To: Manuherekia River Technical Advisory Group

From: Dean Olsen

Date: 18 July 2023

Subject: Periphyton and macroinvertebrate communities of the Manuherekia River

1. Introduction

The purpose of this memo is to present information relevant to setting flows for the management of periphyton and macroinvertebrates in the Manuherekia River. It presents information on the current periphyton and macroinvertebrate communities at sites in the Manuherekia catchment, relationships between observed flows and periphyton biomass/macroinvertebrate indices. Finally, the results of instream habitat modelling are interpreted alongside observations of periphyton and macroinvertebrate communities to provide the real-world context for interpreting the results of instream habitat modelling.

2. Current State

2.1. Periphyton

2.1.1. Chlorophyll a

Periphyton biomass (benthic chlorophyll *a*) and cover has been monitored on a monthly basis since July 2019. Based on this dataset, the three sites on the mainstem of the Manuherekia were in B-band, while the Dunstan Creek at Beattie Road site was in A-band (Table 1). This is based on the analysis of Ozanne *et al.* (2023).

Table 1 Comparison of chlorophyll a concentrations at four sites in the Manuherekia catchment with Table 2 of the National Objectives Framework of NPS-FM. Calculations based on data from the period 2019-2022. From Ozanne et al (2023).

Site	n	92nd percentile	NOF band
Dunstan Creek at Beattie Road	28	47.5	A
Manuherikia at Blackstone Hill	24	67.2	B
Manuherikia at Ophir	26	103.0	B
Manuherikia at Galloway	29	101.9	B

Chlorophyll *a* concentrations observed at each of these sites in relation to flows in the nearest relevant flow site are presented in Figures 1-4.

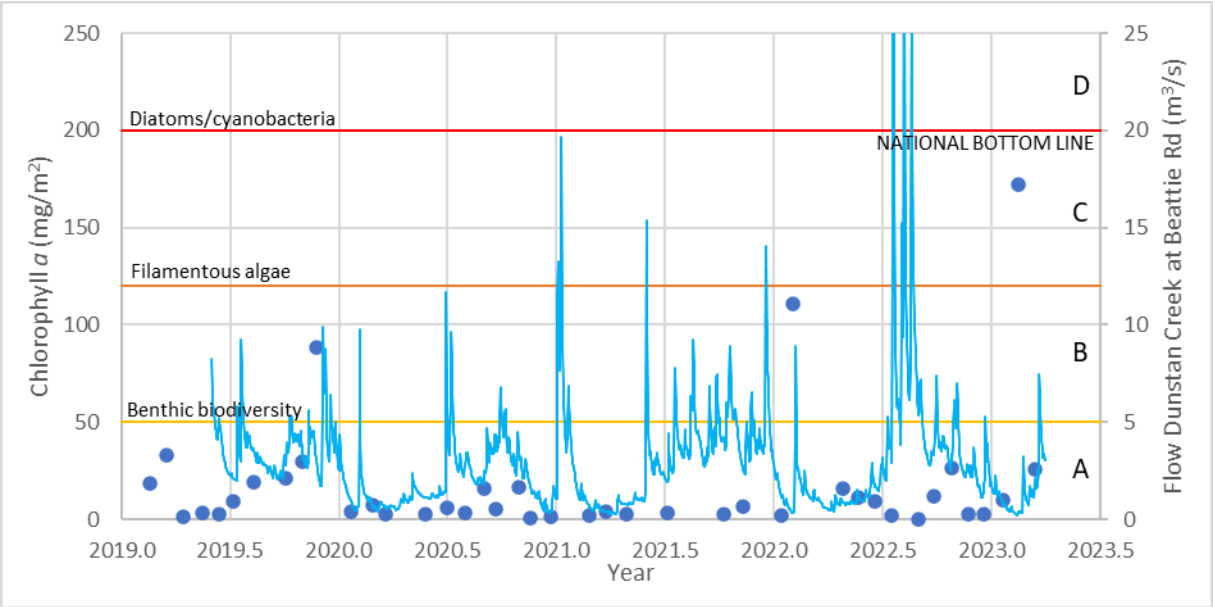

Figure 1 Chlorophyll a concentrations in the Dunstan Creek at Beattie Road over the period 2019-2023. Blue line is the mean daily flow in Dunstan Creek at Beattie Road.

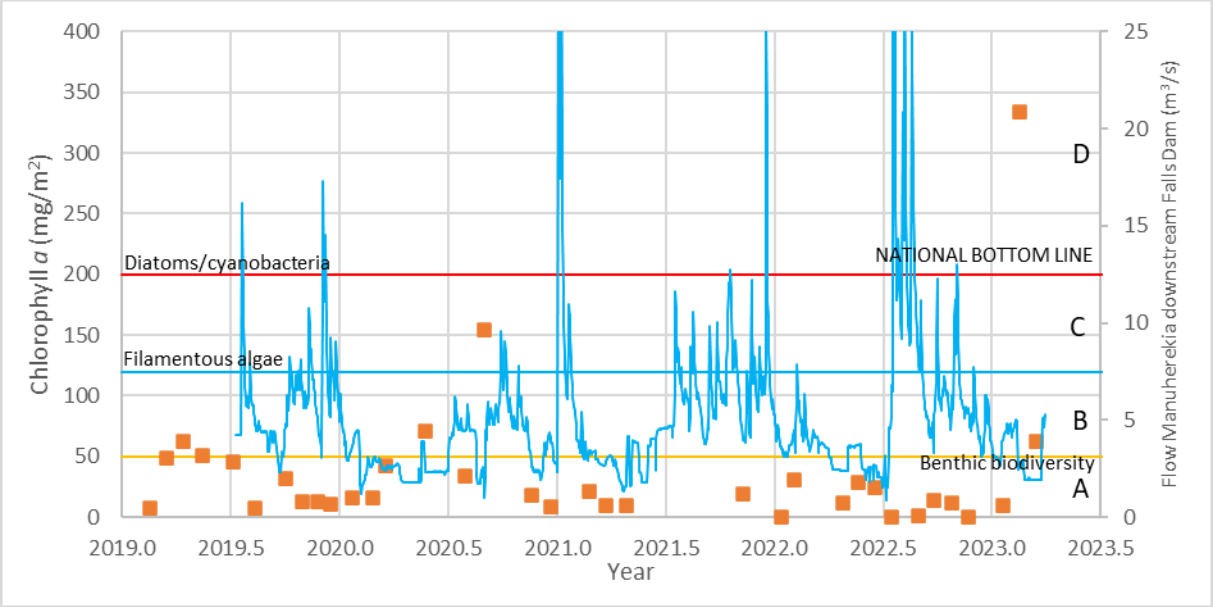

Figure 2 Chlorophyll a concentrations in the Manuherekia at Blackstone Hill over the period 2019-2023. Blue line is the mean daily flow in Manuherekia at Ophir.

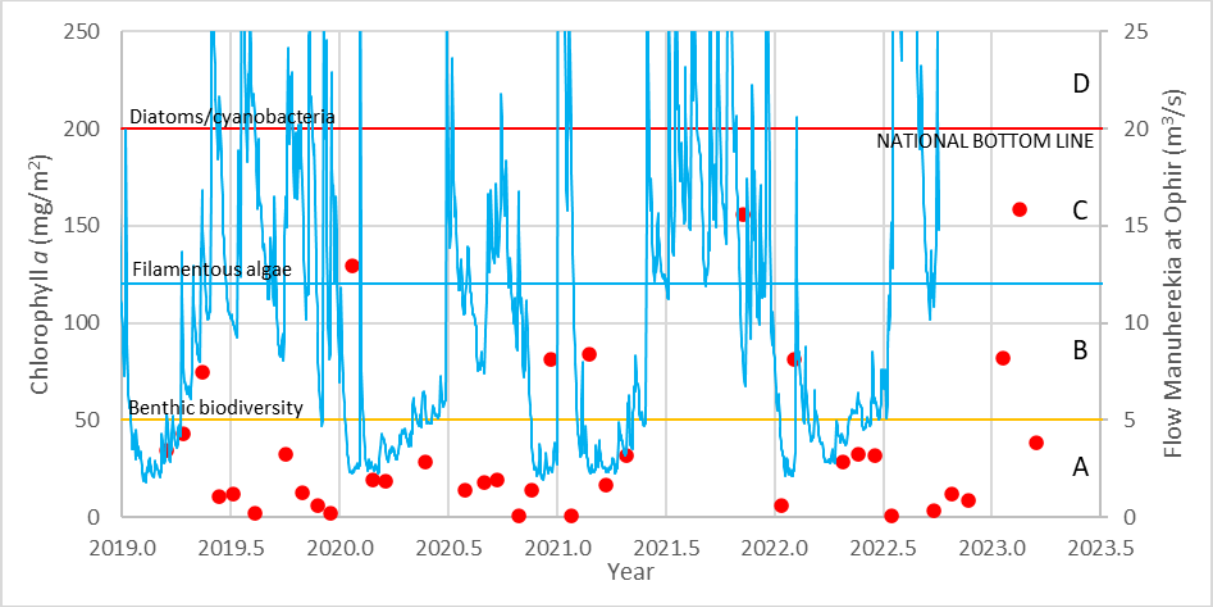

Figure 3 Chlorophyll a concentrations in the Manuherekia River at Ophir over the period 2019-2023. Blue line is the mean daily flow in Manuherekia at Ophir.

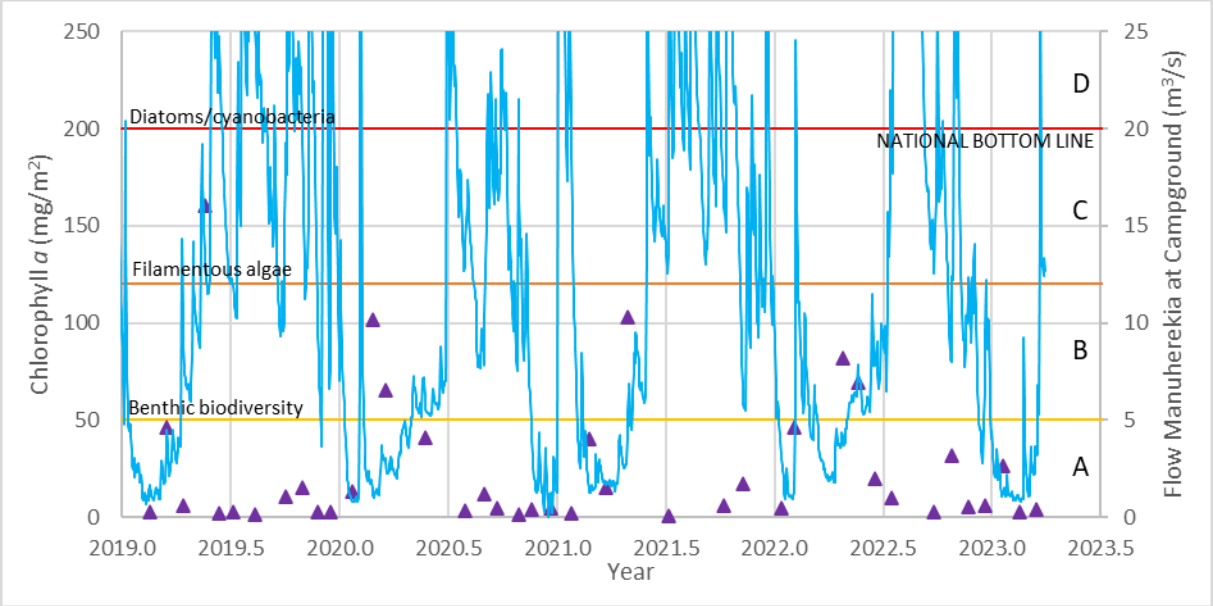

Figure 4 Chlorophyll a concentrations in the Manuherekia River at Galloway over the period 2019-2023. Blue line is the mean daily flow in Manuherekia at Campground.

2.2. Community composition

2.2.1. Dunstan Creek

Periphyton community composition at Dunstan Creek at Beattie Road is typically dominated by thin light brown films (56% of occasions), with medium light brown mats (5%) and short filamentous algae (5%) also among the most abundant periphyton type at this site on occasion. Periphyton cover data is presented in Appendix A.

2.2.2. Blackstone Hill

At the Manuherekia at Blackstone Hill site, periphyton cover is typically dominated by light brown films or medium mats, or thick mats (54%), with this likely to include the invasive diatom, *Didymosphenia geminata*, which has been identified at this site since 2008. Long filamentous algae were among the most abundant periphyton types on a third of occasions, and long filamentous algae exceeded 30% cover on 13% of occasions.

2.2.3. Ophir

Periphyton cover at the Manuherekia at Ophir is consistently dominated by thin light brown films (70%). Medium or thick light brown mats were among the most abundant periphyton (30% of occasions). Short and/or long filamentous algae have been present on occasion and were among the most abundant periphyton types on approximately 20% of occasions but did not exceed 30% cover on any of the 33 sampling occasions.

2.2.4. Galloway

Periphyton cover at the Manuherekia at Galloway is consistently dominated by thin films (64%), with these thin films typically being dominated by diatoms (light brown films; 53% of occasions). Filamentous algae are often present at this site (75% of occasions), but cover is typically low (>5%) and exceeded 30% cover on only one of the 36 sampling occasions (18 March 2019).

2.3. Relationships with flow

Chlorophyll *a* concentrations at both Ophir and Galloway were correlated with flows at the time of sampling, the minimum flow recorded in the preceding 15 days, the minimum flow recorded in the preceding 30 days, and the time since the last fresh of >3 times the median flow (Table 2). Of these variables, the flows at the time of sampling, the minimum flow recorded in the preceding 15 days and the minimum flow recorded in the preceding 30 days were strongly correlated with one-another (all $p<0.001$).

Table 2 Correlations of chlorophyll a concentrations with hydrological variables.

	Ophir		Galloway	
Variable	**Kendall tau**	***p***	**Kendall tau**	***p***
Flows at the time of sampling	-0.457	0.001	-0.458	0.001
Minimum flow in preceding 15 days	-0.391	0.006	-0.446	0.001
Minimum flow in preceding 30 days	-0.301	0.035	-0.388	0.005
Time since 3x median flow	0.318	0.026	0.308	0.027
Time since 6x median flow	0.03	0.833	0.058	0.675

Chlorophyll *a* concentrations in the Manuherekia at Ophir were negatively correlated with flow (Table 2; Figure 3), although concentrations at this site have typically been below 40 mg/m^2 (Figure 5). The highest chlorophyll *a* concentrations observed in the Manuherekia at Ophir were 156 mg/m^2 (7.97 m^3/s), 129.6 mg/m^2 (2.24 m^3/s), 83.7 mg/m^2 (2.37 m^3/s), 81.5 mg/m^2 (2.38 m^3/s), 81.2 mg/m^2 (2.53 m^3/s) (Figure 5). Similarly, chlorophyll *a* concentrations in the Manuherekia at Ophir were negatively correlated with the time since flows >24 m^3/s (3x median flow; Table 2), with high readings observed within as few as 20 days after flows of this magnitude (Figure 6).

Chlorophyll *a* concentrations in the Manuherekia at Galloway were also negatively correlated with flow (*r = -0.488*) but were typically below 50 mg/m^2 (Figure 7). The highest chlorophyll *a* concentrations observed in the Manuherekia at Galloway were 161 mg/m^2 (14.7 m^3/s), 103 mg/m^2 (5.52 m^3/s), 101.6 mg/m^2 (1.40 m^3/s), 81.7 mg/m^2 (4.18 m^3/s), 69.3 mg/m^2 (7.35 m^3/s), 65.2 mg/m^2 (2.81 m^3/s) (Figure 7). Chlorophyll *a* concentrations in the Manuherekia at Galloway were also negatively correlated with the time since flows >30 m^3/s (3x median flow; Table 2), with high readings observed within as few as 21 days after flows of this magnitude (Figure 3).

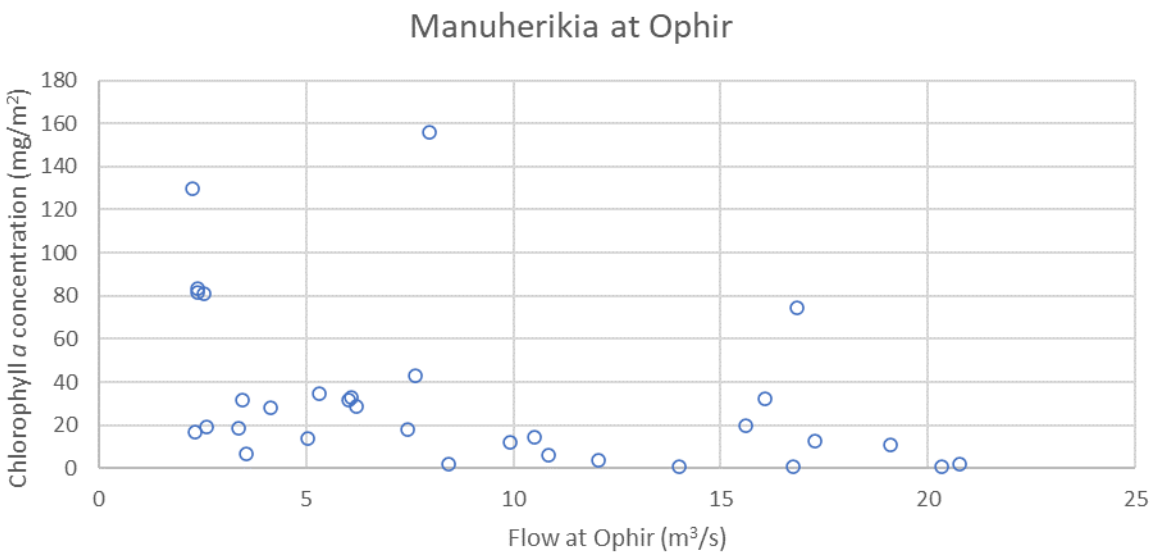

Figure 5 ***Relationship between chlorophyll a concentrations and flow in the Manuherekia at Ophir, based on data from between July 2019 and September 2022.***

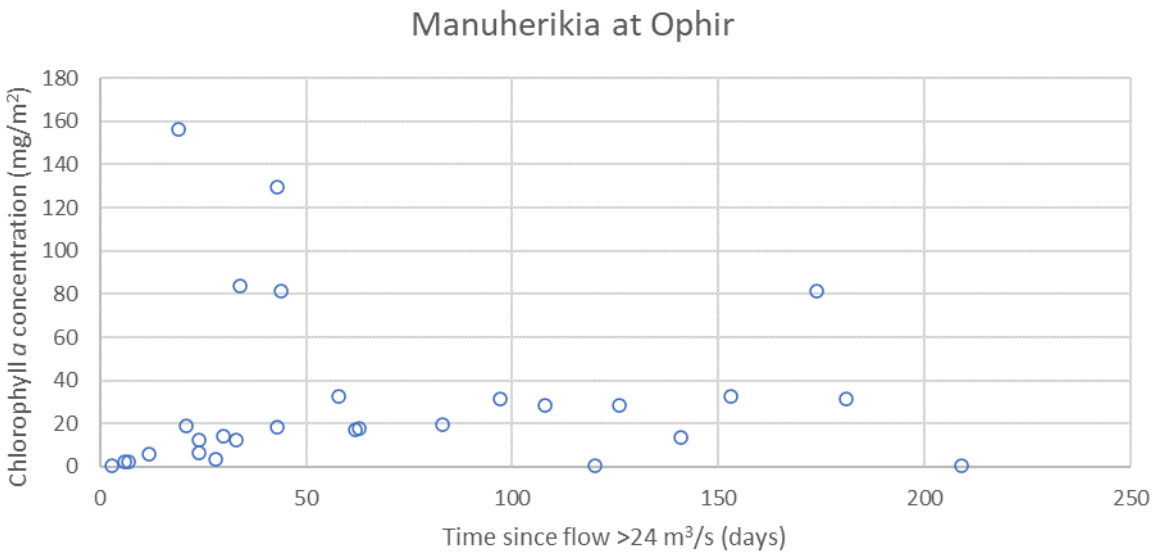

Figure 6 ***Relationship between chlorophyll a concentrations and time since flows >24 m³/s (3x median flow) in the Manuherekia at Ophir, based on data from between July 2019 and September 2022.***

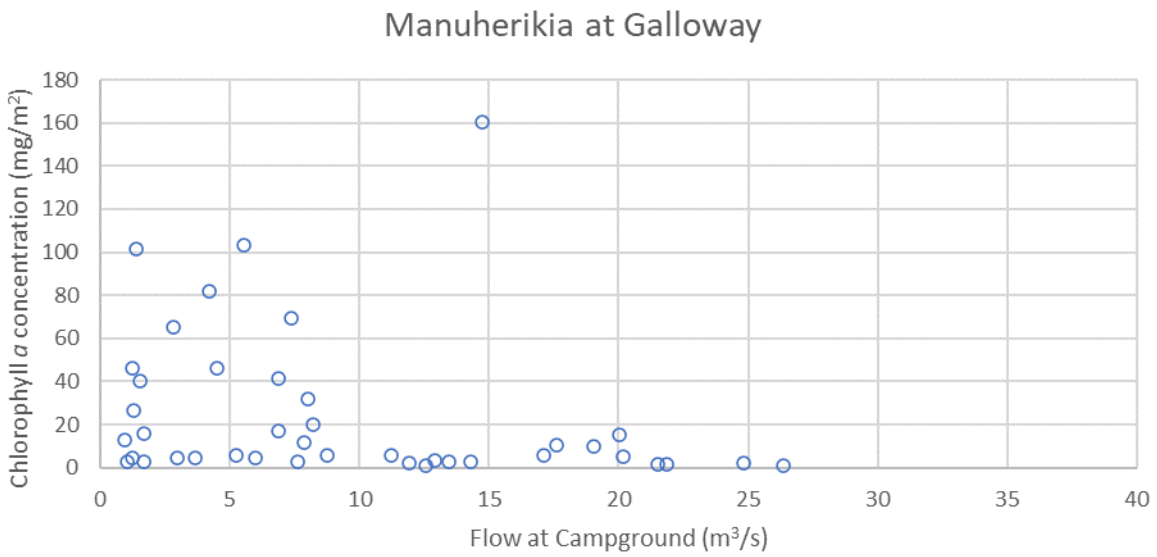

Figure 7 Relationship between chlorophyll a concentrations in the Manuherekia at Galloway and flow at Campground, based on data from between July 2019 and May 2022.

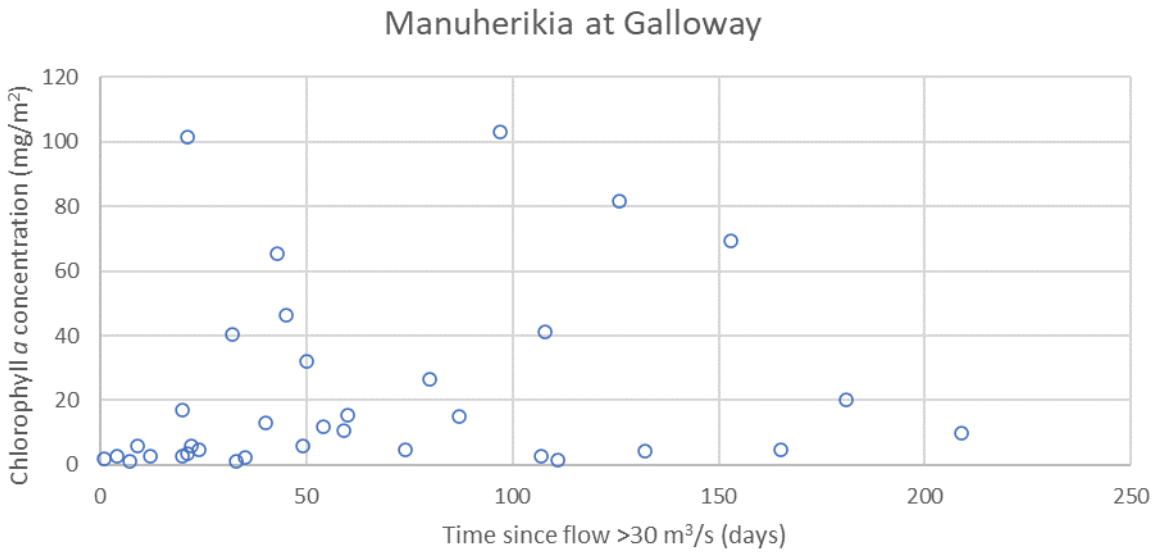

Figure 8 ***Relationship between chlorophyll a concentrations in the Manuherekia at Galloway and time since flows >30 m³/s (3x median flow), based on data from between July 2019 and May 2022.***

3. Macroinvertebrates

3.1. Macroinvertebrate indices

Macroinvertebrate indices at five sites in the Manuherekia are summarised in Table 3. The MCI score for Dunstan Creek at Beattie Road is in B-band, while SQMCI[1] and ASPM are in A-band (Table 3). All indices for the Manuherekia downstream of Fork and Ophir were in B-band, while the MCI score for Manuherekia at Blackstone Hill is in C-band, while SQMCI[1] and ASPM are in B-band (Table 3). Finally, the MCI score for the Manuherekia at Galloway is in C-band, while SQMCI[1] is in A-band and ASPM is in B-band (Table 3). These analyses are based on those of Ozanne *et al.* (2023).

Table 3 Comparison of macroinvertebrate indices at five sites in the Manuherekia catchment with Tables 14 & 15 of the National Objectives Framework of NPS-FM. From Ozanne et al. (2023).

Site	n	MCI	NOF band	SQMCI*	NOF band	ASPM	NOF band
Dunstan Creek at Beattie Road	5	118	B	7.41	A	0.63	A
Manuherikia downstream of Fork	1	116	B	5.80	B	0.51	B
Manuherikia at Blackstone Hill	5	101	C	5.67	B	0.53	B
Manuherikia at Ophir	4	110	B	6.32	B	0.52	B
Manuherikia at Galloway	4	105	C	7.08	A	0.57	B

Macroinvertebrate indices observed in Dunstan Creek at Beattie Road, Manuherekia at Ophir and Manuherekia at Campground in relation to flows in the nearest relevant flow site are presented in Figures 5-7.

The percentage of macroinvertebrate taxa that were mayflies (Ephemeroptera), stoneflies (Plecoptera), or caddis flies (Trichoptera)(%EPT) in Dunstan Creek at Beattie Road exceeded 40% on all occasions between February 2019 and April 2021 (Figure 9a), while all MCI scores at this site were between 110 and 130, which is B-band (Figure 9b). QMCI scores were more variable, with scores ranging from 4.53 to 7.61 (Figure 9c). The lowest scores were observed in late October (4.53) and November 2019 (4.88), when flows at this site exceeded 3 m^3/s (Figure 9c). The next lowest value was in October 2020 (5.81), when flows exceeded 4.78 m^3/s (Figure 9c).

The %EPT for the Manuherekia at Ophir exceeded 39% on all occasions between February 2019 and April 2021 (Figure 10a), while all MCI scores at this site were between 95 and 112, with most in C-band (Figure 10b). QMCI scores were more variable, with scores ranging from 5.21 to 7.46 (Figure 10c). The lowest scores were observed in mid-April (5.56) when the flow at this site was 7.6 m^3/s and October 2020 (5.57) when flows at this site was 16.7 m^3/s and in January 2021 (5.21), when the flow at this site was 20.3 m^3/s (Figure 10c).

The %EPT in the Manuherekia at Campground exceeded 33% on all occasions between February 2019 and April 2021 (Figure 10a), while all MCI scores at this site were between 86 and 105, with most in C-

[1] Table 14 of the NOF presents attribute bands for MCI and QMCI. SQMCI scores presented above are comparable to QMCI

band (Figure 10b). QMCI scores were more variable, with scores ranging from 5.21 to 7.46 (Figure 10c). The lowest scores were observed in mid-April (5.56) when the flow at this site was 7.6 m3/s and October 2020 (5.57) when flows at this site was 16.7 m3/s and in January 2021 (5.21), when the flow at this site was 20.3 m3/s (Figure 10c).

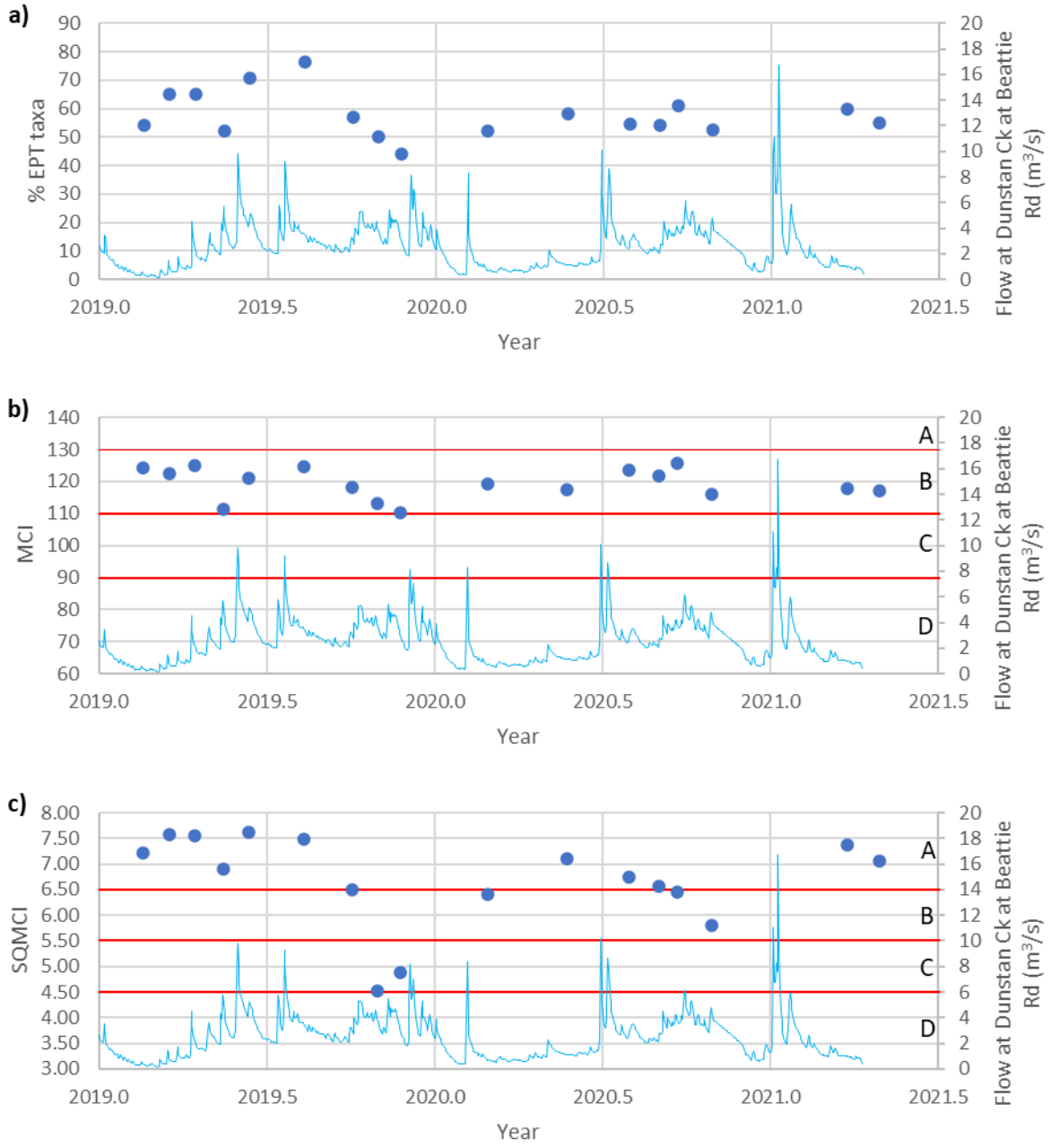

Figure 9 Macroinvertebrate indices in the Dunstan Creek at Beattie Road over the period 2019-2021. Blue line is the mean daily flow in Dunstan Creek at Beattie Road.

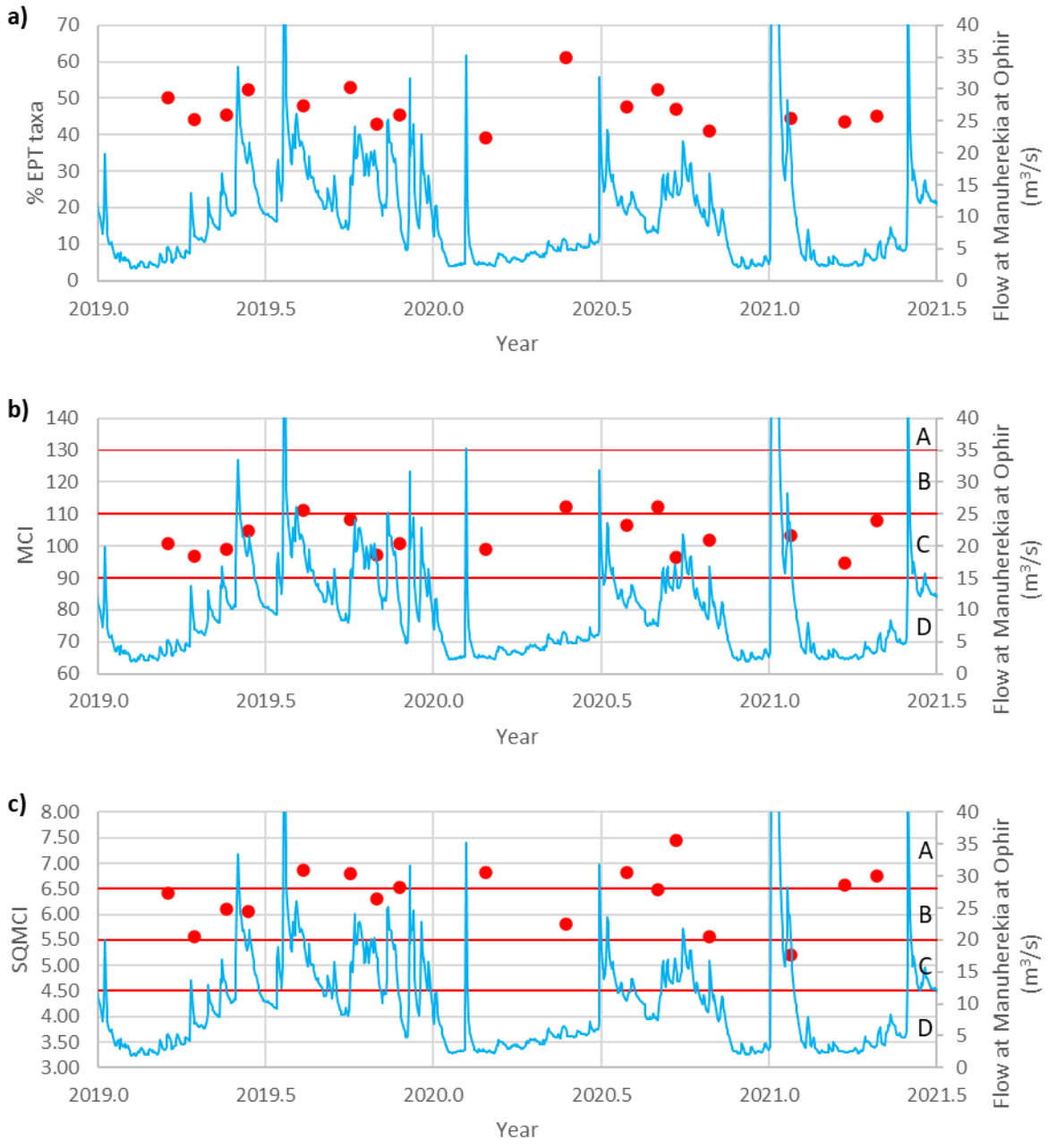

Figure 10 ***Macroinvertebrate indices in the Manuherekia at Ophir over the period 2019-2021. Blue line is the mean daily flow in Manuherekia at Ophir.***

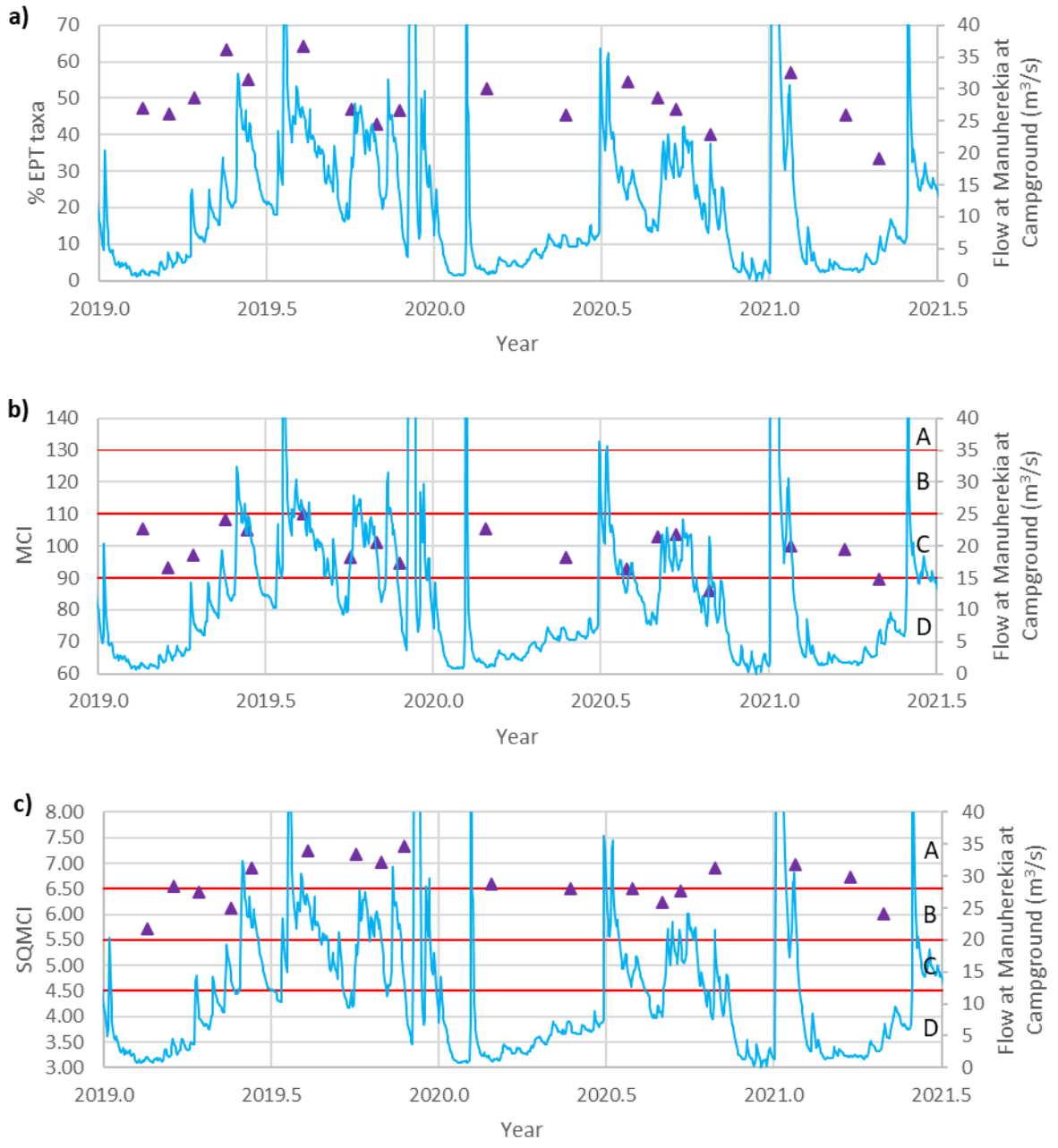

Figure 11 ***Macroinvertebrate indices in the Manuherekia at Campground over the period 2019-2021. Blue line is the mean daily flow in Manuherekia at Campground.***

3.2. Macroinvertebrate community composition

The mayfly *Deleatidium* was consistently the most abundant macroinvertebrate taxon in Dunstan Creek at Beattie Road, while riffle beetles (Elmidae), the stonefly *Zelandoperla* and the caddis flies *Aoteapsyche*[2], *Olinga*, *Pycnocentria and Pycnocentrodes* were abundant at this site at times.

The mayfly *Deleatidium* was consistently the most abundant macroinvertebrate taxon at the Ophir monitoring site, while the net-spinning caddis fly *Aoteapsyche*[2] was among the most abundant taxa at this site at times. Other taxa that were occasionally abundant at this site include the sand-cased caddis *Pycnocentrodes*, riffle beetles and the mudsnail *Potamopyrgus.* Compositional data for this site is presented in Appendix B.

The mayfly *Deleatidium* was consistently the most abundant macroinvertebrate taxon at the Galloway monitoring site, while the net-spinning caddis fly *Aoteapsyche* was among the most abundant taxa at this site along with sandfly larvae (*Austrosimulium*), the mudsnail *Potamopyrgus* and the sand-cased caddis *Pycnocentrodes*. Compositional data for this site is presented in Appendix B.

3.3. Relationships with flow

Figures 11-13 present scatterplots of %EPT, MCI and SQMCI and mean daily flow on the day of sampling for Dunstan Creek at Beattie Road (Figure 12), Manuherekia at Ophir (Figure 13) and Manuherekia at Galloway (Figure 14).

There was no relationship between %EPT and flow in Dunstan Creek at Beattie Road (Figure 12a), while MCI scores exceeded 116 when flows were less than 3 m^3/s, while the lowest scores (110-113) occurred when flows exceeded 3 m^3/s (Figure 12b). Similarly, SQMCI scores exceeded 6.39 when flows were less than 3 m^3/s, while the lowest scores (<6.00) occurred when flows exceeded 3 m^3/s (Figure 12c).

There was no relationship between %EPT and flow in the Manuherekia at Ophir, although the lowest %EPT value was recorded at a flow of 2.6 m^3/s (Figure 13a). There was no apparent relationship between MCI and flow at this site, and the lowest MCI score observed at this site (95) was recorded at a flow of 2.3 m^3/s (Figure 13b). There was no apparent relationship between SQMCI and flow at this site, although scores exceeded 6.00 on the four occasions when flows were less than 6 m^3/s, while the lowest score (5.21) occurred when flows exceeded 20 m^3/s (Figure 13c).

There was no apparent relationship between %EPT and flow in Manuherekia at Galloway, and the lowest %EPT value (33%) was recorded at a flow of 5.5 m^3/s (Figure 14a). There was no apparent relationship between MCI and flow at this site, and the lowest MCI score observed at this site (86) was recorded at a flow of 21.5 m^3/s (Figure 14b). The lowest SQMCI score recorded in the Manuherekia at Galloway (5.71) was recorded at a flow of 1.68 m^3/s, although scores exceeded 6.50 on the two other occasions when flows were less than 1.7 m^3/s (Figure 14c). The highest SQMCI scores were observed when flows exceeded 13 m^3/s (Figure 14c), although most of these values occurred in samples collected between August and November 2019, during a prolonged period of high flows, when flows did not drop below 10 m^3/s (as evident in Figure 11c). Other values exceeded 6.90 on two

[2] Now considered a sub-genus within *Hydropsyche* but is used here for consistency with the original habitat suitability curve.

other occasions in October 2020 (6.91) after a prolonged period of high flows (>7.5 m^3/s) and January 2021 (6.98), after a high flow event (as evident in Figure 11c).

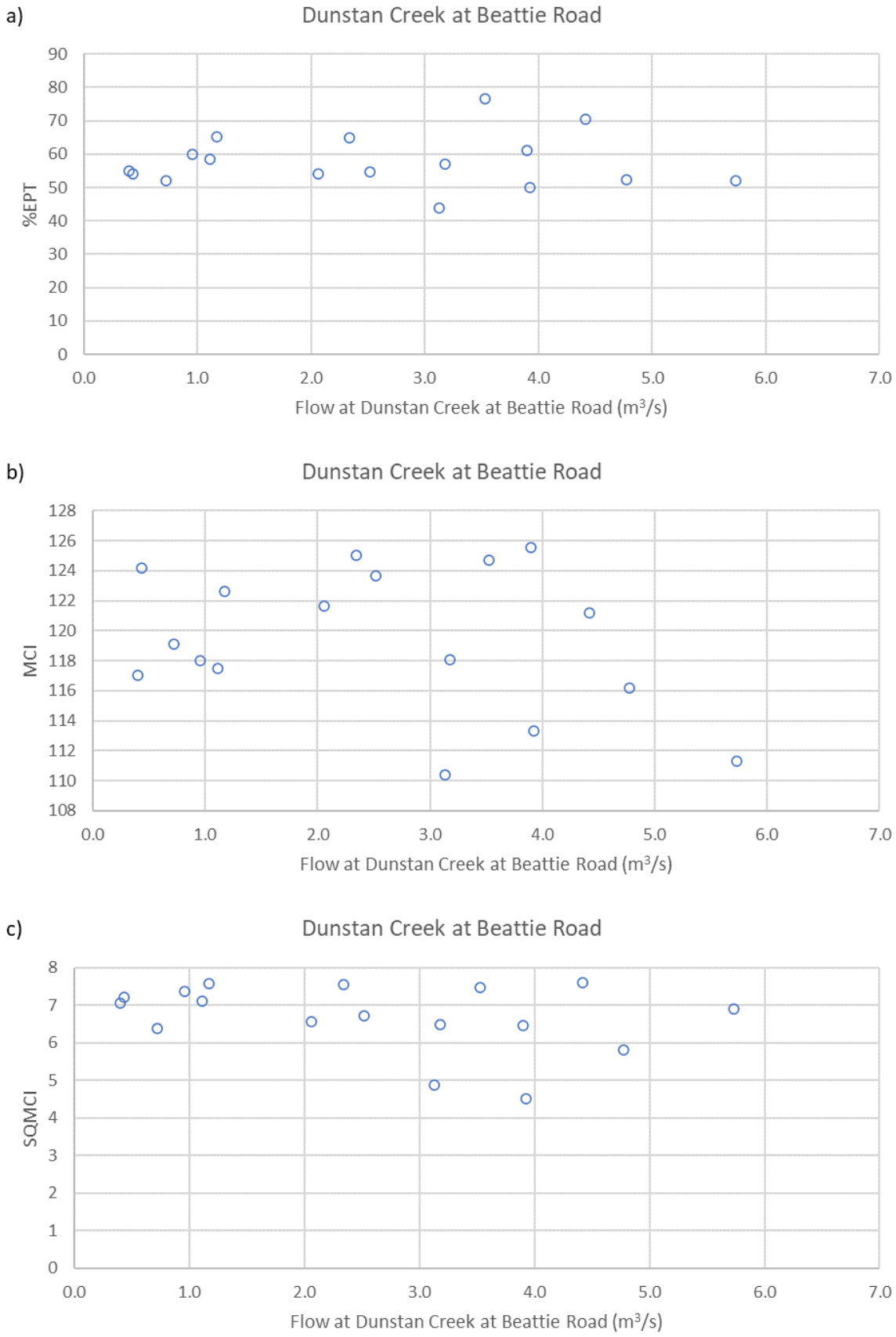

Figure 12 ***Relationship between a) %EPT, b) MCI, and c) SQMCI flow in Dunstan Creek at Beattie Road based on data from between July 2019 and May 2023.***

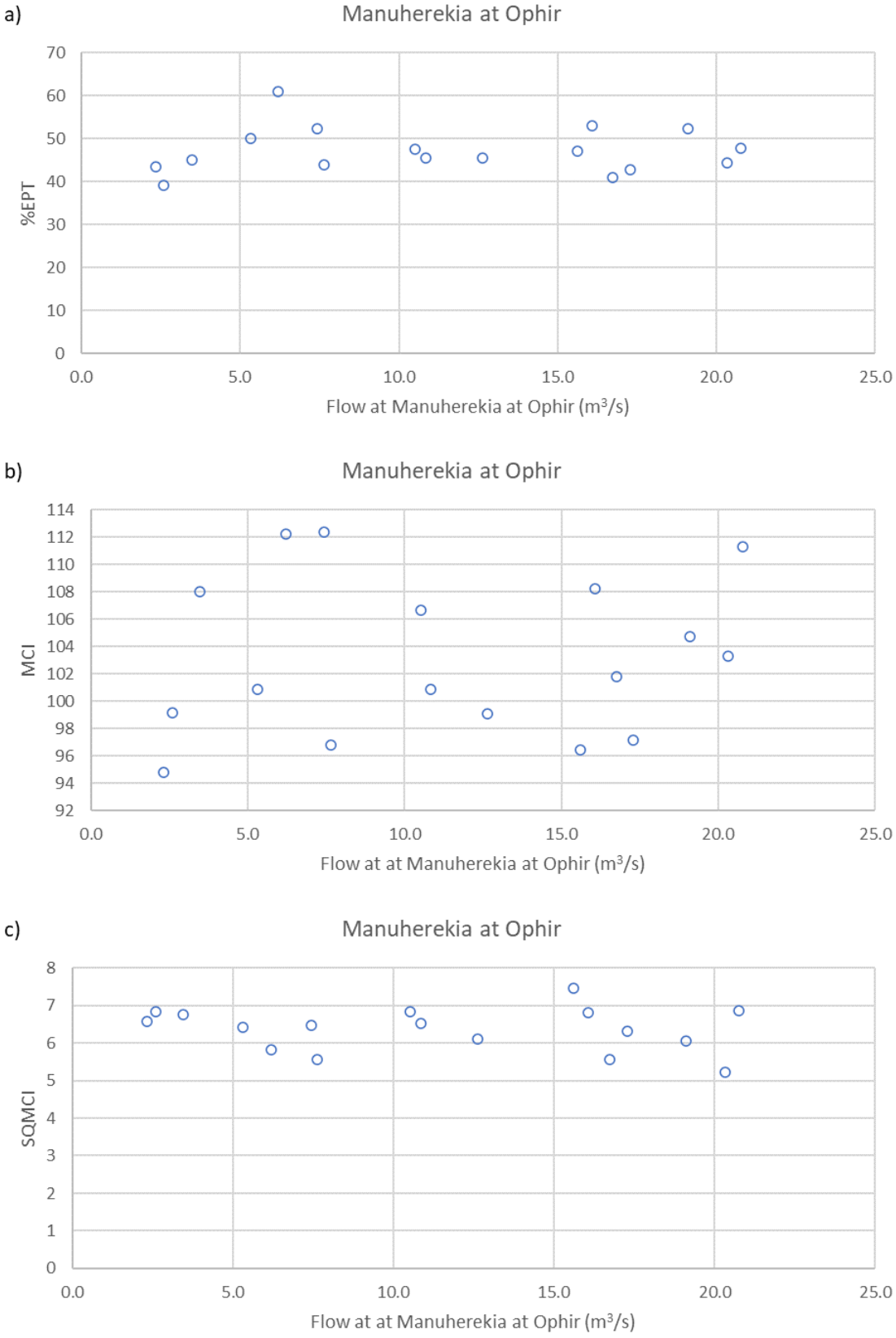

Figure 13 ***Relationship between a) %EPT, b) MCI, and c) SQMCI and flow in the Manuherekia at Ophir, based on data from between July 2019 and March 2023.***

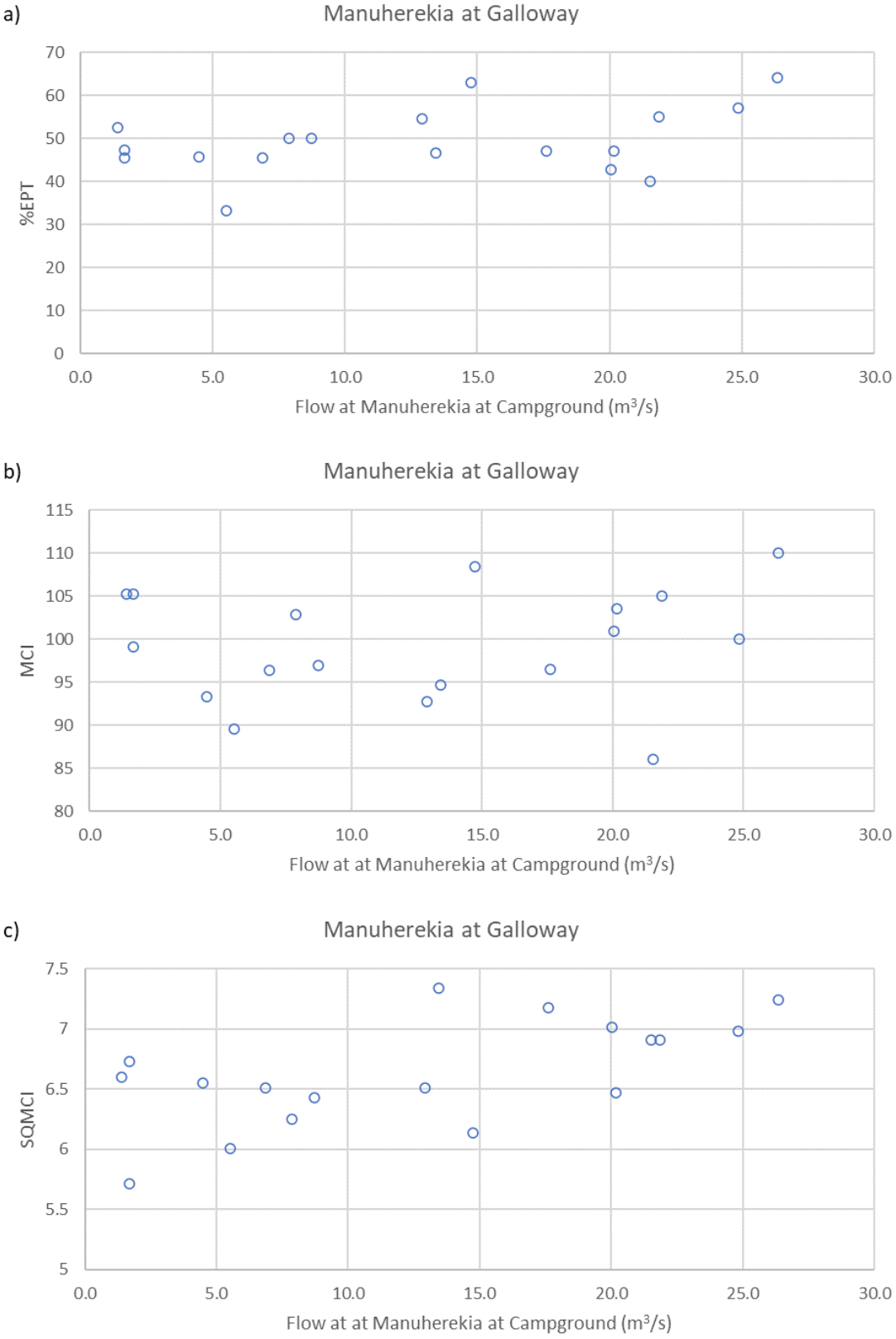

Figure 14 ***Relationship between a) %EPT, b) MCI, and c) SQMCI in the Manuherekia at Galloway and flow at Campground, based on data from between July 2019 and March 2023.***

4. Flow setting

4.1. Periphyton

The main purpose of considering instream habitat modelling for periphyton is to understand how changes in flow are likely to affect how much of the riverbed is covered by periphyton and the relative contribution of the different types of periphyton to the overall community. Given this, it is the percentage of the wetted channel covered by periphyton, not the total area of suitable habitat that is of interest. For this reason, the habitat suitability index (reach-averaged CSI) is typically used instead of weighted usable area (RAWS) in instream habitat analyses for periphyton.

It should be recognised that instream habitat modelling only considers the physical habitat present at a flow, namely water depth, velocity and substrate. It does not take other important factors into consideration. Periphyton biomass at a point in time reflects the balance of two opposing processes – biomass accrual and biomass loss. The rate of biomass accrual is driven by the rate of cell division which is, in turn, affected by factors such as the supply of resources (nutrients and light) and water temperature, while biomass loss is driven by two main mechanisms: disturbance caused by high flows (resulting in high water velocities, substrate instability and/or abrasion caused by suspended or saltating sediments) and physical removal by grazing my macroinvertebrates (Biggs 2000).

Where possible, instream habitat modelling should be interpreted in conjunction with real-world observations of periphyton communities, where these are available – as is the case in the mainstem of the Manuherekia and Dunstan Creek (Section 2.1).

4.1.1. Manuherekia at Galloway

Instream habitat modelling for the Galloway site predicts that flow would have little effect on habitat quality for benthic cyanobacteria (*Phormidium*) except at very low flows (<0.6 m3/s) (Figure 15). Habitat suitability for didymo is predicted to increase with decreasing flows, particularly at flows of less than 2 m^3/s until it reaches an optimum at approximately 0.75 m^3/s (Figure 15). In contrast, thin to medium mats of diatoms are predicted to increase with increasing flow across the modelled range (Figure 15).

Habitat suitability for short filamentous algae is predicted to increase with increasing flows up to 1.8 m^3/s, with peak suitability between 1.6 m^3/s and 3 m^3/s before gradually dropping as flows increase (Figure 15).

Habitat suitability for long filamentous algae is predicted to increase with decreasing flows as flows drop below 3 m^3/s until it reaches an optimum at very low flows (Figure 15). A flow of 1.2 m^3/s is predicted to increase habitat suitability for long filamentous algae (50% increase relative to naturalised MALF), while a flow of approximately 0.560 m^3/s is predicted to double the habitat suitability for long filamentous algae compared to the naturalised MALF.

Periphyton monitoring in the Manuherekia at Galloway between 2019 and 2023 has found that cover at is typically dominated by thin diatom films and cover by filamentous algae is typically low and rarely exceeds 30% cover. Thus, any minimum flow that is higher than the status quo (0.9 m^3/s) is expected to increase suitability for diatoms and short filamentous algae and will reduce suitability for long filamentous algae (Table 4). Habitat suitability for benthic cyanobacteria and Didymo is not expected to be affected much by flow (Table 4). Thus, periphyton cover in the Manuherekia at Galloway is expected to continue to be dominated by thin films and medium diatom mats (Table 4). The risk of proliferation of long filamentous algae is expected to decline with increasing minimum flows up to approximately 3 m^3/s (Table 4), although observations of the periphyton community in the Manuherekia at Galloway suggests that proliferations of long filamentous algae are relatively infrequent at this site under the *status quo* conditions.

Chlorophyll *a* biomass at the Galloway site is negatively correlated with flow, with the high readings observed when flows are less than 5.5 m^3/s (Figure 4), suggesting that flows of <6 m^3/s are expected to be capable of supporting a high periphyton biomass at this site. However, particularly high concentrations can be observed at higher flows (161 mg/m^2 observed on 20 May 2019, at 14.7 m^3/s).

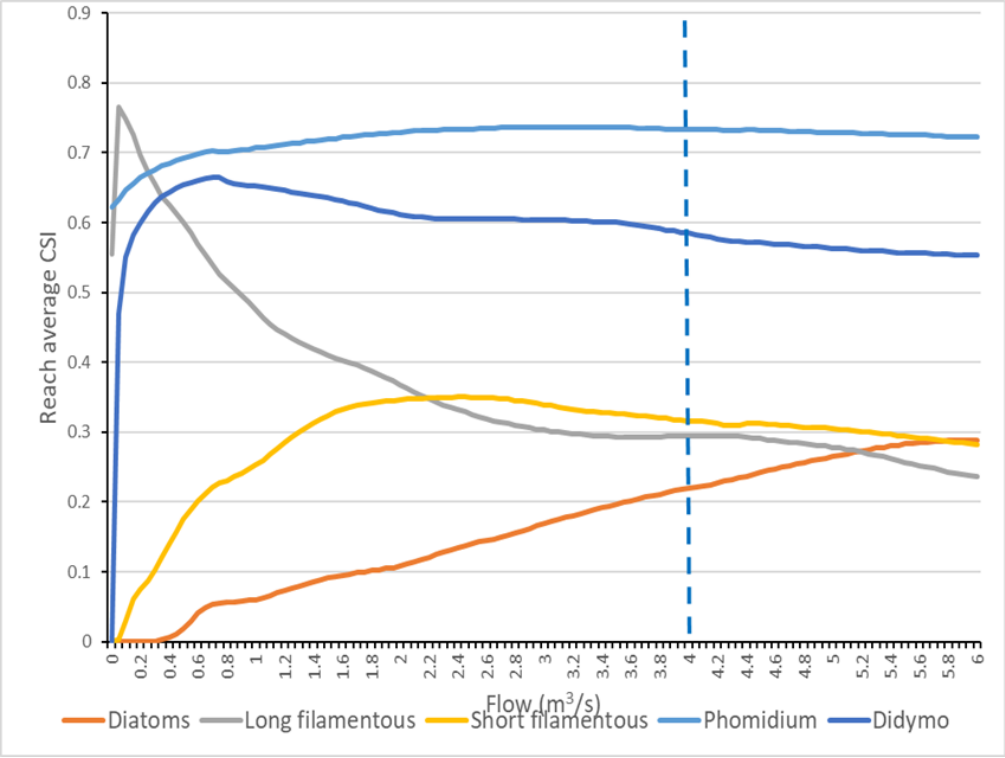

Figure 15 ***Combined suitability index for periphyton taxa in the Manuherekia at Galloway based on the model of Water Ways Consulting.***

Table 4 Habitat quality (CSI) retention for periphyton classes in the Manuherekia at Galloway and risk assessment based on instream habitat modelling and observations.

Scenario	7dMALF	Diatoms	Long filamentous	Short filamentous	Phomidium	Didymo
Full Dam no irrigation	4.040	100	100	100	100	100
Estimated existing	0.860	26	171	75	96	112
0.900	1.130	31	153	87	97	111
1.100	1.270	35	147	94	97	110
1.200	1.340	38	145	97	97	110
1.500	1.610	43	137	106	98	108
1.700	1.790	46	132	109	99	106
2.000	2.060	50	123	110	99	104
2.500	2.520	64	110	111	100	104
3.000	2.970	76	103	108	100	103
RISK ASSESSMENT						
Full Dam no irrigation	4.040	Natural	Natural	Natural	Natural	Natural
Estimated existing	0.860	Low/mod*	Moderate†	Low	Low	Low
0.900	1.130	Low/mod*	Moderate†	Low	Low	Low
1.100	1.270	Low/mod*	Low/mod	Low	Low	Low
1.200	1.340	Low/mod*	Low/mod	Low	Low	Low
1.500	1.610	Low/mod*	Low/mod	Low	Low	Low
1.700	1.790	Low/mod*	Low/mod	Low	Low	Low
2.000	2.060	Low/mod*	Low/mod	Low	Low	Low
2.500	2.520	Low/mod*	Low	Low	Low	Low
3.000	2.970	Low*	Low	Low	Low	Low

* Current community usually dominated by thin to medium diatom mats. Analysis indicates higher flows favour these communities, so dominance expected to continue or increase with higher minimum flows i.e. >900 l/s.

† Proliferation by long filamentous algae at this site is uncommon. Analysis indicates higher flows are less favourable for these communities, so rare occurrence of long filamentous blooms is expected to continue to be low or decrease with higher minimum flows.

4.1.2. Manuherekia River at Ophir

Periphyton cover at the Manuherekia at Ophir is consistently dominated by thin light brown films, medium or thick light brown mats (Section 2.1). Short and/or long filamentous algae have been present on occasion and were among the most abundant periphyton types at this site on approximately 20% of occasions but did not exceed 30% cover on any of the 33 sampling occasions (Section 2.1). Instream habitat modelling suggests that higher flows in this reach are likely increase suitability for diatoms but decrease suitability for long filamentous algae (Figure 16). Chlorophyll *a* biomass at the Ophir site is negatively correlated with flow, with the highest readings observed when flows are less than 6m^3/s (Figure 3), suggesting that flows of <6 m^3/s are expected to be capable of supporting a high periphyton biomass at this site.

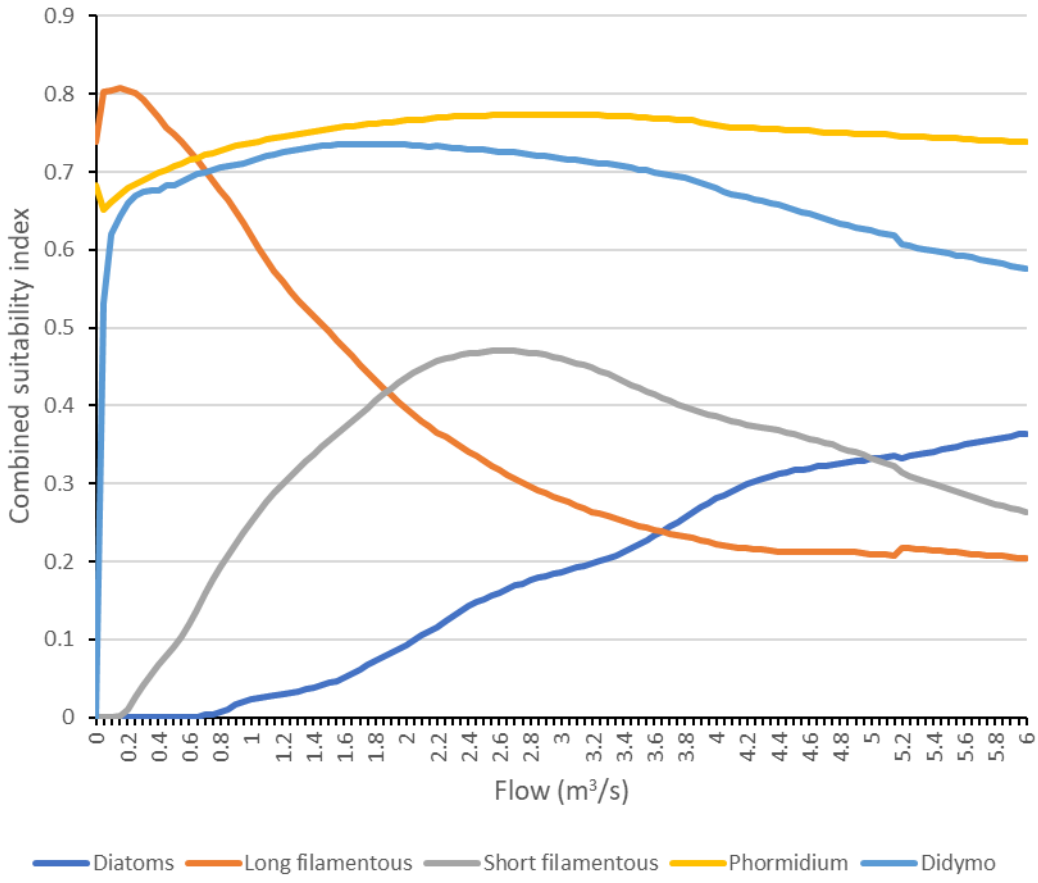

Figure 16 ***Combined suitability index for periphyton taxa in the Manuherekia at Ophir based on the model of Water Ways Consulting.***

Table 5 Habitat quality (CSI) retention for periphyton classes in the Manuherekia at Ophir and risk assessment based on instream habitat modelling and observations.

Scenario	7dMALF	Diatoms	Long filamentous	Short filamentous	Phomidium	Didymo
Full Dam no irrigation	3.400	100	100	100	100	100
Estimated existing	2.020	28	181	89	98	104
0.900	1.780	45	156	102	99	104
1.100	2.090	48	152	103	99	104
1.200	2.130	51	149	104	99	104
1.500	2.250	58	143	107	100	104
1.700	2.340	64	138	108	100	103
2.000	2.460	70	133	109	100	103
2.500	2.720	80	120	109	100	102
3.000	2.980	87	112	107	100	102
RISK ASSESSMENT						
Full Dam no irrigation	3.400	Natural	Natural	Natural	Natural	Natural
Estimated existing	2.020	Low/mod*	Moderate†	Low	Low	Low
0.900	1.780	Low/mod*	Moderate†	Low	Low	Low
1.100	2.090	Low/mod*	Moderate†	Low	Low	Low
1.200	2.130	Low/mod*	Low/mod	Low	Low	Low
1.500	2.250	Low/mod*	Low/mod	Low	Low	Low
1.700	2.340	Low/mod*	Low/mod	Low	Low	Low
2.000	2.460	Low*	Low/mod	Low	Low	Low
2.500	2.720	Very low*	Low/mod	Low	Low	Low
3.000	2.980	Very low*	Low	Low	Low	Low

* Current community usually dominated by thin, medium and thick diatom mats. Analysis indicates higher flows favour these communities, so dominance expected to continue or increase with higher minimum flows i.e. >900 l/s.

† Proliferation by long filamentous algae at this site is uncommon. Analysis indicates higher flows are less favourable for these communities, so rare occurrence of long filamentous blooms is expected to continue to be low or decrease with higher minimum flows.

4.2. Macroinvertebrates

4.2.1. Manuherekia at Galloway

Of the modelled taxa, the mayfly *Deleatidium* was consistently the most abundant macroinvertebrate taxon at the Galloway monitoring site, while the net-spinning caddis fly *Aoteapsyche*[3] was among the most abundant taxa at this site along with sandfly larvae (*Austrosimulium*), the mudsnail *Potamopyrgus* and the sand-cased caddis *Pycnocentrodes*. Habitat for all macroinvertebrate taxa considered increased with increasing flow up to the natural MALF (~4,000 l/s). Thus, the risk is expected to reduce with higher flows for all of the taxa considered (Table 6). Flows below 2 m^3/s are predicted to retain less than 50% of the habitat for *Aoteapsyche*, deemed to represent a "high risk" (Table 6), although *Aoteapsyche* are usually among the most abundant macroinvertebrate taxa collected at this site under *status quo* flows. Modelling suggests that flows of less than 0.9 m^3/s represent a low-moderate risk (habitat retention <70%) for *Deleatidium* and *Pycnocentrodes* (Table 6), although *Deleatdiium* is consistently the most abundant taxon present in the Manuherekia River at Galloway under *status quo* flows and *Pycnocentrodes* can be very abundant at times. Flows of more than 1.5 m^3/s are expected to represent low-moderate risk for Food Producing habitat and benthic invertebrate densities (Table 6).

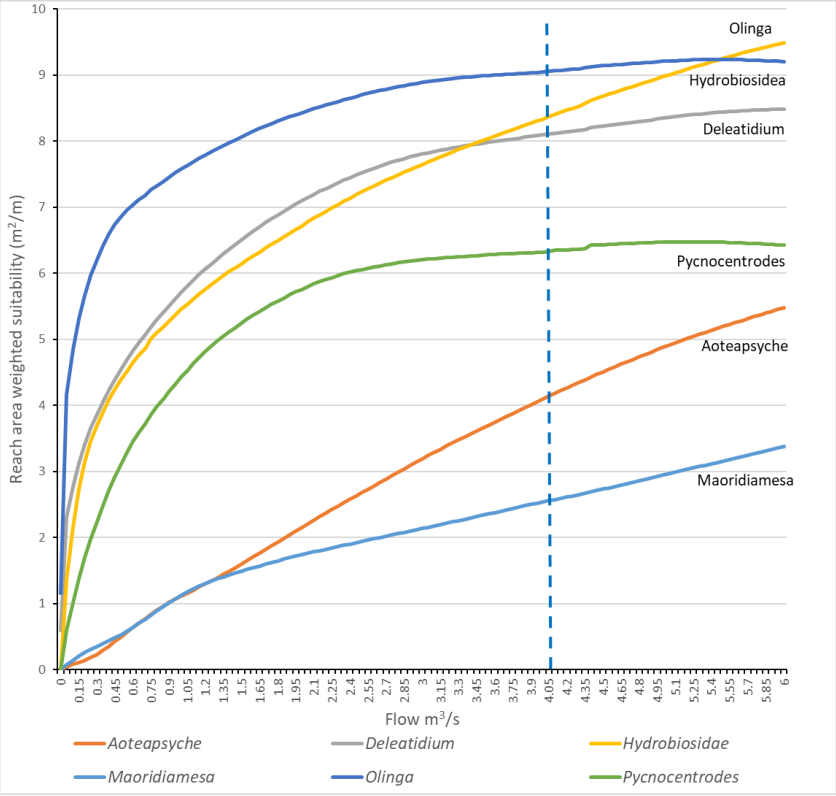

Figure 17 ***Variation in instream habitat for macroinvertebrates, in relation to flow, in the Galloway survey reach. The dashed line represents the naturalised 7-d MALF.***

[3] Now considered a sub-genus within *Hydropsyche* but is used here for consistency with the original habitat suitability curve.

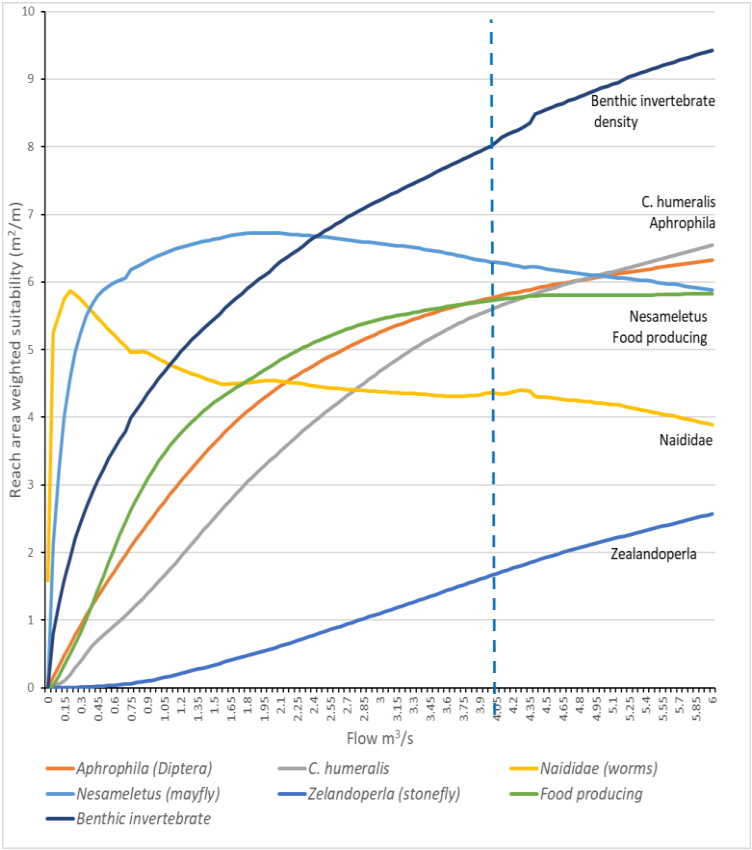

Figure 18 ***Variation in instream habitat for macroinvertebrates, in relation to flow, in the Galloway survey reach. The dashed line represent the naturalised 7-d MALF.***

Table 6 Habitat (RAWS) retention for common macroinvertebrate taxa in the Manuherekia at Galloway and risk assessment based on instream habitat modelling and observations.

Scenario	7dMALF	*Aoteapsyche*	*Deleatidium*	*Hydrobiosidae*	*Pycnocentrodes*	Food producing	Benthic invertebrate
Full Dam no irrigation	4.040	100	100	100	100	100	100
Estimated existing	0.860	24	67	62	65	52	53
0.900	1.130	30	73	68	74	63	60
1.100	1.270	33	76	70	78	68	63
1.200	1.340	35	78	71	80	70	65
1.500	1.610	42	82	75	85	76	70
1.700	1.790	47	85	78	88	79	73
2.000	2.060	54	88	81	92	84	77
2.500	2.520	65	93	87	96	90	84
3.000	2.970	77	96	91	98	95	89
RISK ASSESSMENT							
Full Dam no irrigation	4.040	Natural	Natural	Natural	Natural	Natural	Natural
Estimated existing	0.860	High	Moderate	Moderate	Moderate	High/Mod	High/Mod
0.900	1.130	High	Low/Mod	Moderate	Low/Mod	Moderate	High/Mod
1.100	1.270	High	Low/Mod	Low/Mod	Low/Mod	Moderate	Moderate
1.200	1.340	High	Low/Mod	Low/Mod	Low/Mod	Moderate	Moderate
1.500	1.610	High	Low	Low/Mod	Low	Low/Mod	Moderate
1.700	1.790	High	Low	Low/Mod	Low	Low/Mod	Low/Mod
2.000	2.060	High/Mod	Low	Low	Low	Low	Low/Mod
2.500	2.520	Moderate	Low	Low	Low	Low	Low
3.000	2.970	Low/Mod	Low	Low	Low	Low	Low

4.2.2. Manuherekia at Ophir

Of the modelled taxa, the mayfly *Deleatidium* was consistently the most abundant macroinvertebrate taxon at the Ophir monitoring site, while the net-spinning caddis fly *Aoteapsyche* was among the most abundant taxa at this site at times. Other taxa that were occasionally abundant at this site include the sand-cased caddis *Pycnocentrodes*, riffle beetles (Elmidae) and the mudsnail *Potamopyrgus.*

Instream habitat modelling for the Ophir reach predicted that habitat for *Deleatidium* and *Aoteapsyche* increases with increasing flow across the modelled flow range, while habitat for *Pycnocentrodes* increased to a maximum between 2.6-3.3 m^3/s before decreasing at higher flows (Figure 17). Food producing habitat increased to a maximum between 3.5 – 4.6 m^3/s before decreasing at higher flows (Figure 18).

All scenarios (minimum flow >0.9 m3/s) were predicted to be a low risk for all species considered except *Aoteapsyche*. Flows of >1.5 m^3/s were predicted to be moderate-high risk (habitat retention <60%), while the 2.5 m^3/s scenario was predicted to be low/moderate risk and the 3 m^3/s scenario was considered to be low risk for this species. The existing flows (*status quo*) was predicted to be high risk, despite *Aoteapsyche* consistently being one of the most abundant taxa at this site.

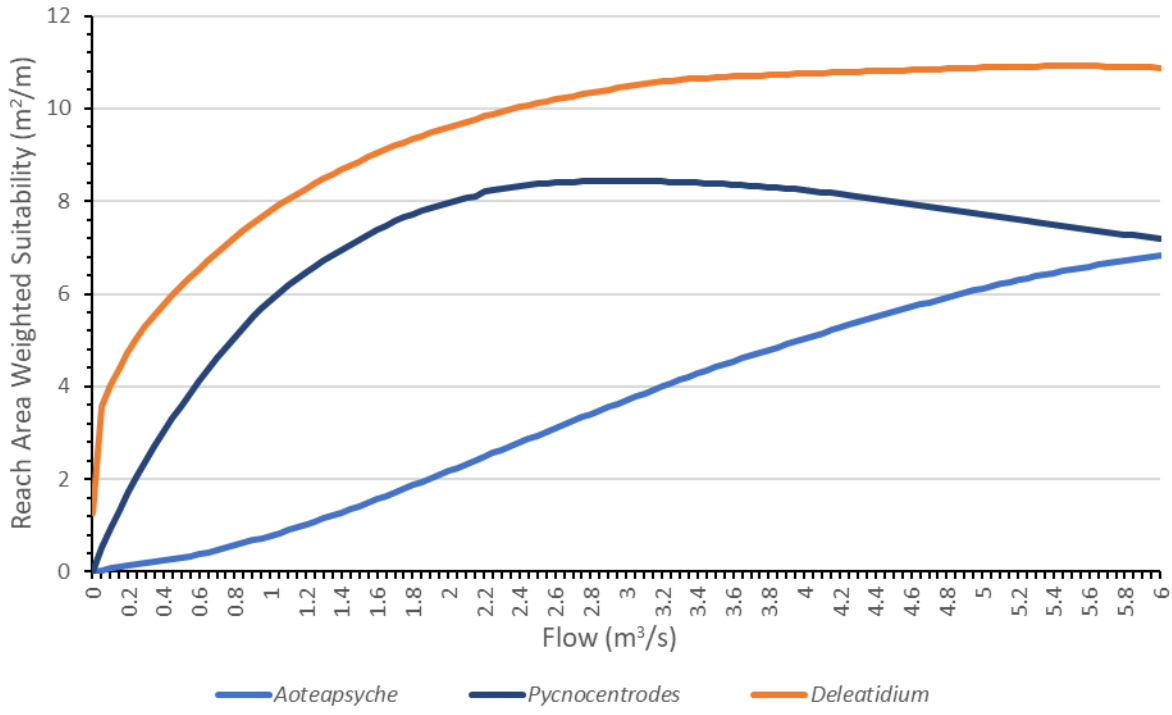

Figure 19 ***Variation in instream habitat for macroinvertebrates in relation to flow, in the Ophir survey reach. The dashed line represents the naturalised 7-d MALF.***

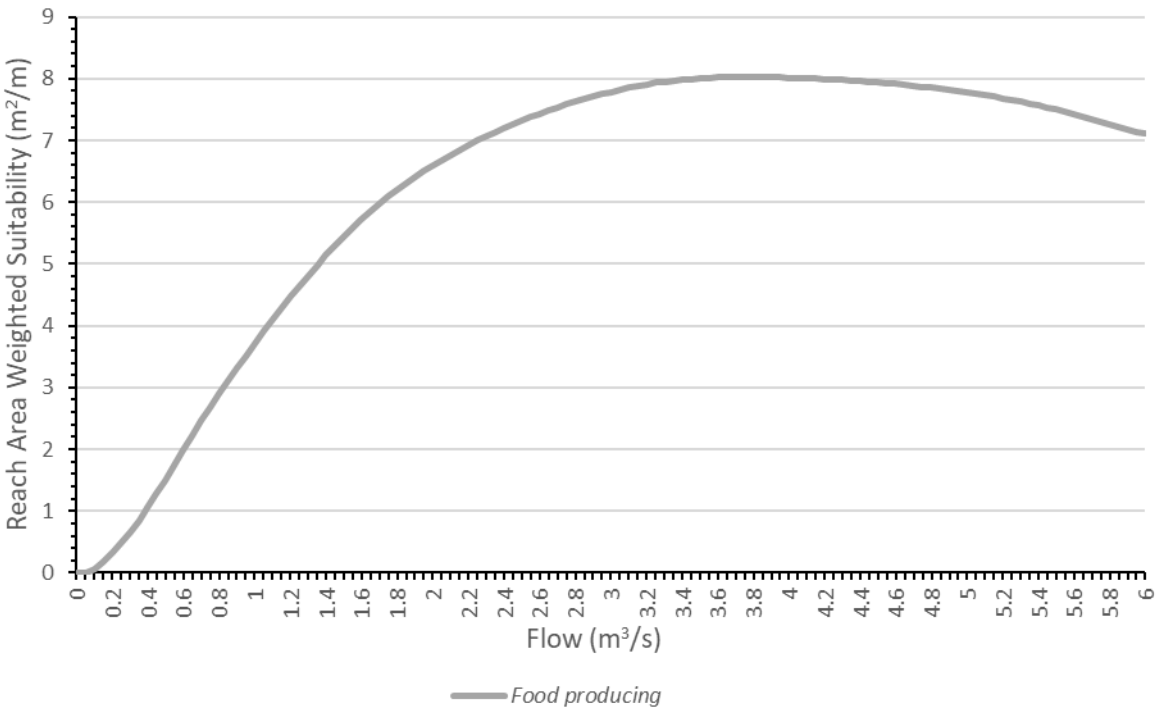

Figure 20 ***Variation in instream habitat for food producing habitat in relation to flow, in the Ophir survey reach. The dashed line represent the naturalised 7-d MALF.***

Table 7 Habitat (RAWS) retention for common macroinvertebrate taxa in the Manuherekia at Ophir and risk assessment based on instream habitat modelling and observations.

Scenario	7dMALF	*Aoteapsyche*	*Deleatidium*	*Hydrobiosidae*	*Pycnocentrodes*	Food producing	Benthic invertebrate
Full Dam no irrigation	3.400	100	100	100	100	100	100
Estimated existing	2.020	39	86	85	90	74	77
0.900	1.780	51	90	89	95	83	83
1.100	2.090	54	91	90	96	85	84
1.200	2.130	55	91	90	96	85	84
1.500	2.250	60	93	92	98	88	87
1.700	2.340	63	94	93	99	89	89
2.000	2.460	67	95	94	99	91	90
2.500	2.720	77	97	96	100	95	93
3.000	2.980	86	98	98	101	97	96
RISK ASSESSMENT							
Full Dam no irrigation	3.400	Natural	Natural	Natural	Natural	Natural	Natural
Estimated existing	2.020	High	Low	Low	Low	Low/Mod	Low/Mod
0.900	1.780	High/Mod	Low	Low	Low	Low	Low
1.100	2.090	High/Mod	Low	Low	Low	Low	Low
1.200	2.130	High/Mod	Low	Low	Low	Low	Low
1.500	2.250	High/Mod	Low	Low	Low	Low	Low
1.700	2.340	Moderate	Low	Low	Low	Low	Low
2.000	2.460	Moderate	Low	Low	Low	Low	Low
2.500	2.720	Low/Mod	Low	Low	Low	Low	Low
3.000	2.980	Low	Low	Low	Low	Low	Low

5. Conclusions

5.1. Periphyton

The periphyton communities in the Manuherekia River and Dunstan Creek are typically dominated by light brown thin films or medium mats, dominated by diatoms. Filamentous algae are often present, but cover is typically low and cover rarely exceeds 30% at any of these sites. Chlorophyll *a* biomass was typically low to moderate, with the three sites on the mainstem of the Manuherekia in B-band, while the Dunstan Creek at Beattie Road site was in A-band.

Chlorophyll *a* concentrations at both Ophir and Galloway were correlated with flows at the time of sampling, the minimum flow recorded in the preceding 15 days, the minimum flow recorded in the preceding 30 days, and the time since the last fresh of >3 times the median flow. High chlorophyll *a* concentrations were recorded when flows were less than 6 m^3/s, suggesting that such events have the potential to occur under any of the minimum flows scenarios being considered.

Periphyton cover in the Manuherekia River at the Galloway and Ophir monitoring sites is expected to continue to be dominated by thin films and medium diatom mats under all of the minimum flow scenarios considered. The risk of proliferation of long filamentous algae is expected to decline with increasing minimum flows up to approximately 3 m^3/s, although observations of the periphyton community in the Manuherekia at Galloway suggests that proliferations of long filamentous algae are relatively infrequent at this site under the *status quo* conditions.

5.2. Macroinvertebrates

The mayfly *Deleatidium* was consistently the most abundant macroinvertebrate taxon at all of the monitoring sites in the Manuherekia River, while the net-spinning caddis fly *Aoteapsyche,* sand-cased caddis *Pycnocentrodes* and free-living predatory caddis fly larvae (Hydrobiosidae) were among the most abundant taxa at these sites.

Macroinvertebrate community indices in the mainstem of the Manuherekia River were in B-band at the Downstream of Forks site (upstream of Falls Dam), B or C-band at Blackstone Hill, B-band at Ophir and A (QMCI), B (ASPM) and C (MCI) bands at Galloway when compared with Tables 14 and 15 of the National Objectives Framework in the NPS: FM.

Habitat in the Galloway reach for all macroinvertebrate taxa considered increased with increasing flow up to the natural MALF (~4,000 l/s). Thus, the risk is expected to reduce with higher flows for all of the taxa considered. Flows below 2 m^3/s are predicted to retain less than 50% of the habitat for *Aoteapsyche*, deemed to represent a "high risk", although *Aoteapsyche* are usually among the most abundant macroinvertebrate taxa collected at this site under *status quo* flows. Modelling suggests that flows of less than 0.9 m^3/s represent a low-moderate risk (habitat retention <70%) for *Deleatidium* and *Pycnocentrodes* and *Deleatdiium* is consistently the most abundant taxon present in the Manuherekia River at Galloway under *status quo* flows and *Pycnocentrodes* can be very abundant at times. Flows of more than 1.5 m^3/s are expected to represent low-moderate risk for Food Producing habitat and benthic invertebrate densities.

All scenarios (minimum flow >0.9 m3/s) were predicted to be a low risk for all species considered except *Aoteapsyche*. Flows of >1.5 m^3/s were predicted to be moderate-high risk (habitat retention <60%), while the 2.5 m^3/s scenario was predicted to be low/moderate risk and the 3 m^3/s scenario

was considered to be low risk for this species. The existing flows (*status quo*) was predicted to be high risk, despite *Aoteapsyche* consistently being one of the most abundant taxa at this site.

Appendix A

Table 8 Periphyton cover at Dunstan Creek at Beattie Road between February 2019 and May 2020.

Category	Thickness	18/02/2019	18/03/2019	15/04/2019	16/05/2019	13/06/2019	7/07/2019	12/08/2019	3/10/2019	31/10/2019	25/11/2019	22/01/2020	27/02/2020	20/03/2020	24/05/2020
Thin green film	<0.5mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thin light brown film	<0.5mm	91	54	8	11	1	42	12	1	10	1	77	46	94	91
Thin black/dark brown film	<0.5mm	0	0	0	1	2	1	0	0	0	0	0	0	1	2
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	0	0	0	1	1	30	12	16	0	0	0	0	1
Medium black/dark brown mat	0.5-3mm	1	4	0	1	1	0	1	1	2	1	0	0	0	1
Thick green/light brown mat	>3mm	0	0	0	0	0	0	0	0	20	21	0	0	0	0
Thick black/dark brown mat	>3mm	3	3	0	0	0	1	0	0	0	0	0	0	0	1
Short green filaments	<2cm	0	0	0	0	0	1	12	2	0	0	0	0	0	0
Short brown/reddish filaments	<2cm	0	0	0	0	0	0	0	55	0	0	0	0	0	0
Long green filaments	>2cm	0	0	0	0	0	0	0	12	0	0	0	0	0	0
Long brown/reddish filaments	>2cm	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
Total algal % cover		**95**	**60**	**8**	**14**	**3**	**46**	**55**	**83**	**48**	**23**	**77**	**46**	**95**	**96**

Table 9 Periphyton cover at Dunstan Creek at Beattie Road between July 2020 and January 2022.

Category	Thickness	1/07/2020	30/07/2020	1/09/2020	21/09/2020	28/10/2020	18/11/2020	21/12/2020	24/02/2021	24/03/2021	28/04/2021	6/07/2021	7/10/2021	9/11/2021	13/01/2022
Thin green film	<0.5mm	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Thin light brown film	<0.5mm	35	43	65	27	1	0	3	0	58	80	86	3	57	3
Thin black/dark brown film	<0.5mm	2	1	0	0	0	0	0	1	0	0	2	0	0	0
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	0	3	22	2	0	1	0	0	0	0	1	0	4
Medium black/dark brown mat	0.5-3mm	0	0	1	2	6	2	0	5	0	0	1	0	0	0
Thick green/light brown mat	>3mm	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Thick black/dark brown mat	>3mm	0	0	0	0	5	0	0	0	0	0	0	0	0	1
Short green filaments	<2cm	0	0	0	1	0	0	0	1	0	0	1	0	0	0
Short brown/reddish filaments	<2cm	0	0	9	2	0	0	0	0	0	0	0	1	0	0
Long green filaments	>2cm	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Long brown/reddish filaments	>2cm	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Sludge		0	0	0	1	0	0	0	0	0	0	0	0	0	0
Total algal % cover		**37**	**44**	**77**	**53**	**13**	**2**	**4**	**6**	**58**	**80**	**89**	**5**	**63**	**9**

Table 10 Periphyton cover at Dunstan Creek at Beattie Road between February 2022 and May 2023.

Category	Thickness	2/02/2022	25/04/2022	22/05/2022	19/06/2022	17/07/2022	27/08/2022	25/09/2022	25/10/2022	22/11/2022	19/12/2022	19/01/2023	15/02/2023	15/03/2023	17/04/2023	16/05/2023
Thin green film	<0.5mm	0	3	0	0	1	0	0	3	36	0	1	0	0	1	0
Thin light brown film	<0.5mm	39	0	77	89	81	0	6	14	11	44	60	35	45	63	36
Thin black/dark brown film	<0.5mm	3	78	0	0	9	0	0	0	0	0	0	0	0	0	0
Medium green mat	0.5-3mm	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	0	8	0	2	0	7	0	3	0	4	0	0	3	11
Medium black/dark brown mat	0.5-3mm	0	0	1	2	0	0	0	0	0	0	0	32	0	0	3
Thick green/light brown mat	>3mm	1	0	4	4	0	0	0	0	0	0	1	1	0	0	0
Thick black/dark brown mat	>3mm	3	0	0	0	0	0	0	1	0	0	0	2	10	0	7
Short green filaments	<2cm	0	12	0	0	0	0	7	0	0	0	0	0	0	0	0
Short brown/reddish filaments	<2cm	6	0	0	0	0	0	0	12	1	8	1	0	0	1	3
Long green filaments	>2cm	0	0	0	0	0	0	4	4	1	0	0	0	0	0	0
Long brown/reddish filaments	>2cm	2	0	0	0	0	0	0	5	1	3	1	1	0	1	1
Sludge		0	0	0	0	0	0	0	2	0	16	8	0	10	6	6
Total algal % cover		**54**	**93**	**90**	**95**	**94**	**0**	**23**	**38**	**51**	**70**	**75**	**70**	**64**	**74**	**65**

Table 11 Periphyton cover at Manuherekia at Blackstone Hill between February 2019 and March 2020.

Category	Thickness	18/02/2019	18/03/2019	15/04/2019	16/05/2019	13/06/2019	8/07/2019	12/08/2019	3/10/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	20/03/2020
Thin green film	<0.5mm	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Thin light brown film	<0.5mm	23	11	0	1	0	32	1	21	19	1	2	13	3	0
Thin black/dark brown film	<0.5mm	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	6	33	48	0	9	4	4	1	0	5	29	8	5
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thick green/light brown mat	>3mm	0	3	0	19	0	32	0	58	36	33	10	0	0	19
Thick black/dark brown mat	>3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short green filaments	<2cm	0	22	3	0	0	0	0	0	0	0	0	5	5	2
Short brown/reddish filaments	<2cm	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Long green filaments	>2cm	45	45	41	2	0	0	0	0	0	0	0	4	18	25
Long brown/reddish filaments	>2cm	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
Total algal % cover		**67**	**87**	**77**	**69**	**0**	**72**	**4**	**83**	**55**	**34**	**17**	**51**	**44**	**51**

Table 12 Periphyton cover at Manuherekia at Blackstone Hill between May 2020 and May 2022.

Category	Thickness	24/05/2020	30/07/2020	1/09/2020	18/11/2020	21/12/2020	24/02/2021	24/03/2021	28/04/2021	6/07/2021	9/11/2021	13/01/2022	2/02/2022	25/04/2022	22/05/2022
Thin green film	<0.5mm	0	0	0	0	0	0	0	0	0	0	0	0	11	1
Thin light brown film	<0.5mm	0	28	11	0	0	0	24	0	0	38	1	7	14	29
Thin black/dark brown film	<0.5mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Medium light brown mat	0.5-3mm	20	41	18	0	0	0	13	11	0	0	26	7	11	1
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thick green/light brown mat	>3mm	15	0	31	51	1	24	4	0	0	8	0	0	9	25
Thick black/dark brown mat	>3mm	0	0	3	0	0	0	0	0	0	0	0	1	0	0
Short green filaments	<2cm	6	0	0	1	0	1	0	0	0	0	0	0	0	0
Short brown/reddish filaments	<2cm	0	0	0	0	0	0	0	0	0	1	25	7	0	0
Long green filaments	>2cm	0	0	0	0	10	0	0	0	0	4	0	3	1	0
Long brown/reddish filaments	>2cm	0	0	0	0	0	0	0	0	0	4	0	8	0	0
Sludge		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total algal % cover		**41**	**68**	**63**	**52**	**12**	**25**	**41**	**11**	**0**	**55**	**51**	**32**	**46**	**55**

Table 13 Periphyton cover at Manuherekia at Blackstone Hill between June 2022 and March 2023.

Category	Thickness	19/06/2022	17/07/2022	30/08/2022	25/09/2022	25/10/2022	22/11/2022	19/12/2022	19/01/2023	15/02/2023	15/03/2023
Thin green film	<0.5mm	0	0	1	0	1	0	0	0	1	0
Thin light brown film	<0.5mm	5	1	0	29	3	48	55	54	37	11
Thin black/dark brown film	<0.5mm	4	1	0	0	0	0	0	0	0	0
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	3	8	0	40	21	0	0	0	1	7
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0
Thick green/light brown mat	>3mm	15	2	0	0	0	0	0	0	0	0
Thick black/dark brown mat	>3mm	1	0	0	0	0	0	0	0	0	0
Short green filaments	<2cm	0	0	0	0	3	0	0	2	0	0
Short brown/reddish filaments	<2cm	0	0	0	0	8	2	1	0	0	6
Long green filaments	>2cm	0	0	0	0	1	0	0	23	43	1
Long brown/reddish filaments	>2cm	0	0	0	0	4	0	8	0	0	46
Sludge		0	0	0	0	14	0	0	0	9	27
Total algal % cover		**27**	**11**	**1**	**68**	**54**	**50**	**64**	**78**	**89**	**96**

Table 14 Periphyton cover at Manuherekia at Ophir between March 2019 and July 2020.

Category	Thickness	18/03/2019	15/04/2019	20/05/2019	12/06/2019	7/07/2019	12/08/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	20/03/2020	24/05/2020	30/07/2020
Thin green film	<0.5mm	58	49	11	0	0	0	0	4	0	0	0	0	1	0
Thin light brown film	<0.5mm	23	1	3	0	12	3	57	11	35	15	67	87	60	34
Thin black/dark brown film	<0.5mm	5	0	0	0	0	0	0	0	0	0	0	1	5	0
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	12	15	0	0	0	9	5	0	4	3	0	7	1
Medium black/dark brown mat	0.5-3mm	2	0	0	0	0	0	2	3	0	10	0	1	2	0
Thick green/light brown mat	>3mm	0	0	0	0	2	0	0	0	0	8	0	0	1	0
Thick black/dark brown mat	>3mm	0	0	0	0	0	0	1	1	0	3	0	0	0	0
Short green filaments	<2cm	4	0	0	0	0	0	1	0	0	2	4	0	0	0
Short brown/reddish filaments	<2cm	2	3	0	0	0	0	0	0	0	5	1	0	0	0
Long green filaments	>2cm	5	7	3	0	0	0	0	0	0	6	4	3	0	0
Long brown/reddish filaments	>2cm	0	0	0	0	0	0	0	0	0	28	0	0	0	0
Sludge		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total algal % cover		**98**	**72**	**32**	**0**	**15**	**3**	**68**	**24**	**35**	**81**	**78**	**93**	**76**	**34**

Table 15 Periphyton cover at Manuherekia at Ophir between November 2020 and October 2022.

Category	Thickness	18/11/2020	21/12/2020	24/02/2021	24/03/2021	28/04/2021	9/11/2021	13/01/2022	2/02/2022	25/04/2022	22/05/2022	19/06/2022	17/07/2022	25/09/2022	25/10/2022
Thin green film	<0.5mm	0	0	0	32	0	0	0	0	79	0	0	0	0	4
Thin light brown film	<0.5mm	0	0	0	35	0	38	1	44	5	77	89	15	89	29
Thin black/dark brown film	<0.5mm	0	3	0	0	68	1	0	2	2	0	1	0	0	0
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	0	0	0	1	0	0	0	7	1	0	0	0	8
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0	0	0	0	2	0	0	0	0	1
Thick green/light brown mat	>3mm	29	0	0	0	0	0	4	0	1	4	6	0	0	0
Thick black/dark brown mat	>3mm	1	11	34	0	0	0	0	0	0	1	2	0	0	2
Short green filaments	<2cm	1	1	4	0	0	0	0	0	0	0	0	0	0	1
Short brown/reddish filaments	<2cm	0	0	11	0	0	4	4	0	0	0	0	0	0	0
Long green filaments	>2cm	0	0	0	0	1	2	2	5	0	0	0	0	0	0
Long brown/reddish filaments	>2cm	0	0	0	0	0	4	6	5	0	1	0	0	0	0
Sludge		0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total algal % cover		**31**	**14**	**48**	**67**	**70**	**48**	**16**	**55**	**96**	**84**	**97**	**15**	**89**	**46**

Table 16 Periphyton cover at Manuherekia at Ophir between November 2022 and March 2023.

Category	Thickness	22/11/2022	19/12/2022	19/01/2023	15/02/2023	15/03/2023
Thin green film	<0.5mm	0	0	0	1	1
Thin light brown film	<0.5mm	65	74	36	44	53
Thin black/dark brown film	<0.5mm	2	0	0	0	0
Medium green mat	0.5-3mm	0	1	0	0	0
Medium light brown mat	0.5-3mm	8	1	21	0	0
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0
Thick green/light brown mat	>3mm	0	0	0	0	0
Thick black/dark brown mat	>3mm	0	0	9	17	15
Short green filaments	<2cm	0	0	1	0	0
Short brown/reddish filaments	<2cm	0	2	3	6	0
Long green filaments	>2cm	0	1	2	4	0
Long brown/reddish filaments	>2cm	0	1	5	0	1
Sludge		0	0	0	0	0
Total algal % cover		**75**	**79**	**76**	**72**	**69**

Table 17Periphyton cover at Manuherekia at Galloway between February 2019 and July 2020.

Category	Thickness	18/02/2019	18/03/2019	15/04/2019	20/05/2019	12/06/2019	8/07/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	20/03/2020	24/05/2020	30/07/2020
Thin green film	<0.5mm	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Thin light brown film	<0.5mm	0	9	4	2	0	24	78	74	0	2	84	62	63	6
Thin black/dark brown film	<0.5mm	97	9	68	4	0	13	0	0	1	0	0	0	21	0
Medium green mat	0.5-3mm	0	1	3	3	0	0	0	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	0	0	0	0	0	1	6	1	0	2	1	0	7	0
Medium black/dark brown mat	0.5-3mm	0	0	0	4	0	0	0	2	0	0	1	0	2	0
Thick green/light brown mat	>3mm	0	0	1	0	0	0	1	0	0	0	0	4	0	0
Thick black/dark brown mat	>3mm	0	1	0	11	0	0	0	0	0	1	0	0	0	0
Short green filaments	<2cm	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Short brown/reddish filaments	<2cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long green filaments	>2cm	0	0	0	0	0	0	0	0	0	3	6	26	2	0
Long brown/reddish filaments	>2cm	3	44	1	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
Total algal % cover		**100**	**64**	**77**	**23**	**0**	**37**	**84**	**76**	**1**	**9**	**92**	**92**	**100**	**6**

Table 18Periphyton cover at Manuherekia at Galloway between November 2020 and June2022.

Category	Thickness	18/11/2020	21/12/2020	24/01/2021	24/02/2021	24/03/2021	30/04/2021	6/07/2021	7/10/2021	9/11/2021	13/01/2022	3/02/2022	25/04/2022	22/05/2022	19/06/2022
Thin green film	<0.5mm	0	0	0	0	2	0	0	0	0	0	0	0	3	0
Thin light brown film	<0.5mm	3	0	0	0	37	29	61	1	47	1	1	91	0	72
Thin black/dark brown film	<0.5mm	0	0	0	0	0	13	0	0	0	0	0	1	75	13
Medium green mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	3	5	0
Medium light brown mat	0.5-3mm	21	3	0	0	1	9	0	0	0	1	0	1	0	0
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0	0	0	0	0	0	0	1	0	5
Thick green/light brown mat	>3mm	0	0	0	18	0	0	0	0	2	5	0	1	5	0
Thick black/dark brown mat	>3mm	8	1	0	0	0	0	0	0	0	0	0	0	2	0
Short green filaments	<2cm	2	0	0	0	0	6	0	0	1	0	1	0	3	0
Short brown/reddish filaments	<2cm	0	0	0	0	0	3	1	0	1	1	3	0	0	0
Long green filaments	>2cm	0	1	0	0	2	2	0	0	0	2	2	2	0	0
Long brown/reddish filaments	>2cm	0	0	0	0	0	5	0	0	8	5	12	0	1	0
Sludge		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total algal % cover		**33**	**4**	**0**	**18**	**41**	**67**	**62**	**5**	**63**	**9**	**54**	**93**	**90**	**95**

Table 19 Periphyton cover at Manuherekia at Galloway between July 2022 and March 2023.

Category	Thickness	17/07/2022	25/09/2022	25/10/2022	22/11/2022	19/12/2022	19/01/2023	15/02/2023	15/03/2023
Thin green film	<0.5mm	0	0	0	71	0	1	4	1
Thin light brown film	<0.5mm	10	95	88	0	76	68	66	72
Thin black/dark brown film	<0.5mm	0	0	0	0	0	0	2	2
Medium green mat	0.5-3mm	1	0	0	0	0	0	0	0
Medium light brown mat	0.5-3mm	1	0	8	1	0	0	0	1
Medium black/dark brown mat	0.5-3mm	0	0	0	0	0	0	0	1
Thick green/light brown mat	>3mm	0	0	0	0	0	0	0	0
Thick black/dark brown mat	>3mm	0	0	0	0	0	0	0	0
Short green filaments	<2cm	0	0	0	0	0	0	0	0
Short brown/reddish filaments	<2cm	0	0	0	0	2	0	0	1
Long green filaments	>2cm	0	0	0	0	1	2	1	0
Long brown/reddish filaments	>2cm	0	0	0	4	1	0	0	3
Sludge		0	0	0	0	0	0	0	0
Total algal % cover		**94**	**23**	**38**	**51**	**79**	**70**	**73**	**79**

Appendix B

Table 20 Macroinvertebrate community data from the Manuherekia at Ophir monitoring site between March 2019 and May 2020, and February 2021.

TAXON	MCI score	Manuherikia River at Ophir													
		18/03/2019	15/04/2019	20/05/2019	13/06/2019	8/07/2019	12/08/2019	3/10/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	24/05/2020	24/02/2021
ACARINA	5						R								
COLEOPTERA															
Berosus species	5						R			R					
Elmidae	6	A	VA	VA	A	A	R	A	A	VA	VA	VA	A	A	A
COLLEMBOLA	6					R									
CRUSTACEA															
Cladocera	5										R				
Copepoda													R		
Ostracoda	3		C	C	C	R			R			R	R		
Paracalliope fluviatilis	5		C				R				R	R	R	C	
DIPTERA															
Aphrophila species	5					R			R						
Austrosimulium species	3	A	A	VA	VA	A	A	C	A	A	A	A	C	A	
Ceratopogonidae	3										R				R
Chironomus species	1									R	R	R			
Empididae	3										R				
Eriopterini	9						R	R					R		
Hexatomini	5			R	R					R					
Maoridiamesa species	3	R		C					C	R					
Molophilus species	5								R						
Muscidae	3	R									R				C
Orthocladiinae	2	R	C	A	C	C	C	C	A	A	C	A	C	A	A
Tanypodinae	5									R	R				R
Tanytarsini	3	R	R	C	R		R	C	C	C	A	C	C		C

Table 20 Macroinvertebrate community data from the Manuherekia at Ophir monitoring site between March 2019 and May 2020, and February 2021.

TAXON	MCI score	Manuherikia River at Ophir													
		18/03/2019	15/04/2019	20/05/2019	13/06/2019	8/07/2019	12/08/2019	3/10/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	24/05/2020	24/02/2021
EPHEMEROPTERA															
Austroclima species	9	C	C	A	C	C	C			C	R		C	A	
Deleatidium species	8	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VA
Nesameletus species	9						R								
Zephlebia species	7	R													
HIRUDINEA	3		R												
MEGALOPTERA															
Archichauliodes diversus	7	R	C	R	C	R	R	R	C	C	R	R	C	C	R
MOLLUSCA															
Gyraulus species	3		R			R									
Physa / Physella species	3	R	A	A	C	R	C						R		
Potamopyrgus antipodarum	4	VA	VA	VA	VA	VA	A	C	VA	A	VA	A	A	A	A
Sphaeriidae													R		
NEMATODA	3		R			R									
NEMERTEA	3	C	R	C					R				R		
OLIGOCHAETA	1	A	C	C	A	A	C	R	C	C		A	A	C	
PLATYHELMINTHES	3					C									
PLECOPTERA															
Zelandobius species	5	R	A	A	A	A	A	A	A	R	R		R	C	
TRICHOPTERA															
Costachorema species	7				R									C	
Hudsonema amabile	6	C	A	A	A	A	R	C	R	R	C		R	C	
Hydrobiosis species	5	A	C	A	VA	A	A	C	A	A	A	A	C	A	C
Hydropsyche - Aoteapsyche grp	4	VA	VVA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VVA	C

Table 20 Macroinvertebrate community data from the Manuherekia at Ophir monitoring site between March 2019 and May 2020, and February 2021.

TAXON	MCI score	Manuherikia River at Ophir													
		18/03/2019	15/04/2019	20/05/2019	13/06/2019	8/07/2019	12/08/2019	3/10/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	24/05/2020	24/02/2021
TRICHOPTERA (continued)															
Neurochorema species	6		R												
Olinga species	9	R	A	C	C	C	R	R	C	R	C	R		R	
Oxyethira albiceps	2											R			A
Plectrocnemia maclachlani												R			
Psilochorema species	8	R	R	C	R	C	R	R	R	R	R	R	R	C	R
Pycnocentria species	7	VA	A	A	C	C	R	C	C	R		R	A	A	R
Pycnocentrodes species	5	VA	VVA	A	A	A	C	VA	VA	VA	VA	A	A	VA	C
Number of taxa		22	25	22	21	23	23	17	21	22	22	19	23	18	15
Number of EPT taxa		11	11	10	11	10	11	9	9	10	9	9	9	11	6
% EPT taxa		50	44	45	52	43	48	53	43	45	41	47	39	61	40
MCI score		101	97	99	105	100	111	108	97	101	103	96	99	112	96
SQMCI score		6.41	5.56	6.11	6.05	6.43	6.86	6.80	6.30	6.52	6.35	6.55	6.83	5.82	5.76

Table 21 Macroinvertebrate community data from the Manuherekia at Galloway monitoring site between March 2019 and May 2020, and February 2021.

TAXON	MCI score	Manuherikia River at Galloway														
		18/02/2019	18/03/2019	15/04/2019	20/05/2019	12/06/2019	8/07/2019	12/08/2019	3/10/2019	31/10/2019	25/11/2019	17/12/2019	22/01/2020	27/02/2020	24/05/2020	24/02/2021
ACARINA	5										R					
CNIDARIA										R						
Hydra species	3															
COLEOPTERA																
Berosus species	5															
Dytiscidae	5															
Elmidae	6	C	A	C	A	C	R	R	R		C	A	A	A	A	A
Scirtidae	8															
Staphylinidae	5			R												
COLLEMBOLA	6															
CRUSTACEA																
Cladocera	5															
Ostracoda	3	R	C	C	A	C	C								C	R
Paracalliope fluviatilis	5	R													R	R
Paraleptamphopus species	5	R								R						
DIPTERA																
Aphrophila species	5									R						
Austrosimulium species	3	VA	C	VA	VA	A	A	C	A	A	A	VA	R		A	C
Ceratopogonidae	3											R	R			
Chironomus species	1															R
Corynoneura scutellata	2															
Empididae	3															
Eriopterini	9								R							
Hexatomini	5										R					

Table 21 ***Macroinvertebrate community data from the Manuherekia at Galloway monitoring site between March 2019 and May 2020, and February 2021.***

		Manuherikia River at Galloway														
TAXON	**MCI score**	**18/02/2019**	**18/03/2019**	**15/04/2019**	**20/05/2019**	**12/06/2019**	**8/07/2019**	**12/08/2019**	**3/10/2019**	**31/10/2019**	**25/11/2019**	**17/12/2019**	**22/01/2020**	**27/02/2020**	**24/05/2020**	**24/02/2021**
DIPTERA (continued)																
Maoridiamesa species	3		R						R						R	
Molophilus species	5						R			R						
Muscidae	3			R		R				R						
Orthocladiinae	2	A	C	C	A	R		R	A	A	A	R		C	A	C
Paralimnophila skusei	6															
Polypedilum species	3		R												R	
Tanypodinae	5									R				R		C
Tanytarsini	3		R	C					A	A	R	R		R	R	R
Zelandotipula												R				
EPHEMEROPTERA																
Austroclima species	9	A				R	R	R					R	C	C	
Coloburiscus humeralis	9															
Deleatidium species	8	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA	VVA
Nesameletus species	9	R	R		R											
Zephlebia species	7															
HIRUDINEA	3															
MEGALOPTERA																
Archichauliodes diversus	7	C	R		R	R			R	R		R		C	C	R
MOLLUSCA																
Gyraulus species	3															
Physa / Physella species	3	R	C	C	A	R	R								C	R
Potamopyrgus antipodarum	4	A	VA	A	VA	A	A	C	R	C	C	VA	A	VA	VA	A

Table 21 ***Macroinvertebrate community data from the Manuherekia at Galloway monitoring site between March 2019 and May 2020, and February 2021.***

		Manuherikia River at Galloway														
TAXON	**MCI score**	**18/02/2019**	**18/03/2019**	**15/04/2019**	**20/05/2019**	**12/06/2019**	**8/07/2019**	**12/08/2019**	**3/10/2019**	**31/10/2019**	**25/11/2019**	**17/12/2019**	**22/01/2020**	**27/02/2020**	**24/05/2020**	**24/02/2021**
NEMATODA	3															
NEMERTEA	3		C											C		
OLIGOCHAETA	1	C	C	R		R	R	R	R	C	C	C	C	A		
PLATYHELMINTHES	3		A				R					R	R	C		
PLECOPTERA																
Megaleptoperla species	9															
Stenoperla species	10															
Zelandobius species	5		C	A	A	A	A	R	A	A	R				C	
Zelandoperla species	10															
TRICHOPTERA																
Confluens species	5															
Costachorema species	7			R	R	R		R								
Hudsonema alienum	6															
Hudsonema amabile	6	C	C	R	C	R	R	R		R				C	C	
Hydrobiosidae early instar	5													R	R	
Hydrobiosis species	5	A	A	A	A	A	A	C	C	A	C	A	A	C	C	R
Hydropsyche - Aoteapsyche grp	4	VVA	A	VA	VA	VA	A	VA	A	A	C	VVA	VVA	VA	VA	A
Neurochorema species	6															
Olinga species	9		R	C	C	R		R		R	R			R		
Oxyethira albiceps	2		C		R				R						R	C
Plectrocnemia maclachlani													R			
Psilochorema species	8	A	R	C	A	C	C	C	C	C	C	A	A	C	C	C
Pycnocentria species	7	A	A	C	A	R	R		R	C			R	C	A	
Pycnocentrodes species	5	A	VA	A	C	C	C		C	A	A	A	R	C	A	
Number of taxa		19	24	20	19	20	17	14	17	21	15	15	14	19	22	16
Number of EPT taxa		9	11	10	12	11	9	9	8	9	7	5	8	10	10	4
% EPT taxa		47	46	50	63	55	53	64	47	43	47	33	57	53	45	25
MCI score		105	93	97	108	105	100	110	96	101	95	91	106	105	96	86
SQMCI score		5.71	6.55	6.43	6.13	6.91	7.29	7.24	7.17	7.01	7.34	5.58	5.96	6.60	6.51	7.44