from 1 February 2015 to 31 January 2017 median flow at this site was $0.63 \text{ m}^3/\text{s}$ and thus three times the median flow was $1.89 \text{ m}^3/\text{s}$. We did not find any significant relationships between the number of days since a flow greater than or equal to three times the median and periphyton biomass or cover. In contrast, we found a highly significant relationship between the number of days elapsed since a three times the median flow event and the percentage of the channel cross-sectional area or volume occupied by macrophytes (i.e., macrophyte CAV) (Figure 3-22). The relationship with the percentage of the channel water surface area occupied by macrophytes was not significant (data not shown). Periphyton chlorophyll *a* was positively correlated with macrophyte CAV but the relationship was not statistically significant ($p = 0.07$) (Figure 3-23).

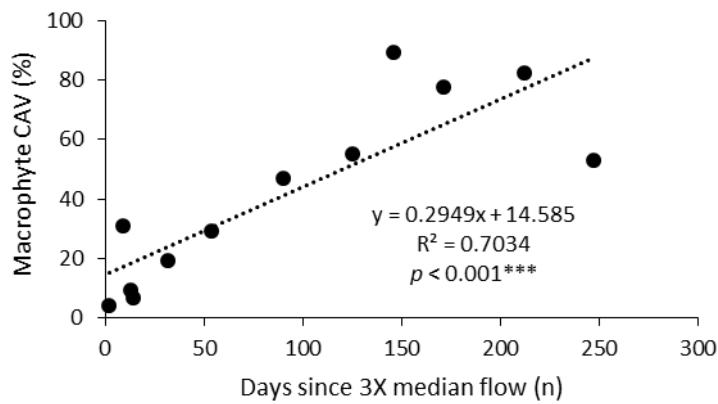


Figure 3-22: Percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes versus days since an event greater than or equal to three times the median flow at the Piako River - Kiwitahi site. Data shown corresponds to each monthly sampling event.

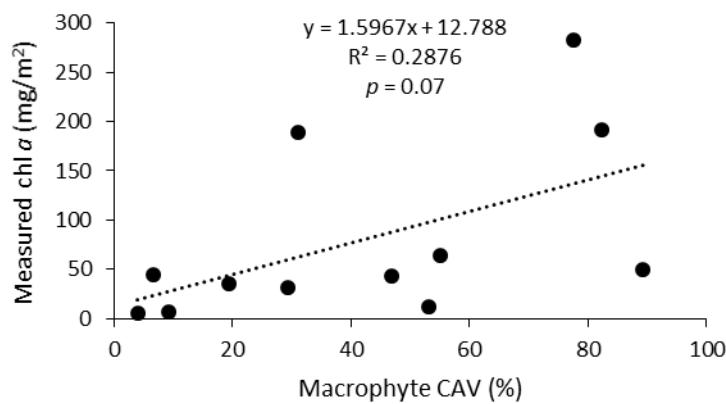


Figure 3-23: Measured periphyton biomass as chlorophyll α versus the percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes. Data shown corresponds to each monthly sampling event.

3.5 Piako River – Paeroa-Tahuna Rd

The Paeroa-Tahuna Rd (PT Rd) monitoring site was located c. 20 m downstream of the Regional Council monitoring station (Figure 3-24).



Figure 3-24: Piako River - Paeroa-Tahuna Rd site. View looking downstream from position on true right bank just upstream of first transect. Photo taken in December 2016 (Photo: F. Matheson).

The PT Rd site was monitored 12 times between 1 February 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed, usually by wading, but occasionally by snorkelling (Figure 3-25). The two months not sampled were May and July.

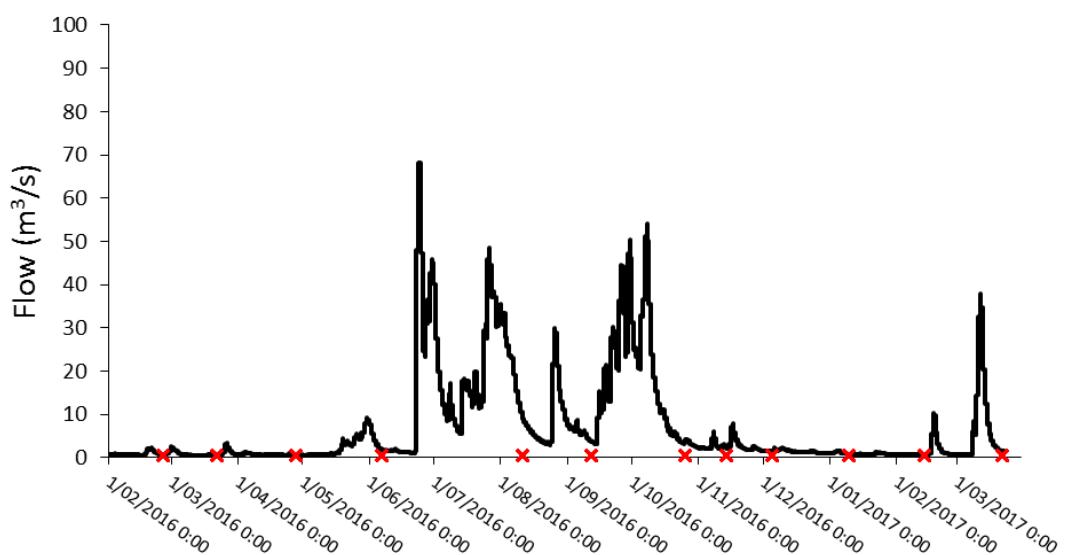


Figure 3-25: Piako River - Paeroa-Tahuna Rd flow from 1 February 2016 to 23 March 2017. Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

River wetted width at this site was c. 10 m. Average water depth on sampling dates ranged from 0.64 m in April to 1.59 m in August with an overall range of 0.09 m to 2.40 m (See Table 3-5 on following page). The substrate at the PT Rd site was predominantly sand or silt, with patches of gravel and compact clay. Average shading of the site was low and ranged from 0% in October and March 2017 to 9% in April.

At this site nuisance cover of periphyton as long filaments (i.e., >30%) was observed in March 2016 (green) and February 2017 (red), covering >50% of the available attachment surface (Figure 3-26). Non-nuisance cover of long green filaments and short filaments were present at other times in the period from February to June 2016 and in January 2017. The red algae, *Compsopogon* spp., was regularly encountered at this site. However, the green appearance of this algae meant that it was classified as long green filaments. During July to November, the period of extended high flows and low macrophyte abundance (see later), periphyton cover was negligible.

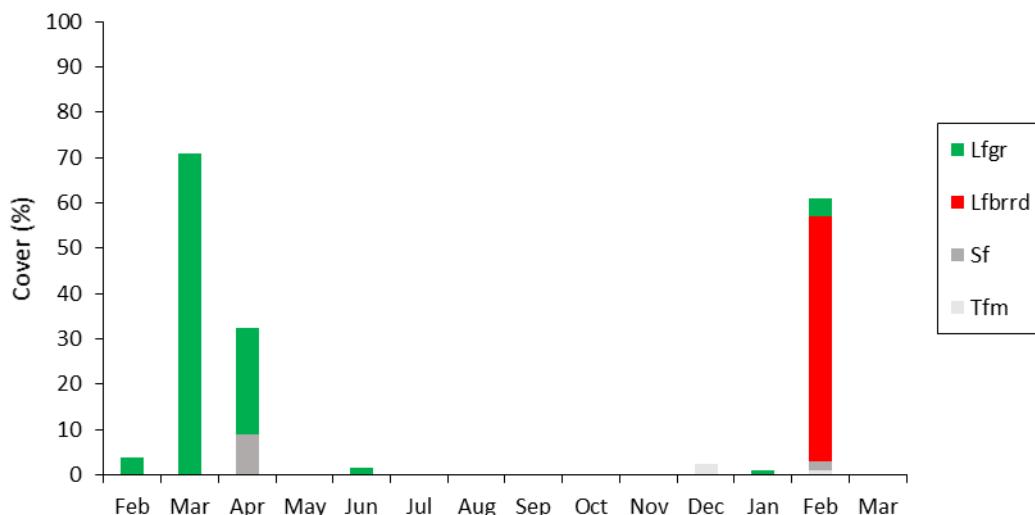


Figure 3-26: Piako River - Paeroa-Tahuna Rd periphyton cover on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in May and July 2016. Tfm = Thin film, Sf = Short filaments, Lfbrrd = Long filaments brown red, Lfgr = Long filaments green. See Appendix A for underlying data including standard error values.

Measured periphyton biomass at this site ranged from a low of 1 mg/m² in June to a very high nuisance level of 775 mg/m² in March 2016. There was evidence of a seasonal pattern at this site with low abundance during winter and peak abundances in late summer and early autumn. At this site measured chlorophyll *a* was significantly correlated with chlorophyll *a* derived from periphyton cover information using Kilroy et al. (2013) conversion factors (Figure 3-27). We also found a significant relationship between periphyton biomass and cover, which was virtually all in the form of long filaments (Figure 3-28).

Table 3-5: Piako River - Paeroa-Tahuna Rd monthly summary data for shade, water depth, substrate, chlorophyll *a* and days since an event greater than or equal to three times the median flow. Values are means with range in parentheses where applicable.

Parameter	Month													
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	4 (0-68)	8 (0-30)	9 (0-30)	-	3 (0-14)	-	-	-	0 (0-1)	-	1 (0-7)	3 (0-18)	4 (0-32)	0 (0-2)
Water depth (m)	0.87 (0.34-1.43)	0.83 (0.43-1.17)	0.64 (0.15-1.15)	-	1.07 (0.32-1.80)	-	1.59 (0.25-2.40)	1.14 (0.09-2.02)	1.22 (0.20-2.00)	1.10 (0.50-2.00)	0.96 (0.40-1.80)	0.82 (0.40-1.19)	0.82 (0.50-1.23)	1.01 (0.50-1.50)
Substrate	T (L-S)	S (L-S)	S (L-S)	-	T (L-S)	-	T (L-S)	T (L-S)	T (L-S)	T (L-S)	T (L-G)	T (L-S)	S (L-G)	T (L-S)
Measured Chl <i>a</i> (mg/m ²)	50	775	188	-	1	-	4	45	3	48	3	21	27	6
Derived Chl <i>a</i> (mg/m ²)	9	307	175	-	5	-	1	1	1	1	1	5	104	1
Ratio of derived to measured Chl <i>a</i>	0.2	0.4	0.9	-	5.0	-	0.3	<0.1	0.3	<0.1	0.3	0.2	3.9	0.2
Days since 3Xmedian flow event	89	114	151	-	5	-	0	3	6	24	18	54	89	6

'-' = missing data.

G=Gravel, S=Sand, T=Silt, L=Clay

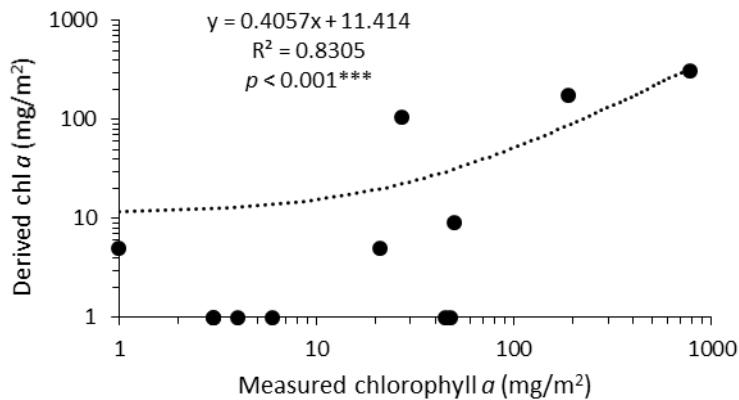


Figure 3-27: Derived versus measured periphyton biomass as chlorophyll *a* at the Piako River - Paeroa-Tahuna Rd site. Note log scale on x-axis. Derived chlorophyll *a* values were calculated from periphyton cover data using conversion factors of Kilroy et al. (2013).

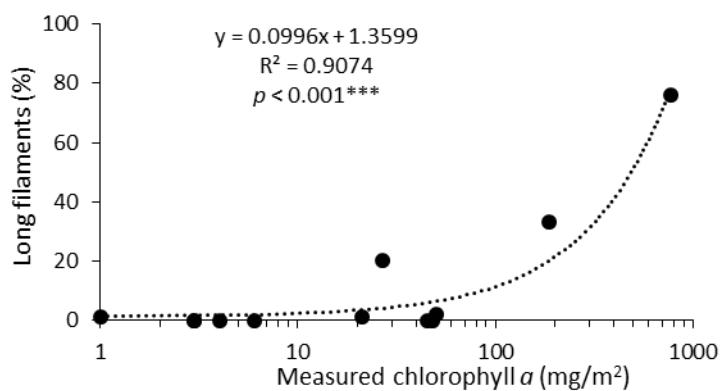


Figure 3-28: Cover of long filaments vs measured periphyton biomass as chlorophyll *a* at the Piako River - Paeroa-Tahuna Rd site. Note log scale on x-axis. Black dots represent monthly (cover) mean values for transect where chlorophyll *a* was sampled.

At their peak in February 2016 and 2017, aquatic macrophytes at the PT Rd site occupied c. 50-60% of the channel cross-sectional area or volume (Figure 3-29). In January 2016 and 2017 and from March to June 2016 the CAV was c. 35-45%. In early March 2017, an unseasonal storm event reduced macrophyte CAV to c. 20%. The most abundant species at this site were the exotic submerged plants, *Egeria densa*, *Ceratophyllum demersum* and *Potamogeton crispus*, and the native pondweed, *Potamogeton ochreatus*. The sprawling emergent, *Persicaria* spp., was also present in moderate abundance, especially in 2016, and also the native charophyte, *Nitella* aff. *cristata* in lower amounts. A number of these species were flushed out in the winter months but a very low abundance of *Persicaria* spp., *Egeria densa*, and *Potamogeton ochreatus* persisted. In addition to the above species, the sprawling emergents, parrots feather (*Myriophyllum aquaticum*) and gypsywort (*Lycopus europaeus*), and the oxygen weed, *Elodea canadensis*, were occasionally encountered during summer and/or early autumn. We observed that parrots feather was apparently spreading throughout this area of the river during this study.

Macrophytes never occupied more than 50% of the channel water surface area at this site (Figure 3-30). Maximum total WSA was 33% in March 2016 comprising mostly surface-reaching *Ceratophyllum demersum* and the two emergent species, *Persicaria* spp., and *Lycopus europaeus*. Very low WSA was occupied by macrophytes from August to December 2016, and in March 2017 after the storm event.

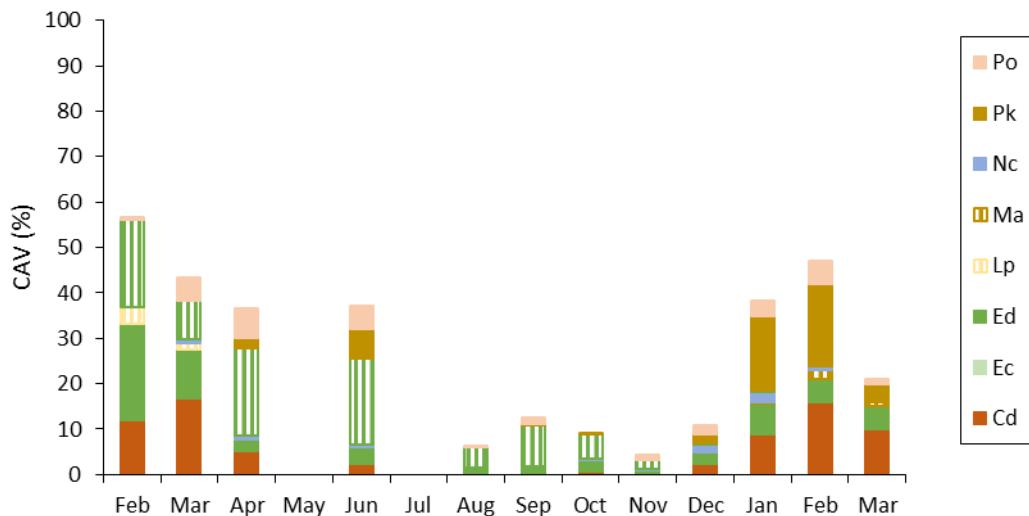


Figure 3-29: Piako River - Paeroa-Tahuna Rd percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes on monthly sampling dates from Feb 2016 to Jan 2017. Note that sampling did not occur in April and July 2016. Solid bars indicate submerged species and striped bars show emergent species. Cd = *Ceratophyllum demersum*, Ec = *Elodea canadensis*, Ed = *Egeria densa*, Lp = *Lycopus europaeus*, Ma = *Myriophyllum aquaticum*, Nc = *Nitella aff. cristata*, Pd = *Persicaria* spp., Pk = *Potamogeton crispus*, Po = *Potamogeton ochreatus*. See Appendix A for underlying data including standard error values.

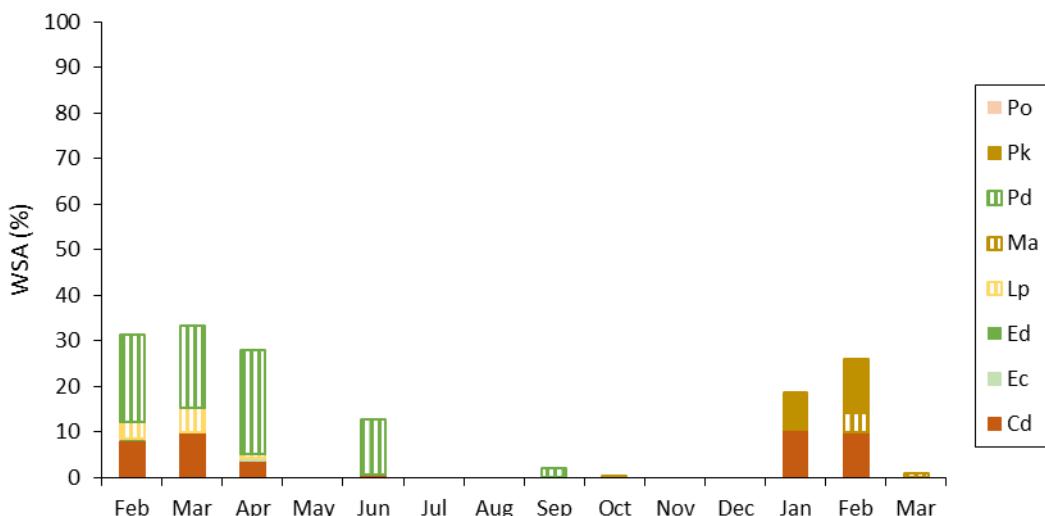


Figure 3-30: Piako River - Paeroa-Tahuna Rd percentage of channel water surface area (WSA) occupied by macrophytes on monthly sampling dates from Feb 2016 to Jan 2017. Note that sampling did not occur in May and July 2016. Solid bars indicate submerged species and striped bars show emergent species. Cd = *Ceratophyllum demersum*, Ec = *Elodea canadensis*, Ed = *Egeria densa*, Lp = *Lycopus europaeus*, Ma = *Myriophyllum aquaticum*, Pd = *Persicaria* spp., Pk = *Potamogeton crispus*, Po = *Potamogeton ochreatus*. See Appendix A for underlying data including standard error values.

We did not examine periphyton and macrophyte relationships with shade at this site due to the generally low levels of shading.

For the period from 1 February 2015 to 31 January 2017 median flow at this site was $2.03 \text{ m}^3/\text{s}$ and thus three times the median flow was $6.09 \text{ m}^3/\text{s}$. We found a significant positive correlation between the number of days since an event greater than or equal to three times the median flow and periphyton cover (as long filaments) (Figure 3-31) but not biomass. Relationships with the two macrophyte metrics were also significant, especially with WSA (Figure 3-31).

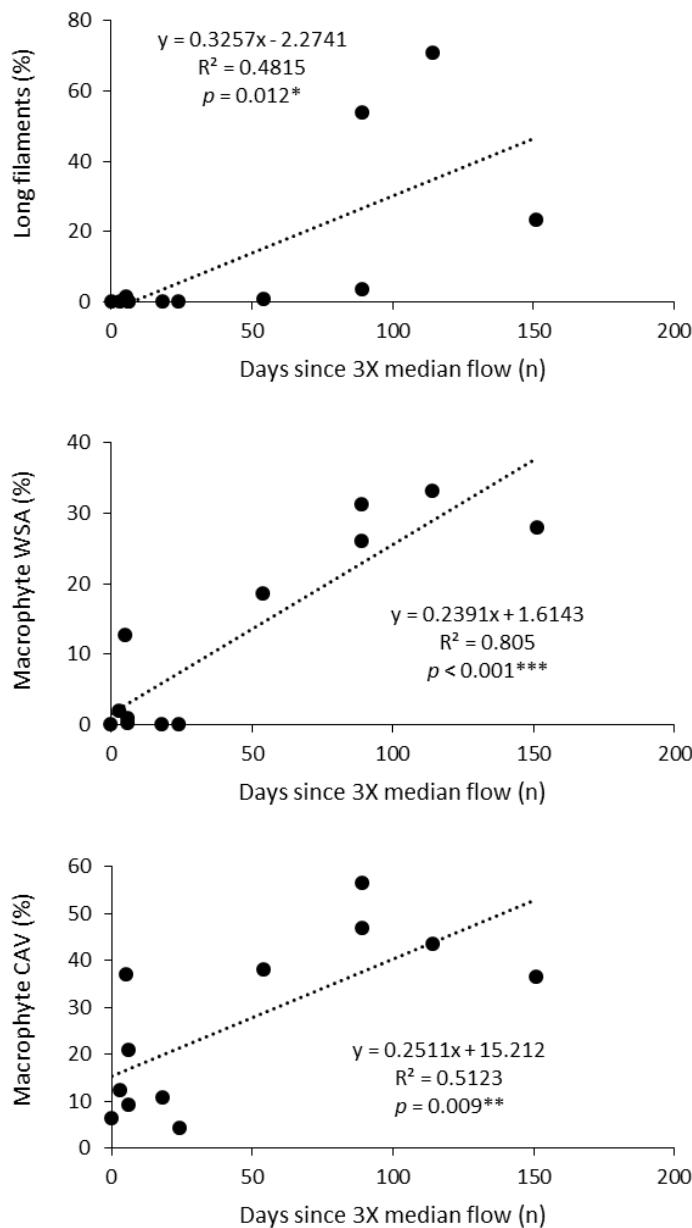


Figure 3-31: Periphyton and macrophyte metrics versus days since an event greater than or equal to three times the median flow at the Piako River - Paeroa-Tahuna Rd site. Data shown corresponds to each monthly sampling event.

3.6 Waihou River

The Waihou River monitoring site was located immediately downstream of the SH26 road bridge at Te Aroha (Figure 3-32).



Figure 3-32: Waihou River site. View looking upstream towards the upper transects from the true right bank. Photo taken in December 2016 (Photo: F. Matheson).

The Waihou River site was monitored nine times between 1 February 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed (Figure 3-33) by snorkelling from a small boat. The three months not sampled were June, August and January.

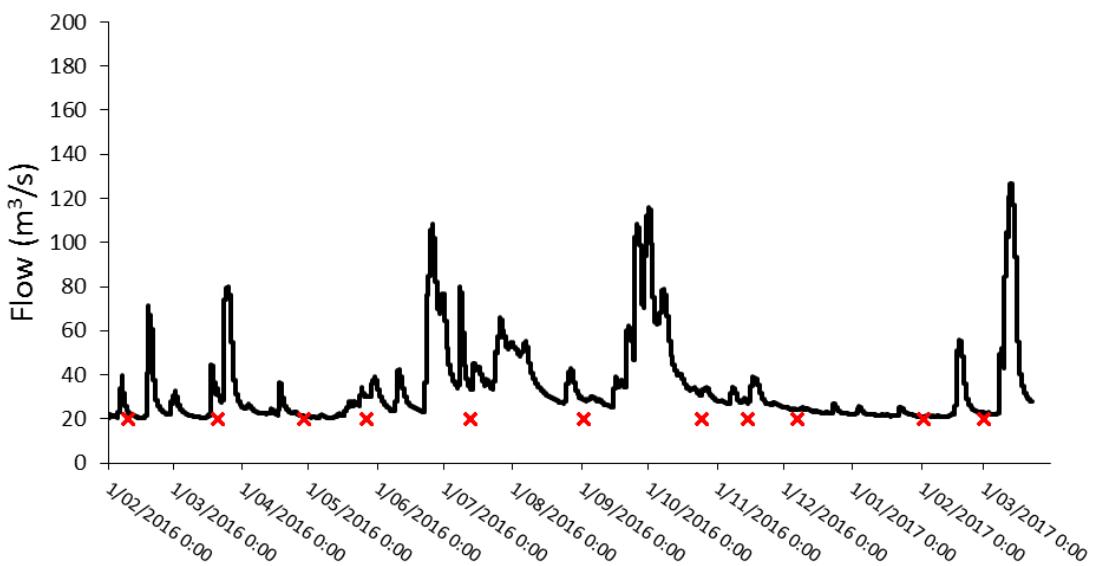


Figure 3-33: Waihou River flow from 1 February 2016 to 23 March 2017. Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

River wetted width at this site was c. 35 m. Average water depth on sampling dates ranged from 1.43 m in February 2017 to 2.53 m in August with an overall range of 0.50 m to 3.50 m (See Table 3-6 on following page). The substrate at this site was predominantly sand with silt on the margins and occasional patches of clay, gravel or boulder. Average shading of the site from ranged from 2 to 8%.

At this site obvious periphyton cover was observed only in February 2016 where we recorded an average 3% cover of long filaments and 1% cover of both thick black dark brown mats and thin films. In contrast, we were able to detect periphyton chlorophyll a in our biomass samples in all months, although it was frequently at very low levels. The highest periphyton biomass ($32\text{-}36 \text{ mg/m}^2$) was recorded in February (2016 and 2017).

Table 3-6: Waihou River monthly summary data for shade, water depth, substrate, chlorophyll a and days since an event greater than or equal to three times the median flow. Values are means with range in parentheses where applicable.

Parameter	Month													
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	7 (0-65)	8 (0-30)	4 (0-50)	3 (0-27)	-	2 (0-28)	-	2 (0-28)	4 (0-46)	2 (0-34)	3 (0-28)	-	3 (0-46)	3 (0-32)
Water depth (m)	1.66 (0.75- 2.80)	1.84 (0.95- 2.60)	1.50 (0.50- 2.70)	1.90 (1.05- 2.75)	-	2.53 (1.12- 3.50)	-	1.61 (0.75- 3.15)	1.77 (0.61- 3.15)	1.59 (0.75- 3.20)	1.52 (0.50- 3.10)	-	1.43 (0.51- 3.00)	1.49 (0.79- 2.80)
Substrate	S (T-G)	S (T-S)	S (T-S)	S (T-S)	-	S (L-S)	-	S (T-B)	S (T-B)	S (T-B)	S (S-B)	-	S (S-S)	S (S-G)
Measured Chl <i>a</i> (mg/m ²)	32	2	22	1	-	8	-	4	10	10	2	-	36	13
Derived Chl <i>a</i> (mg/m ²)	14	1	1	1	-	1	-	1	1	1	1	-	1	1
Ratio of derived to measured Chl <i>a</i>	0.4	0.5	<0.1	1.0	-	0.1	-	0.3	0.1	0.1	0.5	-	<0.1	0.1
Days since 3Xmedian flow event	157	197	33	61	-	5	-	56	17	38	60	-	117	145

'-' = missing data.

B = Boulder, G=Gravel, S=Sand, T=Silt, L=Clay.

Only four species of macrophyte were detected at the Waihou river site: three exotic species, *Ceratophyllum demersum*, *Elodea canadensis* and *Potamogeton crispus*, and the native charophyte *Nitella aff. cristata*. At their peak in February 2016 they occupied 16% of the channel cross-sectional area or volume (CAV) and <5% of the channel water surface area (WSA). They were barely detectable from July to December.

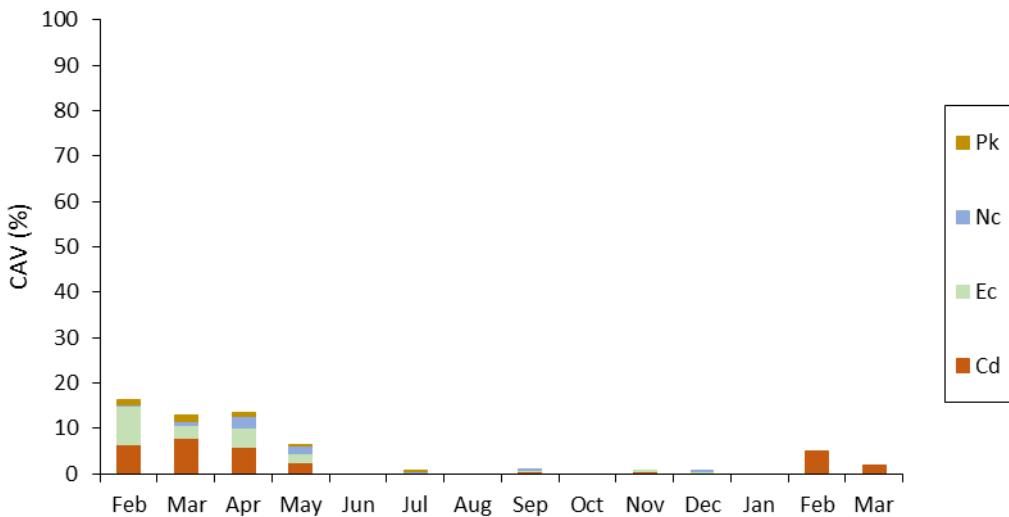


Figure 3-34: Waihou River percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in June and August 2016, and January 2017. Cd = *Ceratophyllum demersum*, Ec = *Elodea canadensis*, Nc = *Nitella aff. cristata*, Pk = *Potamogeton crispus*. See Appendix A for underlying data including standard error values.

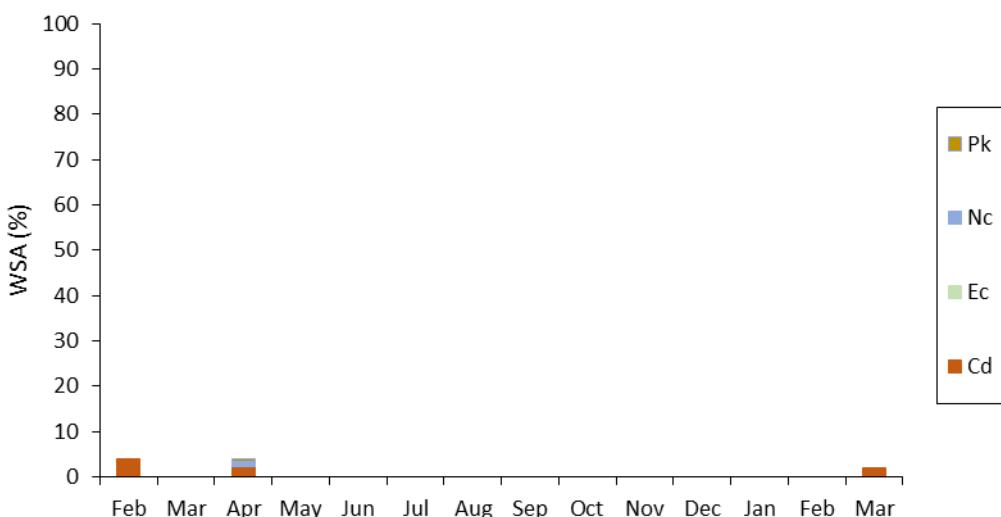


Figure 3-35: Waihou River percentage of channel water surface area (WSA) by macrophytes on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in June and August 2016, and January 2017. Cd = *Ceratophyllum demersum*, Ec = *Elodea canadensis*, Nc = *Nitella aff. cristata*, Pk = *Potamogeton crispus*. See Appendix A for underlying data including standard error values.

We did not examine periphyton and macrophyte relationships with shade at this site due to the generally low levels of shading.

For the two-year period from 1 February 2015 to 31 January 2017 median flow at this site was 26.2 m³/s and thus three times the median flow was 78.7 m³/s. We found a strong positive correlation between the number of days since an event greater than or equal to three times the median flow and macrophyte CAV (Figure 3-36), but not periphyton biomass or cover, or macrophyte WSA.

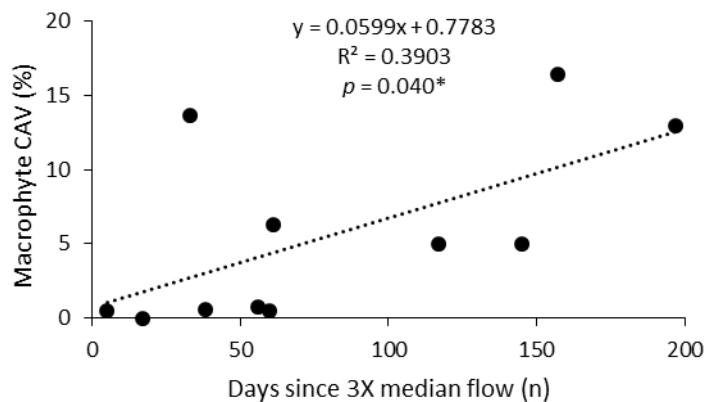


Figure 3-36: Percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes versus days since an event greater than or equal to three times the median flow at the Waikato River site. Data shown corresponds to each monthly sampling event.

3.7 Waitoa River

The Waitoa River monitoring site was located c. 50 m downstream of the Regional Council's flow monitoring station (Figure 3-37).



Figure 3-37: Waitoa River site. View looking downstream from true left bank. The most upstream transect is located c. 20 m above small tree visible on true right bank. Photo taken in December 2016 (Photo: F. Matheson).

The Waitoa River site was monitored nine times between 1 February 2016 and 31 March 2017 on a monthly basis as river flow conditions allowed (Figure 3-38), by wading and, occasionally, by snorkelling. The three months not sampled were April, July and September.

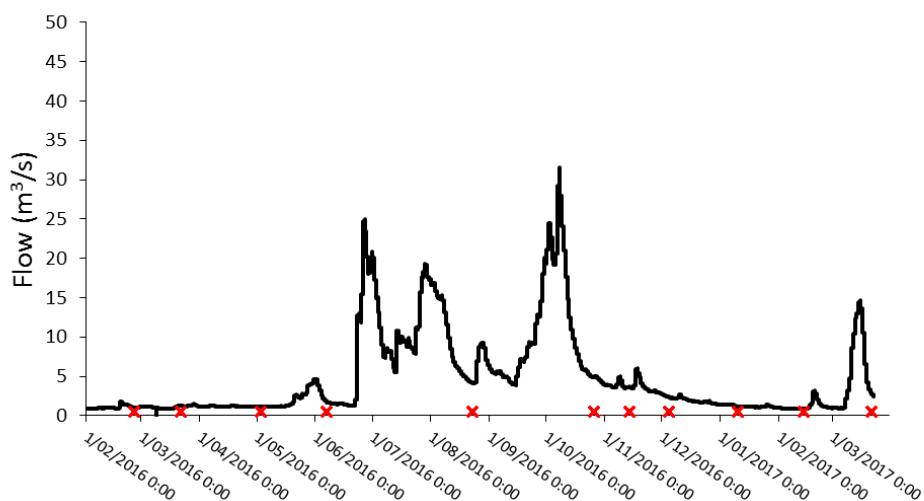


Figure 3-38: Waitoa River flow from 1 February 2016 to 23 March 2017. Flow data from Waikato Regional Council. Sampling dates are marked with a red cross.

River wetted width at this site was c. 9 m. Average water depth on sampling dates ranged from 0.74 m in January to 1.12 m in October with an overall range of 0.18 m to 1.80 m (See Table 3-7 on following page). The substrate at this site was predominantly sand. Patches of compact clay, silt gravel and boulder were also often encountered. Average shading of the site from riparian vegetation was low and ranged from 0 to 9%.

At this site a nuisance cover of periphyton, as predominantly long green filaments (i.e., >30%), was observed in March 2016 and February 2017, covering >40% of the available attachment surface (Figure 3-39). Non-nuisance covers of long green and, occasionally, brown/red filaments were present at other times during the summer, autumn and early winter months. The red algae, *Compsopogon* spp., was regularly encountered at this site. The green appearance of this algae meant that it was classified as long green filaments.

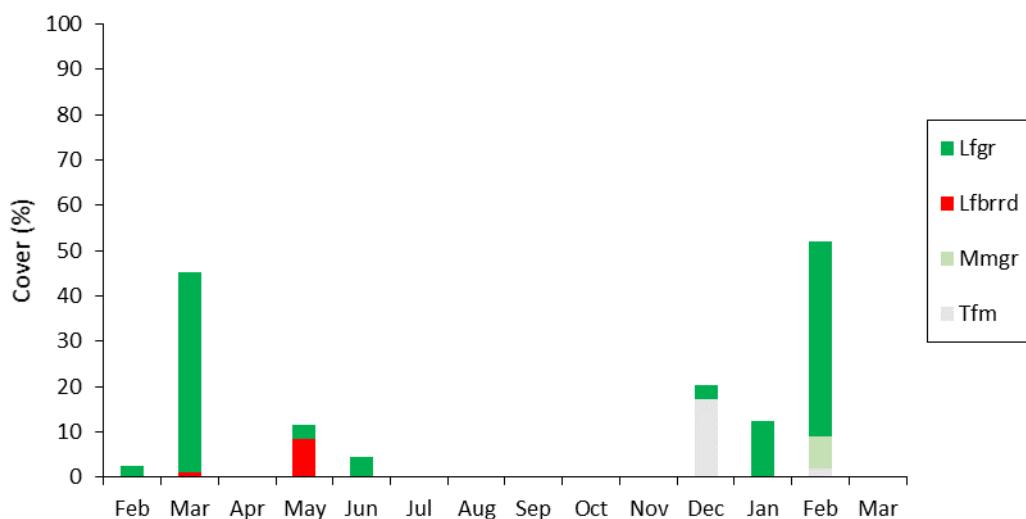


Figure 3-39: Waitoa River periphyton cover on monthly sampling dates from February 2016 to March 2017.
Note that sampling did not occur in April, July and September. Tfm = Thin film, Lfbrrd = Long filaments brown/red, Lfgr = Long filaments green. See Appendix A for underlying data including standard error values.

Periphyton biomass at this site ranged from a low of 2 mg/m² in June to a very high nuisance level of 558 mg/m² in March 2016 (Table 3-7). There was evidence of a seasonal pattern at this site with low abundance during winter and peak abundances in early autumn. At this site, we found that measured and derived periphyton biomass were significantly correlated but derived values were always lower than measured values. We also found a significant relationship between periphyton biomass and cover, the latter occurring predominantly as long filaments (Figure 3-41).

Table 3-7: Waitoa River monthly summary data for shade, water depth, substrate, chlorophyll *a* and days since an event greater than or equal to three times median flow. Values are means with range in parentheses where applicable.

Parameter	Month													
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Shade (%)	6 (0-47)	9 (0-45)	-	4 (0-20)	1 (0-3)	-	-	-	0 (0-6)	-	-	2 (0-23)	0 (0-3)	0 (0-0)
Water depth (m)	0.81 (0.18-1.34)	0.79 (0.40-1.34)	-	0.83 (0.29-1.40)	1.05 (0.54-1.60)	-	1.06 (0.19-1.60)	-	1.12 (0.60-1.75)	1.09 (0.70-1.60)	0.86 (0.40-1.45)	0.74 (0.34-1.48)	0.79 (0.35-1.26)	1.04 (0.55-1.80)
Substrate	S (S-S)	S (L-S)	-	S (T-S)	S (T-C)	-	S (L-S)	-	S (T-B)	G (S-B)	G (S-B)	T (L-S)	G (S-B)	S (L-C)
Measured Chl <i>a</i> (mg/m ²)	-	558	-	70	6	-	2	-	6	21	79	37	167	16
Derived Chl <i>a</i> (mg/m ²)	5	244	-	45	5	-	1	-	1	1	25	34	162	1
Ratio of derived to measured Chl <i>a</i>	-	0.5	-	0.6	0.8	-	0.5	-	0.2	<0.1	0.3	0.9	1.0	0.2
Days since 3Xmedian flow event	150	175	-	227	262	-	9	-	7	26	47	83	118	4

'-' = missing data, February measured chlorophyll *a* data missing due to laboratory analytical error

B=Boulder, C=Cobble, G=Gravel, S=Sand, T=Silt, L=Clay

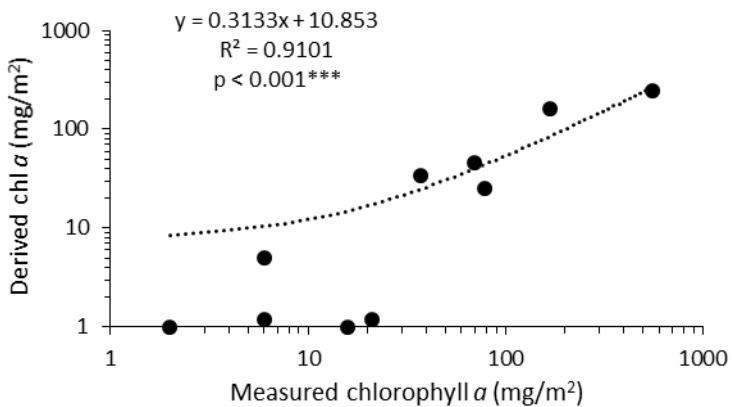


Figure 3-40: Derived versus measured periphyton biomass as chlorophyll α at the Waitoa River site.

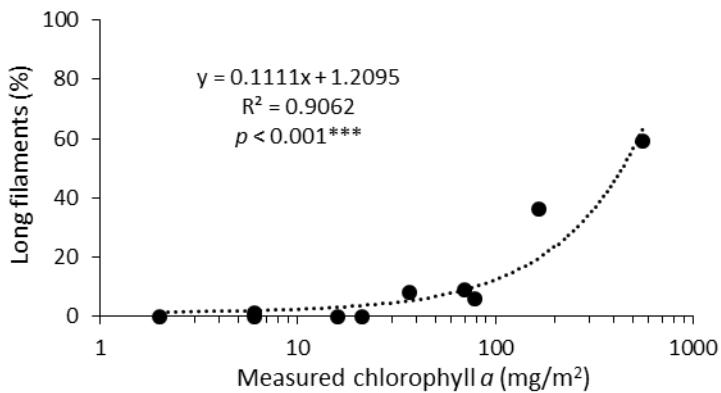


Figure 3-41: Cover of long filaments versus measured periphyton biomass as chlorophyll α at the Waitoa River site. Black dots represent monthly (cover) mean values for the transect where biomass (chlorophyll α) was sampled.

At their peak in February 2016, aquatic macrophytes occupied c. 60% of the river channel cross-sectional area or volume (Figure 3-42) and c. 40% of the water surface area (Figure 3-43). Through to June, macrophyte CAV and WSA remained relatively high; however by August CAV had been reduced to <10% and WSA to <5%. In summer 2017 the peak abundance was lower than the previous year (28% CAV, 10% WSA). This is linked to a higher frequency of flushing flows in summer 2017 (see Figure 3-44 below). The dominant species at all times were the marginal emergent species, reed canary grass (*Phalaris arundinacea*) and the submerged species, *Egeria densa* and *Potamogeton crispus*. Other species that were periodically present at moderate abundance were hornwort (*Ceratophyllum demersum*), duckweed (*Lemna* spp.,) and water pepper (*Persicaria* spp.).

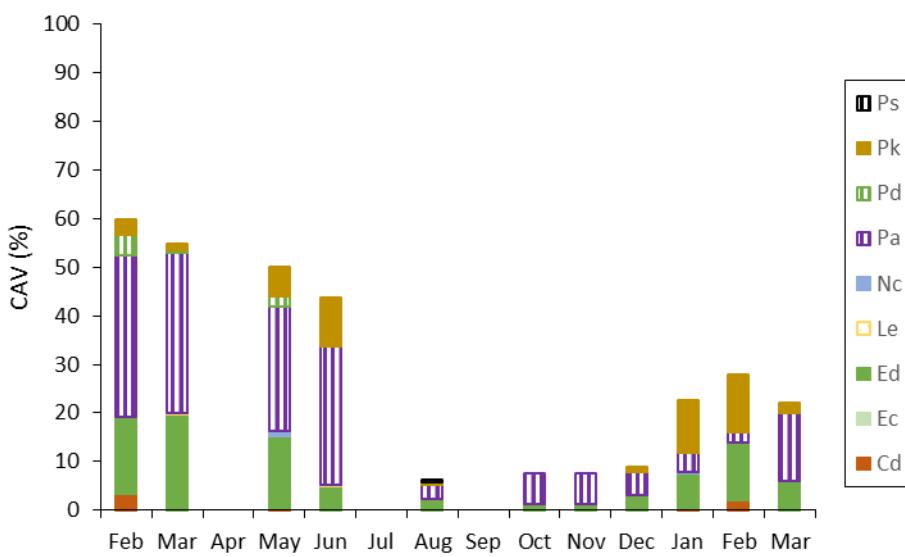


Figure 3-42: Waitoa River percentage of channel cross-sectional area or volume (CAV) occupied by macrophytes on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in April, July and September 2016. Cd = *Ceratophyllum demersum*, Ed = *Egeria densa*, Nc = *Nitella aff. cristata*, Pa = *Phalaris arundinacea*, Pd = *Persicaria* spp., Pk = *Potamogeton crispus*, Ps = *Paspalum dischitum*. See Appendix A for underlying data including standard error values.

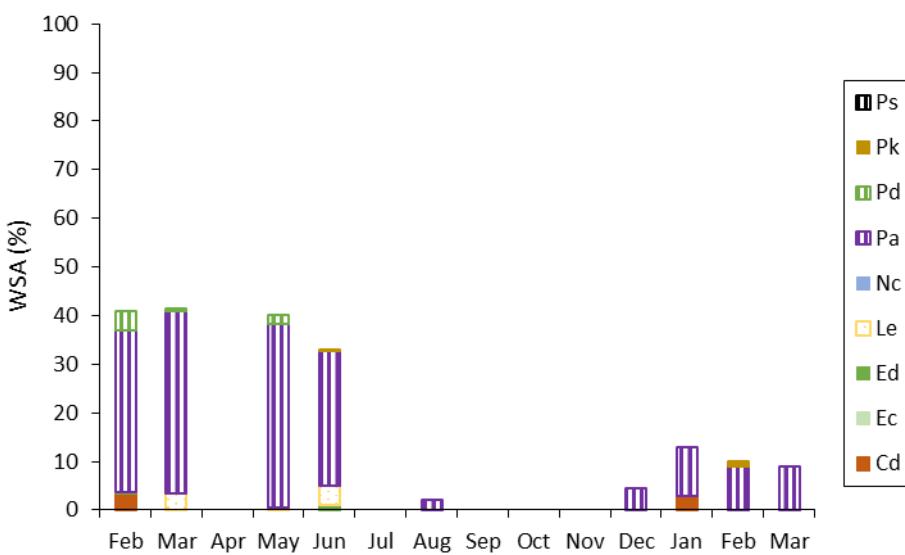


Figure 3-43: Waitoa River percentage of channel water surface area (WSA) occupied by macrophytes on monthly sampling dates from February 2016 to March 2017. Note that sampling did not occur in April, July and September 2016. Cd = *Ceratophyllum demersum*, Ed = *Egeria densa*, Le = *Lemna* spp., Nc = *Nitella aff. cristata*, Pa = *Phalaris arundinacea*, Pd = *Persicaria* spp., Pk = *Potamogeton crispus*, Ps = *Paspalum dischitum*. See Appendix A for underlying data including standard error values.

We did not examine periphyton and macrophyte relationships with shade at this site as shading of the channel was minimal.

For the two-year period from 1 February 2015 to 31 January 2017 median flow at this site was 2.23 m³/s and thus three times the median flow was 6.69 m³/s. We found a strong positive correlation between the number of days since an event greater than or equal to three times the median flow and macrophyte CAV and WSA, (Figure 3-44) but not periphyton biomass or cover.

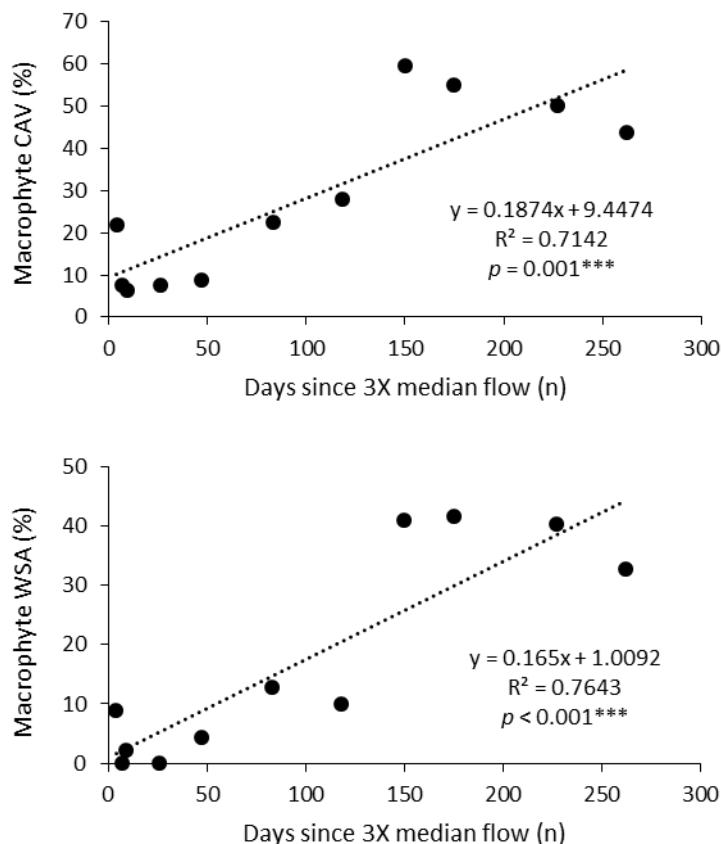


Figure 3-44: Percentage of channel cross-sectional area or volume (CAV) or water surface area (WSA) occupied by macrophytes versus days since an event greater than or equal to three times the median flow at the Waitoa River site. Data shown corresponds to each monthly sampling event.

4 Discussion

4.1 Provisional NOF periphyton attribute states

The National Objectives Framework requires monthly periphyton biomass data (as chlorophyll *a*) at a site for a 3-year period before an attribute state can be defined (MfE 2015). This longer-term monitoring requirement allows for expected inter-annual variation in river flows, because river-flow variability, and in particular flood frequency, is one of the major determinants of periphyton standing crop at any particular time. This study has monitored periphyton at seven Hauraki-Coromandel sites for a period of only just over one year, hence only a provisional attribute state can be assigned at this stage. We have done this on the basis of the first 12 months of data collected for each site.

All of the sites in this study, except Piako - PT Road, sit within the ‘default’ river classes of the periphyton attribute so to be assigned to a band the site must not exceed the numeric criteria for this band more than 8% of the time. In the ‘productive’ river classes (i.e., River Environment Classification WDSS, CDSS, WDVA, CDVA, WDVB and CDVB, where WD = Warm Dry, CD = Cool Dry, SS = Soft Sedimentary, VA = Volcanic Acidic and VB = Volcanic Basic) this frequency of exceedance criterion relaxes to 17%. Our 14-month dataset had some missing values, particularly during the autumn and winter months when flow conditions made it difficult to find a window of opportunity for sampling, so we used interpolation between measured data points to fill these gaps in a systematic manner (Table 4-1).

Table 4-1: Periphyton biomass data for Hauraki-Coromandel rivers showing interpolated missing values. Interpolated values are shown in parentheses.

Site	2016												2017		
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Kauaeranga	15	21	8	(16)	23	6	21	23	17	2	25	15	26	2	
Ohinemuri	30	84	50	45	(23)	1	4	7	36	27	78	(54)	67	275	
Waiwawa	-	-	10	(14)	17	6	46	17	15	19	15	56	49	1	
Kiwitahi	50	283	(237)	191	12	9	6	45	7	35	32	44	64	189	
PT Rd	50	775	188	(95)	1	(3)	4	45	3	48	3	21	27	6	
Waihou	32	2	22	1	(5)	8	(6)	4	10	10	2	(17)	36	13	
Waitoa	-	558	(314)	70	6	(4)	2	(4)	6	21	79	37	167	16	

The provisional periphyton attribute states assigned to the rivers show that two sites (Piako River at Kiwitahi, and Waitoa River) currently lie within the D band, i.e., below the national bottom line for this attribute (Table 4-2). There is some uncertainty about these assignments as one of the two high chlorophyll *a* values that placed these sites in the D band, as opposed to the C band, have been interpolated. The Piako-PT Rd site currently sits within the B band. As the only site with a productive river class assignment, there would need to be three monthly samples exceeding the 120 mg/m² chlorophyll *a* threshold to place the Piako PT Rd site within the C band. The Waihou River site sits within the A band but this result likely reflects light limitation and a lack of suitable attachment surface for periphyton at this site, rather than negligible nutrient enrichment. This site had deep, usually turbid, water, a predominantly mobile sand bed, and macrophytes restricted to a narrow band on channel margins.

Table 4-2: Provisional periphyton attribute states assigned to Hauraki-Coromandel rivers.

Site	REC climate/ geology	Band	Provisional periphyton attribute state	
			Numeric state	Narrative state
Kauaeranga at Smiths Cableway	WW/VA	A	$\leq 50 \text{ mg/m}^2$, exceeded no more than 8% of time	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.
Ohinemuri at Karangahake	WW/VA	B	$>50 \text{ and } \leq 120 \text{ mg/m}^2$, exceeded no more than 8% of time	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat.
Waiwawa at Rangihau Rd	WW/VA	A	$\leq 50 \text{ mg/m}^2$, exceeded no more than 8% of time	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.
Piako at Kiwitahi	WW/VA	D	$>200 \text{ mg/m}^2$, exceeded more than 8% of time	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.
Piako at Paeroa-Tahuna Rd	WD/VA	B	$>50 \text{ and } \leq 120 \text{ mg/m}^2$, exceeded no more than 16% of time	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat.
Waihou at Te Aroha	WW/SS	A	$\leq 50 \text{ mg/m}^2$, exceeded no more than 8% of time	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.
Waitoa at Mellon Rd	WW/SS	D	$>200 \text{ mg/m}^2$, exceeded more than 8% of time	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.

4.2 Substituting cover for biomass

The NOF requires that periphyton is monitored as biomass (chlorophyll *a*). However, the periphyton monitoring programmes of a number of Regional Councils, including Waikato, have formerly focused on visual assessments of periphyton cover. We have measured these two metrics simultaneously in this study to determine whether a significant correlation exists and, consequently, whether it might be possible to convert periphyton cover to biomass in a robust manner. We have also evaluated the cover to chlorophyll *a* conversion factors derived from Canterbury waterways by Kilroy et al. (2013) for potential application in Hauraki-Coromandel rivers.

At the three hard-bottom river sites in this study (Kauaeranga, Ohinemuri and Waiwawa), we did not find a significant relationship between measured biomass and cover, and between measured and derived biomass, likely because periphyton biomass and cover levels at these sites were usually low. At the four soft-bottom sites, with a broader range of periphyton abundance, both as biomass and cover, we did find significant relationships. Combining the data from all seven sites, periphyton biomass was most strongly (and significantly) related to the weighted composite cover of nuisance periphyton (i.e., cover of long filaments plus [cover of thick mats/2]), and secondly, with the cover of long filaments (Figure 4-1, top two panels). We also found a significant relationship between measured and derived biomass (Figure 4-1, lower panel). These relationships could potentially be used to estimate periphyton biomass from visual assessment data in the Hauraki-Coromandel rivers. However, we caution that there was considerable scatter in these datasets, and that these relationships were driven by data from soft-bottom sites where a much broader range of periphyton abundance (cover and biomass) occurred. It is therefore likely that these relationships would only provide a crude approximation of biomass at quite a coarse scale.

Furthermore, undertaking periphyton cover assessments across five transects would likely take longer than collecting biomass samples from a single transect. Therefore it may be more cost-effective to collect biomass samples only. Sampling for this study took c. 1.5 to 2 h per site, sometimes a little longer under challenging flow conditions, but this also included visual assessment of macrophytes. We estimate that sampling for periphyton biomass on a single transect alone would take c. 0.5 h per site, and undertaking visual assessments of periphyton cover alone at five transects would take 0.5 to 1 h per site. The downside of the former approach is that biomass measurements alone provide no information about the types of periphyton that are present (see Kilroy et al. 2013 for further discussion of this point). Moreover, collecting periphyton biomass samples over multiple transects would be preferable to collecting samples from a single transect only (C. Kilroy, pers. comm.). Visual assessment of macrophytes is also very informative, particularly in soft-bottom rivers where they form the primary attachment surface for periphyton, can be a nuisance in their own right, but can also provide important habitat at low to moderate abundance.

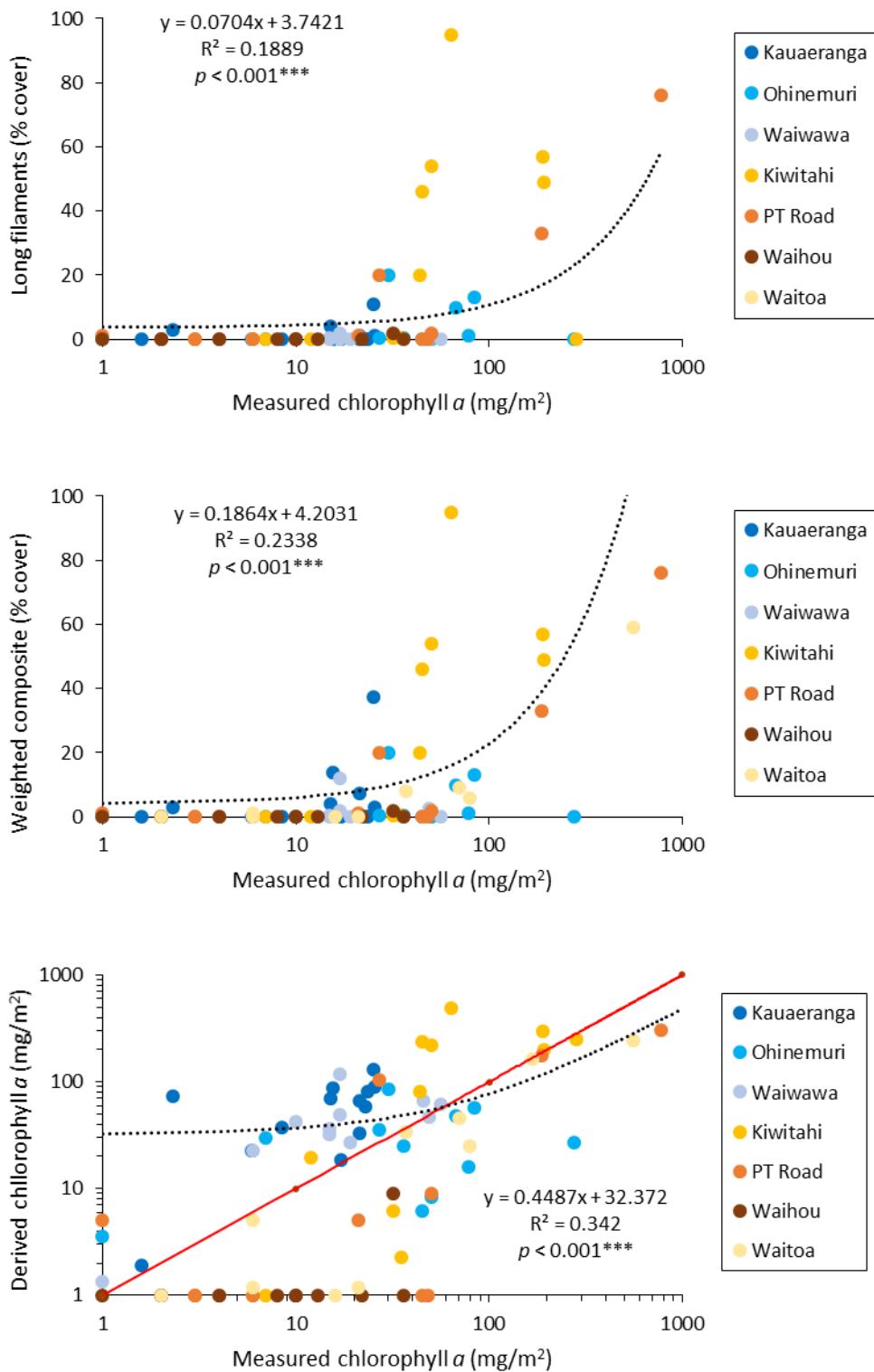


Figure 4-1: Relationships between measured periphyton biomass and cover, and measured and derived periphyton biomass, in Hauraki-Coromandel rivers. Axes are log scale. The dashed line and equation indicates the linear regression for all data points. The red line shows the ideal 1:1 relationship between measured and derived chlorophyll *a*.

4.3 Options to manage D band sites

The NOF requires that rivers with a periphyton attribute state below the national bottom line require remedial action. Primary drivers of periphyton abundance in rivers are flow, light, nutrients, temperature and invertebrate grazing. Larger (and more frequent) flood events and grazing increase periphyton losses, while increased light, nutrient availability and temperature favour periphyton accrual. In general, it is unlikely that invertebrate grazing could be feasibly manipulated to control periphyton in these, or other, river systems. In these un-regulated Hauraki-Coromandel rivers it is also unlikely that flow could be manipulated to “flush out” periphyton at high-risk periods.

The two sites most at risk of being assigned a D band periphyton attribute state, Piako at Kiwitahi and Waitoa at Mellon Rd are amongst those that are most nutrient-enriched (Vant 2016). This suggests that reducing nutrient concentrations in these rivers could reduce periphyton abundance and thus lift these sites above the national bottom line. However, it would likely be very difficult to reduce water column nutrients in these rivers to levels which would be expected to limit periphyton growth, i.e., <40-100 µg/L DIN and <15-30 µg/L DRP in general terms (MfE 1992) or at least <295 µg/L DIN and <26 µg/L DRP where days of accrual are less than 20 (see MfE 2000 for [lower] nutrient limiting criteria associated with longer accrual period scenarios). These two rivers lie in catchments that are highly modified by productive land use.

The most feasible option to bring about a reduction in nuisance periphyton abundance at the three high risk sites identified in this study is riparian shading. At present all of these sites have negligible shade. Results from the three hard-bottom sites, all of which had a substantial riparian canopy, clearly showed that nuisance periphyton (i.e., long filaments and thick mats) only occurred where shading was less than c. 60%. At these sites, where the typical channel width was greater than 30 m, high levels of shade were prevalent along the margins, particularly on the most northerly bank, due to the influence of the riparian canopy.

At the Piako and Waitoa river sites channel width was only c. 9-10 m so it is possible that a high degree of shading could be achieved across a moderate proportion of the channel width at these sites. Modelling with sWAIORA suggests that with active native tree planting, streams of 6.6 and 14 m width could ultimately achieve shading >90% and >60%, respectively (Davies-Colley et al. 2009). The planting of riparian margins to create shade also brings a number of potential co-benefits including lower water temperatures, provision of more diverse stream habitat and carbon resource to support the food-web through enhanced leaf and wood inputs, improved aesthetic appeal of waterways. Enhanced interception and trapping of sediment and nutrient contaminants from adjacent land by riparian trees and shade-tolerant understorey, might also be possible. A recent synthesis of existing information also suggests that riparian shading >70% would likely be effective at reducing the abundance of instream macrophytes to levels likely to improve the dissolved oxygen status of impacted lowland NZ rivers (Matheson et al. 2017).

A potential downside of riparian shading to reduce periphyton (and macrophyte) abundance is less nutrient uptake from river water during the spring and summer growing season (Quinn et al. 1997, Matheson et al. 2011, 2012b, Howard-Williams & Pickmere 1999, 2010). However, instream uptake by periphyton and macrophytes may exert no influence where nutrient concentrations are high (O'Brien et al. 2014). Moreover, this could be offset by enhanced interception and transformation of nutrients from land runoff by the reinstated riparian vegetation (McKergow et al. 2016) used to create shade and, potentially, by reduced release of phosphorus from river sediments. The latter is hypothesised to occur under anoxic conditions and high pH associated with prolific growth of

macrophytes in unshaded channels (Matheson et al. 2017). Furthermore, nutrient uptake by periphyton (and macrophytes) is a generally regarded as a temporary sink for nutrients, as seasonal dieback of plants re-releases the assimilated nutrients, although a small proportion may be converted into refractory (i.e., biologically unavailable) forms.

5 Conclusions

Periphyton and macrophyte monitoring in seven Hauraki-Coromandel rivers for a period of 14 months has shown the following:

- Two of the four soft-bottom river sites monitored (Piako – Kiwitahi and Waitoa) have a provisional NOF periphyton attribute state below the national bottom line and a third river site (Piako – Paeroa-Tahuna Rd) has a B band assignment.
- These sites also have nuisance macrophytes occupying more than 50% of the channel cross-sectional area or volume (and up to 90%) during the summer-autumn period which exceeds provisional guidelines to protect aesthetic, angling, ecological condition and flow conveyance values (Matheson et al. 2012a, 2016).
- At these soft-bottom sites, macrophyte abundance was strongly correlated with the number of days since a flushing flow event equivalent to three times the median flow or higher, so the risk of nuisance abundance will be elevated in dry summers.
- The most promising approach to reduce periphyton biomass and nuisance macrophyte abundance at these sites is riparian planting to produce shading >60% across a large proportion of the channel. There are also a number of significant co-benefits of this approach.
- The three hard-bottom river sites monitored (Kauaeranga, Ohinemuri and Waiwawa) and the fourth soft-bottom river site (Waihou) have provisional NOF periphyton attribute states in the A and B bands.
- While, overall, we found that periphyton biomass was significantly correlated with several periphyton cover metrics and with biomass estimates derived from cover data using conversion factors derived for Canterbury streams, considerable scatter in the dataset and the strong influence of wide-ranging data from the soft-bottom sites, means it is likely that these relationships would only provide a crude approximation of biomass at quite a coarse scale.

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7 Glossary of abbreviations and terms

Attribute	According to the NPS-FM this is defined as: a measurable characteristic of fresh water, including physical, chemical and biological properties, which supports particular value.
Macrophyte	A macrophyte is an aquatic plant that grows in or near water and is either emergent, submerged, or floating.
CAV	Channel cross-sectional area or volume (as in the percentage of CAV occupied by macrophytes).
NOF	National Objectives Framework.
NPS-FM	National Policy Statement for Freshwater Management (2014).
Periphyton	Periphyton refers to communities of algae in aquatic systems that are attached to the sediment surface or to aquatic, macrophyte vegetation.
WRC	Waikato Regional Council.
WSA	Channel water surface area (as in the percentage of WSA occupied by macrophytes).

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Appendix A Periphyton and macrophyte summary data

Table A-1: Kauaeranga River periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	33 (5)	53 (6)	10 (3)	-	19 (3)	70 (5)	25 (4)	18 (3)	27 (5)	18 (3)	19 (3)	27 (4)	12 (2)	89 (2)
Thin film	29 (6)	36 (5)	66 (5)	-	40 (7)	12 (3)	35 (5)	28 (6)	62 (4)	56 (6)	0 (0)	0 (0)	27 (6)	11 (2)
Short filaments	0 (0)	0 (0)	1 (0)	-	2 (1)	0 (0)	0 (0)	3 (1)	0 (0)	9 (3)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat light brown	32 (5)	4 (1)	22 (4)	-	26 (7)	18 (6)	34 (4)	50 (6)	0 (0)	0 (0)	23 (6)	51 (6)	44 (7)	0 (0)
Medium mat dark brown	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)
Medium mat green	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	10 (3)	15 (4)	0 (0)	0 (0)	1 (1)	0 (0)
Long filaments brown red	1 (1)	0 (0)	0 (0)	-	0 (0)	0 (0)	3 (1)	0 (0)	0 (0)	0 (0)	3 (3)	0 (0)	0 (0)	0 (0)
Long filaments green	6 (4)	6 (3)	0 (0)	-	1 (0)	0 (0)	1 (0)	1 (0)	0 (0)	2 (1)	8 (3)	0 (0)	5 (3)	0 (0)
Thick mat black dark brown	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thick mat green light brown	0 (0)	0 (0)	0 (0)	-	11 (5)	0 (0)	3 (3)	1 (0)	0 (0)	0 (0)	48 (8)	22 (6)	10 (4)	0 (0)
Sludge	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Submerged bryophytes	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Iron bacteria	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-2: Ohinemuri River periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	30 (5)	61 (7)	25 (3)	32 (6)	-	60 (8)	-	18 (4)	27 (6)	16 (5)	21 (4)	-	14 (3)	11 (3)
Thin film	48 (6)	24 (8)	73 (3)	67 (6)	-	40 (8)	-	70 (6)	58 (7)	78 (5)	72 (4)	-	73 (4)	55 (6)
Short filaments	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	2 (1)	0 (0)	6 (2)	3 (1)	-	0 (0)	0 (0)
Medium mat light brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Medium mat dark brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Medium mat green	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	4 (4)	14 (7)	0 (0)	3 (1)	-	0 (0)	16 (4)
Long filaments brown red	0 (0)	0 (0)	2 (1)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Long filaments green	23 (6)	15 (4)	0 (0)	1 (1)	-	0 (0)	-	6 (3)	1 (0)	0 (0)	0 (0)	-	11 (2)	5 (2)
Thick mat black dark brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Thick mat green light brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	2 (2)	0 (0)
Sludge	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	1 (1)	13 (3)
Submerged bryophytes	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Iron bacteria	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)

Table A-3: Waiwawa River periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	-	-	9 (2)	-	3 (1)	53 (9)	35 (6)	29 (6)	23 (4)	24 (6)	19 (6)	40 (7)	10 (3)	85 (2)
Thin film	-	-	58 (8)	-	7 (4)	24 (7)	19 (5)	15 (6)	50 (6)	61 (6)	34 (6)	5 (4)	47 (6)	15 (2)
Short filaments	-	-	2 (1)	-	5 (4)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat light brown	-	-	31 (9)	-	82 (6)	16 (6)	39 (7)	19 (5)	0 (0)	0 (0)	0 (0)	56 (8)	37 (7)	0 (0)
Medium mat dark brown	-	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat green	-	-	0 (0)	-	0 (0)	7 (5)	4 (3)	0 (0)	27 (7)	0 (0)	46 (8)	0 (0)	0 (0)	0 (0)
Long filaments brown red	-	-	0 (0)	-	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Long filaments green	-	-	0 (0)	-	1 (0)	0 (0)	0 (0)	0 (0)	1 (0)	15 (6)	0 (0)	0 (0)	0 (0)	0 (0)
Thick mat black dark brown	-	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thick mat green light brown	-	-	0 (0)	-	0 (0)	0 (0)	3 (3)	35 (7)	0 (0)	0 (0)	0 (0)	0 (0)	5 (2)	0 (0)
Sludge	-	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)
Submerged bryophytes	-	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Iron bacteria	-	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-4: Piako River - Kuitihi periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	75 (7)	40 (9)	-	49 (7)	83 (5)	-	100 (0)	47 (8)	100 (0)	95 (4)	58 (8)	82 (6)	35 (7)	25 (6)
Thin film	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	4 (4)	20 (7)	0 (0)	1 (1)	2 (1)
Short filaments	0 (0)	60 (9)	-	0 (0)	17 (5)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (3)
Medium mat light brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	14 (6)	0 (0)	0 (0)
Medium mat dark brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat green	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	7 (5)	0 (0)	0 (0)	0 (0)
Long filaments brown red	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	53 (8)	0 (0)	0 (0)	1 (0)	0 (0)	53 (7)	67 (8)
Long filaments green	25 (7)	0 (0)	-	51 (7)	0 (0)	-	0 (0)	0 (0)	0 (0)	1 (0)	15 (6)	4 (3)	1 (1)	0 (0)
Thick mat black dark brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thick mat green light brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Sludge	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (5)	3 (3)
Submerged bryophytes	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Iron bacteria	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-5: Piako River - Kiwitahi macrophyte CAV summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Azolla</i> spp.	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	0 (0)
<i>Egeria densa</i>	74 (7)	71 (6)	-	73 (6)	44 (6)	-	4 (1)	6 (3)	8 (4)	14 (5)	22 (7)	38 (9)	49 (7)	30 (7)
<i>Lemna</i> spp.	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)
<i>Persicaria</i> spp.	11 (6)	5 (4)	-	6 (4)	6 (4)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Potamogeton crispus</i>	4 (2)	1 (1)	-	3 (2)	4 (3)	-	0 (0)	0 (0)	1 (1)	5 (2)	7 (3)	9 (4)	3 (1)	1 (1)
<i>Paspalum distichum</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-6: Piako River - Kiwitahi macrophyte WSA summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Azolla</i> spp.	1 (1)	4 (3)	-	16 (6)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	15 (4)	0 (0)
<i>Egeria densa</i>	38 (8)	7 (5)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	11 (6)	18 (7)	15 (4)	6 (4)
<i>Lemna</i> spp.	1 (1)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Persicaria</i> spp.	11 (6)	9 (5)	-	7 (4)	4 (3)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Potamogeton crispus</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	7 (3)	8 (5)	1 (0)	0 (0)
<i>Paspalum distichum</i>	0 (0)	1 (1)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-7: Piako River - Paeroa Tahuna Rd periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	96 (2)	29 (8)	67 (7)	-	98 (1)	-	100 (0)	100 (0)	100 (0)	100 (0)	98 (2)	99 (1)	39 (8)	100 (0)
Thin film	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	2 (2)	0 (0)	0 (0)	0 (0)
Short filaments	0 (0)	0 (0)	9 (5)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (2)	0 (0)
Medium mat light brown	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat dark brown	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat green	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Long filaments brown red	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	54 (8)	0 (0)
Long filaments green	4 (2)	71 (8)	23 (6)	-	2 (1)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	4 (4)	0 (0)
Thick mat black dark brown	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thick mat green light brown	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Sludge	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Submerged bryophytes	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Iron bacteria	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-8: Piako River - Paeroa-Tahuna Rd macrophyte CAV summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Ceratophyllum demersum</i>	12 (5)	17 (6)	5 (3)	-	2 (1)	-	0 (0)	0 (0)	1 (0)	0 (0)	2 (1)	9 (4)	16 (6)	10 (5)
<i>Elodea canadensis</i>	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Egeria densa</i>	21 (6)	11 (3)	3 (1)	-	4 (2)	-	1 (0)	1 (1)	3 (2)	1 (0)	2 (1)	7 (3)	5 (2)	5 (2)
<i>Lycopus europaeus</i>	4 (2)	2 (1)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Myriophyllum aquaticum</i>	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (2)	1 (1)
<i>Nitella aff. cristata</i>	0 (0)	1 (1)	1 (1)	-	1 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	2 (1)	1 (1)	0 (0)
<i>Persicaria</i> spp.	19 (7)	9 (4)	19 (7)	-	19 (7)	-	5 (2)	9 (5)	5 (3)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Potamogeton crispus</i>	0 (0)	0 (0)	2 (1)	-	6 (3)	-	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	16 (6)	18 (4)	4 (2)
<i>Potamogeton ochreatus</i>	0 (0)	5 (4)	6 (3)	-	5 (2)	-	0 (0)	1 (1)	0 (0)	1 (0)	2 (1)	3 (2)	5 (2)	1 (0)

Table A-9: Piako River - Paeroa-Tahuna Rd macrophyte WSA summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Ceratophyllum demersum</i>	8 (4)	10 (5)	4 (3)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (5)	10 (5)	0 (0)
<i>Elodea canadensis</i>	0 (0)	0 (0)	1 (1)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Egeria densa</i>	1 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Lycopus europaeus</i>	4 (4)	5 (4)	1 (1)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Myriophyllum aquaticum</i>	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (3)	1 (1)
<i>Nitella aff. cristata</i>	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Persicaria</i> spp.	19 (7)	18 (7)	23 (8)	-	12 (5)	-	0 (0)	2 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Potamogeton crispus</i>	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	8 (4)	12 (5)	0 (0)
<i>Potamogeton ochreatus</i>	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-10: Waihou River periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	95 (3)	100 (0)	100 (0)	100 (0)	-	100 (0)	-	100 (0)	100 (0)	100 (0)	100 (0)	-	100 (0)	100 (0)
Thin film	1 (1)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Short filaments	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Medium mat light brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Medium mat dark brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Medium mat green	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Long filaments brown red	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Long filaments green	3 (1)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Thick mat black dark brown	1 (1)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Thick mat green light brown	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Sludge	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Submerged bryophytes	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
Iron bacteria	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)

Table A-11: Waihou River macrophyte CAV summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Ceratophyllum demersum</i>	6 (4)	8 (4)	6 (3)	2 (2)	-	0 (0)	-	1 (1)	0 (0)	0 (0)	0 (0)	-	5 (3)	2 (2)
<i>Elodea canadensis</i>	9 (4)	3 (1)	4 (2)	2 (1)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
<i>Nitella aff. cristata</i>	0 (0)	1 (0)	2 (1)	2 (1)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
<i>Potamogeton crispus</i>	1 (1)	1 (1)	1 (1)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)

Table A-12: Waihou River macrophyte WSA summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Ceratophyllum demersum</i>	4 (4)	0 (0)	2 (2)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	2 (2)
<i>Elodea canadensis</i>	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
<i>Nitella aff. cristata</i>	0 (0)	0 (0)	1 (1)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)
<i>Potamogeton crispus</i>	0 (0)	0 (0)	1 (1)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)

Table A-13: Waitoa River periphyton cover summary data. Values are means with standard errors in parentheses.

Periphyton type	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
Bare	97 (1)	55 (10)	-	88 (4)	95 (2)	-	100	-	100	100	79 (7)	87 (4)	48 (5)	100
Thin film	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	17 (7)	0 (0)	2 (2)	0 (0)
Short filaments	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat light brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat dark brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Medium mat green	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	7 (3)	0 (0)
Long filaments brown red	0 (0)	1 (1)	-	8 (3)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Long filaments green	3 (1)	44 (9)	-	3 (2)	5 (2)	-	0 (0)	-	0 (0)	0 (0)	4 (1)	12 (3)	43 (6)	0 (0)
Thick mat black dark brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thick mat green light brown	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Sludge	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Submerged bryophytes	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Iron bacteria	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-14: Waitoa River macrophyte CAV summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Ceratophyllum demersum</i>	3 (3)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	0 (0)
<i>Elodea canadensis</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Egeria densa</i>	16 (5)	20 (6)	-	15 (4)	5 (2)	-	2 (1)	-	1 (0)	1 (0)	3 (1)	7 (3)	12 (4)	6 (2)
<i>Lemna</i> spp.	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Nitella aff. cristata</i>	0 (0)	0 (0)	-	1 (1)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Phalaris arundinacea</i>	33 (9)	33 (9)	-	26 (8)	29 (8)	-	3 (1)	-	7 (4)	6 (3)	5 (3)	4 (2)	2 (2)	14 (5)
<i>Persicaria</i> spp.	4 (4)	1 (0)	-	2 (2)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Potamogeton crispus</i>	3 (2)	1 (1)	-	6 (3)	10 (3)	-	1 (0)	-	0 (0)	0 (0)	1 (1)	11 (4)	12 (3)	2 (1)
<i>Paspalum distichum</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	1 (1)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table A-15: Waitoa River macrophyte WSA summary data. Values are means with standard errors in parentheses.

Macrophyte species	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16	Jan 16	Feb 17	Mar 17
<i>Ceratophyllum demersum</i>	3 (3)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)	0 (0)
<i>Elodea canadensis</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Egeria densa</i>	0 (0)	0 (0)	-	0 (0)	1 (1)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Lemna</i> spp.	0 (0)	3 (3)	-	1 (0)	4 (3)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Nitella aff. cristata</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Phalaris arundinacea</i>	33 (9)	37 (9)	-	38 (9)	28 (8)	-	2 (2)	-	0 (0)	0 (0)	4 (3)	10 (4)	9 (6)	9 (4)
<i>Persicaria</i> spp.	4 (4)	1 (1)	-	2 (2)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
<i>Potamogeton crispus</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)
<i>Paspalum distichum</i>	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

