Review of the hydrological characteristics and instream ecological values of the Opihi catchment

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Executive summary

The Orari-Temuka-Opihi-Pareora (OTOP) Zone Committee and Environment Canterbury (ECan) are working with the community to develop a set of recommendations for water quality and quantity limits for inclusion in the Canterbury Land and Water Regional Plan (LWRP) through the OTOP Healthy Catchments Project. As part of the project, NIWA is carrying out field studies to develop recommendations for minimum flows and other flow requirements at key sites in the Opihi catchment (including the Temuka subcatchment). Nine study reaches were initially selected for the field study following consultation with ECan and community representatives.

This report presents a review of current hydrological characteristics and instream ecological values at each of the key sites. The information in this review will be used to guide the minimum flow assessments to be carried out following the field studies. The review covers all nine sites, although the field component has been reduced to include only five sites because of storm damage to surveyed areas at some sites early in February 2018.

Sites included were on the following rivers (starting at the highest point in Opihi catchment): North Opuha, South Opuha, Opihi upstream of the Opuha confluence (Opihi @ Gorge), Te Ngawai, Opuha, Opihi downstream of the Opuha confluence (Opihi @ Butlers), Te Moana, Waihi, Temuka. We reviewed the following at each site: catchment characteristics (land cover and climate); hydrological conditions; status in relation to the key instream ecological characteristics of periphyton, macroinvertebrates and freshwater fish; recreational values and usage.

Catchments at all nine sites included at least 12% cover by indigenous vegetation, up to 61% (South Opuha). Land under intensive agriculture ranged from 4% (South Opuha) to 70% (Te Ngawai). Rainfall exceeds evapotranspiration only in the upper catchment, implying potential water deficits in most of the lower catchment.

Low flow and flood metrics were standardised to multiples of median flows for comparison among sites. The North Opuha and Opihi @ Butlers had the lowest proportions of time under very low flows (< 0.5 x median flow for < 7% of the time). Longest low flows were in the Te Ngawai and Opuha Rivers (> 21% of the time). Flood events (ranging from 3 to 10 x median flow) occurred most frequently in the small tributary rivers (Te Ngawai, Te Moana, Waihi).

Periphyton was assessed mainly in terms of exceedances of regional objectives (e.g., in the Opihi River Regional Plan (ORRP) and the LWRP) and national guidelines (e.g., the periphyton attribute in the National Policy Statement for Freshwater Management). We also included frequency of high cover by the potentially toxic cyanobacterium *Phormidium*. The best sites (i.e., lowest periphyton, as determined by ranking all the sites for nuisance cover and occurrence of *Phormidium*) were the North and South Opuha. The worst site was the reach represented by the Opihi @ Butlers, which has regular high cover by periphyton mats and filaments, and by *Phormidium*. *Phormidium* was also a regular feature of the periphyton at Opihi @ Gorge, Opuha, Te Moana, Waihi and Temuka.

The status of macroinvertebrate (invertebrate) communities was compared across sites and with the LWRP objective based on assessments carried out by ECan since 2011. The LWRP objective uses the Quantitative Macroinvertebrate Community Index (QMCI). Lower QMCI scores indicate poorer invertebrate community health. Only the two sites on the Opihi mainstem (Opihi @ Gorge, Opihi @ Butlers) met the LWRP objective (QMCI ≥6). Mean QMCI was lowest in the Opuha, and had also declined over the years at that site. At all sites invertebrate health and habitat health (ranked on scales of Very good to Very poor) varied across years but were consistently only Fair or worse in the Temuka River. No data were available from the North Opuha.

Information on fish communities was obtained from the New Zealand Freshwater Fish Database (NZFFD). Eighteen fish species have been recorded in the OTOP catchment. Some species (e.g., upland bully and Canterbury galaxias) were present at all sites. Others were found only at the very top of the catchment (e.g., alpine galaxias) or the very bottom (e.g., migratory inanga). Highest diversity was recorded in the Temuka River, with 12 species.

Finally, recreational values of the sites were reviewed mainly based on the results of Fish & Game angler usage surveys, the most recent of which was in 2014/15. The main stem of the Opihi River accounts for most of the angling activity in the catchment, followed by Lake Opuha. Angling effort has apparently declined in the catchment in recent years (except in Lake Opuha). The decline likely reflects a general New Zealand-wide decline in angling effort in lowland rivers between 1994/95 and 2014/15. A further significant instream recreational activity for which there is documentation is kayaking in the Opihi Gorge. The gorge was identified as a “Scenic River Gorge” in an assessment of kayaking opportunities in Canterbury. Sites on most rivers may be used for swimming but we are not aware of quantitative data on usage. Sites on the Opihi, Te Moana, Waihi and Temuka are monitored by ECan for swimmability and the results posted on a public website. At the time of finalising this report, sites at Opihi @ SH1, Opihi @ Pleasant Point, and Waihi @ Geraldine were deemed swimmable.

The findings of the review were summarised by ranking the nine sites on the bases of their catchment characteristics, flow characteristics, periphyton, invertebrate and fish communities, and recreational values. The purpose of the ranking exercise was to highlight ecological differences between the sites to (a) guide selection of biological variables for modelling during the instream-habitat-assessment component of the project, and (b) inform discussion of the results of the habitat modelling. The ranking highlighted that there was limited consistency between flow and biological characteristics and recreational values at each site. For example, although the Temuka River ranked relatively low for flow characteristics (i.e., prolonged low flows and few flood events), highest fish diversity and some angler usage placed the site third highest for biological and recreational values.

1 Introduction

The Orari-Temuka-Opihi-Pareora (OTOP) Zone Committee and Environment Canterbury (ECan) are working with the community to develop a set of recommendations for water quality and quantity limits for inclusion in the Canterbury Land and Water Regional Plan (LWRP) through the OTOP Healthy Catchments Project. As part of the project, NIWA was contracted by ECan to develop recommendations for minimum flows and other aspects of the flow regimes at key locations in each Surface Water Allocation Zone in the Opihi catchment (including the Temuka catchment).

The work leading to the recommendations was proposed to be in two parts. The first part would focus on reviewing and summarising, for each key site and the catchment it represents, current flow regimes and ecological conditions and then identifying instream ecological values. The second and main part of the project was to comprise field-based instream habitat assessments at the key sites. The two components of the project will be combined in a final report in which the instream habitat assessments will be used to recommend minimum flows / flow regimes designed to maintain the identified values.

This report is the outcome of the first part of the work. For the review we obtained information from recent technical reports (e.g., Dodson & Steel 2016, Hayward et al. 2016), recent data collections, and databases. We focussed on mainly current rather than historical information to provide a contemporary understanding of the relevant catchments.

In parallel with the traditional flow setting approach (being carried out as the second part of the project), cultural flow assessment work is being undertaken in the Opihi and Temuka catchments, led by Dr Gail Tipa. The cultural work will feed into the overall flow setting process but cultural flow information will not be included in the present review report as it is outside of the expertise of the authors.

The original locations of the key sites in the Opihi and Temuka catchment are shown in Figure 1-1 and Table 1-1. The sites are broadly those for which ECan requested the assessments in the request for proposals, prior to contracting the work. The exact locations of the sites were discussed and refined at a meeting of the Opihi Flow and Allocation Working Group in Pleasant Point on 8 December 2017. Locations of habitat assessment reaches were initially identified during a field visit on 21 December 2017, with input from ECan (Shirley Hayward and others), Ryder Consulting Ltd (Greg Ryder) and NIWA. Reaches for the assessments were selected based on physical suitability for instream habitat assessments (e.g., position of flow controls and tributaries, variety of habitat conditions along the reach), representativeness of the river in general (from local knowledge), access, and appropriateness in terms of locations of water takes upstream or downstream.

Since the project commenced, the locations of the habitat assessment sites have had to be reviewed following storm damage to surveyed areas during Cyclone Gita on 21 February 2018. The number of sites surveyed for the full habitat assessment procedure has been reduced from nine to five. The storm resulted in very high flows at all of the study sites, which negated surveys of reach cross sections carried out during low flows in January. For example, flows in the Te Ana a Wai @ Cave Picnic Grounds peaked at 185 m^3/s (instantaneous flow) and 121 m^3/s (daily mean flow, or 70 x median flow) on 21 February 2018. Sites farther north were more severely affected. Changes to the original reach locations and omitted sites will be documented in the final report on the habitat assessments.

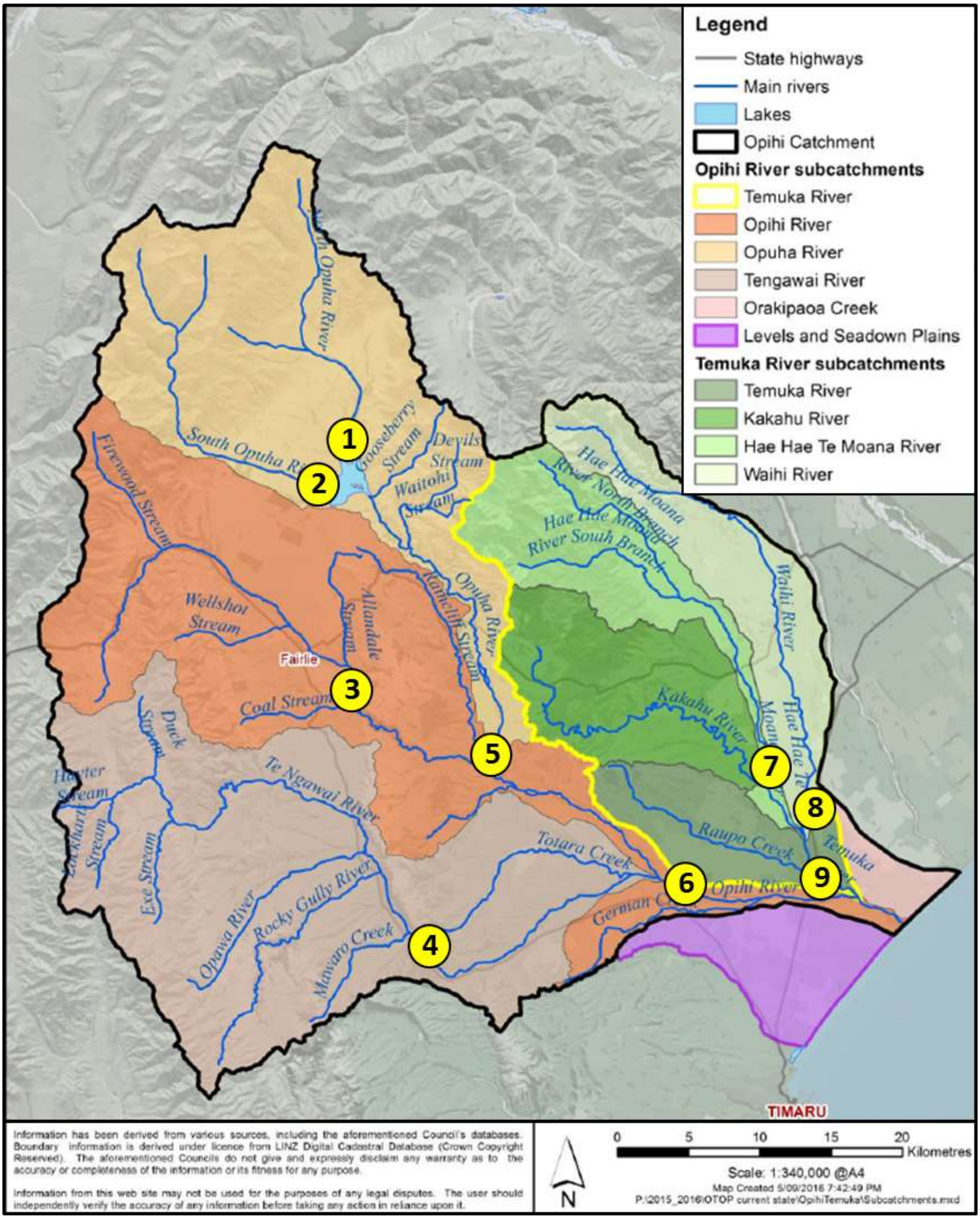


Figure 1-1: Instream habitat modelling locations in the Opihi catchment. 1 = North Opuha, 2 = South Opuha, 3 = Opihi @ Gorge, 4 = Te Ngawai, 5 = Opuha @ Confluence, 6 = Opihi @ Butlers, 7 = Te Moana, 8 = Waihi, 9 = Temuka.

This review comprises sections summarising current information (from the literature and databases) at all nine originally selected sites. The following topics are included: catchment characteristics (land cover and climate); hydrological conditions; status in relation to the key instream ecological characteristics of periphyton, macroinvertebrates and freshwater fish; recreational values and usage. Historical information is referred to when available. Each section includes tabular information and a narrative comparing the sites and identifying information gaps.

Table 1-1: Sites in the Opihi catchment included in the review. The listed sites are those initially selected during the field visit on 21 December 2017, or during subsequent visits in January 2018 when the first surveys were conducted. Changes to the reach locations and site inclusion in the study will be detailed in the report on the habitat assessments. *Note that flow site 69650 (Opihi @ Saleyards Bridge) was set up for low flows only and is not rated at high flows. Therefore flood statistics relevant to the habitat assessment reach were calculated using the record from site 696501, Opihi @ SH1 (see Section 3).

Surface Water allocation zone	Minimum flow site no.	Flow site name	Habitat reach name and location details
North Opuha	69615	N. Opuha @ Clayton Br	**North Opuha**: upstream of Clayton Settlement Rd bridge
South Opuha	69616	S. Opuha @ Monument Br	**South Opuha**: upstream of Clayton Rd bridge, starting about 200 m from the bridge
Opihi Rockwood	69618	Opihi @ Rockwood	**Opihi @ Gorge**: access from Opihi Gorge Rd.
Te Ngawai (Te Ana a Wai)	69635	Te Ana a Wai @ Cave Picnic Grounds	**Te Ngawai**: angler's access 2.5 km northwest of Cave on SH8.
Opuha	69624	Opuha @ Skipton Bridge	**Opuha @ Confluence**: access across Opihi River south of Raincliff Bridge
Opihi Saleyards	69650	Opihi @ Saleyards Bridge*	**Opihi @ Butlers**: river access down Mill Road
Hae Hae Te Moana	69644	Te Moana @ Glentohi	**Te Moana**: upstream and downstream of Goodwin Rd ford
Waihi	69643	Waihi @ Waimarie	**Waihi**: upstream of Te Awa Rd bridge
Temuka	69602	Temuka @ Manse Bridge	**Temuka**: from Manse bridge downstream

Throughout this review, the reaches being surveyed for the instream habitat assessments are referred to as "habitat assessment" sites or reaches, with site names as in Table 1-1. For the flow assessments we refer to the names of the flow sites associated with the habitat sites (Table 1-1) except that for consistency the Te Ngawai (Te Ana a Wai) River is referred to as Te Ngawai. Note that the habitat assessment reaches and the flow sites are not necessarily in the same place (See Appendix A).

In a final synthesis we provide a summary of key findings from the review for all sites. The summary is structured around ranking all of the sites on flow characteristics (durations of low and frequencies of high flows), periphyton (occurrence of nuisance growths), invertebrates (meeting LWRP objectives), fish communities (species richness) and recreational values (primarily angler usage).

2 Catchment land cover and climate

Maps of climate (rainfall and potential evapotranspiration), land cover and land use for the whole of the Opihi / Temuka catchment were presented in Dodson & Steel (2016). To expand on these maps, we extracted numerical data on land cover and climate from the New Zealand Land Cover Database (LCDB) (version 3) values attached to the River Environment Classification (REC, version 2) for the catchment upstream of each site.

2.1 Land cover

The land cover variables in the LCDB were combined into eight categories (Table 2-1). Indigenous vegetation is the predominant land cover type upstream of the sites in the North Opuha, South Opuha and Opuha @ confluence. The Te Moana site catchment has slightly higher cover by exotic vegetation (other than agriculture) than by intensive agriculture. The remaining five catchments are predominantly under intensive farming (>50%). All nine catchments include at least 12% cover by indigenous vegetation (Figure 2-1, Table 2-2).

Table 2-1: Explanations of land cover categories in Figure 3-1 and Table 3-2. Categories were combinations of multiple variables in the New Zealand Land Cover Database.

Category	Description
Urban / built	All urban and built-up areas including parks, roading, landfills and mines
Water	Areas of open water (lakes, rivers)
Intensive agriculture	Cropland, horticulture/orchards/vineyards, high-producing pasture
Low intensity agriculture	Low producing grassland and depleted grassland
Exotic vegetation	Plantation forestry, gorse/broom, other exotic scrub, shelterbelts, willow
Wetland	Freshwater wetlands
Indigenous vegetation	Native forest, shrubs (kanuka/manuka, matagouri), tussock, alpine vegetation
Rock and ice	Alpine rock, gravel and ice; landslides

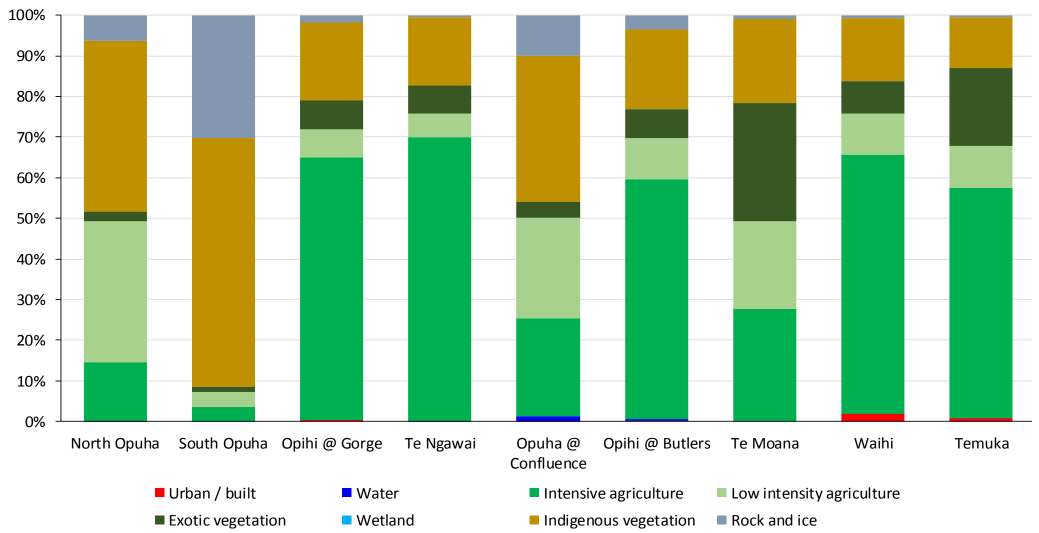


Figure 2-1: Percentages of the catchments upstream of each site occupied by different types of land cover. Refer to Table 2-1 for details of each category.

Table 2-2: Percentages of the catchments upstream of each site occupied by different types of land cover. The area covered by wetlands is too low to be visible on Figure 2-1.

	Area ('000 ha)	Percentage of upstream catchment in land-cover category							
		Urban / built	Water	Intensive agric.	Low intens. agric.	Exotic vege.	Wetland	Indig. vege.	Rock & ice
North Opuha	14.1	0.006	0.04	14.6	34.7	2.3	0	41.9	6.4
South Opuha	12.0	0	0.04	3.7	3.5	1.5	0	61.2	30.1
Opihi @ Gorge	34.2	0.4	0.02	64.5	7.1	7.1	0.03	19.0	1.9
Te Ngawai	48.0	0.02	0.003	70.0	5.8	6.9	0	16.8	0.5
Opuha @ Confluence	48.3	0.007	1.25	24.2	24.8	3.8	0.01	36.0	10.0
Opihi @ Butlers	171.0	0.1	0.42	59.1	10.1	7.2	0.01	19.5	3.6
Te Moana	14.8	0	0	27.8	21.5	29.1	0.01	20.5	1.0
Waihi	18.7	1.9	0.02	63.8	10.1	8.0	0	15.5	0.6
Temuka	55.8	0.8	0.01	56.6	10.4	19.2	0.003	12.4	0.6
Whole catchment	**226.8**	**0.3**	**0.3**	**58.5**	**10.1**	**10.1**	**0.01**	**17.8**	**2.9**

The proportions of land cover upstream of Opihi @ Butlers and Temuka (@ Manse Bridge) integrate land cover of the entire catchment (including the smaller upstream sub-catchments) (bottom line of Table 2-2).

Note that these land cover percentages were calculated from the LCDB version 3 database. There may be small differences compared to later versions (v. 4.1, referred to in Dodson & Steel 2016).

2.2 Climate

The maps in Dodson & Steel (2016) highlighted the gradients in rainfall and potential evapotranspiration (PET) across the catchment. Mean annual rainfall in the headwaters of the North and South Opuha Rivers (1050 mm) is almost double that in the headwaters of the Te Ngawai River (550 – 600 mm). Rainfall exceeds evapotranspiration in the headwaters of the Opuha and Te Moana Rivers but is lower than evapotranspiration in much of the rest of the catchment, implying potential water deficits at times.

Modelled climate characteristics for each site, extracted from the databases linked to the REC, quantify the climatic differences among the sites.

During the warmest month North and South Opuha sites are expected to be, on average, 1°C cooler than the sites nearest to the coast (Waihi and Temuka) and during the coldest month at least 2.5°C cooler (Table 2-3). Reflecting the rainfall patterns, the North and South Opuha sites have more heavy rain events than the downstream sites. Modelled solar radiation at each reach shows slightly higher solar radiation at the higher altitude sites than at the lower sites in both summer and winter (Table 2-3).

Table 2-3: Physical and climatic features of the nine study sites, extracted from the databases linked to the River Environment Classification. Temperature, rainfall days and solar radiation are modelled values specific to the survey reaches.

Site name	Distance to sea (km)	Altitude (m)	Stream order	Mean monthly temperature (°C)		Annual days with rain		Mean solar radiation (W/m²)	
				Coldest	Warmest	>10 mm	>25 mm	June	Dec
North Opuha	66.7	431	5	-2.5	15.1	2.6	0.6	500	2235
South Opuha	66.9	472	4	-2.7	15.1	2.5	0.6	501	2241
Opihi @ Gorge	49.6	274	5	-2.5	15.5	1.9	0.6	494	2221
Te Ngawai	40.6	167	5	-1.1	15.8	1.7	0.5	490	2212
Opuha @ Confluence	37.1	157	6	-1.5	15.9	1.8	0.6	484	2200
Opihi @ Butlers	16.7	53	6	-0.4	16.0	1.5	0.4	483	2201
Te Moana	16.8	62	4	-0.5	16.0	1.8	0.4	483	2200
Waihi	13.4	29	4	-0.2	16.1	1.7	0.4	483	2198
Temuka	8.5	11	5	0.0	16.1	1.6	0.3	487	2203

3 River flows

Dodson & Steel (2016) provided a comprehensive account of surface water hydrology in the Opihi and Temuka catchments. Their main focus was on the current state of water quantity and water use compared to the historic state, including an assessment of the impact of irrigation takes on flows. The purpose of the present review is to describe the current characteristics of the flow regimes at the flow recorders linked to each study site from an ecological perspective. The assessment includes quantifying hydrological statistics at each site, such as duration of low flows conducive to accrual of nuisance periphyton, and frequencies and durations of high flows relevant to periphyton removal and fish migration cues or fish population bottlenecks. While the field work in this project (to be presented in the second report) is concerned with defining ecologically relevant minimum flows at each site, this section covers the potential for maintaining flow variability at each site.

We obtained records of daily mean flows at each site for the 10 years from January 2008 to December 2017, or for as long as possible if the record started later than January 2008. Short records were available at Opuha @ Skipton (May 2011 to December 2017) and Waihi (September 2012 to December 2017). The following flow statistics were extracted from each record: mean and median flow; ratio of mean / median flow; mean annual maximum flow; mean annual minimum flow; mean annual 7-day low flow, proportion of time flow was less than 0.5 x median flow, and exceeded 2, 3, 5, 7 and 10 x median flow; mean annual number of events (Frequency, or FRE) exceeding 2, 3, 5, 7 and 10 x median flow (hence FRE2, FRE3 and so on). Hydrographs and flow duration curves plotted from five years of data (2013 – 2017) at each site were compared.

3.1 Comparison of flow metrics

3.1.1 North and South Opuha

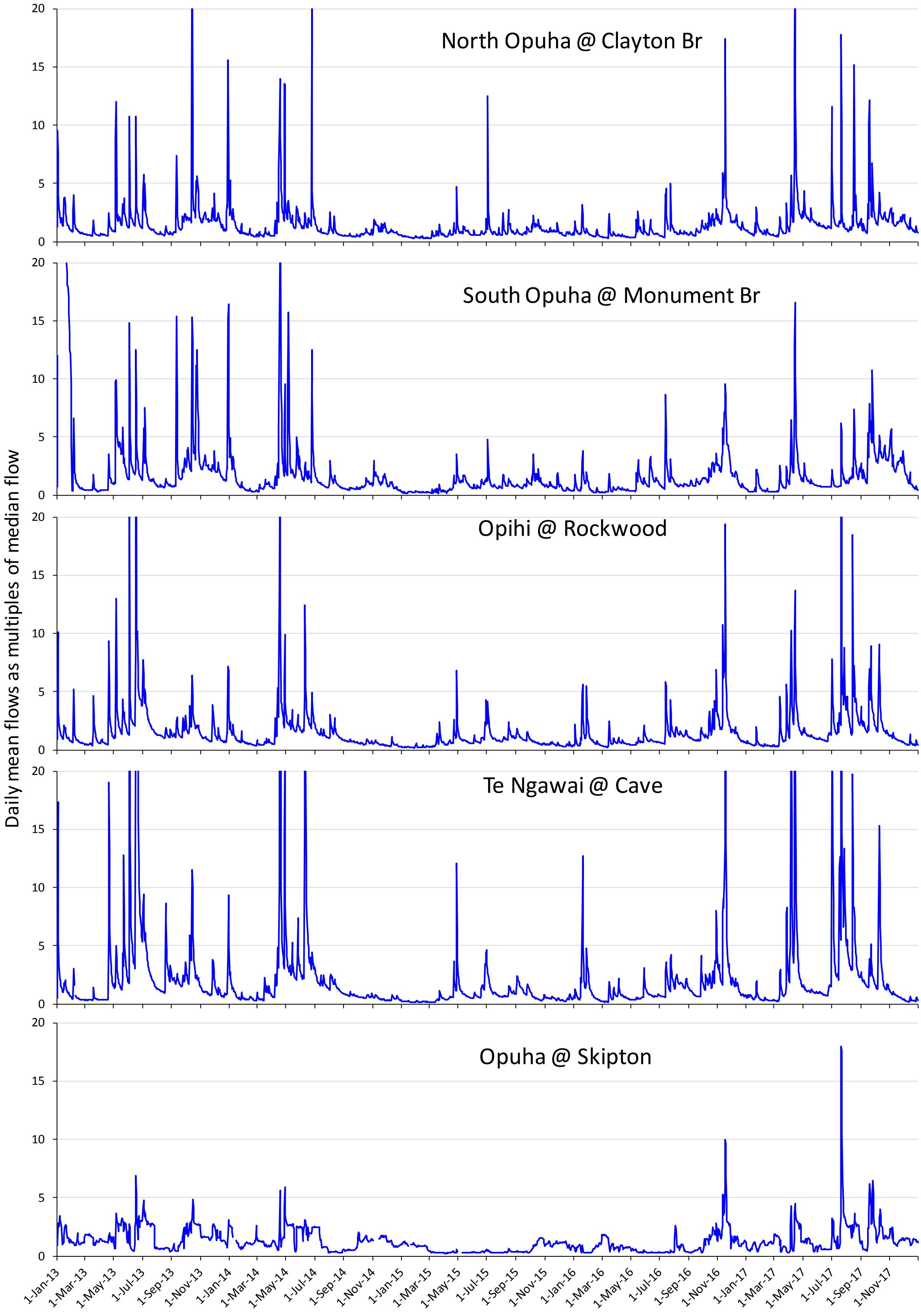
Apart from the Opuha River (see below), the North and South Opuha Rivers had the lowest ratios of mean to median flow. Both sites lie in the net positive PET zone identified by Dodson & Steel (2016), and so would be expected to have, on average, higher base flows relative to mean flows than rivers in the net negative zone. Mean annual maxima of 17 and 16 times the median flow (i.e., in the low range compared to the other rivers) also reflected high baseflows (Table 3-1). Although their catchment sizes (Table 2-2) and mean and median flows (Table 3-1) were similar, the North and South Opuha differed in other aspects of their flow regimes. The North Opuha had lower proportions of time under both low (<0.5 x median) and high flows (all thresholds >2 x median) than the South Opuha, and had somewhat lower flood frequencies. The differences indicate a more "flashy" flow regime in the South Opuha than in the North Opuha. However, compared to the small tributaries lower down in the catchment (Te Ngawai, Te Moana, Waihi), both the North and South Opuha had relatively low flood frequencies and lower proportions of time under high flows (Table 3-1).

3.1.2 Opihi @ Rockwood

Flows in the Opihi @ Rockwood had a low ratio of mean/median flow, and mean annual maximum and minimum in the middle of the range across all the sites (Table 3-1). Proportions of time under high flows were relatively low compared to the sites nearer to the coast, and similar to those in the North and South Opuha. Flows at Rockwood include gains from groundwater within the gorge (Dodson & Steel 2016), which may lead to higher mean annual low flows (relative to the median) than in the South Opuha. The mean annual maximum flow was 35 x median flow, which is higher than those in the North and South Opuha Rivers, but lower (relative to the median) than at the sites nearer to the coast (46 to 112 x median, Table 3-1).

Table 3-1: Flow statistics calculated from the flow records linked to the nine study sites. Flow site names are shown in full in Table 1-1. All flow statistics were based on daily mean flows calculated for the 10-year record from 2008 to 2017, or as long as available if the record began after 2008. The records for Opuha @ Skipton and Waihi started in 2011 and 2013 respectively because of missing data. Periphyton removal was calculated only for these five sites. *Flood frequencies and durations calculated from the flow record at SH1 as the record at Saleyards is rated at low flows only. Discrepancies between flows in m^3/s and multiples of the median are caused by rounding. MAMax = mean annual maximum flow; MALF = mean annual low flow. The green cells in the numbers of events panel are frequencies of events (see Section 3.3).

	North Opuha	South Opuha	Opihi @ Rockwood	Te Ngawai	Opuha @ Skipton	Opihi @ Saleyards /SH1*	Te Moana @ Glentohi	Waihi @ Waimairie	Temuka @ Manse Br
Flow statistics (m^3/s)									
Median	1.9	1.9	3.0	1.6	6.9	9.7	0.4	0.4	3.1
Mean	2.7	3.0	5.1	4.2	8.8	20.9	1.1	0.9	6.4
Mean/Median	1.4	1.6	1.7	2.6	1.3	2.2	2.5	2.0	2.1
MAMax	33	29	107	150	56	467	48	20	187
MALF	0.75	0.43	0.95	0.42	2.05	3.96	0.14	0.16	1.22
7d-MALF	0.86	0.49	1.06	0.46	2.19	4.36	0.16	0.19	1.27
Flow statistics (multiples of median flow)									
MAMax	17	16	35	92	8	48	112	46	60
MALF	0.41	0.24	0.31	0.26	0.29	0.41	0.30	0.36	0.39
7d_MALF	0.44	0.27	0.35	0.29	0.31	0.45	0.37	0.43	0.41
Percentages of time when flows were below or above thresholds									
< 0.5 x med	6.7	18.9	15.0	21.6	23.7	6.7	14.9	12.0	16.3
> 2 x med	15.1	22.5	19.9	27.9	18.1	24.0	24.2	22.1	19.2
> 3 x med	5.2	12.1	10.2	16.6	4.2	14.9	14.9	13.8	11.0
> 5 x med	1.9	4.3	4.5	8.6	1.0	6.5	8.6	7.4	6.3
> 7 x med	1.0	2.2	2.5	6.1	0.3	3.7	5.7	4.5	4.2
> 10 x med	0.7	1.1	1.3	4.0	0.1	1.9	3.6	2.5	2.5
Mean annual number of events									
< 0.5 x med	3.6	6.8	5.4	6.3	6.8	3.5	6.9	7.8	2.4
> 2 x med	15.3	11	11.4	10.1	9.0	8.8	10.9	14.6	7.4
> 3 x med	8.4	8.9	9.4	8.9	4.5	7.0	9.7	12.0	6.0
> 5 x med	4.1	5.5	6.5	6.4	1.7	4.9	6.7	9.4	5.5
> 7 x med	2.4	3	4.7	6.0	0.5	4.1	6.0	7.4	4.9
> 10 x med	1.9	1.7	3.1	4.7	0.2	3.2	4.9	4.6	3.5


North Opuha @ Clayton Br
South Opuha @ Monument Br
Opihi @ Rockwood
Te Ngawai @ Cave
Opuha @ Skipton
Daily mean flows as multiples of median flow
0
5
10
15
20
1-Jan-13
1-Mar-13
1-May-13
1-Jul-13
1-Sep-13
1-Nov-13
1-Jan-14
1-Mar-14
1-May-14
1-Jul-14
1-Sep-14
1-Nov-14
1-Jan-15
1-Mar-15
1-May-15
1-Jul-15
1-Sep-15
1-Nov-15
1-Jan-16
1-Mar-16
1-May-16
1-Jul-16
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1-Sep-17
1-Nov-17

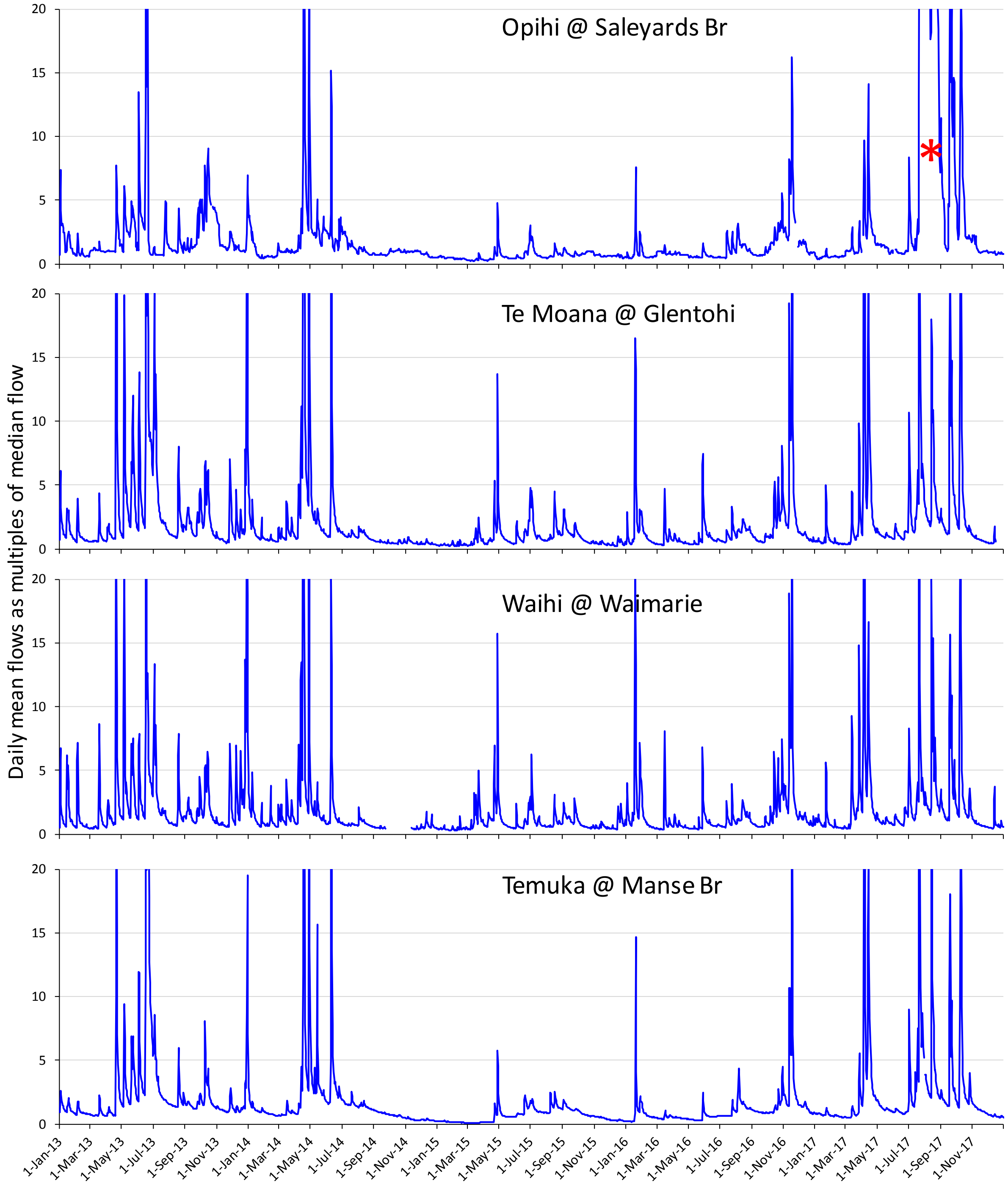

Figure 3-1: Hydrographs of flows at all nine sites from 2013 to 2017. Flows are shown as multiples of median flow to aid comparisons between sites. The y-axis is truncated at 20 x median flow so that smaller events can be seen more clearly. The red asterisk on the right of the plot for Opihi @ Saleyards Bridge indicates a prolonged high flow event in the record, which appears to be an error.

3.1.3 Te Ngawai (Te Ana a Wai)

Flows in the Te Ngawai @ Cave Picnic Grounds were characterised by a high ratio of mean / median flow (the highest of all sites), a high proportion of time at low flows (>21% of the time at < 0.5 median flow), relatively frequent high flow events, a very high mean annual maximum relative to median flows (>90 times) and the highest proportion of time of all sites under very high flows (>6% of the time at > 7 x median) (Table 3-1). Flood frequencies and durations of high flows were similar to those in the Te Moana. The hydrograph reflects these statistics, with extremely low flows during the dry period from July 2014 to May 2015, and large flood peaks relative to the median flows, compared to those in the North and South Opuha and Opihi @ Rockwood (Figure 3-1).

3.1.4 Opuha River

The regulated regime in the Opuha River results in distinctive flow statistics compared to the other rivers. The Opuha @ Skipton had the lowest ratio of mean to median flow, reflecting high baseflows and low flood sizes relative to median flow in a regulated river. The mean annual maximum flow was only eight times the median flow, compared to at least 16 times at all other sites. The percentage of time at low flows (less than 0.5 x median) was almost 24%, and was the highest of all sites. The percentage of time at very high flows (>7 x median) was lowest (0.3% compared to at least 1% at other sites). Frequencies of flow events greater than 3, 5, 7 and 10 x median flow (i.e., FRE3, FRE5, FRE7 and FRE10) were also substantially lower than at all other sites (Table 3-1).

3.1.5 Opihi @ Saleyards

Low flow statistics for the Opihi @ Saleyards Bridge reflected the regulated contribution from the Opuha River during low flows. For example, the proportion of time at low flows (< 0.5 x median) was lower than at all other sites except the North Opuha (see Section 3.1.2). Flood frequencies relevant to the habitat assessment reach were calculated using the flow record from site 69601 Opihi @ SH1, as that record is more accurate for high flows than the Saleyards record. Flood frequency in the Opihi @ SH1 was lower than that in the Opihi @ Rockwood for all flood thresholds except 10 x median (Table 3-1). However, the proportions of time the river exceeded all of the thresholds was higher than at Rockwood, indicating longer events.

3.1.6 Te Moana and Waihi

The Te Moana and Waihi have similar mean and median flows and drain similar-sized catchments, though with different land use (Table 2-2). The proportions of time at high flows were more or less consistent across the two sites. Hydrologically, the sites differed in that frequencies of high flow events were greater in the Waihi, except for the largest events (>10 x median flow), and the largest events in the Te Moana were higher relative to median flow than in the Waihi (Table 3-1). These differences persisted even when equivalent shorter flow records were compared (2012 to 2017 at both sites, see above). Overall, the Te Moana appeared to be slightly less flood-prone than the Waihi, but with potential for much larger peak flows than in the Waihi.

3.1.7 Temuka

Flows in the Temuka @ Manse Bridge combines those from the Waihi and Te Moana. The Waihi and Te Moana flow recorders are both well upstream and these upstream flows make up about 25% of the median flow in the Temuka @ Manse Bridge. This implies substantial contributions from tributaries (e.g., Te Moana North Branch, Kakahu) and groundwater in the intervening reach. In the Temuka, the proportion of time under high flows and the frequencies of high flow events (all relative to the median flow) were lower than in its two tributaries. Lower variability at the lower flow end of the hydrograph in the Temuka compared to the Te Moana and Waihi is clear from the hydrographs (Figure 3-1, second panel, lower three plots).

3.2 Flow duration curves

The flow metric values (Table 3-1) and hydrographs (Figure 3-1) can also be summarised in flow duration curves. A flow duration curve shows flows of different magnitudes at a site sorted to illustrate the percentage of time each flow in the range is exceeded. Typically, high flows are exceeded for a very small proportion of the time, while the lowest flow (in the period being considered) is exceeded for 100% of the time. Flow duration curves are a convenient way to illustrate flow regime differences between sites. Curves for all nine sites are shown in Figure 3-2.

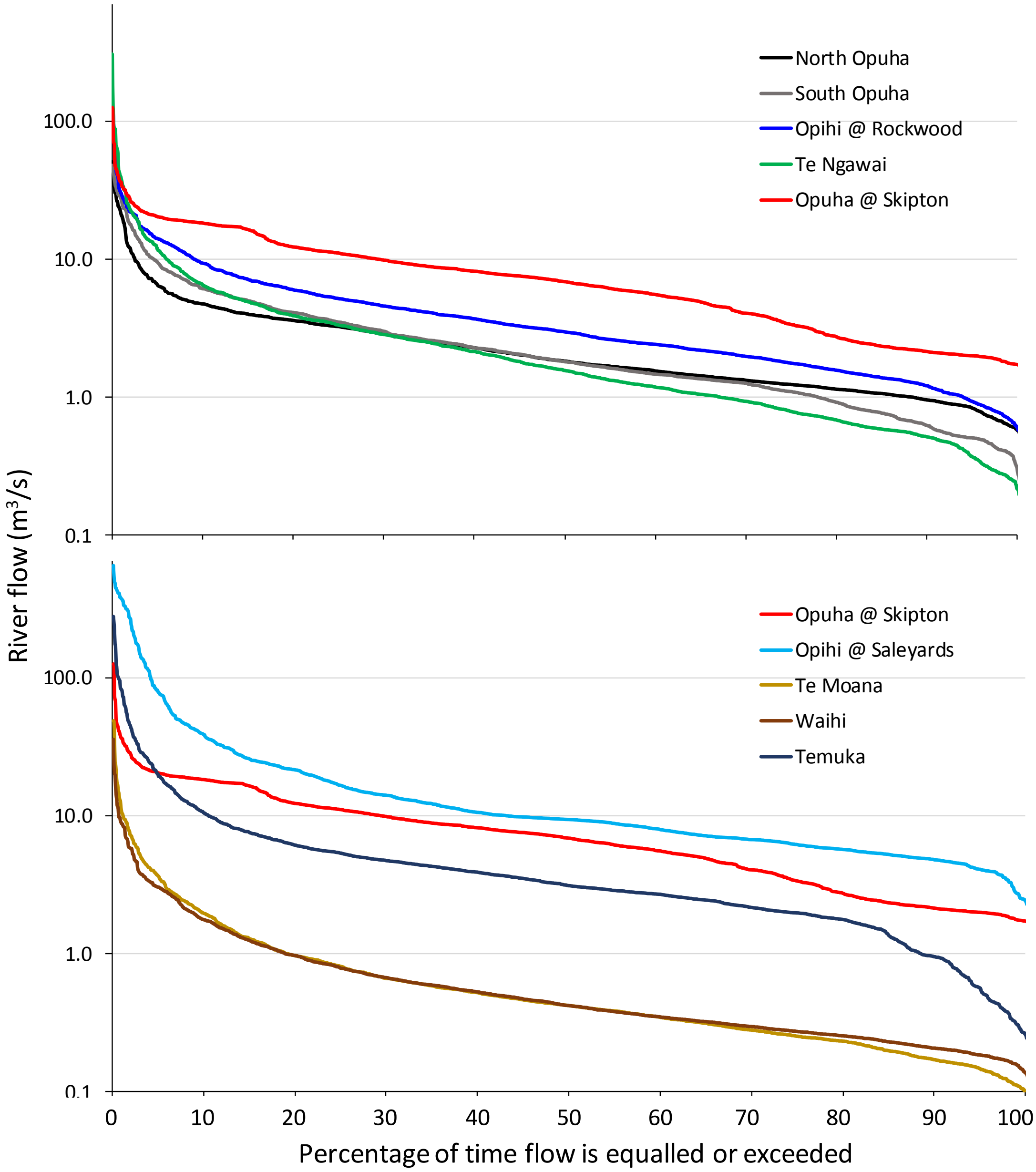

Figure 3-2: Flow duration curves for the nine sites, derived from data from 2013 to 2017. Flows (in m^3/s) are shown on a log scale, which highlights differences in the high and low ranges more clearly. The top plot shows sites in the upper catchment, and the bottom plot in the lower catchment. The curve for Opuha @ Skipton Bridge (red line) is shown on both plots to aid comparison.

The curves show:

- lower durations of both high and low flows in the North Opuha than in the South Opuha;
- similar flow distributions in the South Opuha and Te Ngawai, except that that peak flows in the Te Ngawai were higher (in the period covered by the plots);
- similar flow distributions in the Te Moana and Waihi Rivers;
- small proportions of time in the South Opuha, Te Ngawai, Opihi @ Saleyards, Te Moana and Waihi when flows were extremely low compared to most other times (the sharp downward curve at the right-hand side of the plots);
- the marked downward curve at the right-hand side of the plot for the Temuka River, indicating more prolonged very low flows;
- a distinctive flow distribution in the Opuha @ Skipton, typical of a regulated river with no periods of extremely low flows.

3.3 Periphyton removal thresholds

Removal thresholds for periphyton chlorophyll *a*, mats, filaments and *Phormidium* (see Section 4) were estimated for five sites in the catchment (Opihi @ Rockwood, Opihi @ SH1, Te Ngawai, Te Moana, Temuka) using a three-year time series of periphyton data collected by ECan, and daily mean flows (Kilroy et al. 2017) (Table 3-2). The sites were not in exactly the same locations as those surveyed in the present study, but were within the same general river reach. The removal thresholds are frequencies at the five sites are likely to be indicative of those at the surveyed sites in the current study.

Frequencies of floods estimated to remove chlorophyll *a* to low levels were lowest in the Temuka River, moderate in the Te Ngawai (Te Ana a Wai) and Opihi @ SH1 and highest in the Opihi @ Rockwood and Te Moana. In the Opihi @ Rockwood and Te Moana, the removal thresholds for periphyton mats and filaments were estimated to be higher than for chlorophyll *a* (Table 3-2). This discrepancy may reflect the type of periphyton that typically grows at these sites. For example, some periphyton mats and filaments attached firmly to substrate particles and resist removal.

Table 3-2: Estimated flow thresholds and event frequencies for removal of periphyton at five sites. Part A shows thresholds in multiples of median flow, calculated using daily mean flows. Thresholds were estimated empirically using three years of periphyton data (Kilroy et al. 2017). Part B shows the mean annual frequency of the flow threshold in Part A. *The estimates were made using flow data from the Opihi @ SH1 rather than Saleyards Bridge. The sites are close together and may have similar substrate, flow and periphyton characteristics. NA = no threshold could be calculated, usually because the periphyton cover type occurred infrequently.

	Chlorophyll *a*	**% Mats**	**% Fils**	***Phormidium***
A. Removal thresholds				
Opihi @ Rockwood	5	2	2	NA
Te Ngawai	10	10	10	3
Opihi @ SH1*	5	5	NA	10
Te Moana	7	2	1.5	NA
Temuka	10	10	10	10
B. Mean annual frequency (from Table 3-1)				
Opihi @ Rockwood	6.5	11.4	11.4	NA
Te Ngawai	4.7	4.7	4.7	8.9
Opihi @ SH1*	4.9	4.9	NA	3.2
Te Moana	6.0	10.9	At least 10.9	NA
Temuka	3.5	3.5	3.5	3.5

4 Periphyton and macrophytes

Hayward et al. (2016) reviewed periphyton and macrophytes in the Opihi and Temuka catchments. Some of the following replicates that review, but focusses on the nine sites in this study. The Hayward et al. (2016) review used four main sources of information:

- the results of ECan routine monitoring at multiple sites, using bankside visual assessments;
- data from a three-year ECan programme of more intensive monitoring and sample collection at five sites in the Opihi / Temuka catchment (Opihi @ SH1, Opihi @ Rockwood, Temuka @ Manse Bridge, Te Moana @ Glentohi [Sheep Dip Road], and Te Ngawai @ Cave Picnic Grounds);
- data collected by NIWA at three sites in the National River Water Quality Monitoring Network (Opihi @ Grassy Banks, Opihi @ Rockwood, Opuha @ Skipton Bridge);
- data from summer monitoring at 11 sites of cover by the potentially toxic cyanobacterium *Phormidium*. The sites included one each in the Te Moana and Te Ngawai Rivers, two in the Temuka River, three in the Opihi River and four in the Waihi River.

Most of the sites reviewed by Hayward et al. (2016) were not at the exact locations selected for the instream habitat assessments, but were in the same general reaches. For the present review, additional data on periphyton in the North and South Opuha rivers were provided by ECan (bankside visual assessments by ECan from 2011 to 2017). Data are also available from several sites in the Opuha River and three sites in the Opihi River (at Rockwood and Raincliff, upstream of the confluence with the Opuha River, and at Saleyards Bridge, both upstream and downstream of the confluence with the Te Ngawai) from a monitoring programme funded by Opuha Water Ltd (OWL).

Directly related to this project, we carried out visual assessments of periphyton cover at the habitat assessment sites on 7 February 2018 (North Opuha, South Opuha, Opihi @ Gorge, Te Ngawai) and 16 February 2018 (all sites except Opuha @ Confluence). A significant rain event on 2 February caused high flows in all the rivers, and this was followed by a recession until 20 February. The 16 February survey therefore captured periphyton after two weeks of accrual. The surveys entailed assessing cover by the following different types of algal cover at 20 points in the river at each site, using an underwater viewer:

- no cover (clean stones);
- thin film (green or brown colour, slimy texture);
- loose "sludge" (usually brown);
- cohesive mats (usually brown/black, don't fall apart when handled);
- green slimy filaments;
- other filaments, including tough, brown-coloured coarse filaments;
- cyanobacteria mats (usually dominated by the potentially toxic taxon *Phormidium*: smooth black/brown mats with a white/grey underside);
- didymo (distinctive mats of the introduced stalked diatom, *Didymosphenia geminata*);
- macrophytes (plants rooted on the stream bed, under water).

Historic data on periphyton in the Opihi catchment appears to be limited to the study by Norton (1995). Norton (1995) carried out surveys at 23 sites in the catchment between mid-March and early June 1995 (four surveys). The sites included 10 on the Opihi main stem, between SH1 and Fairlie, five on the Waihi, four on the Temuka, one on the Te Moana and two on smaller tributaries. The focus was on taxonomic composition of the communities rather than cover or biomass.

The measures of interest regarding periphyton and ecological values are: (a) whether the site supports algae at levels considered to exceed levels set to protect ecosystem health (as defined by regional and national guidelines); (b) the frequency of exceedances of guidelines; (c) whether the site supports the potentially toxic cyanobacterium *Phormidium* at levels high enough to affect recreational values; and (d) whether the site supports growth of rare or endangered algal taxa. A commentary for each site follows. Note that most of the discussion refers to periphyton; macrophytes occurred at two sites only (Waihi and Temuka).

4.1 Regional and national objectives and guidelines

The simplest way to assess the potential impact of periphyton on river values is to compare observed values with relevant regional and national guidelines. The guidelines in the periphyton attribute of the National Policy Statement for Freshwater Management (NPS-FM, NZ Government 2017) apply to all freshwater management units in New Zealand. Periphyton objectives in the Canterbury Land and Water Regional Plan (LWRP) are stratified according to stream/river type. As discussed by Hayward et al. (2016), no objective for percentage cover by mats was included in the LWRP. The reason was that mats in many rivers were dominated by the introduced nuisance alga didymo. At the time of development of the LWRP, both the effects and drivers of didymo mats were not well understood.[1]

A maximum percentage cover by algal mats for protection of trout habitat/angling and aesthetic/recreation values was suggested by Biggs (2000). A guideline for the maximum acceptable cover by nuisance periphyton (i.e., mats and/or filaments) is also specified in the Opihi River Regional Plan (ORRP) (ECan 2000). Interim guidelines were developed in 2009 to assist in managing the effects of proliferations of the potentially toxic cyanobacterium *Phormidium* (Wood et al. 2009).

Guidelines relevant to river sites in this study are summarised in Table 4-1.

4.2 Periphyton and macrophytes at individual sites

4.2.1 North Opuha

The North Opuha is an Alpine lower river in the ECan classification. ECan visual assessments within the habitat assessment reach indicated generally low periphyton, but the guideline for percentage cover by algal mats was occasionally exceeded (one exceedance of 60% cover in six years of surveys). The site supports *Phormidium* growth, which has exceeded the Action level of the NZ Cyanobacteria guideline (Table 4-1) once in six years (December 2015). The surveys in February 2018 showed only low cover by thin film six days after the high flow on 2 February (10 x median flow at this site), and thick algae beginning to appear by 16 February, including *Phormidium* (Figure 4-1).

[1] The ecosystem effects of didymo have been researched and are now better understood (Kilroy et al. 2009, Jellyman & Harding 2016). The drivers of didymo blooms in New Zealand are also clearer (Kilroy & Bothwell 2012, Bothwell et al. 2014, Kilroy & Larned 2016). In summary, didymo has the general effect of increasing proportions of low water quality tolerant taxa in the community, and thereby lowering key indices (see Section 5 in this report); there are also probable effects on fish. At the same time, the presence of didymo proliferations in a river is generally indicative of low concentrations of dissolved phosphorus and only moderate concentrations of dissolved nitrogen (i.e., generally good water quality from a nutrient perspective).

Table 4-1: Regional and national guidelines for periphyton cover and biomass relevant to the Opihi catchment. *The 8% exceedance metric in the NPS-FM is based on monthly surveys for at least three years.

Guideline	For protection of:	Applicable to	Indicator	Metric	Levels	Objective or threshold	Units
NPS-FM periphyton attribute	Ecosystem health	All rivers	Chlorophyll *a*	>8% exceed-ance*	Band A, negligible impact	<50	mg/m²
					Band B, low impact	50–120	mg/m²
					Band C, moderate impact	120–200	mg/m²
					Band D, < "bottom line"	>200	mg/m²
LWRP	Aesthetic, recreational and ecosystem values	Alpine lower	Chlorophyll *a*	Max.		120	mg/m²
			Filaments	Max.		20	%
			Cyanobacteria	Max.		30	%
		Hill-fed lower Lake fed	Chlorophyll *a*	Max.		200	%
			Filaments	Max.		30	%
			Cyanobacteria	Max.		50	%
Periphyton guideline, Biggs (2000)	Aesthetic and recreational values	All rivers	Thick mats	Max.		60	%
ORRP	Ecosystem, fishery, recreation, water supply, cultural & aesthetic	Opihi catchment, in relation to discharges	Filamentous growths or mats (> 3mm)	Max.		40	%
Cyano.	Human/animal health	All rivers	*Phormidium*	Max.	Alert	20	%
					Action	50	%

4.2.2 South Opuha

The South Opuha is an Alpine lower river in the ECan classification. The ECan visual assessments indicated noticeable cover by didymo at this site especially from 2015 onwards (Figure 4-2a). However, cover was never high enough to exceed the Biggs (2000) 60% guideline. The highest cover recorded was 50%, on one occasion (September 2016), which exceeded the ORRP guideline of 40% cover by total nuisance periphyton. Low cover (e.g., up to 10%) by green filamentous algae has been recorded regularly in the South Opuha and cover of 20% (i.e., the threshold for 'unacceptable' for Alpine lower rivers in the LWRP, Table 4-1) was reported in January and February 2017.

In 2018, >25% cover by thin film was recorded on 7 February, following the high flow on 2 February (8.5 x median flow). Cover by film had increased to 40% by 16 February, and by that stage there was also low cover by didymo, sludge, green filaments (Figure 4-1).

4.2.3 Opihi @ Gorge

The Opihi River (@ Gorge) is classed as Hill-fed lower in the ECan classification. No routine monitoring of periphyton has been conducted in the habitat assessment reach but both NIWA and ECan have data from Opihi River @ Rockwood (9 km downstream). At Rockwood, the NIWA data indicates predominant cover by mats rather than filaments, with occasional high cover by mats, which may be increasing over time (e.g., one exceedance of the ORRP threshold of 40% during 2013 – 2015, but three exceedances during 2016 – 2017). The NIWA surveys reported high cover by didymo at Rockwood for the first time in 2016, and also high cover by *Phormidium* (both recorded as "mats" but identified as didymo and *Phormidium* in field notes). The ECan surveys at Rockwood between July 2011 and June 2014 showed low to moderate periphyton biomass and percentage cover, with no guidelines breached (Hayward et al. 2016). The Rockwood site is relatively shaded, which reduces the potential for high biomass. However, several exceedances of 120 mg/m^2 chlorophyll *a* placed the site in the C band of the NPS-FM periphyton attribute. Surveys carried out in a programme funded by OWL at an unshaded site ~3 km downstream returned high cover by *Phormidium* (up to 60%) during the summer months, and cover by didymo (up to 80%) in winter (Kilroy et al. 2016).

Phormidium mats and high cover by a distinctive brown film were observed in the Opihi @ Gorge on 21 December 2017 (Figure 4-2c). The high flow on 2 February 2018 (7 x median flow at Opihi @ Rockwood) apparently removed most periphyton cover. Between 7 and 16 February 2018, cover by brown film increased from 5% to 60%, but no *Phormidium* was observed (Figure 4-1). The removal threshold for chlorophyll *a* at Rockwood was assessed as 5 x median flow, with lower thresholds for filaments and mats (2 x median) (Table 3-2). The thresholds are consistent with extremely low cover following the 2 February 2018 event.

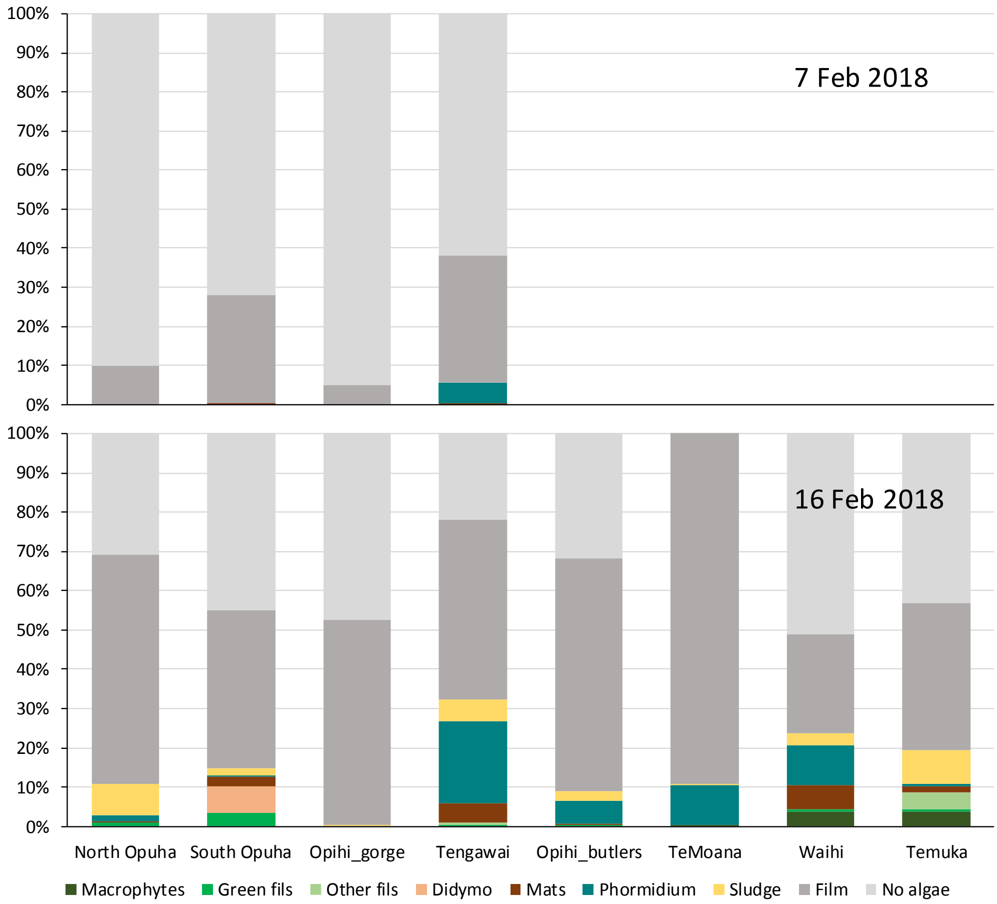

Figure 4-1: Percentage cover by periphyton in nine categories at eight of the nine habitat assessment sites. The omitted site was Opuha @ Confluence.

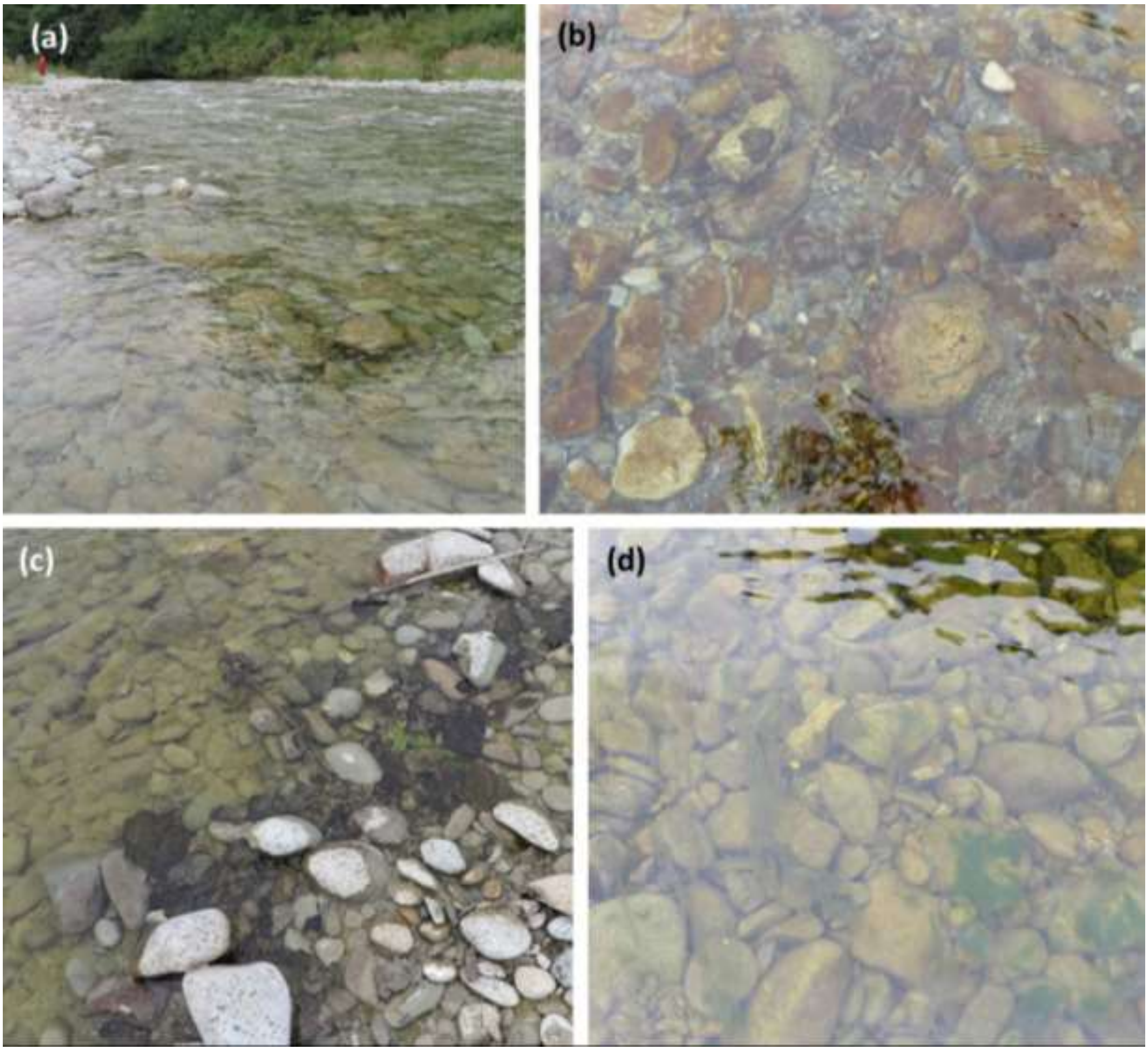

Figure 4-2: Periphyton observed at Opihi catchment sites during site visits on 21 December 2017. (a) Didymo cover in the South Opuha (pale brown mats). (b) Brown film and patches of *Phormidium* in the Opihi @ Gorge. Similar brown film was observed in the Te Ngawai. (c) *Phormidium* mats "stranded" at the water's edge in the Opihi @ Butlers. Detached mats such as this are grounds for Action and a public warning (Wood et al. 2009). (d) Green filamentous algae in the Te Moana River @ Goodwin Road ford.

4.2.4 Te Ngawai

The Te Ngawai River is classed as Hill-fed lower in the ECan classification. ECan data collected between 2011 and 2014 at Clelands Bridge (~5 km downstream of the habitat assessment reach) showed potential for high periphyton biomass. The LWRP objective of 200 mg/m^2 chlorophyll *a* was exceeded twice, in July and August 2011. The site fell into Band B of the NPS-FM periphyton attribute over the three years, with biomass much lower than the 120 mg/m^2 upper threshold for most of the time (Kilroy et al. 2017). More recent ECan visual assessment surveys confirmed potential for high cover by filamentous algae in the river, and exceedance of the LWRP and ORRP guideline. In addition, cyanobacteria (*Phormidium*) exceeded the Cyanobacteria guideline Alert level in 2015–16 (Hayward et al. 2016).

The surveys in 2018 indicated that periphyton development can be rapid in the Te Ngawai. *Phormidium* was already visible at the habitat assessment site on 7 February, six days after a flood 7 x median flow. Cover had increased to >20% by 16 February, and there was low cover by mats and filaments (Figure 4-1). Full removal of periphyton at this site apparently requires flows of about 10 x median; the removal threshold for cyanobacteria was assessed as lower at 3 x median (Table 3-2).

4.2.5 Opuha @ Confluence

The Opuha River is classed as Lake-fed lower in the ECan classification. Since 2007, periphyton in the Opuha River has been dominated by didymo, but growths of green filamentous algae can also be conspicuous. Both NIWA and ECan visual assessments of periphyton cover at Skipton Bridge (~12 km upstream of the habitat assessment reach) indicate regular breaches of the LWRP objective for filamentous cover (Hayward et al. 2016). Early attempts to manage problems caused by high didymo biomass, using flushing flows, were only marginally successful because of limitations on the size of flushing flows that could be generated with OWL's infrastructure (Lessard et al. 2013). In the early trials, a flush of 10 times the preceding baseflow was the most successful in removing significant non-didymo biomass. More recently a series of trials of larger flushing flows (e.g., Measures & Kilroy 2014) led to structural changes at the dam to allow regular release of flow events large enough to remove nuisance didymo-dominated periphyton.

A OWL-funded periphyton monitoring programme is ongoing at two sites in the Opuha River (Opuha Gorge and Skipton Bridge). A summary of the data indicated continued persistent high cover by didymo at both sites, with lower cover by green filamentous algae and *Phormidium* (e.g., Kilroy et al. 2016). Cover by didymo of >70% was recorded at the habitat assessment reach in the current programme during OWL-funded surveys in the summers of 2012-13 and 2013-14 (Measures & Kilroy 2014).

4.2.6 Opihi @ Butlers

The Opihi River (@ Butlers) is classed as Hill-fed lower in the ECan classification. No periphyton data are available from the habitat assessment reach, except for observations in December 2017 (Figure 4-2c) and in 2018 (see below). Periphyton data available from other sites nearby include: cover data from sites upstream and downstream of Saleyards Bridge in the OWL-funded monitoring programme (see above); chlorophyll *a* and cover data at Opihi River @ SH1 collected by ECan from 2011 to 2014, plus data on *Phormidium* cover; cover data collected by NIWA at Opihi River @ Grassy Banks.

All three agencies reported generally high periphyton biomass and cover. Data from the ECan programme from 2011 to 2014 indicated that Opihi @ SH1 fell into Band C of the NPS-FM periphyton attribute (Kilroy et al. 2017) (Table 4-1). LWRP objectives for percentage cover by filaments and the Periphyton Guideline (2000) threshold for mats have been exceeded at Grassy Banks according to the NIWA data; and cover by *Phormidium* regularly exceeds Alert and Action levels in the cyanobacteria guideline (Table 4-1) (Hayward et al. 2016).

A survey at the habitat assessment site on 16 February 2018 returned ~6% cover by *Phormidium*, 14 days after an event of just under 5 x median flow. Removal of chlorophyll *a* at SH1 was assessed by Kilroy et al. (2017) to require a flow of about 5 x median flow (Table 3-2).

4.2.7 Te Moana

The Te Moana River is classed as Hill-fed lower in the ECan classification. Periphyton data are available from ECan surveys at a site in the gorge about 25 km upstream of the habitat assessment reach. In the ECan programme in 2011–14, the gorge site fell into the D band of the NPS-FM periphyton attribute (i.e., below the bottom line). High chlorophyll *a* generally corresponded to high cover by periphyton classed as "sludge". Consistent with this, ECan visual assessment surveys since then have also returned cover by thick algal mats that exceeds the Biggs (2000) guideline and ORRP thresholds. High cover by *Phormidium* was not recorded in the upper Te Moana River (Hayward et al. 2016).

Periphyton in the habitat assessment reach at Goodwin Road ford may differ from that at the ECan site. In December 2017, high cover by green-brown filamentous algae was observed at the Goodwin Road site (Figure 4-2d). In the survey on 16 February 2018, we recorded 10% cover with *Phormidium* plus low cover by sludge and 90% film (Figure 4-1). In contrast, *Phormidium* was recorded at the ECan site only once between July 2011 and June 2014, and at very low cover (0.5%). The February 2018 survey was conducted 14 days after a high flow of 4.6 m^3/s (maximum daily mean flow), equivalent to 11.5 x median flow. At the ECan site 25 km upstream, such a flow was well above the threshold for removal of most periphyton (up to 7 x median flow, Table 3-2). High cover by film suggests that the threshold could be higher at the habitat assessment reach.

4.2.8 Waihi

The Waihi River is classed as Hill-fed lower in the ECan classification. ECan periphyton data for the river appear to be restricted to cyanobacteria cover estimates at recreational sites (Hayward et al. 2016). The guidelines were not exceeded at a site in the Waihi Gorge, over 30 km upstream of the habitat assessment site, but were exceeded at sites farther downstream. Consistent exceedances were recorded in the Waihi River @ SH72, Geraldine (20 km upstream) from 2013/14 (Alert level) to 2015/16 (Action level)

The survey on 16 February 2018 in the habitat assessment reach showed over 5% cover by *Phormidium*, along with low cover by mats, sludge and filaments (up to 3%) and ~25% thin film. About 2% cover by macrophytes was also recorded, suggesting relatively stable substrate at this site. The survey was conducted 14 days after a high flow of about 12.5 x median flow.

4.2.9 Temuka @ Manse Bridge

The Temuka River (@ Manse Bridge) is classed as Hill-fed lower in the ECan classification. The habitat assessment reach includes the site monitored by ECan between July 2011 and June 2014 for biomass and cover, and since 2014 using bankside visual assessments. Monthly chlorophyll *a* measurements in 2011–14 placed the site in the B band of the NPS-FM periphyton attribute (Kilroy et al. 2017) (Table 4-1). During those three years, there was one exceedance of the LWRP objective for percentage cover by filamentous algae, and none occurred in the following two years (Hayward et al. 2016). Cover by *Phormidium* exceeded the cyanobacteria guideline Alert threshold three times between 2011 and 2014, and at least once in the following two years (Hayward et al. 2016).

On 16 February 2018 we recorded ~4% cover by macrophytes and a total of 15% cover by a range of types of thick periphyton (sludge, mats, filaments), 14 days after a high flow event of 2 x median flow. The flow threshold for removal of periphyton to low levels was assessed as 10 x median flow at this site (Table 3-2). A relatively high threshold for removal is consistent with the observation of macrophyte cover at the site, which generally indicates a stable river bed. Cover by macrophytes (up to 3%) was recorded in 12 of 36 surveys in the ECan periphyton study from July 2011 to June 2014, confirming persistent low cover by macrophytes at this site.

5 Benthic macroinvertebrates

ECan uses two methods for assessing stream ecosystem health based on macroinvertebrate community composition (hereafter "invertebrate"). The first metric is QMCI, the quantitative variant of the Macroinvertebrate Community Index (MCI). Both the MCI and QMCI are calculated using scores assigned to different invertebrate taxa based on their tolerance to organic pollution. High-scoring taxa are intolerant (i.e., "good") and low-scoring taxa are tolerant ("poor"). The QMCI weights the scores using the relative (%) abundance of taxa in a sample. In the LWRP, sites classed as Alpine lower and Hill-fed lower have an objective of a QMCI ≥ 6, which is classed as indicative of "excellent" stream health and low pollution.

The second metric is an invertebrate health grade, which combines five invertebrate metrics into a single score, and then assigns a grade on a five-point range (very good to very poor) taking into account the reference condition for the relevant river type. The invertebrate metrics are QMCI and four variants of %EPT (the percentage of the community made up of taxa belonging to the order Ephemeroptera, Plecoptera and Trichoptera). Reference sites are taken as the top-ranked sites in each river type (for an example see Meredith & Vesey 2006).

In addition to the two metrics based on invertebrate community composition, ECan grades sites based on a habitat assessment, which includes catchment land use, riparian features, bank stability, channel features, and instream habitat including substrate and sediments. Refer to Meredith & Vesey (2006) for an example of application of the system.

Hayward et al. (2016) summarised river status at sites in the Opihi catchment based on the two invertebrate metrics and the habitat assessment (see above) using data from 2011 to 2015. That information is further summarised in Table 5-1.

Table 5-1: Summary of river status at key locations the nine Surface Water Allocation Zones, based on ECan invertebrate and habitat metrics. Data from 2011 to 2015, from Hayward et al. (2016). Mean QMCI and ranges of Invertebrate health and Habitat health grades are shown. Trends in QMCI were determined using data from 1999 (Appendix 11 in Hayward et al. 2016). The QMCI objective for Alpine lower and Hill lower sites is ≥6. Under habitat health, a grade in brackets means that grade was assigned only once in the five years.

Surface Water Allocation Zone	QMCI		Invertebrate health		Habitat health	Site notes
	Mean, 2011–15	Trend 1999–2015	Range, 2011–15	Trend?		
North Opuha	no data					
South Opuha	5.6		Fair/Good to Very Poor	declining	Good (Poor)	Clayton Road site
Opihi Rockwood	**6.4***		Very good to Poor	declining	Good (Fair)	Rockwood (ECan data)
Te Ngawai	5.9		Very good to Very poor		Very good to Fair	Te Ngawai Bridge
Opuha	2.3	declining	no data			QMCI, Skipton Br
Opihi Saleyards	**6.3***		Very good to Very poor		Fair	SH1 site (ECan data)
Hae Hae Te Moana	4.8	declining	Fair to Very poor		Very good to Poor	Te Moana Rd site. Glentohi site QMCI 6.4
Waihi	4.8		Good to Very poor		Good to Very poor	Site at Te Awa Rd Gorge sites, QMCI 7.5
Temuka	4.3		Fair to Very poor		Fair to Very poor	SH1 (ECan data)

*NIWA data from the same sites returned QMCI < 6.

The main messages from Table 5-1 are:

- only the two sites on the Opihi mainstem met the LWRP objective for QMCI. NIWA data from the same sites indicates that the objective would not have been met;
- QMCI in the Te Ngawai was close to meeting the LWRP objective. Note that the mean score of 5.9 was caused by an unusually low value in 2015 (3.3). In other years (2011 – 2014), the objective was met (see Appendix 10 in Hayward et al. 2016);
- QMCI in the Opuha River (Skipton Bridge) has shown a significant decline between 1999 and 2015. This is likely attributable to the arrival of didymo as the dominant alga in the river. Didymo has documented effects on macroinvertebrate community composition that would reduce QMCI scores (Kilroy et al. 2009);
- QMCI in the Te Moana River has also declined significantly between 1999 and 2015, although current QMCI is relatively good (4.8) compared to that in the Opuha River (2.3);
- in both the Te Moana and Waihi Rivers, sites farther upstream almost always met the LWRP objective;
- the invertebrate health grade (relative to reference site conditions) varied from year to year at most sites. At two sites (South Opuha and Opuha @ Rockwood) the grade became successively worse over the five years. At this stage it is not known whether these were meaningful trends.

6 Freshwater fish communities

The New Zealand Freshwater Fish Database (NZFFD) was examined to assess what fish species had been recorded from the Opihi River catchment, which includes the Temuka River sub-catchment (Table 6-1). There have been 177 records entered for the catchment and a total of 18 species have been recorded (Table 6-1). The distribution of sampling records for the catchment (see Figure 6-1) shows almost no sampling in the lower 7 km of the main stem and this information gap means native fish diversity is likely to be higher than 18 species recorded in the catchment. Species such as black flounder and giant bully have been captured in the lower reaches of nearby rivers (e.g., Orari, Rangitata). Fish and Game's public brochure for the Opihi River states "In the waters from the mouth to about the State Highway 1 bridge there is a remnant population of rainbow trout, survivors of Acclimatisation Society hatchery releases"; rainbow trout were caught during electrofishing surveys (see Table 6-2).

Table 6-1: List of freshwater fish species present in the Opihi catchment as recorded in the NZFFD. The number of records for a species is influenced by many factors but is generally indicative of how common a species is throughout the catchment. Max. distance inland refers to the farthest inland record of each species.

Family name	Species name	Common name	Number of records	Max. distance inland (km)
Anguillidae	*Anguilla australis* (Richardson 1841)	Shortfin eel	17	72
	Anguilla dieffenbachii (Gray 1842)	Longfin eel	26	79
Eleotridae	*Gobiomorphus breviceps* (Stokell 1940)	Upland bully	101	88
	Gobiomorphus cotidianus (McDowall 1970)	Common bully	30	81
	Gobiomorphus hubbsi (Stokell 1959)	Bluegill bully	8	17
Galaxiidae	*Galaxias brevipinnis* (Günther 1866)	Koaro	3	82
	Galaxias fasciatus (Gray 1842)	Banded kokopu	1	71
	Galaxias maculatus (Jenyns 1842)	Inanga	3	1
	Galaxias paucispondylus (Stokell 1938)	Alpine galaxias	6	86
	Galaxias vulgaris (Stokell 1949)	Canterbury galaxias	68	88
	Neochanna burrowsius (Phillipps 1926)	Canterbury mudfish	2	19
Geotriidae	*Geotria australis* (Gray 1851)	Lamprey	3	50
Mugilidae	*Aldrichetta forsteri* (Valenciennes 1836)	Yelloweye mullet	1	2
Pinguipedidae	*Cheimarrichthys fosteri* (Haast 1874)	Torrentfish	8	38
Retropinnidae	*Retropinna retropinna* (Richardson 1848)	Common smelt	1	2
Salmonidae	*Oncorhynchus tshawytscha* (Walbaum 1792)	Chinook salmon	6	68
	Salmo trutta (Linnaeus 1758)	Brown trout	66	77
	Salvelinus fontinalis (Mitchill 1814)	Brook char	1	84

Most of the species in the catchment have been documented in less than 10 of the 177 sampling records (Table 6-1). The fish fauna throughout the catchment appears to be dominated by six species: longfin and shortfin eel, upland and common bully, Canterbury galaxias and brown trout (Table 6-1). These six species are all recorded within 10 km of the coast and all are also found over 70 km inland (the top of the catchment in the headwaters of the North Opuha is about 95 km inland) so are distributed throughout most of the catchment.

There are nine proposed flow assessment sites in the Opihi catchment (Figure 1-1, Table 1-1) and a number of these sites will have different fish species present. As part of this review, we examined the NZFFD records for 15 km upstream and downstream of each survey site to compile a relevant species list for each site. This is important because species that are typically found close to the coast should not have their flow requirements modelled at inland sites if it is highly unlikely they will ever be present at such a site (and vice versa). Our review of NZFFD records near the nine flow assessment sites identified that some sites had very few records available (e.g., South Opuha, see Table 6-2) so to get a more contemporary understanding of the fish fauna, additional electrofishing was conducted by Central South Island Fish & Game staff. Cyclone Gita cut short the planned electrofishing of all sites, but fortuitously, the sites with the most obvious data gaps were the sites that were electrofished. The combined existing and new information will be used for the habitat simulation modelling (i.e., RHYHABSIM) later in the project so that only species known to be present are modelled at each site.

The review of the NZFFD has shown that species such as upland bully and Canterbury galaxias are present across all sites whereas other species (e.g., alpine galaxias) are restricted to the very top of the catchment and other species, such as migratory inanga, are only recorded at the very bottom of the catchment (Table 6-2). As previously mentioned, ensuring that species which are not present at a site are not modelled will be critical for future decision making for site-specific flow setting.

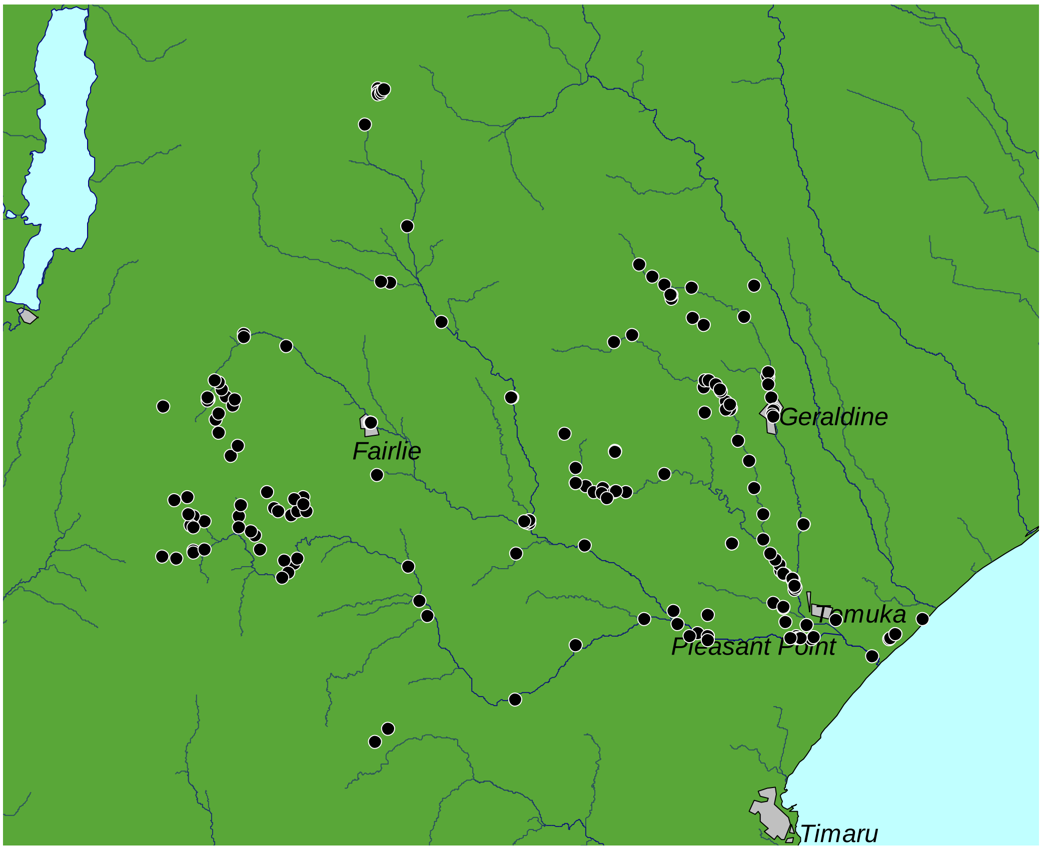

Figure 6-1: The distribution of fish sampling locations (black circles) on the NZFFD within the Opihi catchment. For clarity, only river segments greater than third order are shown on the map.

Table 6-2: Species presence/absence (based on NZFFD data) within 15 km of the Opihi catchment survey sites. U = upstream and D = downstream of the survey sites. Sites with *Present*† indicate where 2018 electrofishing surveys caught these unrecorded species and sites with *Present** are locations Fish & Game know these fish regularly use. Note, distance inland values vary slightly from Table 2-3 because they are calculated from different versions of the REC. ‡ indicates site that were not electrofished in 2018 surveys.

	Site name	**North Opuha**	**South Opuha**	**Opihi @ Gorge**	**Te Ngawai‡**	**Opuha @ Confluence‡**	**Opihi @ Butlers‡**	**Te Moana**	**Waihi**	**Temuka‡**
	Distance inland	**70.8 km**	**69.1 km**	**50.7 km**	**43.5 km**	**37.5 km**	**17.5 km**	**20 km**	**13.4 km**	**8.9 km**
Fish species	**NZFFD records**	**8 U, 1 D**	**0 U, 2 D**	**8 U, 7 D**	**5 U, 2 D**	**10 U, 3 D**	**6 U, 16 D[1]**	**20 U, 30 D**	**5 U, 13 D[2]**	**25 U, 13 D[3]**
Shortfin eel			D	*Present*†	U	D	U & D	D	U & D	U
Longfin eel		*Present*†	D	D	D	U & D	U & D		D	U
Upland bully		U	D	D	U	U & D	U & D	U & D	U & D	U & D
Common bully		D		U & D		U & D	U & D	U	*Present*†	D
Bluegill bully							D			
Inanga										D
Alpine galaxias		U & D	*Present*†							
Canterbury galaxias		U & D	D	U & D	U	U	D	U	U	U
Lamprey						U	D	D	D	D
Yelloweye mullet										D
Torrentfish				U & D		U & D	U & D	D	U & D	U & D
Common smelt										D
Chinook salmon				U	*Present**	U & D	U & D			*Present**
Rainbow trout		*Present*†	*Present*†							
Brown trout		D	*Present*†	U & D	U	U & D	U & D	U & D	U & D	U
	# species	**7**	**7**	**8**	**6**	**9**	**10**	**7**	**8**	**12**

[1] The Temuka River joins the Opihi River c. 12.5 km downstream of the site but no records from the Temuka catchment were included when evaluating the downstream records. [2] Downstream records included all mainstem and tributary sites until the confluence with the Opihi River (8.4 km downstream of the site). No Opihi River sites were included. [3] Downstream records did not include any records from above the confluence of the Temuka and Opihi Rivers.

7 Recreational values

7.1 Angling

Data on river usage for angling throughout New Zealand are available from 6-7-yearly angler surveys conducted by Fish & Game, starting in 1994/95.

The results of surveys in 1994/95, 2001/02 and 2007/08 indicated that the Opihi River catchment trout fishery accounted for at least 10% of the total angling effort in the Central South Island Fish & Game region (Unwin 2016). In the 2014/15 survey, that percentage dropped to 5% of angling effort in Central South Island region (Unwin 2016). Summary results from the four surveys (Table 7-1) show a general decline in angler usage in all rivers in the Opihi catchment between 1994–95 and 2014–15. The only angling water in the catchment to maintain usage was Lake Opuha (from 2007/08 onwards).

Unwin (2016) did not attempt to explain the decline in angling effort in particular catchments, but the data showed:

- a decline in total angling effort in all rivers in the Central South Island region between 2007/08 and 2014/15 as well as in the Opihi catchment;
- a general New Zealand-wide decline in angling effort in lowland rivers between 1994/95 and 2014/15 (Table 7-1);
- no such declining trend in angling effort in Hill, Mountain and Lake-fed rivers;
- a large increase in angling effort in the upper Waitaki canals, which has led to an overall increase in angling effort in the Central South Island region and reduced the proportions of angling effort in individual river catchments (including the Opihi).

Regarding the general decline in angler usage of lowland rivers, Unwin (2016) commented:

> *"The continued decline in usage for lowland river fisheries continues a trend which was first noted in 2007/08 (Unwin 2009), and now spans two decades. This decline amounts to over 120,000 angler-days, or approximately 6,000 angler-days per year. This decline has been partly offset by the sudden rise in popularity of the upper Waitaki canal fisheries, which – with the possible exception of Lake Taupo – are now the most heavily used fishery in New Zealand. It is unclear whether the effort expended on the canal fisheries represents a diversion of effort which would have been spent on other waters, or whether they are attracting anglers who would otherwise not have fished. Regardless of the source of this effort, however, then – without the contribution of the canal fisheries – total angling effort on FGNZ waters in 2014/15 would have been only 1.057 million angler days, and easily the lowest on record."*

Setting aside the trend of declining angler usage of rivers in the Opihi catchment as a whole, the numbers for 2014/15 in Table 7-1 highlight that the mainstem of the Opihi River accounts for most angling effort in the catchment, followed by Lake Opuha. There was minor usage in the Temuka, North Opuha, Opuha and Waihi Rivers (in that order), with the North Opuha featuring in the survey results for the first time.

Table 7-1: Estimated usage for lake and river fisheries in the Opihi catchment recorded in the 1994/95 – 2014/15 National Angling Surveys. Usage reported in mean angling days plus or minus one standard error. The tables do not include FGNZ non-resident licence holders. Adapted from Appendix B in Unwin (2016). Totals shown below the catchment data are: usage for the whole catchment, all Central South Island rivers, all Central South island including lakes and canals, all New Zealand lowland rivers, and all New Zealand rivers.

Angling water	1994/95	2001/02	2007/08	2014/15
Opihi River	18,450 ± 1,660	13,390 ± 1,660	19,160 ± 2,620	8,450 ± 2,060
Temuka River	1,280 ± 280	970 ± 340	970 ± 320	730 ± 320
Waihi River	1,670 ± 790	690 ± 390	580 ± 320	250 ± 150
Hae Hae Te Moana River		10 ± 10		
Kakahu River	120 ± 110	20 ± 20		
Te Ngawai River	90 ± 50	890 ± 390	120 ± 80	70 ± 40
Lake Opuha		2,670 ± 430	4,750 ± 1,110	4,170 ± 910
Opuha River	1,500 ± 490	1,310 ± 390	420 ± 140	330 ± 150
North Opuha River				420 ± 390
Total, Opihi catchment	**23,110 ± 1,930**	**19,960 ± 1,870**	**25,990 ± 2,890**	**14,420 ± 2,320**
All rivers, Central South Is	**118,850 ± 4,830**	**82,000 ± 4,180**	**105,020 ± 5,920**	**85,590 ± 5,820**
Total, Central South Is	**166,140 ± 5,640**	**168,230 ± 5,860**	**241,440 ± 8,980**	**294,430 ± 10,590**
All NZ, Lowland rivers	**259,170 ± 7,020**	**192,650 ± 5,970**	**151,650 ± 5,500**	**136,590 ± 6,100**
All NZ, Total, all rivers	**714,260 ± 13,990**	**629,180 ± 11,950**	**658,250 ± 14,210**	**575,340 ± 14,250**

7.2 Other recreational values

Systematic information on other types of recreational usage of rivers is lacking. Dodson & Steel (2016) provided a brief commentary on jetboating and kayaking in the Opihi catchment. Only the main stem of the Opihi River has potential for jetboating and reported use for kayaking.

- **Jetboating** has been assessed as feasible only in the mainstem of the Opihi River downstream of Rockwood for about 5% of the time, between October and March. Suitable flows are at least 14.3 m^3/s at Rockwood and 32.3 m^3/s at SH1 (Dodson & Steel 2016). These flows are approximately five and three times the median flow, respectively (Table 3-1).

- The Opihi Gorge has been identified as a "Scenic River Gorge" for **kayaking**. Flows at Opihi @ Rockwood of 10 – 20 m^3/s (three to seven times median flow) are suitable for intermediate paddlers, of 20 – 60 m^3/s (up to 20 x median flow) for advanced paddlers, and of 20 – 130 m^3/s (up to 40 x median flow) for expert paddlers (Rankin et al. 2014).

Sites on all of the rivers are likely to be used for recreational swimming/bathing. To our knowledge, no quantitative information on this type of river usage exists. However, sites are identified by ECan as popular swimming spots and these sites are targeted for water quality sampling and surveys for *Phormidium,* so that appropriate health warnings can be issued if the sites become unsafe for swimming. Popular sites (with their current swimmability status) are now listed on the LAWA (Land, Water, Air, Aotearoa) website (https://www.lawa.org.nz/explore-data/swimming). Nine sites in the Opihi catchment were shown when the site was accessed on 4 April 2018. Two unmonitored sites (i.e., no water quality data) were on Lake Opuha. The remaining seven sites included Temuka @ Manse Bridge, Waihi @ Waimarie, Waihi @ Geraldine, Te Moana @ Glentohi, Opihi @ SH1, Opihi @ Pleasant Point, and Opihi @ Waipopo (downstream of SH1). Of these, Opihi @ SH1, Opihi @ Pleasant Point, and Waihi @ Geraldine were deemed swimmable.

8 Synthesis of review: site characteristics and values

To summarise the main features and values identified at key sites in each water allocation zone, we selected representative metrics and ranked them across the nine sites. The purpose of the ranking exercise was to highlight ecological differences between the sites to guide selection of biological variables for modelling during the instream-habitat-assessment component of the project. For example, at sites ranked low for periphyton (i.e., high occurrence of nuisance growths) the modelling should include habitat assessments for filamentous algae. In addition, the ranking for flow characteristics is a straightforward way of summarising which sites already have the most frequent flow events (for example, that could potentially remove nuisance periphyton), and which sites have the least such events. Ranking sites in this way has also provided some understanding of what drives aspects of instream ecology at some sites. For example, low flood frequency in the South Opuha (relative to other sites in the catchment) may explain the prevalence of didymo proliferations in the river (see below).

The narrative around the rankings at each site (see below) combined with the details of the review (see Sections 3 to 6) are intended to inform both (a) variable selection for the instream habitat assessments (as noted above) and (b) any discussion of the results of the modelling.

In the ranking procedure, numerical levels of a feature or value considered to be favourable for instream ecological condition were assigned a high rank (i.e., 9 = the best site), and those considered unfavourable or detrimental were assigned a low rank (i.e., 1 = the worst site). Under catchment characteristics, high % intensive pasture and high summer temperatures were ranked lowest. Longer low flows and less frequent floods were also ranked low. Periphyton ranks were based on frequency of breaches of guidelines for *Phormidium* and the ORRP nuisance periphyton threshold at sites at or close to the habitat assessment reaches. Under invertebrates, QMCI was ranked on the mean values in Table 5-1, with highest QMCI having the highest rank and vice versa. The fish rank was based on species richness in Table 6-2. Under recreational values, angler usage was taken from Table 7-1. For jetboating and kayaking a score of 5 is assigned to suitable rivers and no score to other rivers.

Table 8-1 highlights that there was limited consistency between flow and biological characteristics and recreational values at each site.

The two tributaries of the Temuka River (**Te Moana** and **Waihi**) ranked best for flow characteristics (i.e., a combination of the most frequent high flows and relatively low proportions of time at very low flows). However, low recreational use and low rankings for nuisance periphyton and QMCI placed them in the lowest (worst) ranks for combined biological and recreational values.

The **Opihi @ Butlers** (flows at Saleyards) ranked third for good flows. Augmented flows from the Opuha River led to low durations of times at very low flows. The site also benefits from floods originating in the Opihi River upstream of the confluence. The site was ranked worst for nuisance periphyton and *Phormidium*, but this was offset by good invertebrate communities, and a high rank for angling values (relative to the wider Opihi catchment).

The fourth-ranked site for good flow characteristics was the **North Opuha**, which has relatively high baseflows offset somewhat by low frequencies of moderate to large high flows. The Alpine lower classification of the site implies cool temperatures, which may limit nuisance proliferations of *Phormidium* (Heath et al. 2011). The North Opuha was ranked as the best site for the combination of catchment, flow and periphyton characteristics.

Table 8-1: Ranked catchment, flow and biological characteristics and recreational values of key sites in each flow allocation zone. Ranks are from 1 to 9, with 1 indicating the worst site and 9 the best. Under catchment characteristics, high % intensive pasture and high summer temperatures are ranked low. Under flow characteristics, longer low flows and less frequent floods are ranked low. Periphyton ranks are based on frequency of breaches of guidelines for *Phormidium* and the ORRP nuisance periphyton threshold. Under invertebrates, QMCI is ranked on the mean values in Table 5-1. The fish rank is based on species richness in Table 6-2. Under recreational values, angler usage is from Table 7-1. For Jetboating and kayaking a score of 5 is assigned to suitable rivers and no score to other rivers. Under total ranks, colour coding grades from green – yellow – orange – red (best to worst), with grading colouration specific to each category. The overall rank is shown in parentheses. 'Biol.' in the last line refers to the combination of periphyton, invertebrates and fish. NA = no rank because no QMCI data were available for the North Opuha.

	Alpine lower				Hill lower				
	North Opuha	South Opuha	Opihi @ Gorge	Te Ngawai	Opuha @ Confl.	Opihi @ Butlers	Te Moana	Waihi	Temuka
Catchment characteristics									
% intensive agr.	8	9	2	1	7	5	6	3	4
January temp	9	9	7	6	5	3	3	1	1
Flow characteristics, low flows									
7d_MALF	8	1	4	2	3	9	5	7	6
Time <0.5 median	9	3	5	2	1	9	6	7	4
Flow characteristics, flood frequency									
3 x median	5	4	7	6	1	3	8	9	2
7 x median	2	3	5	8	1	4	8	9	6
10 x median	3	2	4	8	1	5	9	7	6
Periphyton relative to guidelines									
Nuisance cover	9	6	3	6	6	1	3	3	6
Phormidium	7	9	2	7	2	1	2	2	2
Invertebrates relative to guidelines									
QMCI	NA	5	8	5	1	8	3	3	2
Freshwater fish									
Species richness	3	1	6	3	7	8	6	6	9
Recreational values									
Angling usage	6	2	9	3	5	9	2	4	7
Jet boat, kayak	0	0	5	0	0	5	0	0	0
TOTAL RANKS									
Flow only	27 (6)	13 (2)	25 (4)	26 (5)	7 (1)	30 (7)	36 (8)	39 (9)	24 (3)
Catchment, flow, periphyton	59 (9)	46 (6)	39 (3)	45 (5)	26 (1)	40 (4)	50 (8)	48 (7)	37 (2)
Biol., recreation	NA	23 (4)	28 (8)	23 (4)	20 (3)	27 (7)	16 (1)	18 (2)	26 (6)

Flow characteristics were ranked close together (one point apart) at the **Opihi @ Gorge** and in the **Te Ngawai**, though the two sites had different combinations of low and high flows. The Te Ngawai had longer duration low flows and moderate flood frequencies, while the Opihi @ Gorge (represented by flows at Rockwood) had shorter duration low flows but fewer large floods (Table 3-1). Note that the flood size estimated to remove periphyton (in terms of daily mean flows) was higher in the Te Ngawai than in the Opihi @ Rockwood. Therefore, the frequency of effective flows (for clearing nuisance algae) is probably higher in the Opihi @ Rockwood. The Opihi @ Gorge was ranked best for the combination of biological characteristics (periphyton, invertebrates and fish) and recreational values, with high angling value and use as a kayaking location offsetting the tendency of this river reach to support nuisance algae at times, especially *Phormidium*.

The **Temuka River** came in with a total rank of third worst for flows, driven by over 16% of the time under flows less than 0.5 x median, and relatively few high flows, especially small floods. It was estimated that flows greater than 10 x median are required to clear periphyton to low levels in the Temuka River. Such flows occur less than four times annually, on average (Table 3-2). While the river does not experience consistent breaches of guidelines and objectives for periphyton in general, *Phormidium* proliferations occur regularly. Site position (i.e., warm temperatures and high catchment development) contributed to the second-lowest ranking of the site for the combination of catchment, flow and periphyton characteristics. However, the most diverse fish community and some use of the river for angling led to a ranking of third highest for biological and recreational values. We are aware that this site is of particular interest to the local Papatipu Rūnanga, Te Rūnanga o Arowhenua, but this is not included in our rankings. Our rankings should not be considered as reflective of local rūnanga values.

The **South Opuha** ranked second to bottom for flow characteristics, driven by almost 20% of the time under low flows (<0.5 x median), low 7-day MALF relative to median flow and few large floods. These flow characteristics probably explain why didymo is so often visible in the South Opuha. Didymo cover has led to breaches of the ORRP guideline for nuisance periphyton. At the same time, *Phormidium* is apparently not a major problem in the South Opuha possibly partly attributable to the position of the site in the upper Opihi catchment (i.e., coolest water temperatures). The South Opuha lies in the middle of the range for the combinations of catchment, flow and periphyton characteristics, and for biological and recreational values.

Based on the flow record from 2008 to 2017, the **Opuha River** is the lowest ranked of the nine sites for flow characteristics. Regulated flows lead to long periods of low flows and few high flows, condition which also favour proliferations of didymo. The worst didymo proliferations tend to occur in lake-fed or regulated rivers, which are characterised by long periods of stable flows. Didymo tends to have low, sporadic cover in rivers with natural, unregulated flow regimes (Kilroy et al. 2012). Some usage by anglers and the third-highest species richness value for fish communities lifts the ranking for the combination of biological and recreational values.

9 Acknowledgements

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