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APPENDIX F

Aquatic Ecology Assessment of Effects – Ryder Environmental Limited

Trustpower Limited

Motukawa HEPS
Aquatic Ecology AEE

November 2021

Note: Since the lodgement of the resource consent applications for the Motukawa Hydro-Electric Power Scheme in November 2021 (being the application to which this technical assessment relates), the proposal by Manawa Energy has been amended to retain the consented maximum water take from the Manganui River as 5.2 m^3/s. The Assessment of Environmental Effects lodged with the resource consent applications has been amended to reflect this change, but the technical assessments associated with the application (including this one) have not been amended. However, all effects on the environment will either be the same or less than previously assessed in the lodged technical assessments.

ryder

Trustpower Limited

Motukawa HEPS
Aquatic Ecology Assessment of Effects

November 2021

Prepared for ChanceryGreen on behalf of Trustpower Limited

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Document version: 12 November 2021

Cover page: Motukawa HEPS Manganui River intake weir (background) and fish pass (foreground), February 2020.

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Executive Summary

Trustpower is proposing to seek new resource consents for the Motukawa Hydroelectric Power Scheme (the scheme or HEPS), with the current consents due to expire in June 2022. This report, which is one of a series of technical assessment reports, addresses the water quality and aquatic ecology aspects of the scheme.

Existing values - water quality

Physical and chemical measurements of water quality were used to assess pressures on the health of rivers associated with the scheme. Nutrient and faecal bacteria concentrations in the Manganui and Waitara Rivers reflect the agricultural nature of the catchments, with associated non-point source run-off and point source discharges. Ten-year trend analysis for the Manganui River at SH3 (an upstream monitoring site) indicates that water quality is degrading. Nitrogen and faecal bacteria concentrations in the Manganui River downstream of the Motukawa HEPS intake weir are higher than those at SH3. Increases between these two sites are not unexpected given the increasing land use intensity downstream, and are not related to the diversion of water at the Motukawa HEPS intake weir.

The Motukawa Power Station is the scheme's final structure and it discharges water to Makara Stream, a tributary of the Waitara River. Monitoring in the Makara Stream upstream and downstream of the tailrace discharge indicates that when the station is generating, nutrient levels are elevated downstream relative to when the station is not generating, but still well within the NPS-FM bottom lines. Comparing long term monitoring data (5-year median) for the Waitara River upstream of this point to recent monitoring downstream indicates no major differences in water quality.

Water temperatures are generally higher downstream of the Motukawa HEPS intake than upstream during summer, and at times exceed the thermal criteria for brown trout (the fish species most sensitive to high water temperatures). Thermal preferences and incipient lethal temperatures for a range of native fish and macroinvertebrate taxa indicate that water temperatures downstream of the intake are typically within the range of thermal preferences for most native fish species. The artificial freshes required by Condition 5 of Consent 3369 appear to have minimal influence on water temperature increases downstream of the take, although this is not unexpected, as they were not designed to specifically target times of high water temperature.

The pattern of water temperature variation in the Makara Stream downstream of the Motukawa HEPS tailrace discharge closely aligns with variation in the discharge, with water temperature in the stream increasing with generation flow, and typically within the range of thermal preferences for native fish species. Monitoring during 2019-2021 in the Makara Stream downstream of the Motukawa HEPS tailrace discharge found that for all of the monitoring period dissolved oxygen concentration was above the NPS-FM (2020) minimum acceptable state.

Existing values - ecology

Long-term monitoring of periphyton cover and biomass in the Manganui River at SH3 and Bristol Road indicates that long filamentous nuisance algae proliferations occur at times at the Bristol Road site. Monitoring over the 2019-2021 period found that periphyton biomass at the monitoring site 2.3 km downstream of the scheme intake exceeded the guideline for benthic biodiversity of 50 mg/m^2 on one occasion only (January 2020), despite the combination of stable flows and summer water temperatures over the January-February 2020 period providing ideal conditions for periphyton growth.

Macroinvertebrate communities at six sites in the Manganui River were examined to determine if communities downstream of the Motukawa HEPS intake weir differed from those upstream. Overall, macroinvertebrate community metrics in the Manganui River were indicative of the highest quality habitat at the SH3 site ('excellent') and lowest at the Bristol Road site ('fair-poor'). Differences between these two sites (which are 28 km apart) are expected as land-use intensity increases downstream in the catchment. Median macroinvertebrate metrics (MCI and SQMCI scores) at all four of the Motukawa HEPS compliance monitoring sites were similar ('good'), with no major differences apparent between the sites upstream and downstream of the intake weir.

Twenty species of freshwater fish have been identified in the Waitara River catchment. Fifteen of the fish species are native and have threat classifications ranging from 'not threatened' to 'threatened – nationally vulnerable' (shortjaw kokopu and lamprey). The greatest numbers of records are for longfin eels, followed by Cran's bullies, brown trout, redfin bullies and shortfin eels. Recent fish community surveys have confirmed that longfin and shortfin eels, common, Cran's and redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout are all present upstream of the Manganui River intake weir. All of these species, with the exception of Cran's bullies, have migratory life cycles. Lamprey have been recorded in the intake weir fish pass, and the presence of juvenile lamprey within the Motukawa HEPS settling pond in March 2021 indicates that adult lamprey have successfully spawned upstream of the weir. Torrentfish have been recorded in the river at the bottom of the fish pass, but have never been recorded upstream of the weir. A trap and downstream transfer system is operated for eels near the penstock intake in Lake Ratapiko, and a trap and upstream transfer system is operated for elvers at the Motukawa HEPS tailrace.

Overall, the existing environment, which has included the scheme operation, supports a diverse native fish community and passage is provided for brown trout and migratory native fish to the weir fish pass.

Lake Ratapiko is an artificial storage lake formed in the 1920's to provide power generation. Two freshwater mussels were located in the Lake in 2016, and it provides habitat for three native and two introduced fish species. A pass for the upstream migration of elvers is present at the lake spillway to the Mako Stream, and a downstream trap and transfer system for migratory eels is operated at the Motukawa HEPS penstock intake at the lake.

The upper catchment of the Mako Stream was dammed to form Lake Ratapiko. There is no existing residual flow requirement downstream of the dam, however the Mako Stream channel receives seepage flow from the dam and the spillway overflows when the lake level is high. Short-term monitoring (March 2019 - June 2020) in the Mako Stream immediately downstream of the dam found that maximum water temperatures were below critical temperatures for native fish and brown trout. A pass for the upstream migration of elvers is present at the lake spillway to the Mako Stream, and bullies (common, Cran's), eels and brown trout have all been recorded downstream. The fish community diversity in the Mako Stream is as expected given the long distance from the sea, and there is no indication that it is affected by the presence of the Motukawa HEPS.

Effect of flow reductions in the Manganui River downstream of the Motukawa HEPS take

Trustpower is proposing to divert up to 7,500 L/s from the Manganui River, representing approximately 4-7% more than the current inflow to the Motukawa HEPS. There is no proposed change to the existing residual flow requirement of 400 L/s downstream of the intake, and the frequency of low flow periods below 580 L/s will not increase, however, there could be an increase in the frequency of sustained low flow periods in the river downstream of the intake. It is recommended that a temporary reduction in take be implemented if water temperatures at the Downstream 2.3 km site exceed 25 °C. The implementation of this measure will ensure that the adverse effects from the proposed increased abstraction of water from the Manganui River on water temperatures downstream, will in the context of its contribution to ecosystem health, be are no more than minor.

The proposed maximum abstraction of 7,500 L/s could, depending on the timing of the increased take, potentially increase the risk of nuisance algae growths occurring in the river downstream of the intake, although nuisance periphyton growths rarely occur downstream of the intake under the existing conditions. Flushing flows (e.g., FRE3), that can remove accrued periphyton, would reduce slightly. Nonetheless, it is proposed that a flushing flow regime be implemented to ensure that the increased take does not contribute to increased periphyton growths downstream.

Nuisance periphyton growths and high water temperatures can have adverse effects on macroinvertebrate community health as well as fish communities. The implementation of the above measures relating to flushing flows and temperature triggers will ensure that potential risk of adverse effects on fish and macroinvertebrate community health occurring due to the increased abstraction of water from the Manganui River will be no more than minor.

Effects on Lake Ratapiko

Lake Ratapiko is a storage reservoir and its water level fluctuates (by approximately 2 m) as a result of inflows and generation patterns. Changes in water levels result in temporary losses of habitat for some species, and seasonal lowering of the lake for weed control and other maintenance work reduces the level further by approximately 2 m, and results in large areas of lake bed being exposed for one to two weeks. It is unlikely that any fish or mussels stranded as the water levels recedes will survive until the water level is restored. In order to avoid or minimise the risk of stranding, existing consent conditions require that lake level draw down for maintenance occurs gradually over a 7-day period. Lake lowering in autumn reduces the risk of high temperatures impacting aquatic communities (noting that emergency lowering could still be required during summer). The implementation of these measures ensures that the potential risk of adverse effects on the existing aquatic community occurring due to the operation of Lake Ratapiko is no more than minor.

Effects on Makara Stream

Water from Lake Ratapiko is discharged to the Makara Stream via the Motukawa HEPS tailrace. Monitoring in the Makara Stream upstream and downstream of the tailrace discharge indicates that when the Power Station is generating, downstream nutrient levels (nitrogen and phosphorus) are elevated, and dissolved oxygen levels reduced at times. However, all are still well within the NPS-FM (2020) bottom lines. Downstream water temperatures in Makara Stream are typically within the range of thermal preferences for the fish species present. Overall, the risk of adverse effects on water quality in the Makara Stream occurring due to the discharge of water from the Motukawa HEPS with the proposed increased take is no more than minor.

Effects on Fish Passage

The current residual flow of 400 L/s below the intake weir on the Manganui River provides for fish passage in that reach of the river. Because adult eels migrate downstream on freshes, predominantly over the autumn period, it is recommended that reducing the number of FRE3 events from about mid-March to mid-June as a result of abstraction, is avoided.

Passage upstream of the intake weir is provided by the two fish passes and these appear to be effective at providing upstream fish passage for all species, with the possible exception of torrentfish. Ongoing maintenance of the true right bank fish pass is recommended to address potential barriers created by erosion of rock weirs within the pass.

Trash racks on the scheme's intake have vertical bar spacings of 150mm, and these present a low risk of impingement, regardless of the rate of abstraction.

Sluice gates situated approximately 80 m downstream of the intake trash racks leak water into a channel that returns flow back to the Manganui River, and in doing so provides an attractant flow to fish that are migrating upstream and are capable of climbing damp surface. It is recommended that the potential for fish to gain access into this channel is restricted by installing a barrier on the vertical wall at the channel's outlet to the Manganui River.

An in-race generator, situated in the scheme's race between the settling pond and Lake Ratapiko, is unlikely to exclude large and small fish which would pass through the existing trash screen and to the Kaplan turbine. Most small fish are likely to pass safely through this turbine, however larger fish would be more susceptible to damage and even mortality. A trap and transfer programme has been recommended for the settling pond (located upstream of the in-race generator) in association with an intensified trapping programme for Lake Ratapiko. These programmes will enable adult eels to be returned safely back the river and be able to migrate out to sea and complete their life cycle.

The damming of the Mako Stream to form Lake Ratapiko has resulted in a physical barrier (Ratapiko spillway) to upstream fish passage. This structure has an elver pass for upstream migration and Trustpower has recently made improvements to elver passage at the spillway. The are no identified changes to the effects of the HEPS on fish passage in the Mako Stream as a result of an increase in the rate of take from the Manganui River.

An elver trap located in the tailrace of the Motukawa Power Station has operated successfully since 2002 and has recently been subjected to some improvements to attract elvers to the trap. A number of other minor improvements have been recommended to further enhance the effectiveness of the trapping programme.

1. Introduction

1.1. Background

Trustpower is proposing to seek new resource consents for the Motukawa Hydroelectric Power Scheme (the scheme or HEPS), with the current consents due to expire in June 2022. An Assessment of Environmental Effects (AEE), based on the assessment of the effects of the scheme on the environment, is required to support the consent application. This report, which is one of a series of technical assessment reports, addresses the water quality and aquatic ecology aspects of the scheme.

1.2. Scheme physical description

The Motukawa HEPS is located within the Waitara River catchment to the south-east of New Plymouth. The catchment has an area of 1,146 km^2 and has two points of origin, the eastern hill country and Mount Taranaki, which is the source of the Manganui River. The Manganui River enters the Waitara River east of Inglewood, and from there the Waitara River flows north entering the Tasman Sea at Waitara Township.

The Motukawa HEPS first generated electricity in January 1927 and has been modified over the years to improve its efficiency. A location map of structures and surface waters associated with the Motukawa HEPS is provided in Figure 1.1.

Up to 5,200 L/s of water is currently drawn from a weir intake on the Manganui River near Tariki (Figures 1.2 and 1.3). A residual flow of 400 L/s is required by the existing consent conditions to be maintained in the river below the weir. The weir incorporates two fish passes, an older pass on the true left and a new pass on the true right that was constructed in 2002. The combined flow from the fish passes provides the residual flow requirement. Prior to the construction of the new fish pass in 2002 the residual flow requirement was 100 L/s.

From the intake (Figure 1.4) a water race leads to a settling pond approximately 300 m from the take (Figure 1.5). From the settling pond the race continues towards the east, passing through a tunnel and then after approximately 2.3 km, onto an in-race generator, which was constructed in 2006 (Figure 1.6). Here the natural head in the race combined with a small dam are used to generate electricity. After the in-race generator the race crosses the Mangaotea Stream (2.9 km from the intake), a tributary of the Manganui River. From November 2008 up to 450 L/s of water was pumped from this stream (Figure 1.7) and discharged to the water race to supplement the Manganui River take. This take and diversion from the Mangaotea Stream ceased in March 2018 and is not being re-consented as part of this project.

Approximately 5 km from the Manganui River intake the race enters Lake Ratapiko (Figure 1.8), an artificial storage lake resulting from the damming of the Mako Stream. A concrete spillway at the lake allows water to flow into the Mako Stream at times of high lake level (Figure 1.9). From Lake Ratapiko the water is piped through penstocks to the Motukawa Power Station (Figures 1.10 and 1.11), used to generate electricity, and discharged into the Makara Stream (Figure 1.12). The combined flow from the Makara Stream and the Motukawa HEPS tailrace discharge then enters the Waitara River (Figure 1.13). Approximately 25 km downstream of this point the Manganui River enters the Waitara River from the true left.

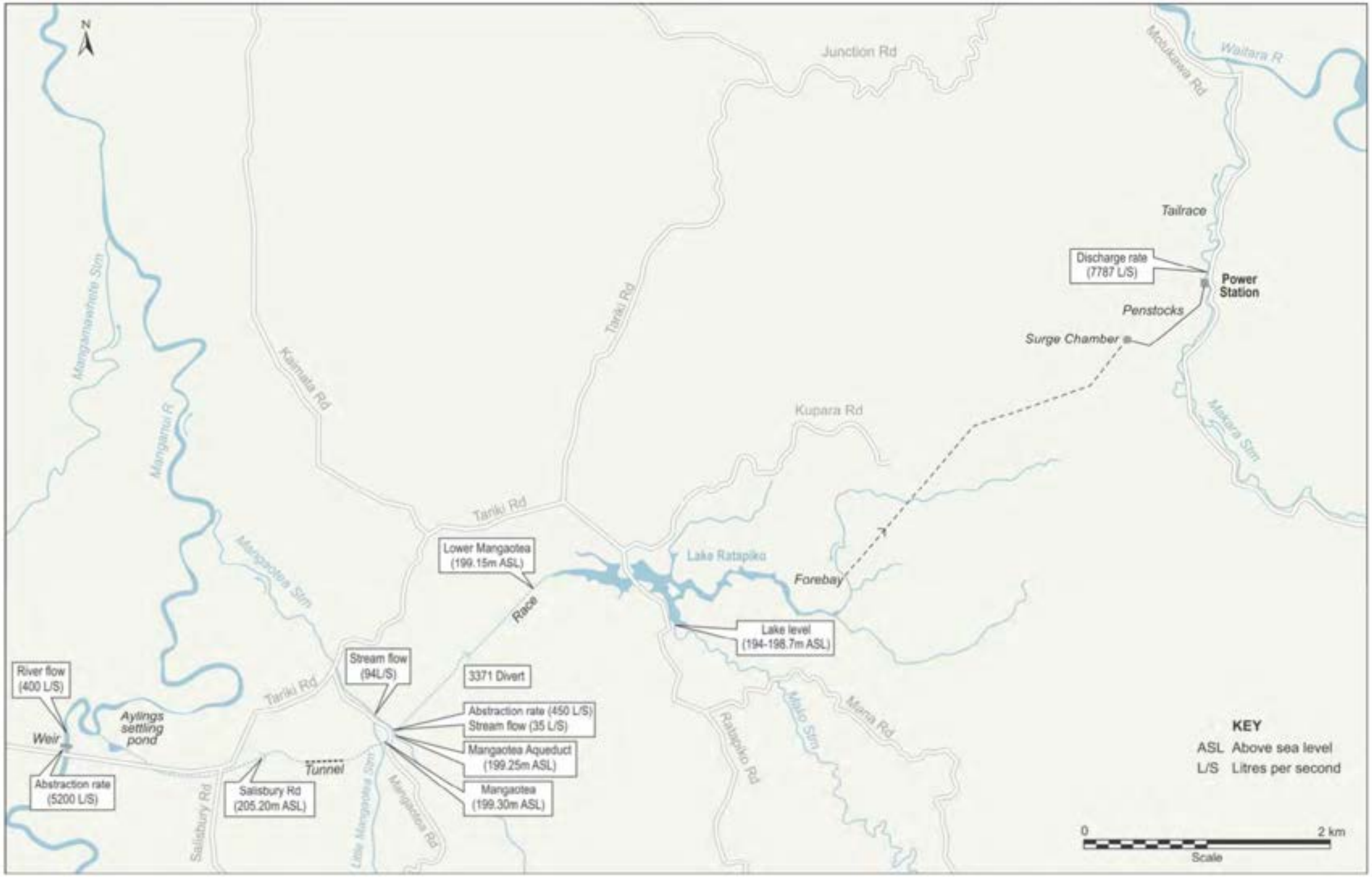


Figure 1.1. *Location map of structures and surface waters associated with the Motukawa HEPS (from TRC 2020b).*

Figure 1.2. *Manganui River upstream of the Motukawa HEPS intake structure and weir, November 2018. Tariki Road South bridge visible in background.*

Figure 1.3. *Motukawa HEPS intake weir and fish passes (left foreground and right background) on the Manganui River, February 2020.*

Figure 1.4. *Motukawa HEPS intake structure on the Manganui River, February 2021.*

Figure 1.5. *Settling pond, April 2021.*

Figure 1.6. *In-race generator, August 2019.*

Figure 1.7. *Mangaotea Stream pump structure, November 2018.*

Figure 1.8. *Lake Ratapiko, November 2018.*

Figure 1.9. *Lake Ratapiko spillway to Mako Stream, August 2019.*

Figure 1.10. *Motukawa HEPS intake to penstock at Lake Ratapiko, February 2021.*

Figure 1.11. *Penstock entering Motukawa Power Station, February 2020.*

Figure 1.12. *Motukawa Power Station tailrace (during generation), November 2018.*

Figure 1.13. *Makara Stream/Motukawa Power Station tailrace discharge entering the Waitara River from the true left (generation was occurring at the time), July 2021 (photo: B. Jansma).*

2. Assessment methods

Available data and reports were reviewed to gain an understanding of the existing information on aquatic communities within the Manganui River catchment. Sources included Taranaki Regional Council (TRC) annual compliance and regional monitoring reports for the scheme (e.g. TRC 2019 a and b, TRC 2020 a and b), and New Zealand Freshwater Fish database records. From this literature review, data and information gaps were identified and a monitoring plan designed in April 2019 to ensure that the additional information required to prepare the assessment of effects was collected. Additional monitoring data was obtained during the period from April 2019 to March 2021. Monitoring methods, including a map of monitoring sites and location information and photographs, are presented in Appendix One.

The report is structured to begin with a review of 'Existing Values' arranged into sub-sections (e.g., water quality, benthic macroinvertebrate communities), including a comparison of these values to relevant standards and limits (e.g., National Policy Statement for Freshwater Management 2020 (NPS-FM), periphyton guidelines). At the start of each existing values sub-section a short 'Summary' paragraph is provided that covers the main findings of the review, a more detailed 'Analysis and Discussion' then follows. The 'Assessment of Effects' section then considers the effect of the Motukawa HEPS on each of the existing values separately, with a 'Summary' provided at the end of each sub-section. The Assessment of Effects includes consideration of Trustpower's proposal to take up to 7,500 L/s of water during higher flow periods. The existing residual flow requirement of 400 L/s would be maintained under this proposal. All of this information is then drawn together in the final 'Summary and Conclusion', which also includes options to reduce any adverse effects of the Motukawa HEPS on aquatic communities.

3. Existing values

3.1. Water quality – nutrients, clarity and bacteria

Summary

Physical and chemical measurements of water quality are used to assess pressures on the health of rivers. Nutrient and faecal bacteria concentrations in the Manganui and Waitara Rivers reflect the agricultural nature of the catchments, with associated non-point source run-off and point source discharges. Ten-year trend analysis for the Manganui River at the State Highway 3 (SH3) site indicates that nutrient and faecal bacteria concentrations are increasing, and water clarity is decreasing (i.e., water quality is degrading). Nitrogen and faecal bacteria concentrations in the Manganui River downstream of the Motukawa HEPS intake weir are higher than those at SH3, however increases within the approximately 15 km long reach between these two sites is not unexpected due to the increasing land use intensity downstream, and differences are not related to the diversion of water at the Motukawa HEPS intake weir.

From the intake weir, water travels approximately 8 km through a race and Lake Ratapiko to the Power Station intake penstocks where it ultimately is discharged via the station tailrace to Makara Stream. Monitoring in the Makara Stream upstream and downstream of the tailrace discharge indicates that when the station is generating, nutrient levels are elevated downstream relative to when the station is not generating, but still well within the NPS-FM bottom lines. Approximately 1.7 km downstream of the confluence of the Makara Stream and the Motukawa HEPS tailrace the combined flow enters the Waitara River. Comparing long term monitoring data (5-year median) for the Waitara River upstream of this point to recent monitoring downstream indicates no major differences in water quality.

Analysis and discussion

Manganui River

NIWA (National Institute of Water and Atmosphere)[1] measures the physical and chemical water quality[2] of the Manganui River at the SH3 bridge in the middle of the catchment near Midhurst (approximately 8 km downstream of the Egmont National Park boundary). The

[1] National River Water Quality Network (NRWQN) site 'WA2'.
[2] These measures include bacteria levels, water clarity, conductivity and acidity (pH levels), nutrient levels, dissolved oxygen levels and the amount of oxygen consumed in the breakdown of organic matter (biochemical oxygen demand). In all, there are 13 individual measures, which the TRC monitors at 13 sites throughout the region.

catchment flows from the eastern side of Mount Taranaki through native bush and then grassed farmland. This site is located approximately 13 km upstream of the Motukawa HEPS intake weir and within this report is referred to as the SH3 site (a map of key monitoring sites, table of location information and photographs of some of the sites is presented in Appendix One). NIWA has undertaken monthly monitoring of a range of water quality parameters at the SH3 site since 1989 (i.e., for 32 years).

Table 3.1 (below) presents 5-year median data for a range of key monitoring parameters at the SH3 site, including phosphorus, nitrogen, clarity and faecal bacteria. Land and Water Aotearoa (LAWA) 10-year trend analysis results for the site are also shown, together with a comparison of median values with relevant National Objectives Framework (NOF) bands (NPS-FM 2020).

Ten-year trend analysis indicates that total and dissolved reactive phosphorus concentrations, and total and ammoniacal nitrogen concentrations are all increasing (i.e., water quality is degrading) at the SH3 site (Table 3.1). This may be related to the intensification of dairying in the catchment. Ammoniacal nitrogen concentrations however fall within NOF band A, indicating current concentrations would have no observed effect on any species (Table 3.1). Dissolved reactive phosphorus concentrations are within NOF Band B, indicating ecological communities may be slightly impacted. Phosphorus levels in the river are influenced by its source on the slopes of Mount Taranaki, which is a naturally high source of phosphorus for Taranaki rivers.

Faecal bacteria concentrations are high (*Escherichia coli (E. coli)*, NOF band D), with trend analysis indicating increasing degradation (Table 3.1). A TRC-led region wide programme of riparian fencing and planting is on-going and as this becomes established, water quality is expected to improve. As per special condition 8 of resource consent 3369, Trustpower also contributes to riparian planting in the Manganui River catchment, through an annual payment of $6,000 to the Taranaki Tree Trust. Water clarity is high in the river at the SH3 site, but likely degrading (based on both black disc and turbidity measurements, Table 3.1).

In order to compare water quality at the SH3 site to that downstream of the Motukawa HEPS intake, additional monthly[3] water quality monitoring was undertaken in the Manganui River 2.3 km downstream of the intake weir from 2019 to 2021. Within this report this site is referred to as Downstream 2.3 km (see map Appendix One). Water quality monitoring data for the two Manganui River sites from April 2019 to March 2021 is presented for key parameters in Appendix Two (Figures A2.1 to A2.7). A summary table of annual median data for each site over the two years is presented in Table 3.2. Note that monthly monitoring in 2020-2021 was disrupted due to Covid-19 travel restrictions in April

[3] Monthly sampling was not possible at some sites in March, April and May 2020 due to Covid-19 travel and access restrictions.

and May 2020, and data for the NIWA SH3 site was only available at the time of reporting up to September 2020. Due to this monitoring data for the two sites are not comparable in 2020-2021.

During the 2019-2020 monitoring period median values of most water quality parameters were similar between the two sites, with the exception of nitrogen and faecal bacteria (Table 3.2). Median concentrations of all forms of nitrogen were at least two times higher at the Downstream 2.3 km site than at SH3. Median faecal bacteria (*E. coli*) concentrations were also higher at the Downstream 2.3 km site than at SH3. Increases in nitrogen and faecal bacteria concentrations downstream in the Manganui River in the approximately 15 km long reach between these two sites is not unexpected due to the increasing land use intensity downstream, and differences are not related to the diversion of water at the Motukawa HEPS intake weir.

Table 3.1. *Five-year median water quality data for the Manganui River SH3 site (2015-2019) and Waitara River upstream site (2016-2020). 10-year trends (January 2011 - December 2019) are also reported for the Manganui SH3 site, as either indicating 'improving' or 'degrading' water quality. Where appropriate the relevant National Objectives Framework (NOF) Bands are also reported ('A', 'B', and 'C' indicates that water quality is considered suitable for the designated use, and 'D' indicates water quality is not considered suitable for the designated use). Data and interpretation sourced from the Land Air Water Aotearoa (LAWA) website.*

	Parameter	**Value**	**Manganui SH3 site**	**Waitara Upstream site (Autawa Road)**
Phosphorus	Total phosphorus (g/m^3)	5-year median	0.017	0.047
		10-year trend	Very likely degrading	-
	Dissolved reactive phosphorus (g/m^3)	5-year median	0.001	0.007
		10-year trend	Very likely degrading	-
		NOF band	B	-
Nitrogen	Total nitrogen (g/m^3)	5-year median	0.19	0.43
		10-year trend	Very likely degrading	-
	Ammoniacal nitrogen (g/m^3)	5-year median	0.008	0.017
		10-year trend	Very likely degrading	-
		NOF band	A	-
Clarity	Black disc (m)	5-year median	3.70	0.37
		10-year trend	Very likely degrading	-
	Turbidity (NTU)	5-year median	1.5	16
		10-year trend	Very likely degrading	-
Bacteria	*E. coli* (per 100 mL)	5-year median	77	295
		10-year trend	Very likely degrading	-
		NOF band	D	-

Table 3.2. *Manganui River SH3 and Downstream 2.3 km median water quality data, April 2019 to March 2020 and April 2020 to March 2021.*

Parameter	Unit	2019-2020 Median		2020-2021 Median	
		SH3	Downstream 2.3 km	SH3	Downstream 2.3 km
		N=12 (April-March)	N=12 (April-March)	N=5 (May-September)	N=10 (June-March)
Biochemical oxygen demand (5-day)	g/m^3	<2	<2	<2	<2
pH	pH	7.6	7.4	7.6	7.3
Conductivity	mS/m	7.8	9.8	9.4	9.0
Turbidity	NTU	1.2	1.2	1.4	1.5
Ammoniacal nitrogen	g/m^3N	0.011	0.024	0.008	0.019
Nitrite-nitrate nitrogen	g/m^3N	0.19	0.49	0.15	0.49
Total nitrogen	g/m^3N	0.28	0.65	0.23	0.76
Dissolved reactive phosphorus	g/m^3P	0.009	0.006	0.008	0.008
Total phosphorus	g/m^3P	0.019	0.020	0.014	0.019
E.coli bacteria	cfu/100 mL	102	160	520	275

Waitara River

From the Manganui River intake weir, water travels approximately 8 km through the race and Lake Ratapiko to the Power Station intake penstocks where it ultimately is discharged via the station tailrace to the Makara Stream. Approximately 1.7 km downstream of the confluence of the Makara Stream and the Motukawa HEPS tailrace the combined flow enters the Waitara River.

TRC began monthly measurements of water quality in the Waitara River at Autawa Road near Tarata in July 2015. This site is located in the middle of the catchment and upstream land-use contains a mixture of native vegetation and upland agricultural development. This site is located approximately 1.5 km upstream of the confluence of the Makara Stream with the Waitara River, and therefore upstream of the Motukawa HEPS tailrace discharge. Within this report the site is referred to as Waitara Upstream (see map/table Appendix One). Trend data is not yet available for this site due to the shorter monitoring period (6 years).

Table 3.1 presents 5-year median data for a range of key monitoring parameters at the Waitara Upstream site. Nutrient and faecal bacteria concentrations indicate poorer water quality than in the Manganui River, with median concentrations at least twice those of the Manganui SH3 site. Water clarity is also low, with a median black disc reading of only 0.37 m (Table 3.1).

In order to compare water quality at the Waitara River Upstream site to that downstream of the Motukawa HEPS tailrace discharge, additional monthly[4] water quality monitoring was undertaken at a further three sites. Two sites were sampled in the Makara Stream, which is the small tributary of the Waitara River that receives the Motukawa HEPS tailrace discharge. There is no long-term hydrology information available for the Makara Stream, but estimated flow statistics from New Zealand River Maps (Whitehead and Booker 2020) suggest that upstream of the tailrace discharge the stream has a median flow of approximately 180 L/s. The third site was in the Waitara River approximately 0.4 km downstream of where the Motukawa HEPS tailrace discharge/Makara Stream enters the river. The three sites are described below:

- Makara Upstream: Makara Stream upstream of the point where the Motukawa HEPS tailrace enters the stream.
- Makara Downstream: Makara Stream downstream of the point where the Motukawa HEPS tailrace enters the stream.
- Waitara Downstream: Waitara River downstream of the point where the Motukawa HEPS tailrace discharge/Makara Stream enters the river.

Water quality monitoring data for the two Makara Stream sites from April 2019 - March 2021 is presented for key parameters in Appendix Two (Figures A2.8 to A2.14). A summary table of annual median data for each site over the two-year period is presented in Table 3.3. Each month both sites were sampled on the same day, noting that monthly monitoring was not competed in April and May 2020 due to COVID-19 travel restrictions. The Motukawa HEPS was generating on most of the sampling occasions (generation discharge ranging from 128 to 6,918 L/s) and therefore the Makara Downstream site was receiving a discharge from the tailrace. The exceptions to this were April 2019, February 2020 and August 2020, when there was no generation discharge at the time of sampling.

During the 2019 - 2020 and 2020 - 2021 monitoring periods median values of nitrogen and phosphorus were higher in the Makara Stream downstream of the tailrace discharge than upstream (Table 3.3). When the Motukawa HEPS was not generating (i.e., in April 2019, February and August 2020) nutrient levels at the two sites were similar. Therefore the discharge from the Motukawa HEPS tailrace appears to increase nutrient levels in the Makara Stream. Based on the available data, nutrient levels in the Makara Stream

[4] Monthly sampling was not possible at some sites in March, April and May 2020 due to Covid-19 travel and access restrictions.

downstream of the discharge are however well within relevant NOF bottom lines (i.e. nitrate and ammonia (toxicity)) (NPS-FM 2020).

The same pattern was not apparent with faecal bacteria. *E. coli* concentrations were similar at the two sites in 2019 - 2020, but in 2020 - 2021 were higher at the upstream site than downstream. Very high *E. coli* concentrations were recorded at both the Makara Stream sites at times, with a maximum of (at least) 10,000 cfu/100 mL recorded at both sites in March 2021 (generation was occurring at the time of sampling). To provide an indication of how faecal bacteria concentrations in Lake Ratapiko relate to those in the Makara Stream downstream of the tailrace discharge, *E. coli* monitoring was undertaken in the lake from November 2020 - March 2021 on the same day as monitoring in the Makara Stream. For periods when the station was generating (November 2020 - March 2021) *E. coli* concentrations in the lake ranged from 5 - 4,000 cfu/100 mL and in the Makara Stream downstream of the discharge ranged from 170 - >10,000 cfu/100 mL. In the Makara Stream upstream of the discharge *E. coli* concentrations ranged from 170 - >10,000 cfu/100 mL. Based on these observations there is no indication that the discharge from the Motukawa HEPS tailrace is increasing *E. coli* concentrations in Makara Stream.

Table 3.3. *Makara Upstream and Makara Downstream median water quality data, April 2019 to March 2020 and April 2020 to March 2021.*

Parameter	Unit	2019-2020 Median		2020-2021 Median	
		Makara Upstream	Makara Downstream	Makara Upstream	Makara Downstream
		N=11 (April-February)	N=11 (April-February)	N=10 (June-March)	N=10 (June-March)
Biochemical oxygen demand (5-day)	g/m^3	<2	<2	<2	<2
pH	pH	7.5	7.2	7.4	7.2
Conductivity	mS/m	9.0	9.4	9.4	9.5
Turbidity	NTU	2.3	2.3	2.2	2.1
Ammoniacal nitrogen	g/m^3N	0.024	0.029	0.027	0.032
Nitrite-nitrate nitrogen	g/m^3N	0.29	0.44	0.37	0.46
Total nitrogen	g/m^3N	0.47	0.64	0.49	0.60
Dissolved reactive phosphorus	g/m^3P	0.002	0.005	0.002	0.003
Total phosphorus	g/m^3P	0.008	0.016	0.012	0.020
E.coli bacteria	cfu/100 mL	280	290	390	175

Water quality monitoring data for the two monitoring sites on the Waitara River from April 2019 to March 2021 is presented for key parameters in Appendix Two (Figures A2.15 to A2.21). A summary table of annual median data for each site over the two year period is presented in Table 3.4. The Motukawa HEPS was generating on most of the sampling occasions (generation discharge ranging from 128 to 6,934 L/s) and therefore the Waitara Downstream site was receiving a discharge from the tailrace. Sampling at the upstream and downstream sites occurred on the same day, with the exception of February 2020 when sampling at the downstream site occurred on the day following that at the upstream site.. Comparing median data between the Waitara Upstream and Waitara Downstream sites in 2020 - 2021 (Table 3.4) indicates that water quality at both sites is very similar. Based on this there is no indication that the discharge from the Motukawa HEPS tailrace is impacting water quality in the Waitara River.

Table 3.4. *Waitara Upstream and Waitara Downstream median water quality data, April 2019 to February 2020 and June 2020 to March 2021.*

Parameter	Unit	2019-2020 Median		2020-2021 Median	
		Waitara Upstream	Waitara Downstream	Waitara Upstream	Waitara Downstream
		N=10 or 11 (April 2019-February 2020)	N=4 (November 2019-February 2020)	N=10 (June 2020-March 2021)	N=10 (June 2020-March 2021)
Biochemical oxygen demand (5-day)	g/m^3	<2	<2	<2	<2
pH	pH	7.4	7.6	7.3	7.3
Conductivity	mS/m	9.9	9.9	9.1	9.0
Turbidity	NTU	8.2	5.7	16.3	9.4
Ammoniacal nitrogen	g/m^3N	0.013	0.011	0.014	0.015
Nitrite-nitrate nitrogen	g/m^3N	0.18	0.10	0.21	0.25
Total nitrogen	g/m^3N	0.41	0.32	0.44	0.45
Dissolved reactive phosphorus	g/m^3P	0.003	0.004	0.003	0.002
Total phosphorus	g/m^3P	0.008	0.006	0.025	0.029
E.coli bacteria	cfu/100 mL	40	80	385	310

3.2. Water quality – water temperature

Summary

Water temperatures outside an optimum range can have adverse effects on aquatic communities. Temperatures above the optimum can cause thermal stress and, if high and prolonged enough, death. Brown trout have lower temperature tolerances than native fish, with acute thermal criteria of 24.6 °C, and chronic thermal criteria of 19.6 °C (Todd *et al.* 2008). In the Manganui River brown trout are therefore the main fish species of concern with respect to water temperature. The highest water temperatures occur in the river over January and February. Water temperatures are generally higher downstream of the Motukawa HEPS intake than upstream during summer, and at times exceed the thermal criteria for brown trout. Unfortunately the optimum temperature has not been determined for any native freshwater organisms. Thermal preferences and incipient lethal temperatures for a range of native fish and macroinvertebrate taxa however have been compiled. These indicate that water temperatures downstream of the intake are typically within the range of thermal preferences for most native fish species.

The artificial freshes required by Condition 5 of Consent 3369 appear to have minimal influence on water temperature increases downstream of the take, although this is not unexpected, as they were not designed to specifically target times of high water temperature.

Short-term monitoring (June 2019 – January 2021) in the Makara Stream downstream of the Motukawa HEPS tailrace discharge found that water temperatures are highest in February. The pattern of water temperature variation in the stream closely aligns with variation in discharge from the Motukawa HEPS, with water temperature in the stream increasing with generation flow. Brown trout are not present in the stream and water temperatures downstream of the discharge are typically within the range of thermal preferences for native fish species.

Analysis and discussion

<u>Manganui River</u>

Water temperature is monitored continuously (15-minute measurements using loggers) at three sites in the Manganui River by TRC:

- Upstream: site code MGN000300 (immediately upstream of the intake weir).
- Downstream 2.3 km: site code MGN000375 (approximately 2.3 km downstream of the intake weir).

- Everett Park: site code MGN000435 (approximately 16 km downstream of the intake weir).

Water temperature at the Everett Park site is measured year round, while at the Upstream and Downstream 2.3 km sites temperatures are only measured between 1 November and 30 April. TRC selected the latter two monitoring sites, and maintain water temperature loggers at both sites over summer to allow the effect of the Motukawa HEPS intake on downstream water temperature to be determined for compliance purposes. The first tributary inflow enters the river approximately 0.3 km downstream of the Downstream 2.3 km site, and a further 1.1 km downstream the Mangaotea Stream enters (estimated median flow 170 L/s). The Downstream 2.3 km site was therefore likely chosen by TRC as being indicative of the maximum temperature that would occur in the river as a result of the take.

Water temperature monitoring data for each site over the period 1 November 2017 – 15 December 2020 is presented in Figure 3.1. As expected, water temperatures are lower in winter and higher in summer. Figures 3.2 to 3.4 focus on the period of maximum water temperatures in each of the three summer seasons; 2017 - 2018, 2018 - 2019 and 2019 - 2020. In all three summer seasons maximum water temperatures at all sites occurred in late-January or early-February (Figures 3.2 to 3.4). Maximum water temperatures are typically higher at the Upstream and Downstream 2.3 km sites than further downstream at Everett Park.

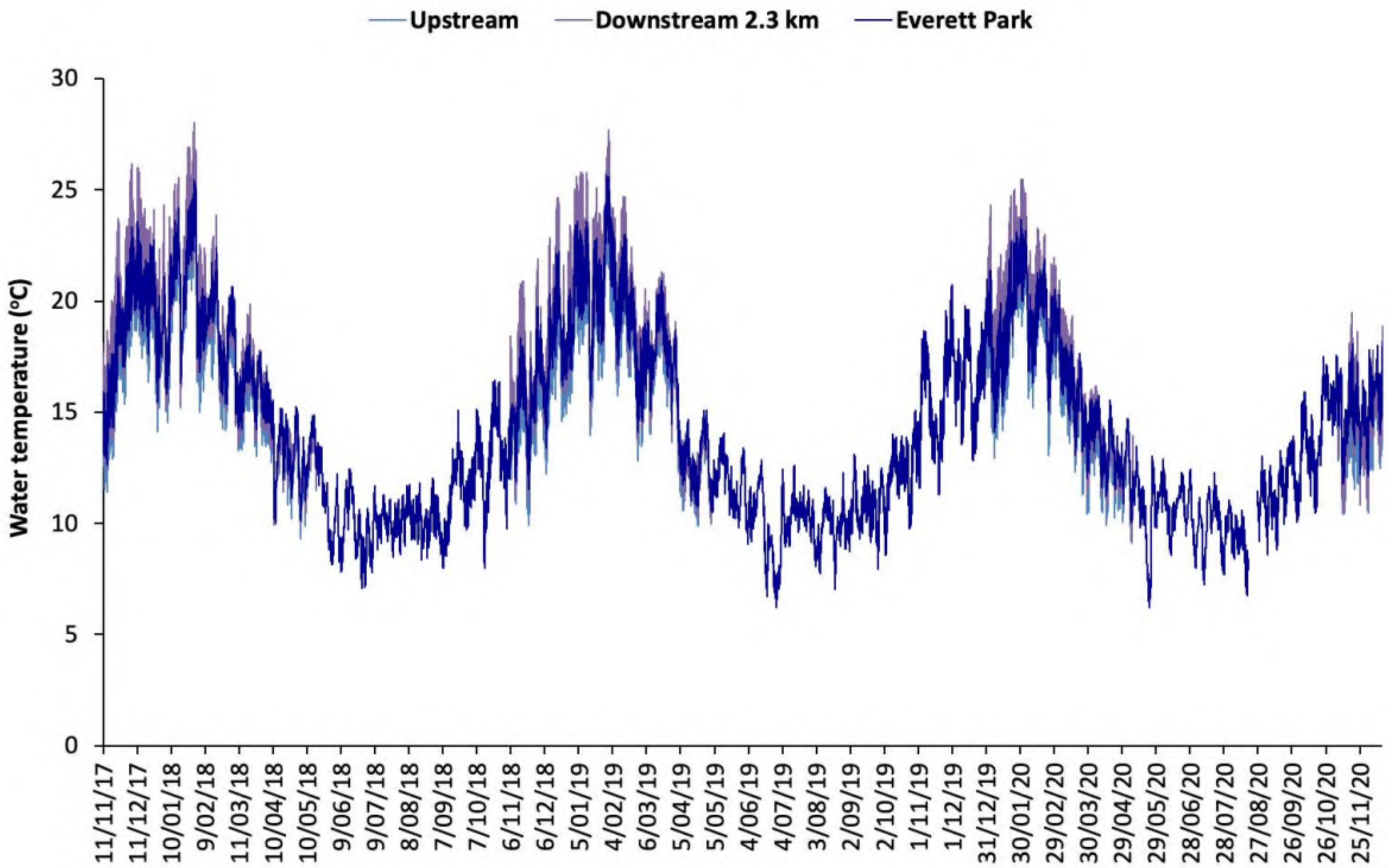


Figure 3.1. *Water temperatures (°C) at three Manganui River sites (15-minute logger measurements), 1 November 2017 – 15 December 2020. Note that water temperatures at the Upstream and Downstream 2.3 km sites are only measured between 1 November and 30 April.*

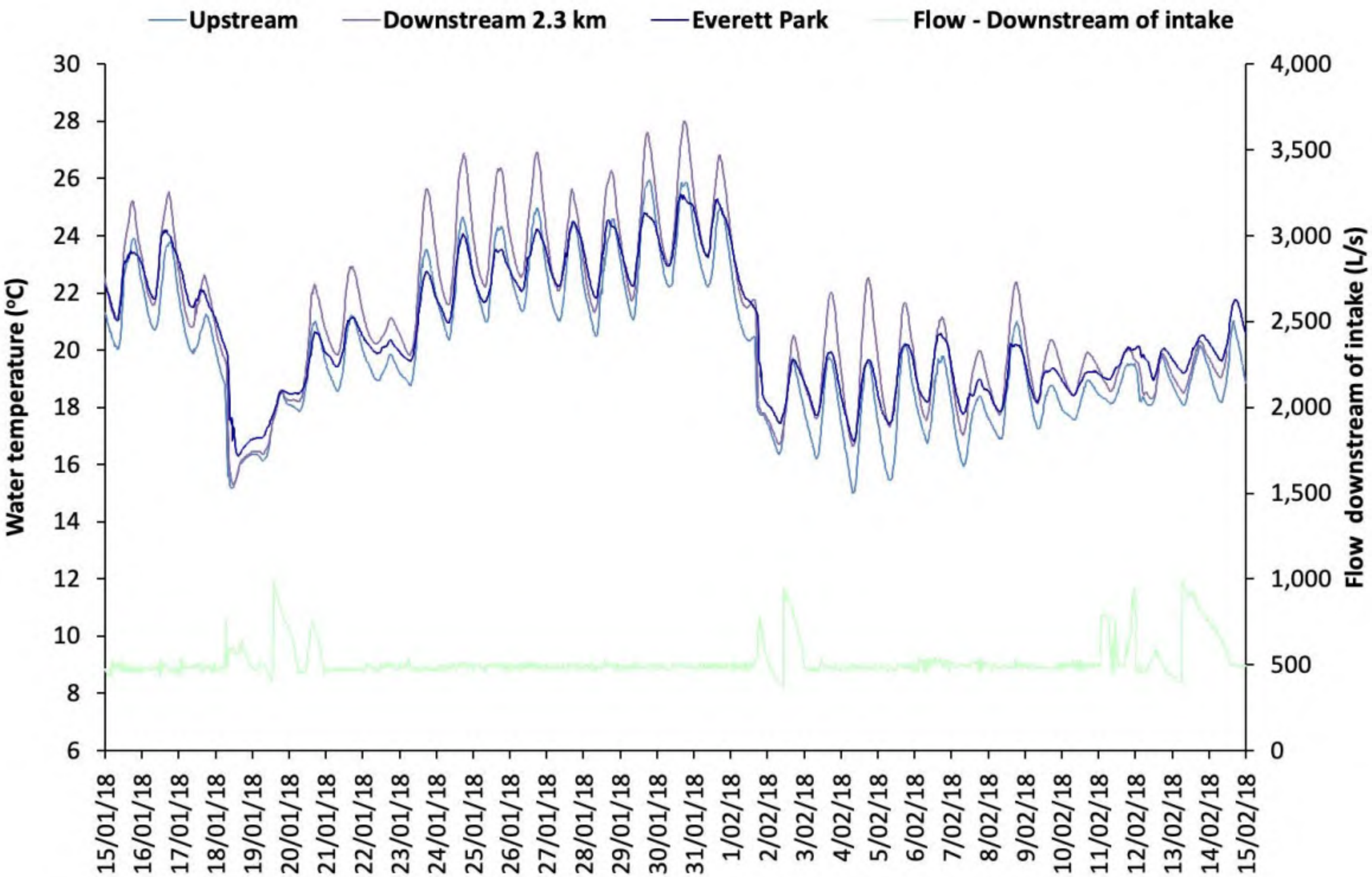


Figure 3.2. *Water temperatures (°C) at three Manganui River sites (15-minute logger measurements) and flow (L/s) downstream of the intake weir (15-minute synthesized data), 15 January – 15 February 2018. Y-axis is truncated.*

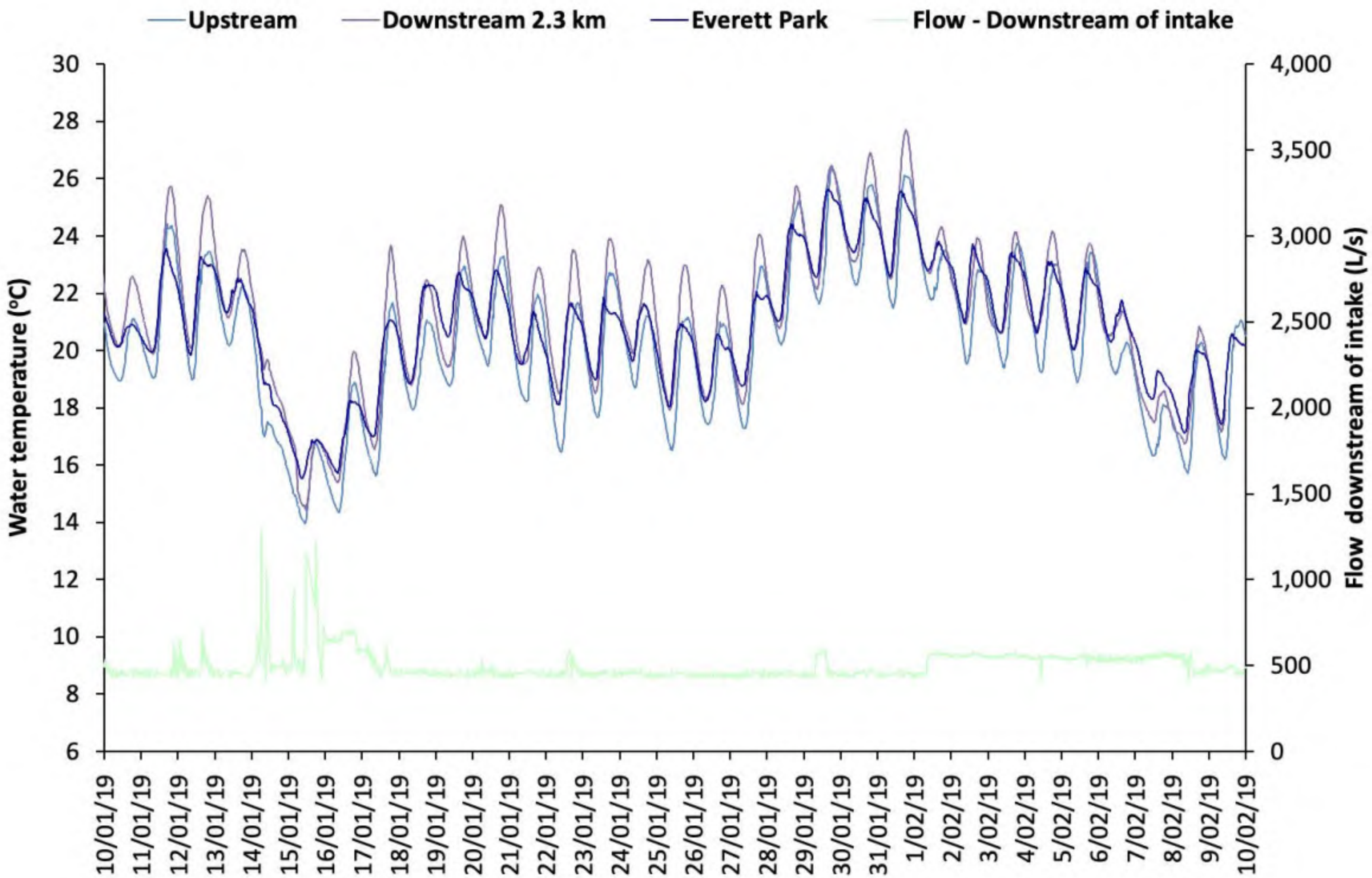


Figure 3.3. *Water temperatures (°C) at three Manganui River sites (15-minute logger measurements) and flow (L/s) downstream of the intake weir (15-minute synthesized data), 10 January – 10 February 2019. Y-axis is truncated.*

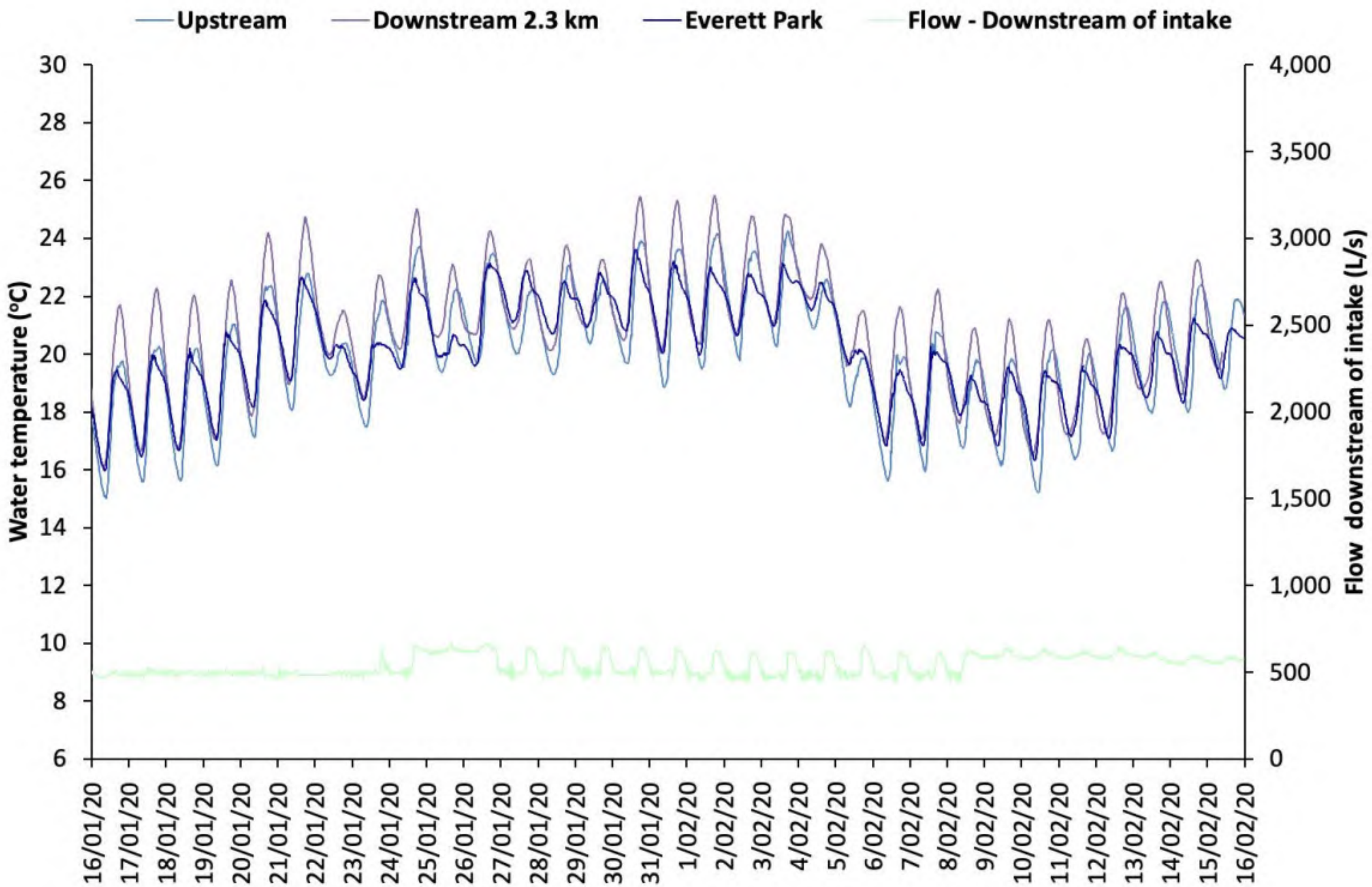


Figure 3.4. *Water temperatures (°C) at three Manganui River sites (15-minute logger measurements) and flow (L/s) downstream of the intake weir (15-minute synthesized data), 16 January – 15 February 2020. Y-axis is truncated.*

The water temperature monitoring data for the sites upstream and downstream of the intake weir is analysed and reported annually as part of the TRC's compliance monitoring of the Motukawa HEPS (TRC 2020b). As already noted, monitoring at the upstream and downstream sites is not year round, but is targeted to the 1 November to 30 April period, which includes the time when the warmest water temperatures occur (i.e., summer). Table 3.5 provides a summary of the maximum daily water temperatures recorded at each of the three Manganui River sites over the long-term (2002 – 2019[5]), and also the two most recent summer periods for which data is available (2018 – 2019 and 2019 – 2020). At both sites maximum daily water temperatures greater than 25 °C have been recorded, although they occur more frequently at the downstream site. Water temperatures were particularly high over the 2018 – 2019 summer, with maximum temperatures greater than 25 °C on five days at the upstream site, and 14 days at the downstream site. Long-term, maximum daily temperatures tend to range higher downstream of the intake than upstream (Table 3.5).

Table 3.5 *Summary of maximum daily water temperatures at three locations in the Manganui River between 1 November and 30 April (TRC 2020b).*

Site	Data range	Number of days monitored	Percentage of maximum temperatures in this range (number of days)			
			10-15 °C	15-20 °C	20-25 °C	>25 °C
Upstream	2002 – 2019	2,945	18.3	59.0	22.3	0.3
	2018 – 2019	177	17.5 (31)	45.8 (81)	33.9 (60)	2.8 (5)
	2019 – 2020	182	19.8 (36)	54.4 (99)	25.8 (47)	0.0 (0)
Downstream 2.3 km	2002 – 2019	2,994	12.1	46.4	38.0	3.5
	2018 – 2019	177	15.8 (28)	35.6 (63)	40.7 (72)	7.9 (14)
	2019 – 2020	182	16.5 (30)	40.1 (73)	41.2 (75)	2.2 (4)

Water temperatures outside an optimum range can have adverse effects on aquatic communities. Most aquatic organisms have little or no ability to thermoregulate, so their growth is strongly linked to temperature and they have an optimum temperature at which growth is maximised. Below the optimum temperature growth gradually declines, but of more concern is temperatures above optimum, which can cause thermal stress and if high enough death (because of effects on cellular function, with enzymes becoming denatured). For most aquatic organisms there is a narrow temperature range between optimum and lethal temperatures (perhaps 5 °C), meaning that temperatures above optimum can rapidly become stressful (Davies-Colley *et al.* 2013).

The goal for long-term (chronic) management should be to avoid temperatures going into the 'stress zone' for organisms, unfortunately the optimum temperature has not been determined for any native freshwater organisms (Davies-Colley *et al.* 2013). Lethal temperatures are less difficult to determine so have been defined for more species (Davies-Colley *et al.* 2013).

Thermal preferences and incipient lethal temperatures for a range of native fish and macroinvertebrate taxa have been compiled by Olsen *et al.* (2012) (Figure 3.5). Of the invertebrate

[5] Prior to 2002 the residual flow requirement downstream of the Manganui River intake weir was 100 L/s. Since 2002 the residual flow requirement has been 400 L/s.

species for which data are available mayflies (Ephemeroptera) and stoneflies (Plecoptera) seem to be most sensitive to high temperatures, with incipient lethal temperatures of approximately 21 - 23 °C. All of the native fish species shown (inanga, smelt, longfin and shortfin eels) have incipient lethal temperatures greater than 25 °C. Brown trout have lower temperature tolerances than native fish, with acute thermal criteria of 24.6 °C, and chronic thermal criteria of 19.6 °C (Todd *et al.* 2008). In the Manganui River, brown trout are therefore the main fish species of concern with respect to water temperature.

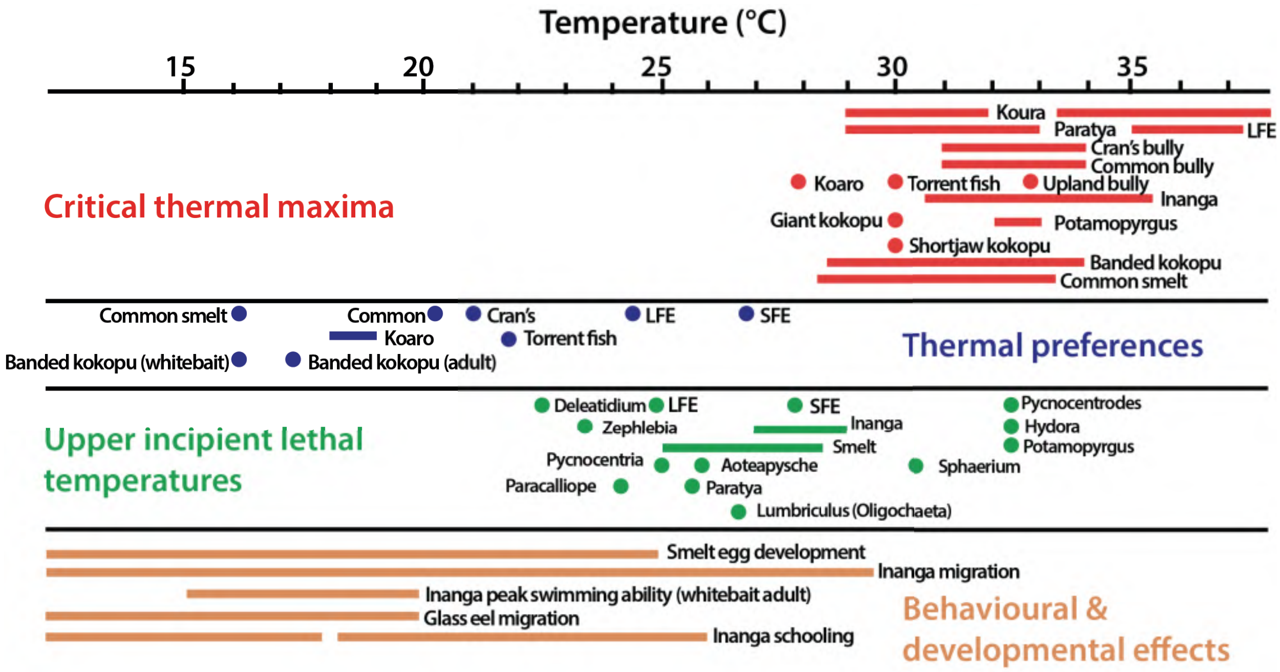


Figure 3.5. *Summary of thermal tolerance of native fish and macroinvertebrates as defined by critical thermal maxima (CTM - red), thermal preferences (blue), upper incipient lethal temperature (UILT — green) and behavioural and developmental effects (orange). Where CTM or UILT have been determined for multiple acclimation temperatures, the range is shown as a bar. Behavioural and developmental effects are shown as bars representing the range of temperatures when normal behaviour/development is apparent. Inanga schooling is dependent on acclimation temperature (redrawn from Olsen* et al. *2011, Hay and Allen 2015).*

In order to understand how existing water temperatures in the river compared to brown trout thermal requirements, long-term (2008 – 2020) water temperature monitoring data was examined for the two sites upstream (Upstream) and downstream (Downstream 2.3 km) of the weir. The number of days within the period that brown trout acute (24.6 °C, lethal but short duration) and chronic (19.6 °C, sub-lethal but prolonged) temperatures were exceeded was calculated for the two sites. For the acute criteria exceedance, we calculated the highest rolling two-hour average water temperature within any given 24-hour period. For the chronic criteria exceedance we calculated the maximum weekly average from the seven-day mean of consecutive daily mean temperatures, where daily means were calculated from multiple 15-minute interval values per day (Todd *et al.* 2008).

At both sites, the highest water temperatures occurred over the January to February period (Table 3.6 and Figure 3.6). Maximum hourly and daily average water temperatures differed by 1.5 to 1.6 °C, respectively, between the two sites. The maximum <u>hourly</u> water temperature recorded at the Upstream site was 26.4 °C in January 2019, and at the Downstream 2.3 km site 28.0 °C in January

2018 (Table 3.6). Maximum daily average temperatures at the Upstream site were 24.0 °C, and at the Downstream 2.3 km site 25.5 °C (Table 3.6).

In general, maximum hourly and maximum daily average water temperatures at both the Upstream and Downstream 2.3 km sites were below the critical thermal maxima temperatures for most native fish species (Figure 3.1). However, at the Downstream 2.3 km site the maximum hourly water temperature was equal to the critical thermal maxima of the most sensitive native species (koaro, 28.0 °C). Maximum hourly and daily temperatures at both sites exceeded incipient lethal temperatures of 'sensitive' benthic macroinvertebrate taxa (e.g., mayflies and stoneflies 21 – 23 °C).

The water temperature analysis found that brown trout acute thermal criteria were exceeded 0.5% of the time at the Upstream site, 4.5% of the time at the Downstream 2.3 km site, and 0.2% of the time at the Everett Park site (Table 3.6). The brown trout chronic thermal criteria were exceeded 8.3% of the time at the Upstream site, 20.0% of the time at the Downstream 2.3 km site, and 11% of the time at the Everett Park site (Figure 3.6).

Table 3.6. *Maximum water temperatures, and exceedance of acute and chronic thermal criteria for the protection of brown trout at two sites in the Manganui River from 1 January 2009 to 5 May 2019. Note that data only includes October to May, annually. Criteria based on Todd* et al. *(2008).*

Site	Number of days in data record	Maximum hourly temperature (°C)	Maximum daily average temperature (°C)	Percentage (and number) of days in data record exceeding thermal criteria	
				Acute (24.6 °C)	Chronic (19.6 °C)
Upstream	1,969	26.4 (29/01/19 17:00 and 18:00)	24.04 (30/01/19)	0.5% (10)	8.8% (173)
Downstream 2.3 km	2,016	28.0 (30/01/2018 17:00 and 18:00)	25.5 (30/01/2018)	4.5% (90)	20% (404)
Everett Park	2,507	25.6 (29/01/2019 15:00 and 16:00)	24.4 (30/01/2019)	0.2% (6)	11% (265)

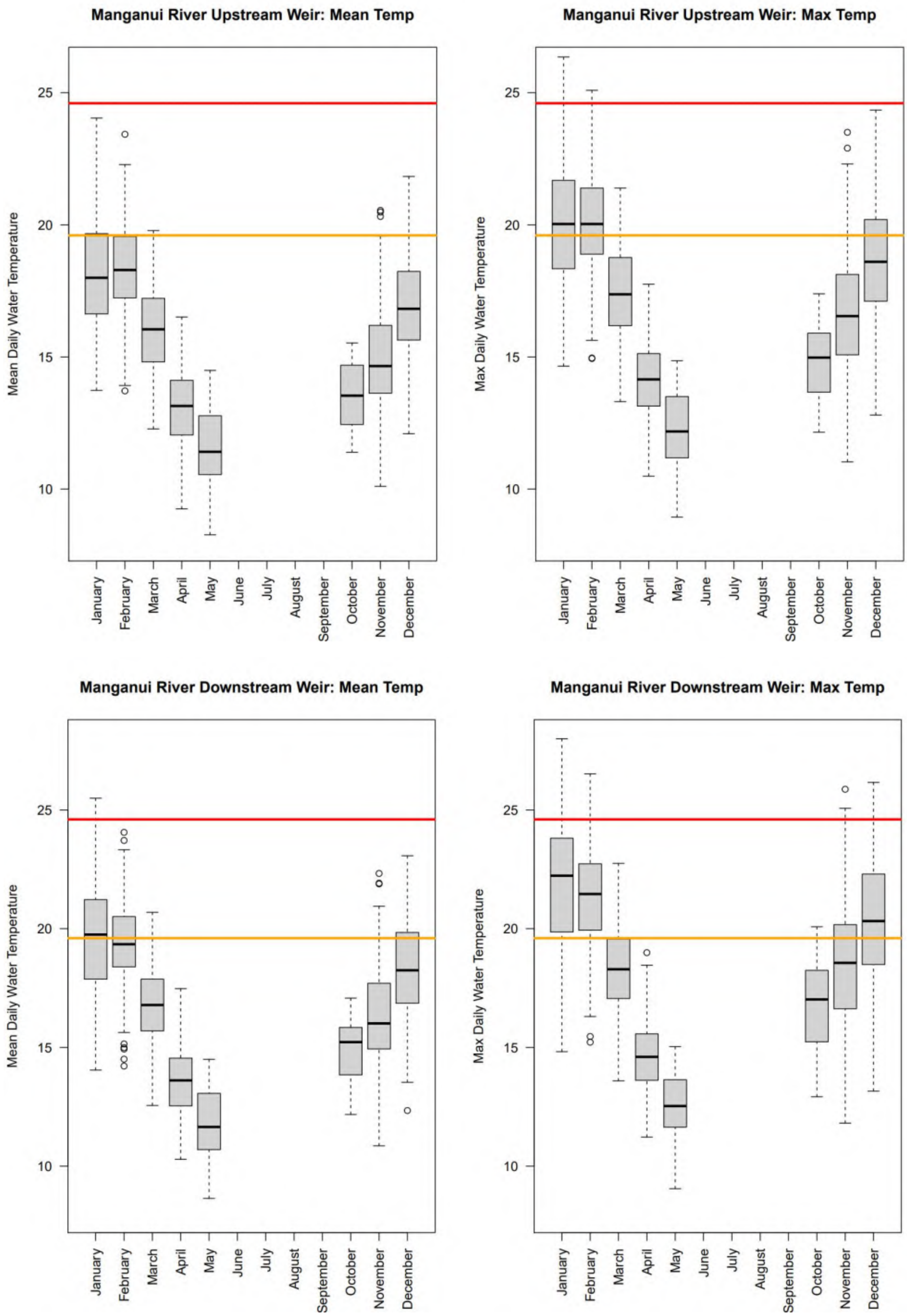


Figure 3.6. *Boxplots showing monthly distribution of daily mean and maximum water temperatures from 2008 – 2020 at the Upstream, Downstream 2.3 km and Everett Park sites in the Manganui River. Brown trout acute thermal criteria (24.6 °C) are shown by the red lines and chronic thermal criteria (19.6 °C) are shown by the orange lines. Criteria based on Todd et al. (2008).*

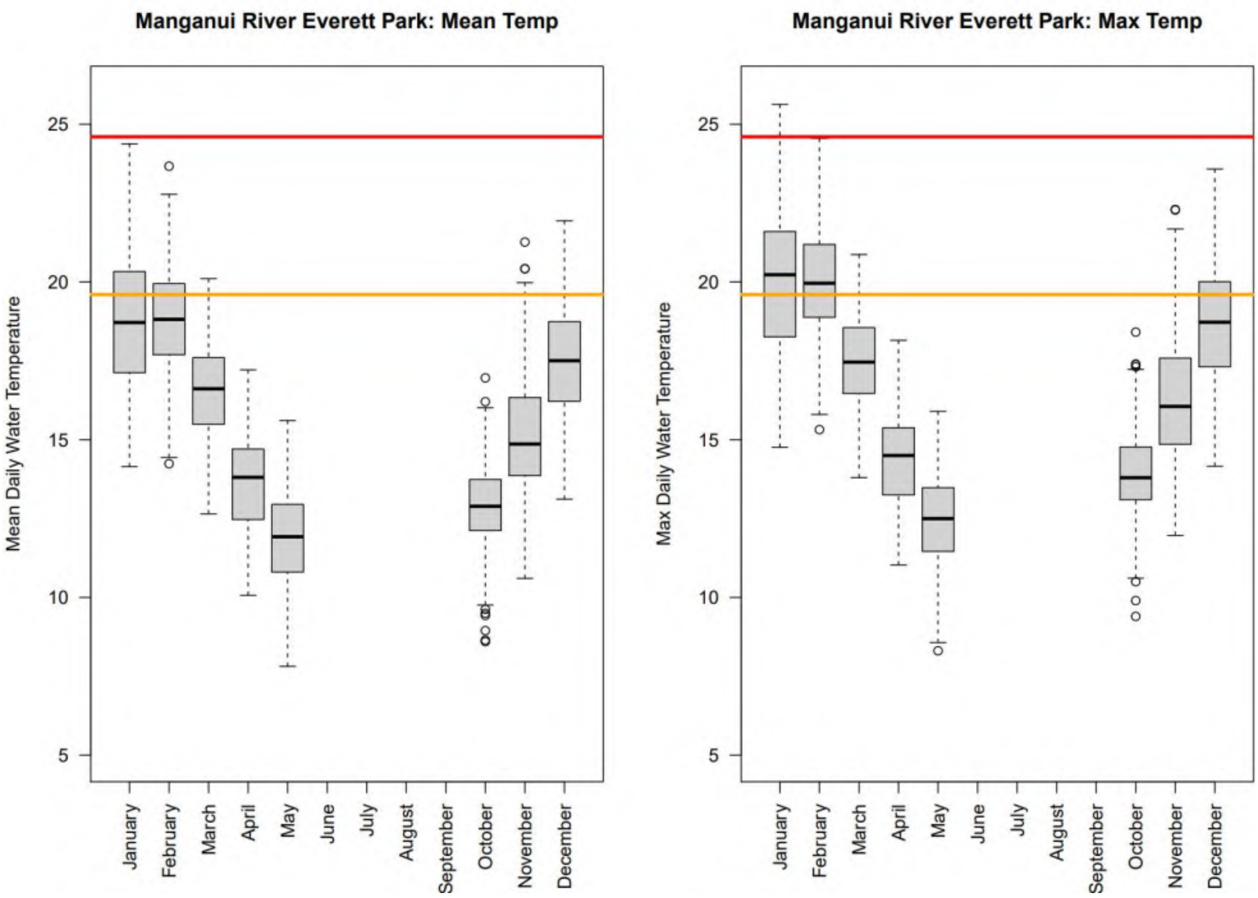


Figure 3.6. *(continued) Boxplots showing monthly distribution of daily mean and maximum water temperatures from 2008 – 2020 at the Upstream, Downstream 2.3 km and Everett Park sites in the Manganui River. Brown trout acute thermal criteria (24.6 °C) are shown by the red lines and chronic thermal criteria (19.6 °C) are shown by the orange lines. Criteria based on Todd et al. (2008).*

Differences in mean summer water temperatures upstream and downstream of the intake on the warmest day each summer for the 2015 – 2016 to 2019 – 2020 seasons are presented in Table 3.7. The effect of water abstraction varies among years. The largest observed increase in mean water temperature downstream of the intake was 1.8 °C in January 2016 (when the mean flow downstream was 476 L/s), and the smallest increase was 0.7 °C in February 2020 (when the mean flow downstream was 770 L/s).

Table 3.7. *Observed mean water temperature differences between Upstream and Downstream 2.3 km sites in the Manganui River on the maximum temperature day, 2015 – 2016 to 2019 – 2020.*

Summer season	**2015 - 2016**	**2016 - 2017**	**2017 - 2018**	**2018 - 2019**	**2019 - 2020**
Maximum Downstream 2.3 km temperature day	25/01/16	10/01/17	30/01/18	31/01/19	1/02/20
Upstream mean flow (L/s)	2,828	3,491	1,959	1,455	1,347
Downstream mean flow (L/s)	476	475	490	594	770
Flow (L/s) reduction downstream	*2,352*	*3,016*	*1,469*	*861*	*577*
Upstream mean temperature (°C)	21.8	19	24	23.8	21.9
Downstream 2.3 km mean temperature (°C)	23.6	20.5	25.5	25.1	22.6
Temperature (°C) increase observed downstream	*1.8*	*1.5*	*1.5*	*1.3*	*0.7*

In addition to the requirement to maintain a residual flow downstream of the intake, there is also a requirement that 400 L/s must be passed over the weir (for three hours daily) if the weir is not naturally overtopped by flows of 400 L/s or higher for a continuous period of 30 days (Consent 3369-2 Condition 5). Condition 5 was included on the existing consent to address concerns raised by the Department of Conservation (DOC) during the reconsenting process in 1996 - 2001 that freshes (either artificial or natural) are a key aspect of flow regimes in river in terms of removing periphyton build-up, enhancing water quality, initiating fish migration etc. (letter from R Miller (DOC) to R Coleman (Powerco Limited), dated 8 November 1996).

The requirement for artificial freshes was only required on five occasions during the 2010 – 2019 period (documented in TRC annual compliance monitoring reports); on four occasions during 2010 – 2014 and most recently in 2017. Water temperatures upstream and downstream of the intake before and after two of these artificial freshes (in March 2013 and February 2014) were examined to determine what impact the freshes had on downstream water temperature (Table 3.8, Figures 3.7 and 3.8).

In March 2013 there was a 32-day period where the Motukawa HEPS weir was not overtopped by a flow of 400 L/s or greater. This triggered the Condition 5 requirement for at least 800 L/s of water to be passed downstream of the weir (i.e. the 400 L/s residual flow, plus an additional 400 L/s) for three hours daily. Trustpower initiated the first of these artificial freshes on 12 March at 8 pm, by reducing the flow into the Motukawa HEPS and allowing an additional 306 L/s to pass downstream (i.e. total downstream flow 706 L/s[6]). An artificial fresh continued to be released daily until 18 March, when a natural fresh event occurred and flow downstream increased to over 2,000 L/s (Figure 3.7). Maximum water temperatures at the Downstream 2.3 km site did not change within the 24-hours following the artificial fresh on 12 March 2013 relative to before (maximum temperature: before 21.0 °C, after 21.0 °C), and, due to a decrease in temperature at the upstream site over the same period, the temperature difference between the two sites was higher than before the artificial fresh (maximum temperature difference: before 1.3 °C, after 1.5 °C) (Table 3.7).

In February 2014 there was a 33-day period without a fresh greater than 400 L/s, beginning on 11 February. The first artificial release was made on 20 February (i.e., sooner than required by Condition 5) for three hours between 3 pm and 6 pm with downstream flows ranging from 718 L/s to 828 L/s over the 3-hour period. These releases continued daily at approximately the same time each day until 6 March (Figure 3.8). Comparing maximum water temperatures upstream and downstream of the weir on the day prior to the release and the day after (Table 3.8) indicates that the artificial release appeared to have minimal influence on water temperature downstream.

Overall, the artificial freshes required by Condition 5 appear to have minimal influence on water temperature increases downstream of the take. This is not unexpected, as they were not specifically designed to target times of high water temperature. The artificial releases may however be beneficial for other aspects of aquatic ecology, such as encouraging upstream fish migration.

[6] There was not sufficient water present in the Manganui River upstream of the weir at the time to provide an 800 L/s flow downstream of the weir, while also maintaining the required minimum flow of 150 L/s in the race i.e., the average flow in the river upstream of the weir during the artifical fresh was less than 950 L/s.

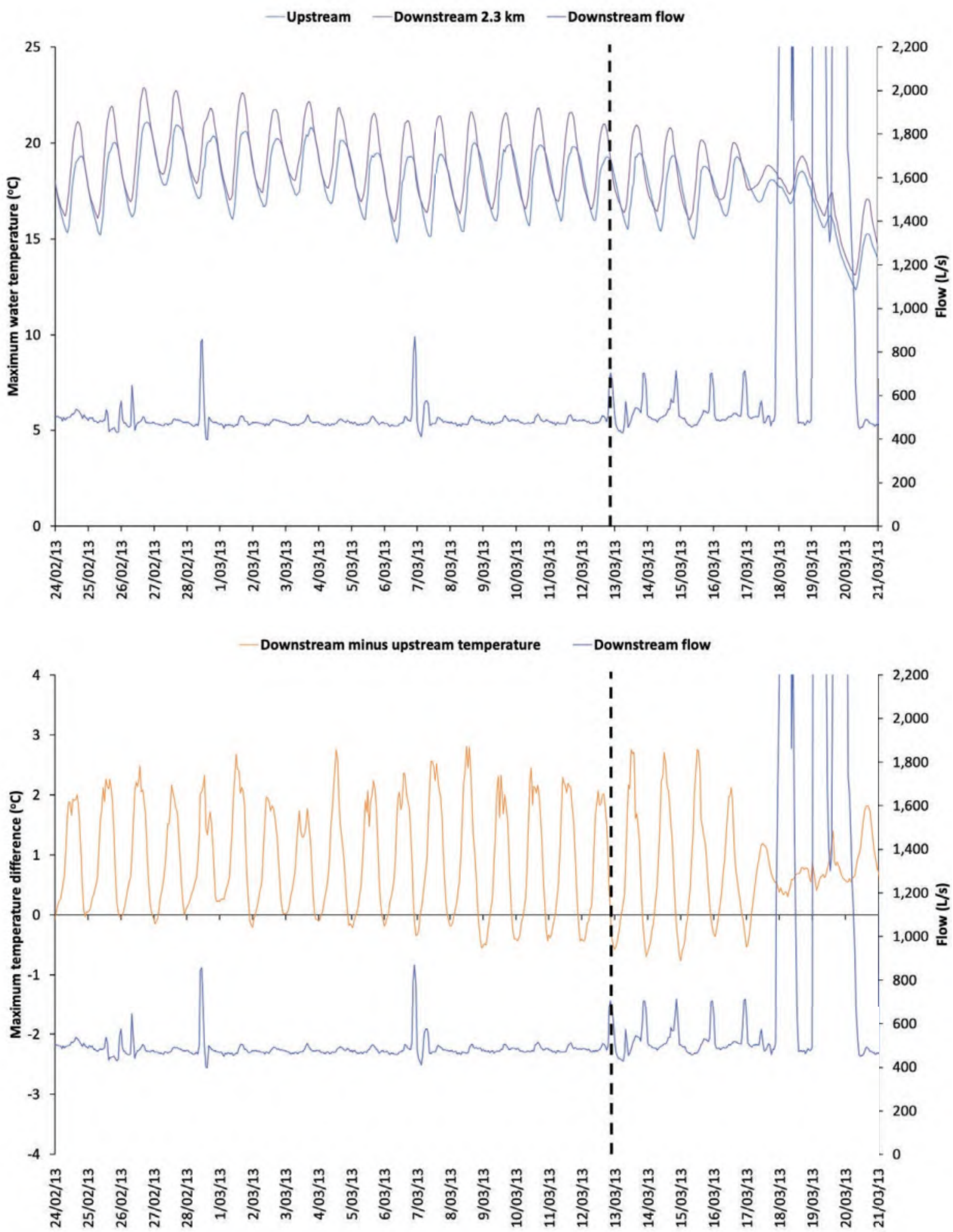


Figure 3.7. *Artificial fresh events downstream of the Motukawa HEPS intake in March 2013. Beginning 12 March (indicated by the vertical dashed line) and continuing daily until 16 March.*

Top: Maximum daily water temperature (°C) at Upstream and Downstream 2.3 km sites and flow in the Manganui River downstream of the Motukawa HEPS intake.

Bottom: Maximum daily water temperature (°C) difference between Upstream and Downstream 2.3 km sites and flow in the Manganui River downstream of the Motukawa HEPS intake.

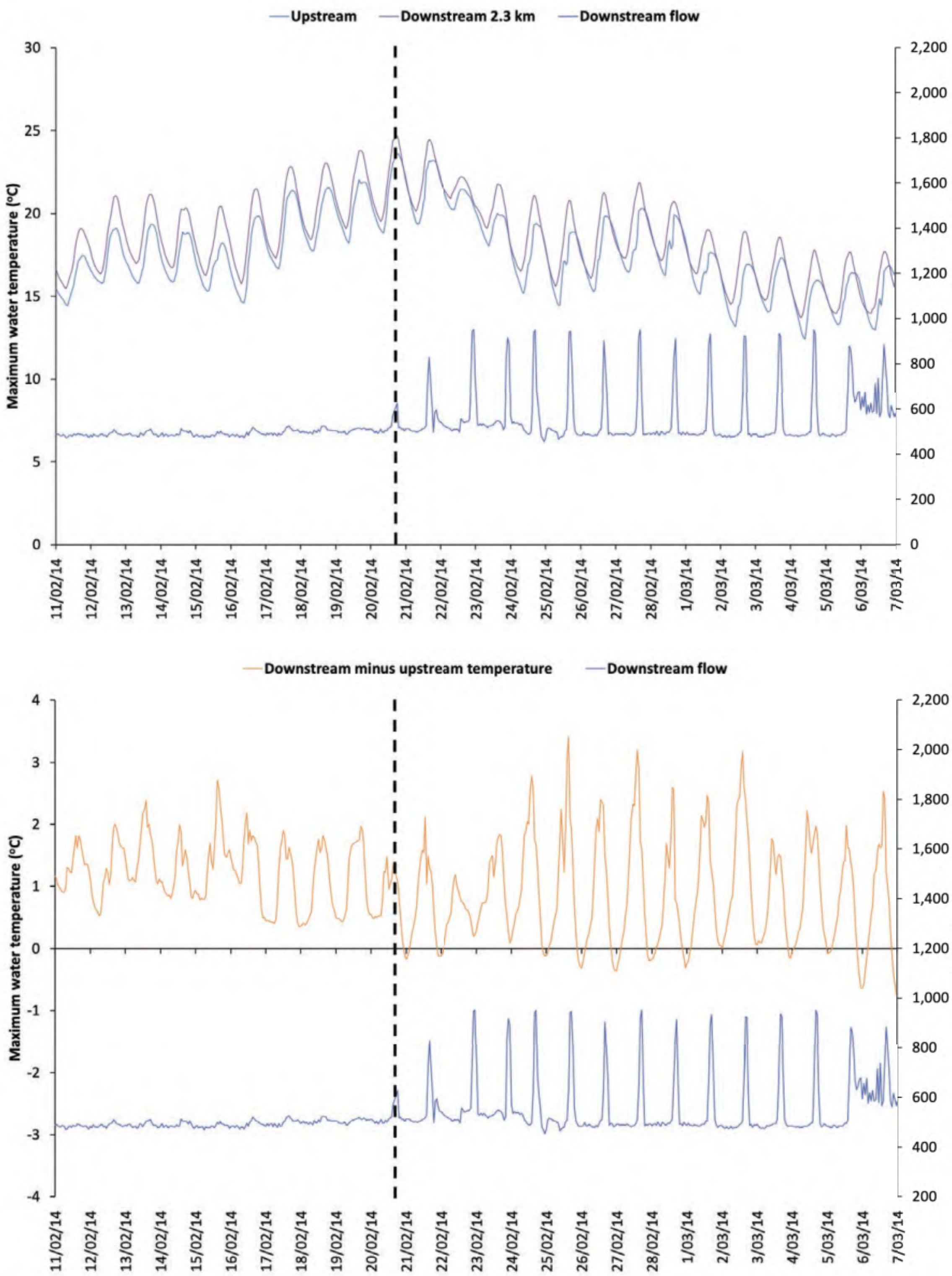


Figure 3.8. *Artificial fresh events downstream of the Motukawa HEPS intake in February 2014. Beginning 20 February (indicated by the vertical dashed line) and continuing daily until 6 March.*

Top: Maximum daily water temperature (°C) at Upstream and Downstream 2.3 km sites and flow in the Manganui River downstream of the Motukawa HEPS intake.

Bottom: Maximum daily water temperature (°C) difference between Upstream and Downstream 2.3 km sites and flow in the Manganui River downstream of the Motukawa HEPS intake.

Table 3.8. *Observed maximum daily water temperature differences between Upstream and Downstream 2.3 km sites in the Manganui River for 24-hour and 48-hours periods before and after artificial freshes in March 2013 and February 2014.*

Artificial fresh period	Upstream maximum temperature (°C)	Downstream 2.3 km maximum temperature (°C)	Maximum temperature (°C) increase observed downstream
March 2013			
24-hours before (11 March 8 pm to 12 March 7 pm)	19.7	21.0	1.3
24-hours after (12 March 8 pm to 13 March 7 pm)	19.5	21.0	1.5
48- hours after (12 March 8 pm to 14 March 7 pm)	19.5	20.9	1.4
February 2014			
24-hours before (20 February 3 pm to 21 February 2 pm)	23.6	24.7	1.1
24-hours after (21 February 3 pm to 22 February 2 pm)	23.2	24.5	1.3
48-hours after (21 February 3 pm to 23 February 2 pm)	23.2	24.5	1.3

Makara Stream

Makara Stream is the small tributary of the Waitara River that receives the Motukawa HEPS tailrace discharge. Estimated mean, median and low (MALF) flows for the stream upstream of where the tailrace discharge enters are 304 L/s, 180 L/s and 46 L/s, respectively (Whitehead and Booker 2020). Water temperature monitoring has not been undertaken previously in the Makara Stream below the Motukawa HEPS tailrace discharge, so, to provide information to determine if the discharge is resulting in high water temperatures downstream, a water temperature logger was installed in the river in May 2019. The logger was located immediately downstream of the confluence of the Motukawa HEPS tailrace and the Makara Stream (approximately 0.5 km downstream of the power station). Water temperature monitoring data for the Makara Stream Downstream site over the period 1 June 2019 – 17 January 2021 is presented in Figure 3.9. Maximum hourly water temperatures of 24.8 °C and daily temperatures of 22.3 °C were recorded in February 2020 (Table 3.9).

The maximum hourly and maximum daily average water temperatures at the Downstream sites were below the critical thermal maxima temperatures for all native fish species (Figure 3.5). Maximum hourly temperatures exceeded incipient lethal temperatures of 'sensitive' benthic macroinvertebrate taxa (e.g., mayflies and stoneflies 21 – 23 °C), and maximum daily temperatures were within the lethal range. Brown trout are not present in Makara Stream so their temperature tolerances were not evaluated.

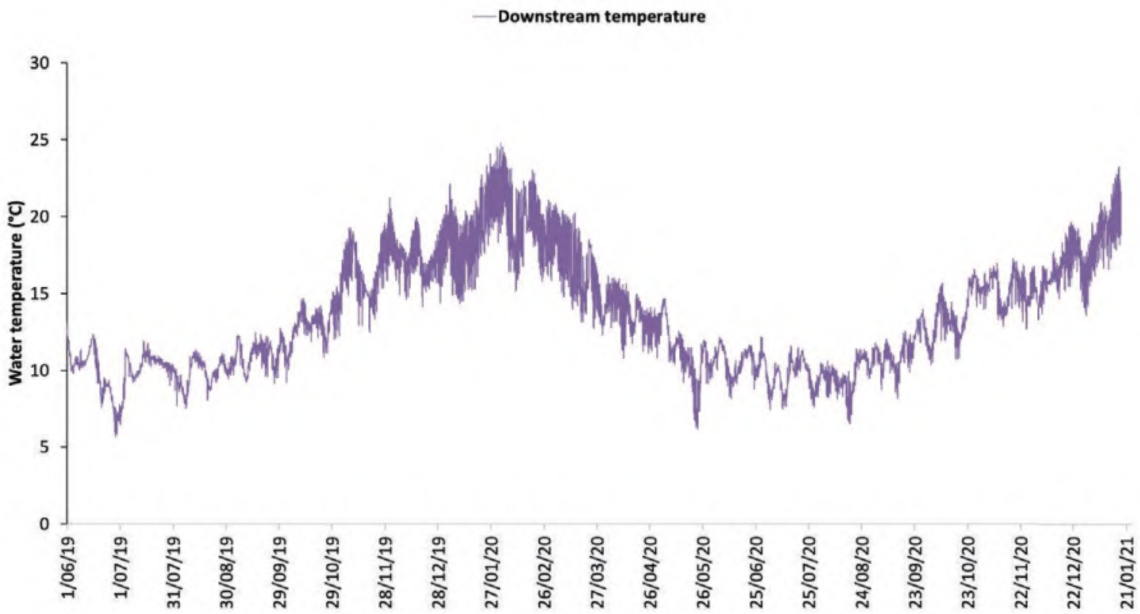


Figure 3.9. *Water temperatures at the Makara Stream Downstream site (15-minute logger measurements), 1 June 2019 – 17 January 2021.*

Table 3.9. *Maximum water temperatures at the Makara Stream Downstream site from 23 May 2019 to 2 February 2021.*

Site	Number of days in data record	Maximum hourly temperature (°C)	Maximum daily average temperature (°C)
Makara Downstream	624	24.8 (1/02/2020 15:00)	22.3 (4/02/2020)

Water temperatures, together with the Motukawa HEPS generation flow, over the January to February 2020 period are shown in Figure 3.10. The pattern of water temperature variation (outside of the typical diurnal variation) closely aligns with variation in the Motukawa HEPS generation flow, with temperature in Makara Stream increasing with generation flow. Comparing field measurements of water temperature at the Makara Upstream and Makara Downstream sites, made on the same day and within 20 minutes of each other, indicates that when generation is occurring water temperature increases between the Upstream and Downstream site can exceed 3 °C (e.g. no generation 13 February 2020 temperature difference 1.4 °C, generation 12 March 2020 temperature difference 4.1 °C (Figure 3.11).

The water temperature in the Waitara River upstream of the Makara Stream/Motukawa HEPS discharge at the same time was slightly higher than that of the generation discharge (i.e., 12 March 2020, during generation: Makara Stream downstream of generation discharge 12:35 pm 18.9 °C, Waitara River downstream 12:05 pm 18.9 °C, Waitara River upstream 12:30 pm 19.4 °C). This indicates that there is no increase in water temperature in the Waitara River as a result of the Makara Stream/Motukawa HEPS discharge.

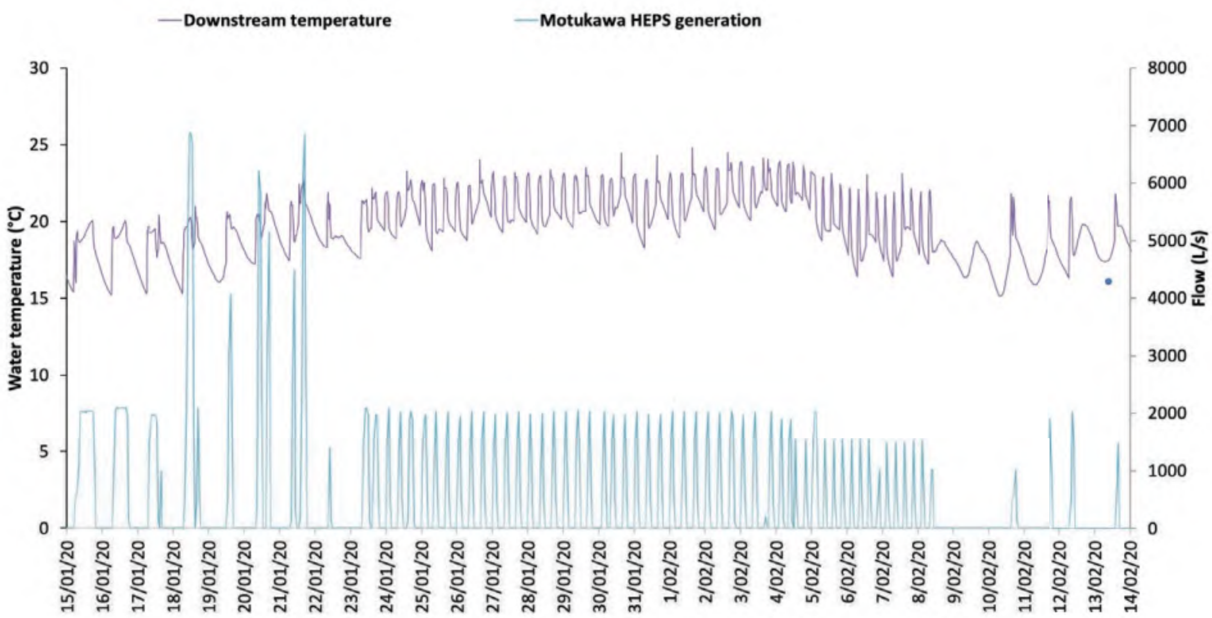


Figure 3.10. *Water temperatures at the Makara Stream Downstream site (15-minute logger measurements) and Motukawa HEPS generation flow, 15 January – 14 February 2020.*

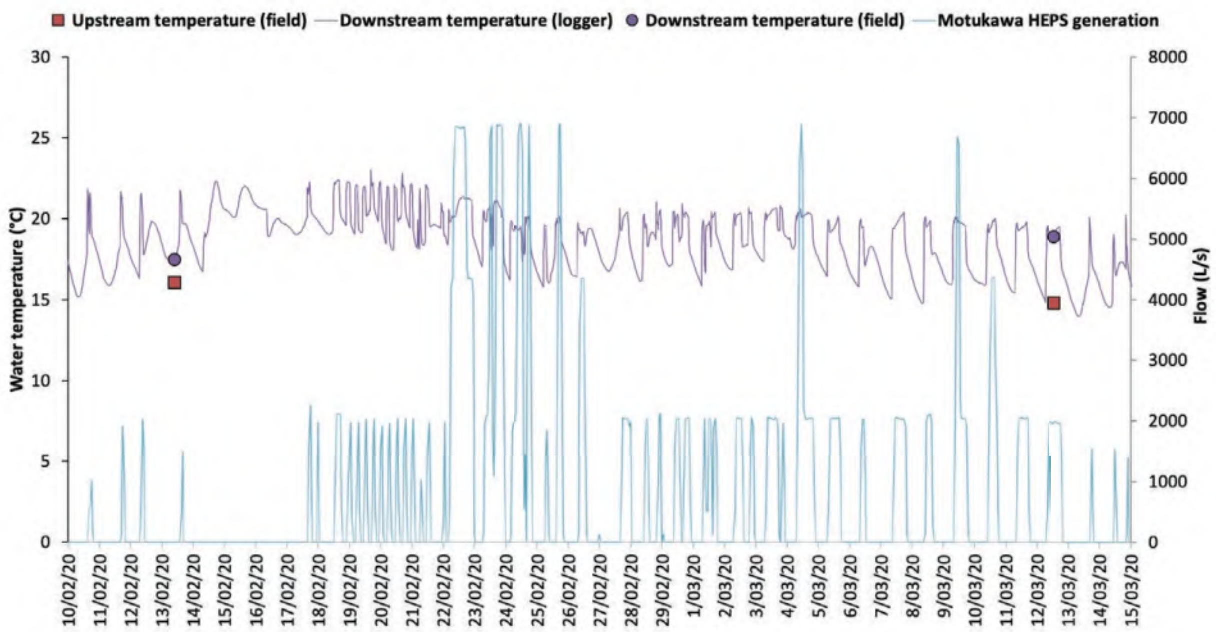


Figure 3.11. *Water temperatures at the Makara Stream Upstream site (field meter measurements) and Downstream site (15-minute logger measurements and field meter measurements) and Motukawa HEPS generation flow, 10 February – 15 March 2020. There was no generation occurring at the time of filed measurements on the 13 February 2020, and generation was occurring at the time of field measurements on the 12 March 2020.*

3.3. Water quality – dissolved oxygen

Summary

Low oxygen levels can have negative impacts on aquatic life particularly fish. The NPS-FM 2020 includes nationally set minimum acceptable states for dissolved oxygen in rivers below point sources. Monitoring during 2019-2021 in the Makara Stream downstream of the Motukawa HEPS tailrace discharge found that for all of the monitoring period dissolved oxygen concentration was above the NPS-FM (2020) minimum acceptable state.

Analysis and discussion

If stratification[7] occurs in a hydroelectric reservoir, power generation can result in oxygen-depleted water being discharged to the river downstream. Low oxygen levels can have negative impacts on aquatic life particularly fish.

Dissolved oxygen monitoring has not been undertaken previously in Lake Ratapiko, or in the Makara Stream below the discharge, so, to provide information to determine if oxygen-depleted water is being discharged from the lake via the power station, a dissolved oxygen logger was installed in Makara Stream in May 2019 immediately downstream of the confluence of the Motukawa HEPS tailrace and the Makara Stream (approximately 0.5 km downstream of the power station).

Dissolved oxygen monitoring data (15-minute measurements) for the Downstream site from May 2019 to January 2021 is presented in Figure 3.12. Regular calibration checks of the dissolved oxygen logger were undertaken during the monitoring period using a hand-held field meter to provide a reference comparison (note that this was not possible during March and April 2020 due to Covid-19 related travel restrictions). The percentage variation between logger and field meter measurements on the 30 calibration occasions ranged from 1.3 to 9.5% for dissolved oxygen concentration (i.e. variation range of 0.16 to 1.17 mg/L concentration) and 2.3 to 10.2% for dissolved oxygen saturation (i.e. variation range of 0.13 to 11.81% saturation). No edits were made to the data to account for these differences as the variation was considered to be within acceptable bounds for the purpose of the analysis.

The NPS-FM (2020) includes nationally set minimum acceptable states for dissolved oxygen in rivers below point sources (which applies to the Motukawa HEPS tailrace discharge). There are two national numeric attribute states for dissolved oxygen, a 7-day mean minimum of 5.0 mg/L and a 1-day mean minimum of 4.0 mg/L. Both apply only over the summer period (defined as 1 November to 30 April).

The pattern of dissolved oxygen variation typically closely aligns with variation in the Motukawa HEPS generation flow, with dissolved oxygen in the Makara Stream decreasing with generation flow (Figure 3.13). For all of the 19-month monitoring period, dissolved oxygen concentration at the Downstream site was however above the NPS-FM acceptable state of a 7-day mean minimum of 5.0 mg/L and a 1-day mean minimum of 4.0 mg/L (Figure 3.12).

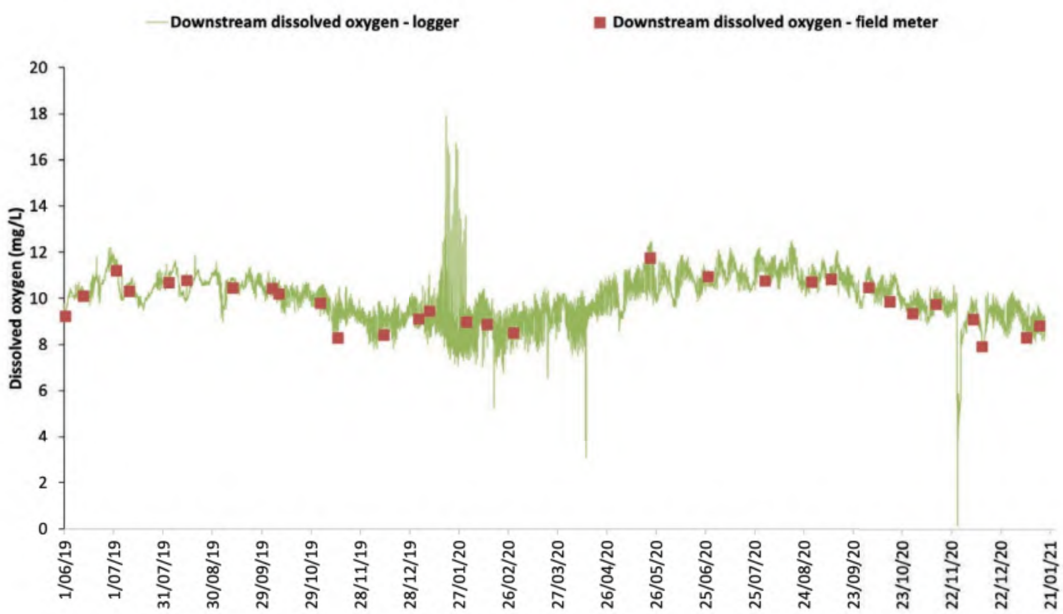
There was an approximately 10-hour period (7:15 – 17:00 hours) on the 13 April 2020 (Figure 3.13), when generation was not occurring, and dissolved oxygen concentrations fell below 4.0 mg/L.

[7] Stratification occurs in some reservoirs and lakes where the temperature profile of the lake stratifies vertically, resulting in an upper layer of warmer water and a deeper layer of cooler water, and limited mixing between the layers. The differences in temperature limits the two layers of water mixing to the extent that oxygen in the deeper water cannot be replenished from the upper layer. Stratification eventually 'breaks down' and when this occurs[7] the oxygen depleted bottom layer of water mixes with the more oxygen rich surface layer, causing oxygen levels in surface waters to decline.

However the 1-day mean minimum was 6.7 mg/L and over the period 7 to 13 April a 7-day mean minimum of 7.1 mg/L was observed (i.e. above the NPS-FM minimum acceptable state).

On 25 November 2020 (Figure 3.14) while generation was occurring, dissolved oxygen concentrations fell below 4.0 mg/L for approximately 7 hours (14:30 – 21:30 hours). The 1-day mean minimum of 6.8 mg/L and the 7-day mean minimum of 6.2 mg/L (25 November to 1 December) were however both above the NPS-FM (2020) minimum acceptable state.

The dissolved oxygen concentration in the Waitara River upstream of the Makara Stream/Motukawa HEPS discharge was similar to that of the generation discharge (e.g. 12 December 2019, during generation: Makara Stream upstream 11.20 am 9.9 mg/L, Makara Stream downstream of generation discharge 11:40 am 8.7 mg/L, Waitara River downstream 11:00 am 9.3 mg/L, Waitara River upstream 12:35 pm 9.0 mg/L). There is no dissolved oxygen monitoring data available for the Waitara River for the two short periods (discussed above) when dissolved oxygen concentrations fell below 4.0 mg/L downstream of the discharge. However, based on the data that is available there is no indication that dissolved oxygen levels in the Waitara River would decrease markedly as a result of the Makara Stream/Motukawa HEPS discharge.



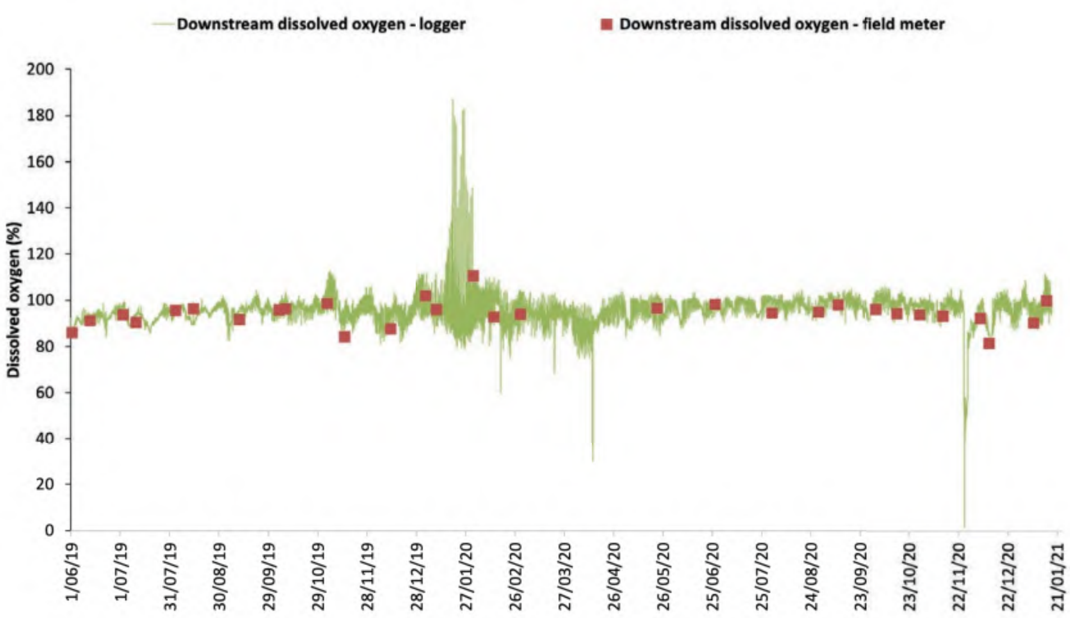


Figure 3.12. *Dissolved oxygen levels at the Makara Stream Downstream site (15-minute logger and field meter spot measurements), 1 June 2019 – 17 January 2021.*

Top: Dissolved oxygen concentration (mg/L). Bottom: Dissolved oxygen saturation (%).

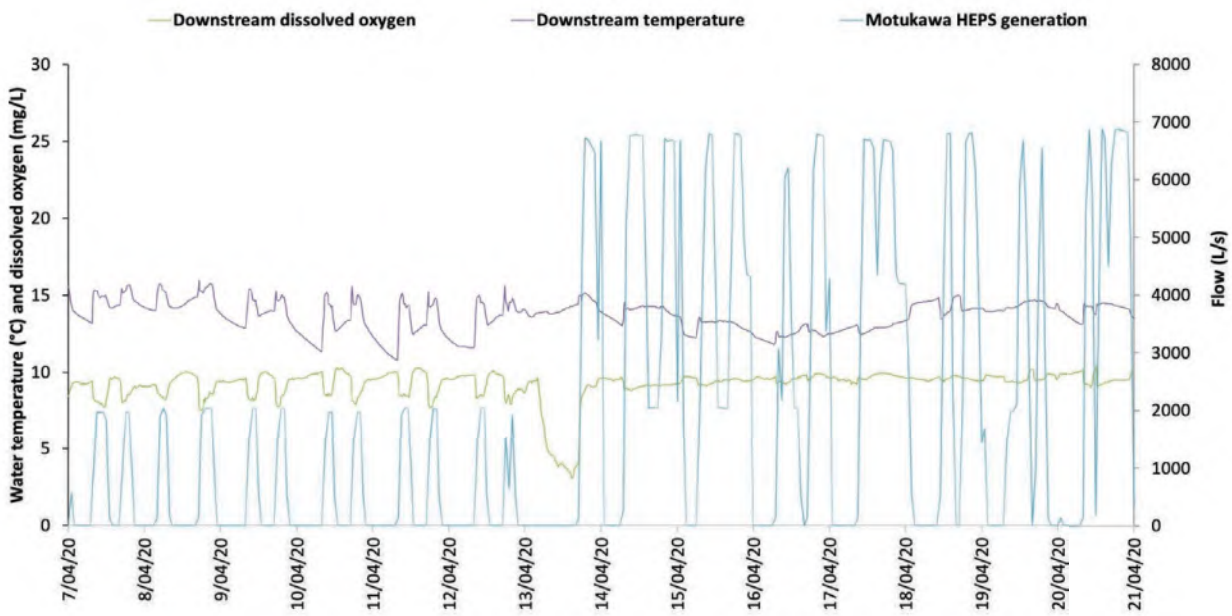


Figure 3.13. *Dissolved oxygen concentrations and water temperature at the Makara Stream Downstream site (15-minute logger measurements), 7 – 20 April 2020. Generation flow (L/s) data for the Motukawa HEPS over the same period is also shown.*

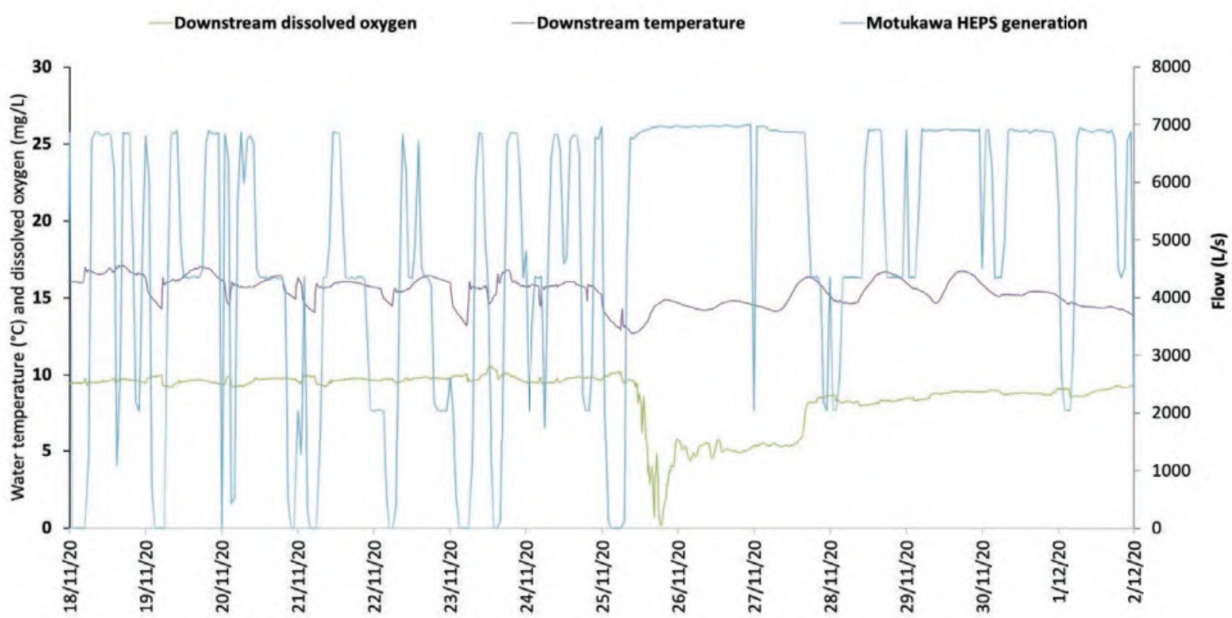


Figure 3.14. *Dissolved oxygen concentrations and water temperature at the Makara Stream Downstream site (15-minute logger measurements), 18 November – 1 December 2020. Generation flow (L/s) data for the Motukawa HEPS over the same period is also shown (flow data provided by Tonkin and Taylor).*

3.4. Periphyton

Summary

Periphyton is essential for the functioning of healthy ecosystems, but when it proliferates it can become a nuisance by degrading instream values. Long-term monitoring of periphyton cover and biomass in the Manganui River at SH3 and Bristol Road indicates that long filamentous nuisance algae proliferations occur at times at the Bristol Road site. Key factors controlling periphyton growth include sunlight, nutrient concentration, temperature, grazing by invertebrates and flow history (i.e. the history of bed disturbance). Monitoring over the 2019-2021 period found that periphyton biomass at the Downstream 2.3 km site exceeded the guideline for benthic biodiversity of 50 mg/m^2 on only one occasion, in January 2020 (83 mg/m^2). This was despite the combination of stable flows and summer water temperatures over the January-February 2020 period providing ideal conditions for periphyton growth.

Analysis and discussion

<u>Manganui River</u>

TRC monitors the periphyton (algae)[8] community at two sites in the Manganui River; SH3 (approximately 13 km upstream of the intake weir) and at Bristol Road (approximately 15 km downstream of the intake weir[9]). The SH3 site is well shaded by riparian vegetation, and this, in conjunction with low nutrient levels, limits periphyton growth (TRC 2021). In contrast, the Bristol Road site has a much wider bed and is not shaded. The Manganui River runs through a substantial amount of agricultural area, and the combination of high sun exposure, water temperature and nutrient levels has caused significant nuisance algae (periphyton) growth at the Bristol Road site in the past (TRC 2021).

Periphyton <u>cover</u> has been monitored at both sites twice annually since 2002 (except at times when high flows have prevented monitoring); in spring (15 September to 31 December) and summer (1 January to 15 April). The percentage cover of thick mats and long filaments is determined and compared to New Zealand Periphyton Guidelines for recreation (Biggs 2000). The guidelines are exceeded when at least 30% of the bed is covered by filamentous algae and/or at least 60% of the bed is covered by thick mats of algae. Thick mat cover has never exceeded guideline levels at either site, however long filamentous algae cover has exceeded the guidelines at the Bristol Road site. At the Bristol Road site long filamentous algae cover exceeded the guideline on five (15%) monitoring occasions over the 18 years of monitoring (2002 to 2020), including most recently in spring 2018 and summer 2019 (TRC 2021). Although there have been varying levels of both thick mat and long filamentous algae cover at the Bristol Road site during the monitoring period, long-term trend analysis found no change through time in the percentage cover of thick mats or the cover of long filaments (TRC 2021).

[8] The TRC freshwater nuisance periphyton programme has been designed to monitor the coverage and biomass of algae in Taranaki streams and rivers which may affect the instream values of these streams.
[9] Note that TRC long-term periphyton monitoring sites were not specifically chosen to assess the effects of the Motukawa HEPS, so the sites are not close to the intake.

Periphyton biomass (chlorophyll-*a*) has been monitored at the SH3 and Bristol Road sites since 2011. Biomass monitoring was initially only undertaken during summer, but in June 2017 the frequency of monitoring at the SH3 site increased to monthly monitoring. Annual summer monitoring has continued at the Bristol Road site.

The New Zealand Periphyton Guideline for the protection of benthic biodiversity is 50 mg/m^2 chlorophyll *a* (Biggs 2000). There is also a requirement through the NPS-FM to ensure streams and rivers are above the D band (chlorophyll *a* 200 mg/m^2 no more than 8% of the time) from 2025 onwards (NPS-FM 2020). TRC's long-established annual chlorophyll *a* sampling protocol however differs from that for the National Objectives Framework (NOF), which requires monthly monitoring, and therefore results cannot yet be directly translated to NOF bands[10].

Periphyton biomass data for the SH3 and Bristol Road sites from March 2011 to February 2020 is presented in Figure 3.15. The full period of data is presented, however TRC (2021) has advised there was a change in chlorophyll *a* methodology between 2015 and 2016 and therefore data prior to 2016 (i.e. 2011 – 2015) should not be included in any analysis. Looking at data from 2016 onwards only, at the SH3 site the guideline for benthic biodiversity (50 mg/m^2) has never been exceeded. The required three years of monthly monitoring data have not yet been collected for the SH3 site, however monitoring to date also indicates that this site would meet the NOF band D requirements, as the maximum concentration of 200 mg/m^2 was never exceeded (Figure 3.15).

At the Bristol Road site the guideline for benthic biodiversity (50 mg/m^2) has been exceeded twice on 50% of monitoring occasions since 2016 (2 out of 4 monitoring occasions).

Overall, the long-term monitoring of periphyton cover and biomass in the Manganui River indicates that long filamentous nuisance algae proliferations occur at times at the Bristol Road site but not at the SH3 site.

[10] The minimum record length for grading a site based on periphyton biomass (chl-*a*) is three years of monthly monitoring (NPS-FM 2020). Monthly monitoring began at the SH3 site in June 2017, however in some months monitoring has not been undertaken. Up until February 2020 there have been 29 measurements made, rather than the expected 36 for three years of monthly monitoring.

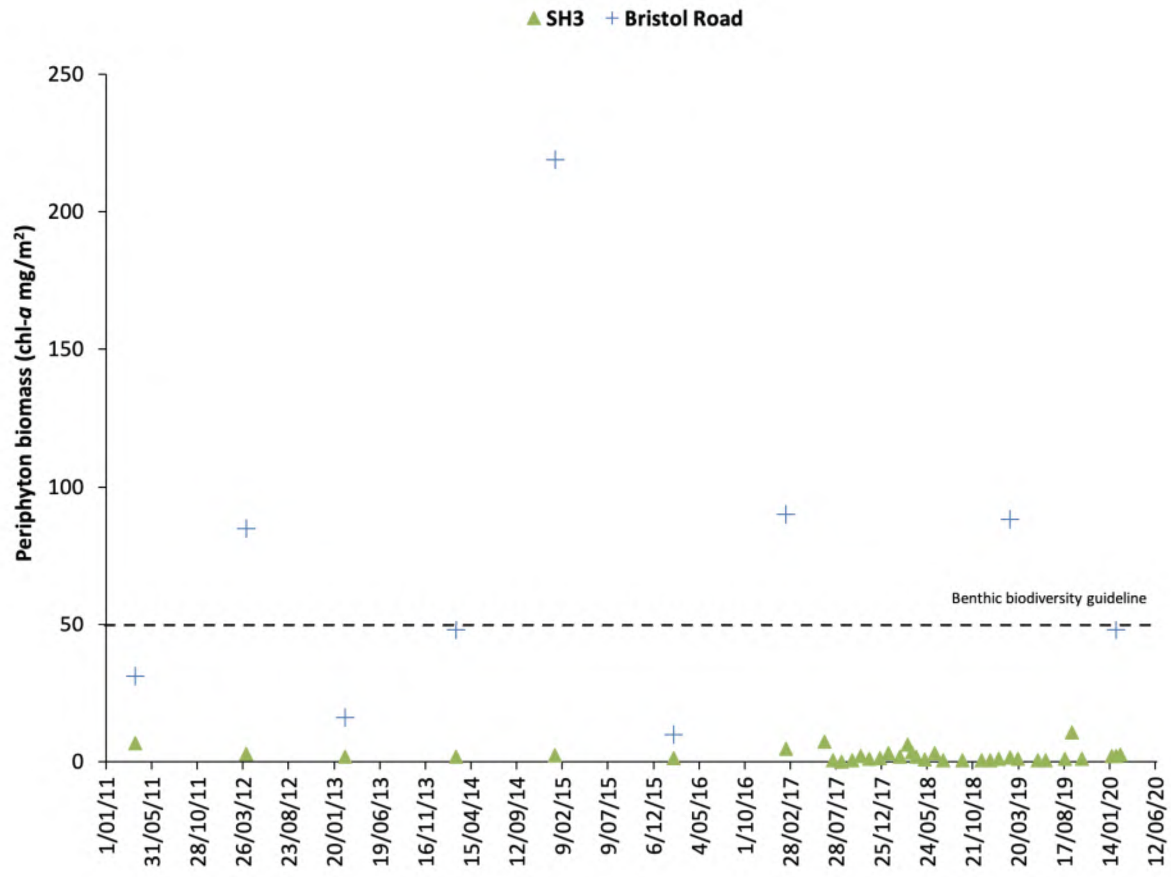
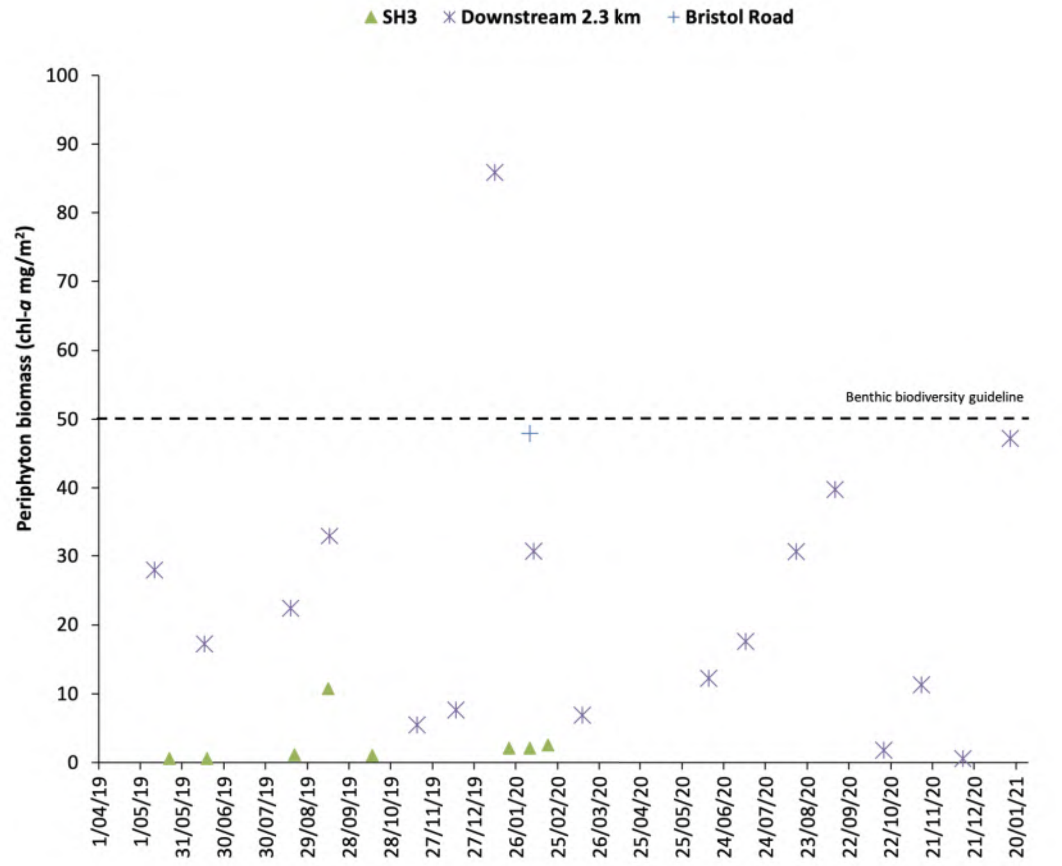


Figure 3.15. *Periphyton biomass (chl-*a *mg/m^2) at Manganui River sites, March 2011 – February 2020. The dashed line shows the New Zealand Periphyton Guideline for the protection of benthic biodiversity, 50 mg/m^2* chlorophyll a *(Biggs 2000).*

The two long-term TRC periphyton monitoring sites (SH3 and Bristol Road) are not located close to the Manganui River HEPS (i.e., they are at least 13 km away from the intake). TRC does not monitor periphyton as part of its annual compliance monitoring at the Motukawa HEPS. To provide information for this assessment periphyton monitoring was therefore undertaken at the Downstream 2.3 km site. Monthly periphyton biomass monitoring was undertaken from May 2019 to January 2021. Monthly monitoring data for the Downstream 2.3 km site from May 2019 to January 2021 is presented in Figure 3.16, along with available data for the TRC SH3 and Bristol Road sites over the same period.

Over the May 2019 to January 2021 period the guideline for benthic biodiversity of 50 mg/m^2 was exceeded on only one occasion at the Downstream 2.3 km site (1 out of 17 monitoring occasions). In January 2020 biomass at the Downstream 2.3 km site was 86 mg/m^2 and biomass at the SH3 site (10 days later) was 2 mg/m^2 (Figure 3.16). Biomass was not measured at the Bristol Road site in January 2020, however in February 2020 biomass at the Bristol Road site was higher than that at the Downstream 2.3 km site (although still within guideline levels). Flows were relatively stable in the river during summer 2020, with the maximum hourly flow from 24 December 2019 – 21 February 2020 being 1,822 L/s (Figure 3.16). The combination of stable flows and summer water temperatures over this period would have provided ideal conditions for periphyton growth, however at both the Downstream 2.3 km and Bristol Road sites in early February 2020 periphyton biomass was below the benthic biodiversity guideline.



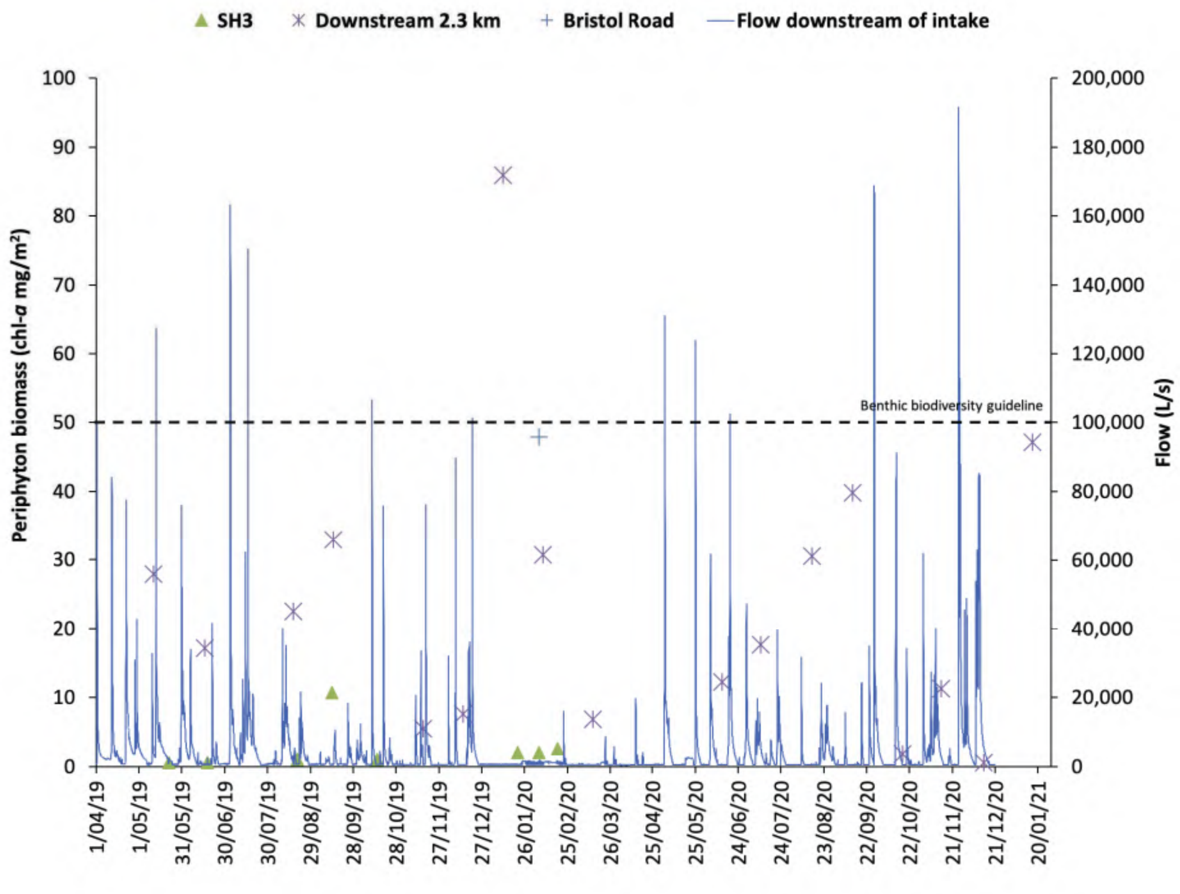


Figure 3.16. *Periphyton biomass (chl-*a *mg/m²) at Manganui River sites, April 2019 – January 2021. The dashed line shows the New Zealand Periphyton Guideline for the protection of benthic biodiversity, 50 mg/m²* chlorophyll a *(Biggs 2000).*

Top: Without flow data. Bottom: Including hourly flow (m³/s) downstream of the intake (flow data provided by Tonkin and Taylor).

3.5. Macroinvertebrates

Summary

Benthic macroinvertebrates are a range of aquatic taxa (e.g. insects, crustaceans, molluscs, worms and leeches) that have a crucial role in freshwater ecology and respond to changes in water quality, hydrological patterns and/or habitat. Warm summer water temperatures, increased periphyton cover, and low flows (combined with lifecycle patterns) can result in less 'sensitive' macroinvertebrate taxa being present and/or increases in the abundance of lower scoring 'tolerant' taxa. Manganui River macroinvertebrate communities at six sites were examined to determine if communities downstream of the Motukawa HEPS intake weir differed from those upstream. Overall, macroinvertebrate community metrics in the Manganui River were indicative of the highest quality habitat at the SH3 site ('excellent') and lowest at the Bristol Road site ('fair-poor'). Differences between these two sites (which are 28 km apart) are expected as land-use intensity increases downstream in the catchment. Median macroinvertebrate metrics (MCI and SQMCI scores) at all four of the Motukawa HEPS compliance monitoring sites were similar ('good'), with no major differences apparent between the sites upstream and downstream of the intake weir.

Analysis and discussion

TRC monitors the benthic macroinvertebrate community at six sites in the Manganui River (listed upstream to downstream):

- SH3: Upstream of the railway bridge, site code MGN000195 (approximately 13 km upstream of the intake weir).
- Upstream 0.4 km: site code MGN000300 (approximately 0.4 km upstream of the intake weir).
- Downstream 0.3 km: site code MGN000320 (approximately 0.3 km downstream of the intake weir).
- Downstream 1.7 km: site code MGN000320 (approximately 1.7 km downstream of the intake weir).
- Downstream 2.3 km: site code MGN000375 (approximately 2.3 km downstream of the intake weir).
- Bristol Road: site code MGN000427 (approximately 15 km downstream of the intake weir).

The SH3 and Bristol Road sites are currently monitored twice each year (spring; 15 September to 31 December and summer; 1 January to 15 April[11]), and the four remaining sites are monitored once annually in summer as part of compliance monitoring for the Motukawa HEPS. Monitoring was also undertaken at the four compliance sites by Trustpower in spring 2019 and 2020 to provide additional data for comparison to the SH3 and Bristol Road sites. Available monitoring data at each

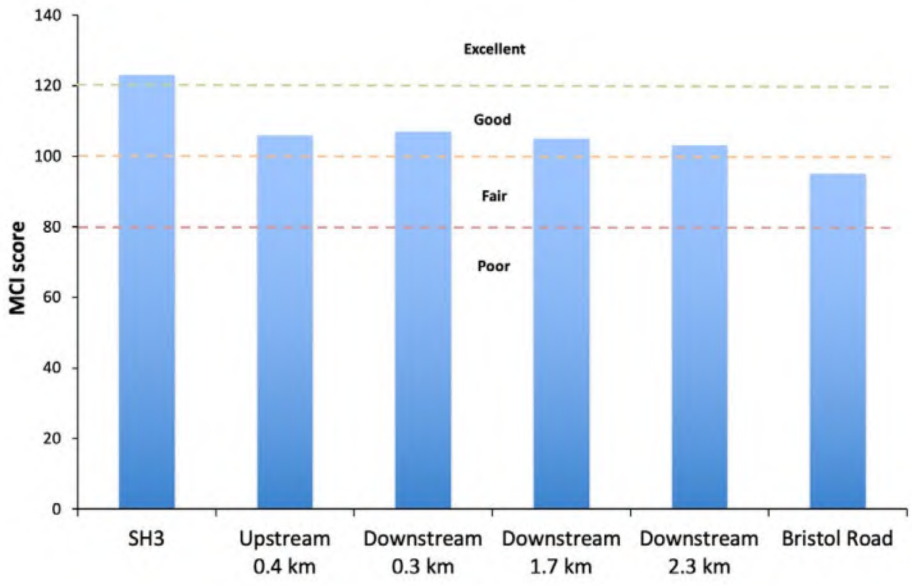
[11] Note that although both the benthic macroinvertebrate and periphyton monitoring take place in spring and summer they are typically not undertaken on the same day-

site for a range of macroinvertebrate community indices (see Appendix One for a description of each) from February 2010 to December 2020 is presented in Appendix Three.

Median macroinvertebrate metrics for each of the six sites over the February 2015 to February 2020 monitoring period are presented in Table 3.10. There were seven matching monitoring occasions at each site over this five-year period (summer 2015, summer 2016, summer 2017, summer 2018, summer and spring 2019, and summer 2020). With the exception of the number of taxa, the median values of all macroinvertebrate metrics were highest at the Manganui River SH3 site, with the MCI and SQMCI scores indicative of 'excellent' habitat (Table 3.10, Figure 3.17). In contrast, at the furthest downstream site macroinvertebrate metrics were lowest. MCI and SQMCI scores at Bristol Road were indicative of 'fair' and 'poor' habitat, respectively, and LAWA 10-year trend analysis indicated degrading health (Table 3.10, Figure 3.17). Differences between the SH3 and Bristol Road sites (which are 28 km apart) are expected as land-use intensity increases downstream in the catchment. Macroinvertebrate metrics at all four of the compliance monitoring sites (which are within 2.7 km of each other) were similar, with no major differences apparent between the sites upstream and downstream of the intake weir. MCI and SQMCI scores at all sites were indicative of 'good' habitat (Table 3.10, Figure 3.17). Although median values at the Upstream site varied little from those at the three downstream sites, variability at the downstream sites was higher (i.e., the range of values was wider).

Table 3.10. *Median (with range in brackets) macroinvertebrate metrics for Manganui River sites, February 2015 – February 2020 (seven matching monitoring occasions at each site). Data provided by TRC. 10-year trend analysis for MCI scores sourced from the Land Air Water Aotearoa (LAWA) website.*

Site	Number of taxa	Percent EPT taxa	MCI score	MCI score condition	SQMCI score	SQMCI score condition	LAWA 10-year MCI trend (2011-2020)
SH3	20 (13 – 25)	63 (43 – 70)	123 (106 – 140)	excellent	7.3 (6.8 – 7.6)	excellent	Indeterminate
Upstream 0.4 km	23 (21 – 25)	45 (42 – 52)	106 (100 – 122)	good	5.4 (4.9 – 6.9)	good	-
Downstream 0.3 km	22 (19 – 26)	48 (32 – 62)	107 (97 – 121)	good	5.5 (2.9 – 7.4)	good	-
Downstream 1.7 km	21 (17 – 32)	44 (25 – 65)	105 (89 – 124)	good	5.6 (3.9 – 7.2)	good	-
Downstream 2.3 km	22 (16 – 25)	47 (32 – 56)	103 (85 – 109)	good	5.7 (3.2 – 7.7)	good	-
Bristol Road	20 (15 – 22)	43 (35 – 53)	95 (86 – 107)	fair	3.8 (3.1 – 4.5)	poor	Very likely degrading



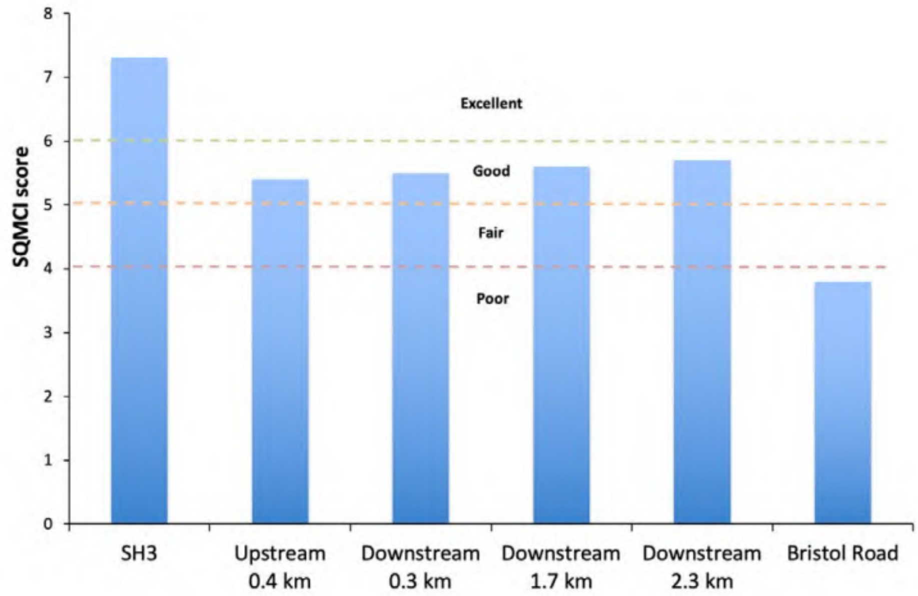


Figure 3.17. *Median macroinvertebrate metrics for Manganui River sites, February 2015 – February 2020 (five years, seven monitoring occasions). Data provided by TRC. Top: MCI score. Bottom: SQMCI score.*

In addition to the benthic macroinvertebrate taxa recorded during Manganui River monitoring, three invertebrate taxa have been recorded from the Waitara River catchment within the New Zealand Freshwater Fish Database (NZFFD) (Table 3.11). Koura and freshwater mussels have threat classifications of 'at risk – declining' and freshwater shrimp are 'not threatened' (Grainger *et al.* 2018). Koura and freshwater shrimp have been recorded from multiple locations throughout the catchment (Figure 3.18). There are only nine records for freshwater mussels, one of these is from the Motukawa HEPS fish pass. Freshwater shrimp and koura have also been recorded from the fish pass. Although not recorded within the NZFFD, freshwater mussels have also been found in Lake Ratapiko, in April 2016 during TRC compliance monitoring when the lake was very low, with large areas of lake bed exposed. An extensive search of the lake bed was undertaken and two live mussels were found and returned to the water (TRC 2016).

Table 3.11. *Number of occurrences of invertebrate species in the Waitara River catchment (including the Manganui River) from the New Zealand Freshwater Fish Database (NZFFD). The number refers to the number of records that report the occurrence of the species and reflects the sampling effort rather than the number of individuals found.*

Common name	Species	Number of NZFFD occurrences	Migratory	Threat classification (Grainger *et al.* 2018)
Koura	*Paranephrops*	199	No	At risk (declining)
Freshwater shrimp	*Paratya curvirostris*	41	No	Not threatened
Freshwater mussels	*Echyridella menziesii*	9	No	At risk (declining)

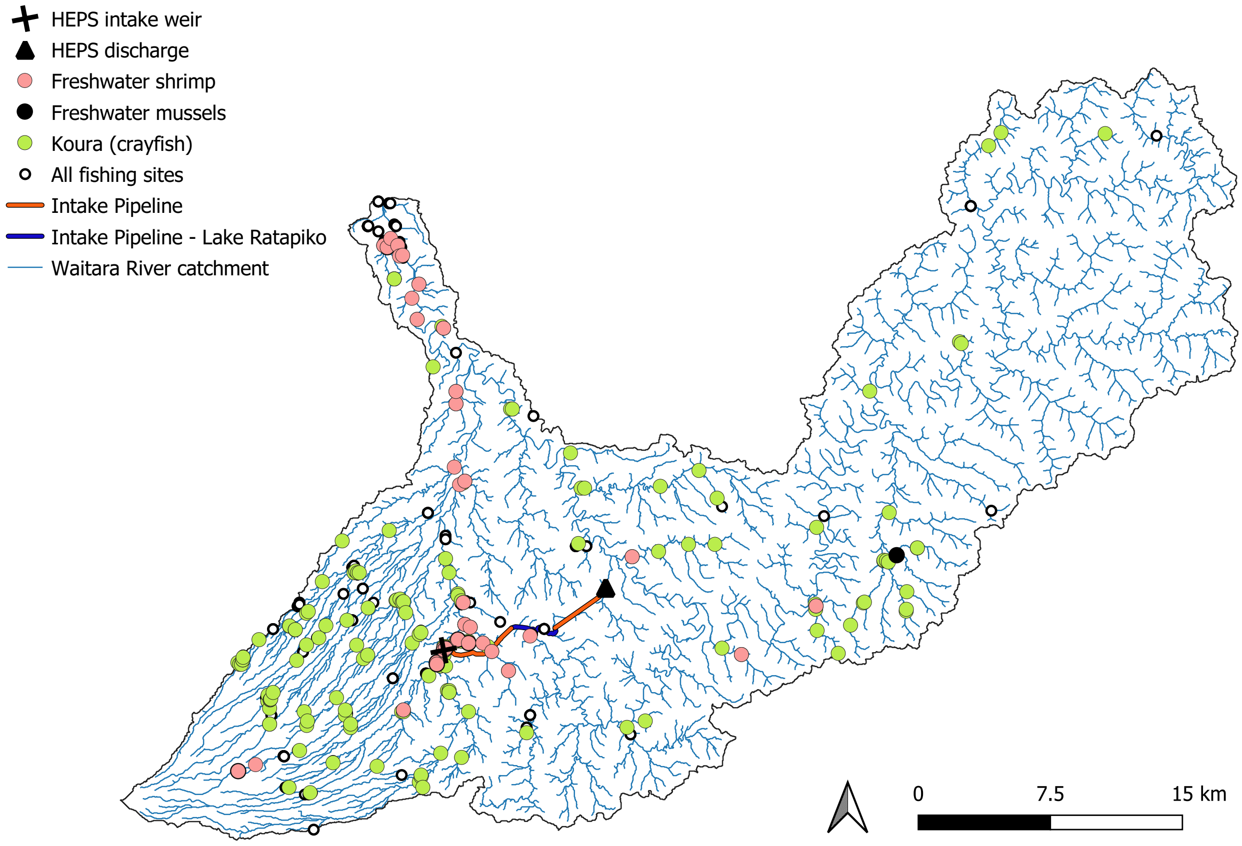


Figure 3.18. *NZFFD records for invertebrate species in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

3.6. Fish

Summary

Twenty species of freshwater fish have been identified in the Waitara River catchment. Fifteen of the fish species are native and have threat classifications ranging from 'not threatened' to 'threatened – nationally vulnerable' (shortjaw kokopu and lamprey). The greatest numbers of records are for longfin eels, followed by Cran's bullies, brown trout, redfin bullies and shortfin eels. Recent fish community surveys have confirmed that longfin and shortfin eels, common/Cran's and redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout are all present upstream of the Manganui River intake weir. All of these species, with the exception of Cran's bullies, have migratory life cycles. Lamprey have been recorded in the intake weir fish pass, and the presence of juvenile lamprey within the Motukawa HEPS settling pond in March 2021 indicates that adult lamprey have successfully spawned upstream of the weir. Torrentfish have been recorded in the river at the bottom of the fish pass, but have never been recorded upstream of the weir. A trap and downstream transfer system is operated for eels near the penstock intake in Lake Ratapiko, and a trap and upstream transfer system is operated for elvers at the Motukawa HEPS tailrace.

Analysis and discussion

The New Zealand Freshwater Fish Database (NZFFD) was used to investigate existing information on fish communities throughout the Waitara River catchment (Table 3.12). There are NZFFD records for 20 species of freshwater fish in the catchment, 15 of which are native (Table 3.12). Maps showing the distribution of each species are presented in Appendix Four (Figures A4.1 to A4.10). The native fish species have threat classifications (Dunn *et al.* 2018) ranging from 'not threatened' (e.g., banded kokopu) to 'threatened – nationally vulnerable' (e.g., shortjaw kokopu, lamprey). There are five 'introduced and naturalised' species; brown trout, gambusia, perch, goldfish and rudd. Trout are periodically released by Fish and Game Taranaki to the Motukawa HEPS settling pond and Lake Ratapiko. The greatest numbers of NZFFD records are for longfin eels, followed by Cran's bullies, brown trout, redfin bullies and shortfin eels (Table 3.12). The remaining species have been recorded 33 or fewer times.

Although not recorded within the NZFFD, juvenile lamprey (piharau, *Geotria australis*) have also been captured in the Motukawa HEPS fish pass, in June 2018 during TRC compliance monitoring (TRC 2019a). This was the first formally documented record of lamprey in the Manganui River, although they have previously been recorded in other tributaries of the Waitara River (Appendix Four, Figure A4.7). In March 2021 two juvenile lamprey were also recovered from the Motukawa HEPS settling pond during sediment excavation works. The most likely explanation for juvenile lamprey being present in the settling pond is from being passively drawn into the diversion whilst naturally moving down the Manganui River (NIWA 2021). NIWA (Cindy Baker) was engaged to further investigate lamprey distribution throughout the Motukawa HEPS and in the Manganui River. NIWA deployed juvenile lamprey pheromone detectors (Polar Organic Chemical Integrative Samplers, POCIS) at 12 sites across the Manganui River, Motukawa HEPS and Makara Stream for approximately four weeks. None of the samples deployed returned levels of pheromone above detection limits. The conclusion from the sampling was that lamprey abundances are too low to be detected using this method and/or could be absent from some of the areas sampled (NIWA 2021).

Fish recovery was also undertaken from the Motukawa HEPS race in April 2021, in association with sediment removal works. A total of 101 shortfin eels (approximate length 130 – 700 mm) and one koura were recovered from excavated sediment. All fish were released in the Manganui River downstream of the intake weir.

Table 3.12. *Number of occurrences of 20 fish species in the Waitara River catchment (including the Manganui River) from the New Zealand Freshwater Fish Database (NZFFD). The number refers to the number of records that report the occurrence of the species and reflects the sampling effort rather than the number of individuals found.*

Common name	Species	Number of NZFFD occurrences	Migratory	Threat classification (Dunn *et al.* 2018)
Longfin eel	*Anguilla dieffenbachii*	209	Yes	At risk (declining)
Cran's bully	*Gobiomorphus basalis*	95	No	Not threatened
Brown trout	*Salmo trutta*	89	Yes	Introduced and naturalised
Redfin bully	*Gobiomorphus huttoni*	65	Yes	Not threatened
Shortfin eel	*Anguilla australis*	37	Yes	Not threatened
Common bully	*Gobiomorphus cotidianus*	33	Yes	Not threatened
Shortjaw kokopu	*Galaxias postvectis*	31	Yes	Nationally vulnerable
Inanga	*Galaxias maculatus*	24	Yes	At risk (declining)
Torrentfish	*Cheimarrichthys fosteri*	17	Yes	At risk (declining)
Gambusia	*Gambusia affinis*	13	No	Introduced and naturalised
Perch	*Perca fluviatilis*	10	No	Introduced and naturalised
Upland bully	*Gobiomorphus breviceps*	10	No	Not threatened
Giant kokopu	*Galaxias argenteus*	10	Yes	At risk (declining)
Banded kokopu	*Galaxias fasciatus*	9	Yes	Not threatened
Koaro	*Galaxias brevipinnis*	7	No	At risk (declining)
Lamprey	*Geotria australis*	6	Yes	Nationally vulnerable
Goldfish	*Carassius auratus*	2	No	Introduced and naturalised
Giant bully	*Gobiomorphus gobioides*	2	Yes	Naturally uncommon
Bluegill bully	*Gobiomorphus hubbsi*	1	Yes	At risk (declining)
Rudd	*Scardinius erythrophthalmus*	1	No	Introduced and naturalised

To inform the preparation of this assessment of effects report Ryder Environmental carried out additional fish surveys at 17 sites in the Manganui and Waitara River catchments in February 2020 and February 2021. Sites were selected to provide information on fish distribution in relation to structures associated with the Motukawa HEPS, such as the Manganui River intake weir and the Power Station. A combination of survey methods was used depending on the type of habitat present (Appendix Four, Table A4.1). Survey methods included single-pass electric fishing (using a Kainga electric fishing machine), overnight sets of Gee-minnow traps (baited with Marmite), spotlighting, and collection of environmental DNA (eDNA[12]) samples (processed at the Wilderlab laboratory in Wellington). Fish survey results are shown in Table 3.13. Longfin eels were the most widely distributed species, being found at 10 of the 17 sites surveyed (Table 3.13). Cran's/common bullies, brown trout and redfin bullies were also widespread.

Table 3.14 provides a summary of the distribution of fish in the Manganui and Waitara River catchments in relation to the Motukawa HEPS (combined information from recent surveys and the NZFFD). At least eight fish species have been recorded upstream of the intake weir; longfin and shortfin eels, common/Cran's and redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout. All of these species, with the exception of Cran's bullies, have migratory life cycles. Torrentfish have

[12] Trace elements of DNA left by the species living in the catchment.

been recorded in the river at the bottom of the fish pass, and lamprey in the pass itself, but both species have never been recorded upstream of the weir. Although not recorded upstream of the weir it is likely that lamprey are present in the catchment upstream. The presence of juvenile lamprey within the Motukawa HEPS settling pond in March 2021 indicates that adult lamprey had successfully spawned upstream.

A trap and downstream transfer system is operated for eels near the penstock intake in Lake Ratapiko, with the total number of eels transferred each year ranging between 1 to 53 eels over the period 2012 to 2020 (Table 3.15). A trap and upstream transfer system is also operated for elvers at the Motukawa HEPS tailrace (Figure 3.19). The total weight of elvers transferred each season has ranged from 8.35 to 69.5 kg (equivalent to approximately 8,000 to 94,000 individuals) over the period 2002-2003 to 2019-2020.

Table 3.13. *February 2020 and February 2021 fish survey results for the Manganui and Waitara River catchments. Length range (mm) is shown in brackets, note some are estimated. '✓' indicates presence identified by eDNA sampling.*

Site	Reference	Common or Cran's bully	Redfin bully	Torrentfish	Giant or shortjaw kokopu	Inanga	Koaro	Longfin eel	Shortfin eel	Unidentified eel	Brown trout	Unidentified bully
Te Popo Stream: at Pembroke Road	E1698863 N5647950						3	1			5	
Te Popo Stream: at SH3	E1708965 N5650543	✓			✓			✓ (150-210)		1 (105)	✓1 (150)	✓
Unnamed true right tributary of Manganui River: at Kaiapoi Road	E1711145 N5652240											
Manganui River: at Croydon Road	E1710432 N5655993	✓7 (41-46)	1 (45)					✓1 (130-315)		7 (85-100)	✓1 (121)	✓
Manganui River: 400 m upstream of HEPS intake	E1710005 N5657893	✓	✓1 (66)					✓	✓		✓	
Manganui River: weir fish pass	E1710132 N5658363	7 (33-51)	3 (40-45)							1 (96)		
Manganui River: 750 m downstream of HEPS intake	E1710352 N5658447							1 (150)		1 (400)		4 (30-40)
Manganui River: 3 km downstream of HEPS intake	E1711008 N5658793	✓						✓	✓		✓	✓
Manganui River: at Bristol Road	E1711125 N5667840		✓					✓				✓
Mako Stream: upstream of Lake Ratapiko	E1716418 N5659863	6 (40-48)								1		
Mako Stream: downstream of Lake Ratapiko spillway	E1715158 N5659159											
Mako Stream: at Mana Road	E1715808 N5658756	4 (40-60)								2 (600-800)		
Mako Stream: at Makara Road	E1716449 N5656644							4 (122-137)		4 (97-500)	1 (observed)	

Site	Reference	Common or Cran's bully	Redfin bully	Torrentfish	Giant or shortjaw kokopu	Inanga	Koaro	Longfin eel	Shortfin eel	Unidentified eel	Brown trout	Unidentified bully
Makara Stream: upstream of tailrace confluence	E1719272 N5660957	✓						✓				✓
Unnamed true left tributary of Makara Stream: upstream of tailrace confluence	E1719319 N5661857							✓	✓			✓
Motukawa HEPS tailrace	E1719365 N5661913									numerous		
Motukawa HEPS tailrace fish trap	E1719365 N5661913		1							numerous		

Table 3.14. *Distribution of fish in the Manganui and Waitara River catchments in relation to Motukawa HEPS structures (combined data from all sources).*

Site	Common or Cran's bully	Redfin bully	Torrentfish	Shortjaw kokopu	Inanga	Koaro	Longfin eel	Shortfin eel	Unidentified eel	Brown trout	Unidentified bully	Perch	Lamprey
Upstream of Manganui River intake weir	✓	✓		✓	✓	✓	✓	✓		✓	✓		
Manganui River weir fish pass	✓	✓		✓	✓		✓	✓	✓				✓
Downstream of Manganui River intake weir	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		
Race, Lake Ratapiko and tributaries	✓						✓	✓	✓	✓		✓	✓*
Motukawa HEPS tailrace									✓				
Motukawa HEPS tailrace fish trap		✓							✓				

*Settling pond record.

Table 3.15. *Number of eels trapped and transferred at the Motukawa HEPS penstock intake in Lake Ratapiko.*

Year	Number of longfin eels	Number of shortfin eels	Number of unidentified eels	Total number of eels
2012			9	9
2013			27	27
2014			4	4
2015			1	1
2016			4	4
2017	20	4		24
2018	7	2		9
2019	26	27		53
2020	18			18

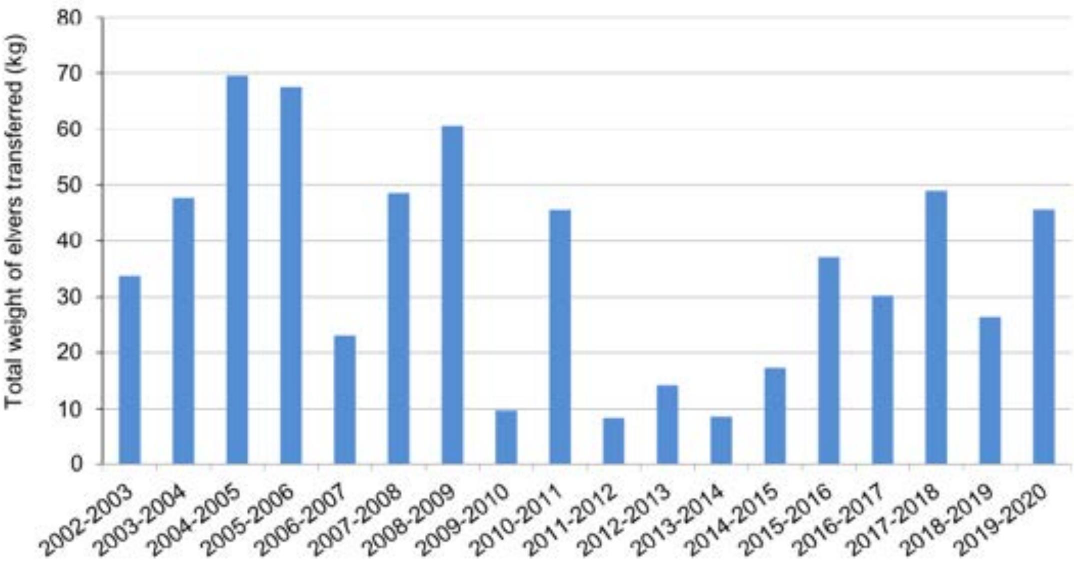


Figure 3.19. *Elver transfer data for the monitoring years to date (from TRC 2020b).*

Currently, a minimum flow of 400 L/s must be maintained in the Manganui River at all times below the Motukawa HEPS intake weir. Prior to 2002 the minimum flow requirement was 100 L/s, but was increased to 400 L/s following a reconsenting process in 1997. The higher minimum flow was considered to better provide for fish habitat and for improved fish passage at the weir.

The 400 L/s requirement was based on an assessment by NIWA of four river cross-sections in a 250 m reach downstream of the intake weir (Jowett 1992). The cross-sections were selected within a reach where channel conditions were considered critical for fish purposes. It was concluded that 300-400 L/s would provide a sufficient flow, not be a barrier to the passage of trout or any native species, and also provide an attractant flow.

In 1988 an instream habitat model was developed for the Manganui River at Croydon Road (approximately 4 km upstream of the intake weir) to determine the extent of brown trout habitat (Jowett 1993). Subsequent to this, in 2004, an instream habitat model was also developed for the Manganui River downstream of the Mangaotea Stream confluence (approximately 4 km downstream of the intake weir) to determine the extent of habitat for a range of fish species (Kingett Mitchell 2005). Given that the intake weir is located between these two locations, combining the two instream models was considered to provide the best representation of habitat downstream of the intake weir. Also, since the Jowett (1993) and Kingett Mitchell (2005) instream habitat analyses were completed, knowledge of the habitat preferences of fish species (particularly native fish species) has increased. The two instream models were therefore obtained, combined, and re-run (using updated habitat suitability curves) within the computer program SEFA[13] (Jowett 2015), for the purposes of assessing the amount of potential habitat for brown trout and native species downstream of the intake weir. Details of the modelling are provided in Appendix Five.

Predictions of the amount of available habitat (measured as 'area weighted suitability') for different fish species (and life history stages) and their food resources (i.e. benthic invertebrate density and food producing habitat) with varying flow are presented in Figures 3.20 to 3.22. The amount of habitat available for a species depends on its habitat requirements, for some species the amount of habitat increases as flows increase (e.g. adult brown trout and torrentfish) and for other species it decreases (e.g. inanga feeding and redfin bully). To determine the effect of the Motukawa HEPS on instream habitat, the amount of habitat for each species at the residual flow of 400 L/s was compared to that at natural minimum flows (i.e. the MALF upstream of the intake weir, 1,180 L/s) and the percentage change in habitat calculated (Table 3.16).

[13] SEFA: System for Environmental Flow Analysis.

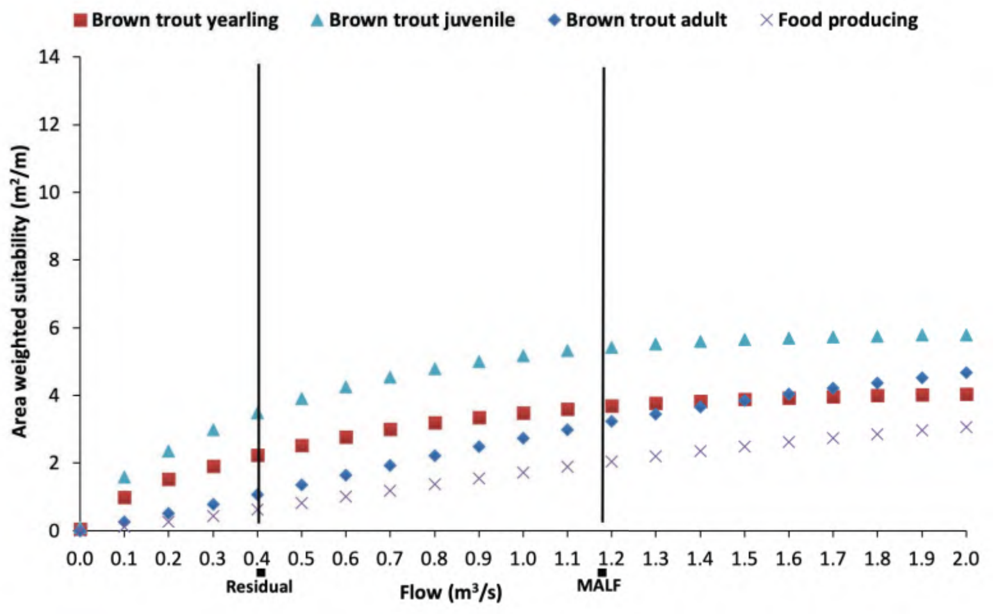


Figure 3.20. *Variation of average weighted suitability (AWS m^2/m) with flow for brown trout and food producing habitat in the Manganui River upstream and downstream of the Motukawa HEPS (combined Jowett (1993) and Kingett Mitchell (2005) models).*

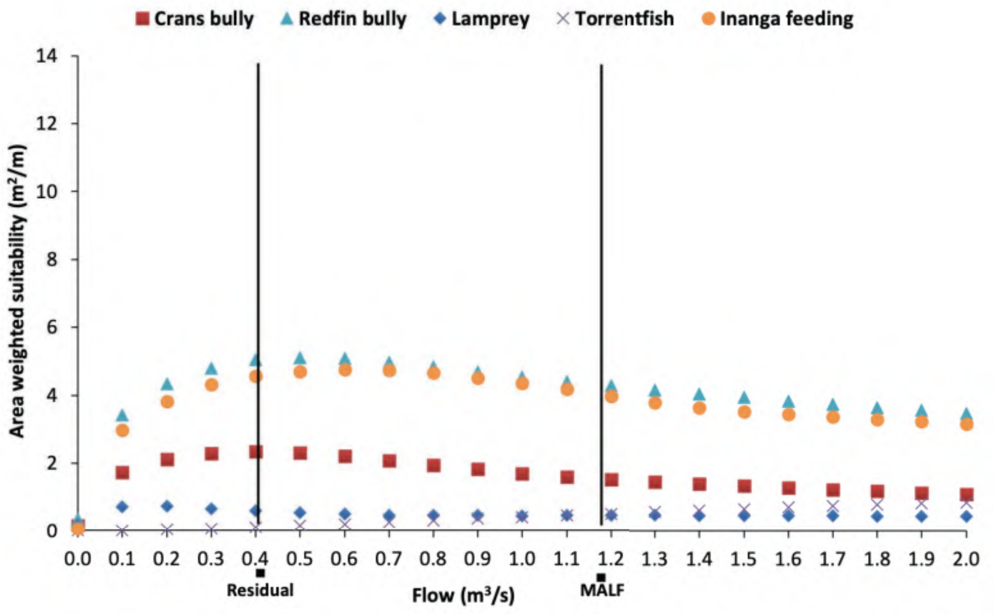


Figure 3.21. *Variation of average weighted suitability (AWS m^2/m) with flow for native fish habitat in the Manganui River upstream and downstream of the Motukawa HEPS (combined Jowett (1993) and Kingett Mitchell (2005) models).*

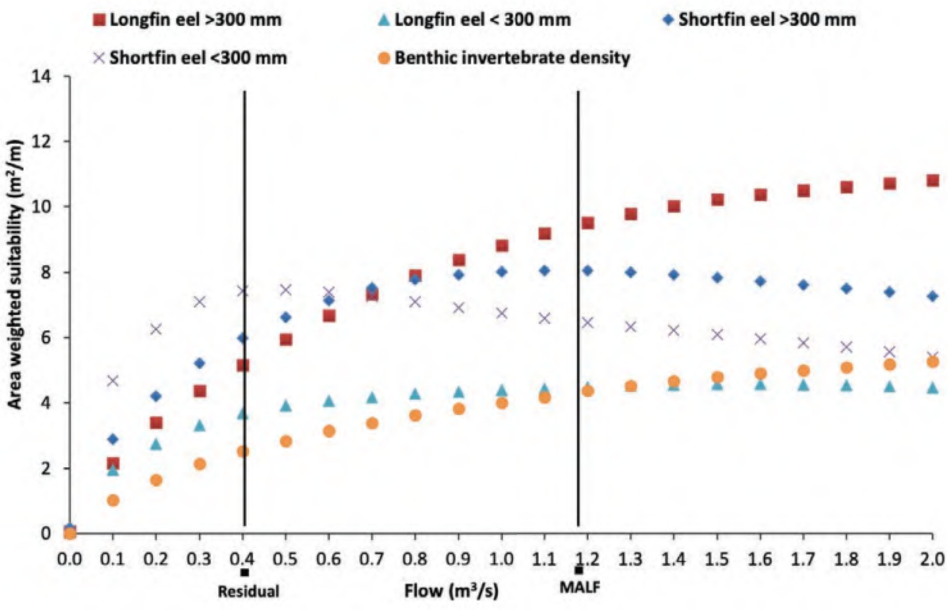


Figure 3.22. *Variation of average weighted suitability (AWS m^2/m) with flow for eels and benthic invertebrate habitat in the Manganui River upstream and downstream of the Motukawa HEPS (combined Jowett (1993) and Kingett Mitchell (2005) models).*

For most native fish species there is an increase in the amount of available habitat under the Motukawa HEPS flow regime relative to natural low flow conditions (i.e. the MALF upstream of the intake). This includes: Cran's bully, inanga feeding, lamprey, shortjaw kokopu, redfin bully and small shortfin eels (<300 mm), which are predicted to have increases in habitat ranging from 15 to 54% (Table 3.16).

There is a moderate decline in habitat for large shortfin eels (>300 mm) and small longfin eels (<300 mm), ranging from 18 to 26%. The largest declines are for torrentfish (79%), as they prefer high water velocities. For brown trout and food resources there are declines in habitat ranging from 36 to 70% (Table 3.16). Predictions of habitat loss represent somewhat of a worst-case scenario. Flows increase downstream in the river as tributaries enter, and for approximately 33% of the time downstream flows are greater than those expected under natural low flow conditions (Tonkin and Taylor 2021).

Fish community surveys undertaken downstream of the weir by TRC in June 2018 confirmed that Cran's and redfin bullies, longfin and shortfin eels, and torrentfish are all present within 1.7 km downstream of the weir (TRC 2019). Lamprey, longfin and shortfin eels, redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout have all been identified in the intake weir fish pass and/or upstream of the weir.

Overall, the existing environment, which has included the scheme operation, supports a diverse native fish community and passage is provided for brown trout and migratory native fish to the weir fish pass. Artificial freshes required by Condition 5[14] also likely contribute to encouraging upstream migration for some native fish species. The Condition 5 requirement for artificial freshes applies year round, but they are typically only necessary during the summer (December to February) period (e.g. March 2013, February 2014, December 2017, see Section 3.2), as this is when periods of stable low flows are most likely to occur. Several of the native fish species present downstream of the intake weir migrate upstream during the summer period (longfin eels, shortfin eels and redfin bullies, NIWA 2014) and increased flows at this time are expected to provide beneficial upstream migration cues.

[14] The requirement that 400 L/s must be passed over the weir (for three hours daily) if the weir is not naturally overtopped by flows of 400 L/s or higher for a continuous period of 30 days.

Table 3.16. *Comparison of the amount of available habitat (average weighted suitability, m^2/m) for a range of key aquatic species in the Manganui River, for the residual flow range of 400 L/s and at the MALF (1,180 L/s). Increases in available habitat compared to that at the MALF are shaded in green and decreases are shaded in yellow. Predicted using the combined Jowett (1993) and Kingett Mitchell (2005) models.*

Common name	**Life history stage**	**Average weighted suitability (m^2/m)**		**Percentage change in available habitat at flow of 400 L/s compared to MALF**
	Flow (L/s)	**400**	**1,180**	
Benthic invertebrate density		2.5	4.4	-42
Food producing habitat		0.6	2.0	-70
Brown trout	Adult (> 400 mm)	1.1	3.2	-67
	Juvenile (100-170 mm)	3.5	5.4	-36
	Yearling (< 100 mm)	2.2	3.7	-40
Cran's bully		2.4	1.5	54
Redfin bully		5.0	4.3	18
Inanga	Feeding	4.6	4.0	15
Lamprey		0.6	0.5	30
Longfin eel	< 300 mm	3.7	4.5	-18
	> 300 mm	5.2	9.5	-46
Shortfin eel	< 300 mm	7.4	6.5	15
	> 300 mm	6.0	8.0	-26
Shortjaw kokopu		2.3	1.8	26
Torrentfish		0.1	0.5	-79

3.7. Lake Ratapiko

Summary

Lake Ratapiko is an artificial storage lake formed in the 1920’s to provide power generation. In addition to this primary function the lake is commonly used for boating and fishing. Summer recreational bathing surveys indicate lake water quality is suitable for this purpose. Two freshwater mussels were located in the Lake in 2016, and it provides habitat for three native and two introduced fish species. Fish and Game has previously released trout to the lake to compensate for a natural lack of trout spawning habitat. A pass for the upstream migration of elvers is present at the lake spillway to the Mako Stream, and a downstream trap and transfer system for migratory eels is operated at the Motukawa HEPS penstock intake at the lake.

Analysis and discussion

Lake Ratapiko is an artificial storage lake resulting from the damming of the Mako Stream in 1927. The lake is relatively shallow (average depth approximately 2.5 m), and depth varies within the lake. Water is shallowest within the western arm where the race enters, and deepest near the penstock intake. Land use within the catchment immediately around the lake is dominated by agriculture, primarily dairy farming.

The majority of the inflow (approximately 88%) to the lake is from the Manganui River intake via the race, with the balance (approximately 12%) coming from small tributaries of the remnant Mako Stream catchment (Tonkin and Taylor 2021). Approximately 98% of the outflow from the lake passes through the Motukawa HEPS to the Makara Stream and the Waitara River. At times of high lake level water also flows over the lake spillway into the Mako Stream (a tributary of the Waitara River).

Trustpower is required to maintain a minimum lake level of 194 m above mean sea level (asl), except during periods of maintenance of aquatic habitat (i.e. aquatic weed control) when the lake level can be temporarily lowered. Weed control is primarily undertaken for the purposes of allowing recreational boating and water skiing activities. Lake lowering also allows maintenance to be undertaken within the race upstream of the lake (lowering the water level in the lake being necessary to lower the water level in the race). This is typically carried out at the end of summer in April each year. The maximum lake level is 198.7 m asl. Lake levels generally fluctuate within a 2 m operating range 80% of the time (between 196.5 and 198.5 m asl). The lowest lake levels typically occur in spring (mean 197 m asl) and the highest in summer (mean 198.3 m asl) (Tonkin and Taylor 2021).

Lake Ratapiko is commonly used for boating and fishing, particularly at weekends and holidays. TRC therefore undertakes recreational bathing surveys for faecal bacteria and cyanobacteria in the lake over the summer. TRC monitoring at the boat ramp over the last three summers (2018 - 2021) found that 100% of samples met the freshwater microbiological water quality guidelines (MfE 2003) and did not exceed the 'Action' level (>550 *E. coli* cfu/100mls). Cyanobacteria is typically not found in the lake, and cyanobacteria monitoring by TRC over the last two summers found none. However in the 2018 – 2019 season there was one occurrence of picocyanobacteria in February 2019, which resulted in a short-term alert (for two weeks). The relatively short lake water residence time may be a factor in the control of these bacteria populations (TRC 2019b).

To provide additional information on water quality in the lake, monthly monitoring was also undertaken in the lake from November 2020. Over the six-month period November 2020 to April 2021 nutrient levels were well within relevant NOF bottom lines for lakes (i.e. total nitrogen, total phosphorus and ammonia (toxicity)), noting however that a full year of data is not yet available (NPS-FM 2020).

Freshwater mussels (at risk – declining) and shrimp have been recorded in the lake, and fish species present in the lake and its tributaries include three native species; common/Cran's bullies (not threatened), longfin eels (at risk – declining) and shortfin eels (not threatened), and two introduced species; brown trout and perch. Common/Cran's bullies are non-migratory so do not need to leave the lake to reproduce. Longfin and shortfin eels are however migratory and their long-term presence within the lake is reliant upon individuals continuing to enter from the Manganui River via the race or by the elver pass at the lake spillway. Fish and Game Taranaki has also released rainbow trout to the lake in the past (most recently 300 to 400 rainbow trout in 2018). These trout releases, in addition to trout entering via the race, are undertaken to maintain the trout population in the lake, as the lake does not have a lot of natural spawning habitat (Allen Stancliff to Rob Greenaway, pers. comm.). It is understood that commercial eeling also occurs within the lake (TRC 2020).

A pass for the upstream movement of elvers is present at the lake spillway to Mako Stream, and a downstream trap and transfer system for migratory eels is operated at the Motukawa HEPS penstock intake at the lake.

The lowering of the Lake Ratapiko lake level for maintenance purposes results in temporary habitat loss for the aquatic species within the lake, particularly at the upstream (western) end of the lake where there are large areas of bed exposed (Figures 3.23 and 3.24). Lowering the lake level exposes aquatic weed, causing it to dry out and die (weed is visible on the edges of the channel in Figure 3.23). In recent years, herbicide has also been trialled to control weed. In places the width of exposed lake bed is 100 m (Figure 3.24). A central wetted channel (with a flow of at least 150 L/s) is however maintained, and in the downstream (eastern) end of the lake there is less exposure of the bed (Figure 3.23 and 3.24).

As the lake is lowered some fish will be able to detect the receding water level and respond by moving to remain within water. However, less mobile individuals such as small fish (e.g., bullies) and freshwater mussels may become stranded on the dry lake bed (as observed in April 2016, refer to Section 3.5), or trapped in isolated pools. In order to minimise the risk of stranding, existing consent conditions require that lake level draw down for maintenance occurs gradually over a 7-day period. TRC and Fish and Game New Zealand are notified at the commencement of the draw down period. Lake lowering in autumn reduces the risk of high temperatures impacting aquatic communities (noting that emergency lowering could still be required during summer). Once maintenance is complete, the Manganui River intake is opened further, to allow increased flow into the water race, and therefore allow the lake level to rise again. Inflowing water from the race will bring with it a source of macroinvertebrates to gradually recolonise the lakebed areas that had previously been exposed, encouraging fish to move back into these areas.

The long-term presence of eels within the lake is reliant upon individuals continuing to enter from the Manganui River via the race or by the elver pass at the lake spillway. However, to complete their lifecycle eels also need to be able to safely leave the lake. Options for improving downstream eel passage from the lake are discussed in Section 4.4. Implementation of these measures will over time reduce the eel population in the lake.

Figure 3.23. *Lake Ratapiko viewed from the northern road culvert, 15 April 2016 (from TRC 2016).*

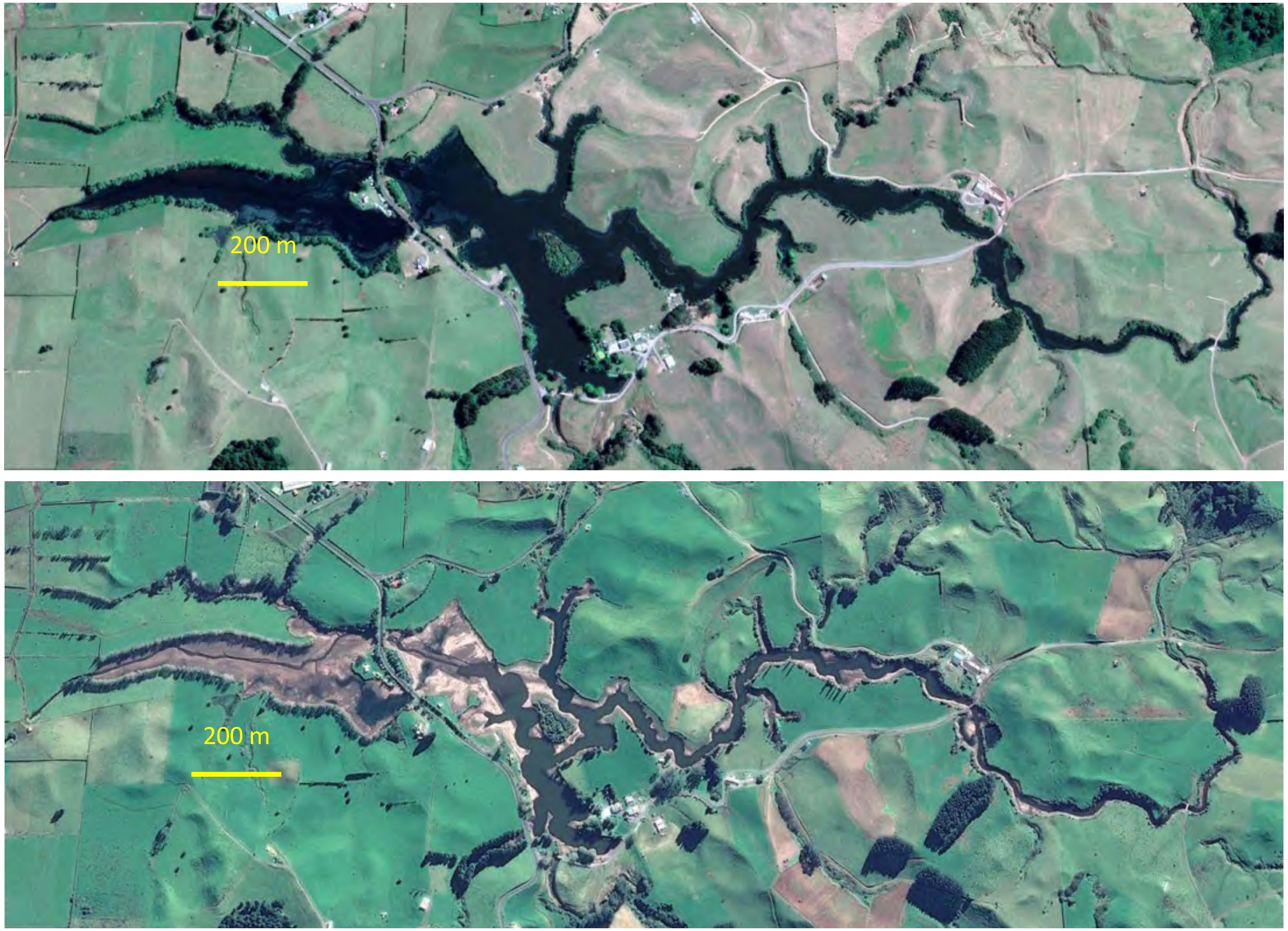


Figure 3.24. *Lake Ratapiko (Google Earth images). Top: Normal lake level, 25 February 2019. Bottom: Lowered lake level, 20 April 2017.*

3.8. Mako Stream

Summary

The upper catchment of the Mako Stream was dammed to form Lake Ratapiko. There is no existing residual flow requirement downstream of the dam, however the Mako Stream channel receives seepage flow from the dam and the spillway overflows when the lake level is high. Short-term monitoring (March 2019 - June 2020) in the Mako Stream immediately downstream of the dam found that maximum water temperatures were below critical temperatures for native fish and brown trout. A pass for the upstream migration of elvers is present at the lake spillway to the Mako Stream, and bullies (common/Cran's), eels and brown trout have all been recorded downstream. The fish community diversity in the Mako Stream is as expected given the long distance from the sea, and there is no indication that it is affected by the presence of the Motukawa HEPS.

Analysis and discussion

The upper catchment of the Mako Stream (approximately 10 km^2) was dammed in 1927 to form Lake Ratapiko. The remnant channels of the Mako Stream and other small tributaries continue to flow into the lake (Figure 3.25), and surveys found common/Cran's bullies and eels in the stream upstream of the lake (Table 3.13). The Mako Stream continues downstream of the Lake Ratapiko dam (Figures 3.26 to 3.28).

There is no existing residual flow requirement downstream of the dam, however the stream channel receives seepage flow from the dam (estimated to average 5 L/s) (Figure 3.26), and the spillway overflows when the lake level is high. Lake level is influenced by the inflow from the Manganui River take, and also from the surrounding catchment, which is estimated to be 413 L/s on average but can be much higher during high rainfall events (Tonkin and Taylor 2021). The average annual spill flow has been estimated at 83 L/s (January 2010 to December 2020), although the majority of this occurred during maintenance works to the scheme in early 2010 (February to May). If this period is excluded then the average annual spill to the Mako Stream is 31 L/s (Tonkin and Taylor 2021). Over the 2010 – 2020 period, spill occurred in only 27 out of 132 months (i.e., 20%). In most years there was no spill during September to May, with spill predominately occurring in the winter months of June to August. When it occurs, mean monthly spill shows a lot of variation, and is typically in the range of 3 to 250 L/s.

Water temperature monitoring data for the Mako Stream downstream of the dam over the period 1 February 2019 – 26 June 2020 is presented in Figure 3.29. There is a data gap between May and August 2019 due to a stolen logger, however as this period is during autumn and winter, water temperatures would have been low. Maximum daily temperatures of 18.7 °C and hourly water temperatures of 20.5°C were recorded in January and February 2020, respectively. Maximum temperatures were below the critical thermal maxima temperatures for native fish species, and the acute (24.6 °C) and chronic (19.6 °C) criteria for brown trout.

Approximately 6 km downstream of Lake Ratapiko, the Mako Stream flows into Makara Stream, which after travelling a further 26 km ultimately flows into the Waitara River (approximately 9 km upstream of where the combined Makara Stream[15]/Motukawa HEPS tailrace flow enters the river and 40 km from the sea). A pass for the upstream migration of elvers is present at the lake spillway to the Mako Stream, and common/Cran's bullies, eels and brown trout have all been recorded in the Mako Stream downstream of Lake Ratapiko (Table 3.13). The fish community diversity in Mako Stream is as expected given the long distance from the sea, which limits the number of migratory fish species that are present, and there is no indication that it is affected by the presence of the Motukawa HEPS.

Figure 3.25. *Mako Stream upstream of Lake Ratapiko, February 2021.*

[15] Note that this is a different Makara Stream from the one which Mako Stream flows into.

Figure 3.26. *Mako Stream immediately downstream of Lake Ratapiko, February 2021.*

Figure 3.27. *Mako Stream approximately 1 km downstream of Lake Ratapiko (at Mana Road Bridge), February 2021.*

Figure 3.28. *Mako Stream approximately 5 km downstream of Lake Ratapiko (at Makara Road Bridge), February 2021.*

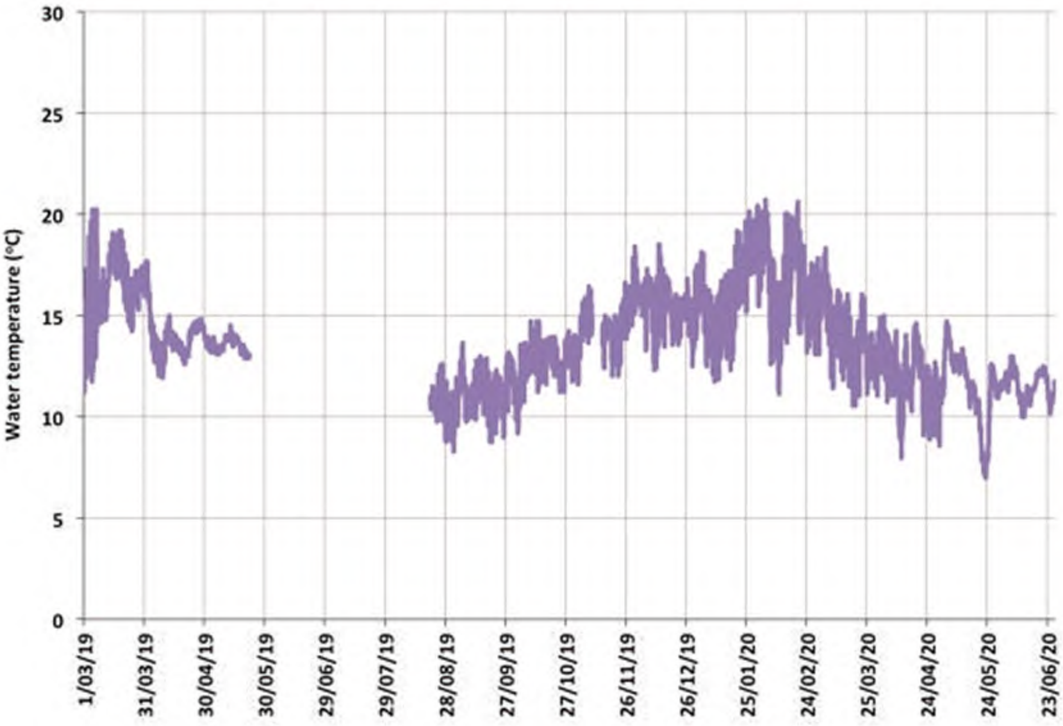


Figure 3.29. *Water temperatures in Mako Stream downstream of the Lake Ratapiko Dam (15-minute logger measurements), 1 March 2019 – 26 June 2020. The data gap between May and August 2019 is due to a stolen logger.*

3.9. Overall summary of existing values

The Motukawa HEPS first generated electricity in 1927. Up to 5,200 L/s of water is drawn into the scheme from a weir intake on the Manganui River. The weir incorporates two fish passes, an older pass on the true left and a new pass on the true right that was constructed in 2002. A flow of 400 L/s is maintained to the river downstream via the two fish passes (prior to 2002 the residual flow was 100 L/s). From the intake a water race flows towards the east, passing via an in-race generator and crossing the Mangaotea Stream. In the past up to 450 L/s of water was pumped from this stream into the water race, however this diversion ceased in March 2018. Approximately 5 km from the Manganui River intake the water race enters Lake Ratapiko, an artificial storage lake resulting from the damming of the Mako Stream in 1927. From the lake the water is piped through penstocks to the Motukawa Power Station then discharged into the Makara Stream and from there travels a further 1.7 km before entering the Waitara River.

During summer, water temperatures in the Manganui River downstream of the intake are generally higher than upstream, and can exceed thermal criteria for brown trout. Temperatures are however typically within the range of thermal preferences for native fish species. Despite the combination at times of stable flows and high water temperatures, nuisance algae growths rarely occur downstream of the intake. Macroinvertebrate communities in the river upstream and downstream of the intake are similar, and are indicative of ‘good’ health. Freshwater mussels, shrimp and koura have been recorded from the new weir fish pass. Fish community surveys have confirmed that longfin and shortfin eels, common/Cran’s and redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout are all present upstream of the Manganui River intake weir. In addition juvenile lamprey have been recorded in the new fish pass and in the settling pond within the race, indicating that adult lamprey have successfully spawned upstream. All of these species, with the exception of Cran’s bullies, have migratory life cycles. Torrentfish have been recorded in the river at the bottom of the fish pass, but have never been recorded upstream of the weir.

Lake Ratapiko is commonly used for boating and fishing, and summer recreational bathing surveys indicate lake water quality is suitable for this purpose. The lake and its tributaries provide habitat for freshwater mussels and shrimp, common/Cran’s bullies, longfin and shortfin eels, brown trout and perch. Fish and Game Taranaki has also released rainbow trout to the lake previously.

There is no existing residual flow requirement in the Mako Stream downstream of the dam, however the channel receives seepage flow from the dam and the spillway overflows when the lake level is high. Water temperatures in Mako Stream immediately downstream of the dam were below critical temperatures for native fish and brown trout. Common/Cran's bullies, eels and brown trout have all been recorded in the stream and the fish community diversity is as expected given the long distance from the sea.

A pass for the upstream migration of elvers is present at the lake spillway to the Mako Stream, and a downstream trap and transfer system for migratory eels is operated at the Motukawa HEPS penstock intake.

When the Power Station is generating nutrient levels (nitrogen and phosphorus) are elevated in the Makara Stream downstream of the Motukawa HEPS tailrace discharge. Elevated nutrient levels are however not apparent further downstream in the Waitara River. Water temperatures in the Makara Stream downstream of the tailrace also increase with generation flow, although they typically remain within the range of thermal preferences for the fish species present (i.e., common/Cran's bullies and eels). Dissolved oxygen monitoring in the Makara Stream downstream of the Motukawa HEPS tailrace discharge found that oxygen concentrations were above guideline levels. A trap and transfer system is operated for upstream migrating fish at the Motukawa HEPS tailrace, and elvers and redfin bullies have been recorded in the trap.

4. Assessment of effects

4.1. Effect of flow reductions in the Manganui River downstream of the Motukawa HEPS take

Trustpower is proposing to divert up to 7,500 L/s from the Manganui River. Approximately 4-7% more of the current inflow to the Motukawa HEPS would be taken. There will be no change to the existing residual flow requirement of 400 L/s downstream of the intake. Trustpower also propose to provide artificial fresh releases between November and March if particular flow conditions are now reached in the Manganui River. Additionally, the requirement will remain that when the flow in the Waitara River (at the Bertrand Road hydrology gauging site downstream of the Manganui River confluence) is less than 5,000 L/s, abstraction of water at the Motukawa HEPS intake weir must cease, or abstracted water must be allowed to pass continuously through the Power Station to the Makara Stream and Waitara River.

Most of the time flows below the intake weir are higher than the consented residual flow of 400 L/s, with median flows of 570 L/s (Table 4.1). Flows continue to increase downstream, with several tributaries entering the river below the intake weir. The first one of significant size being the Mangaotea Stream, which enters the river approximately 4 km downstream of the intake weir. The estimated median flow in the Mangaotea Stream is 170 L/s and the 7-day MALF is 70 L/s[16] (David Leong, Tonkin and Taylor, pers. comm.). Other tributaries such as the Mangamawhete, Waitepuke, Maketawa, and Ngatoro Streams also enter the Manganui River further downstream and by Everett Park (approximately 16 km downstream of the intake weir) the median flow is 10,350 L/s (Table 4.1). Approximately 8 km downstream of Everett Park the Manganui River enters the Waitara River.

[16] Trustpower have an existing consent (RC6381-1) to abstract up to 450 L/s from the Mangaotea Stream, however this has not been exercised since March 2018.

Table 4.1. Manganui River flow statistics (L/s) for locations upstream and downstream of the Motukawa HEPS intake weir, October 2009 – December 2020 (data from Tonkin and Taylor 2021).

Location	Flow statistic (L/s)			
	7-day MALF	Median flow	Mean flow	Mean annual flood
Manganui River at SH3	490	910	1,680	59,000
Manganui River at intake weir	1,180	4,170	6,860	178,000
Manganui River below intake weir	450	570	3,700	174,000
Manganui River at Everett Park	3,680	10,350	19,600	672,000

In February 2021 Ryder Environmental undertook a visual inspection of the Manganui River downstream of the weir when the flow in the river was approximately 470 L/s. The river was walked from a point 3 km downstream of the weir to upstream of the weir. A series of representative photographs of the river in this 3 km long section (from upstream to downstream) is shown in Figures 4.1 to 4.10, the flow downstream of the weir at the time the photographs were taken is also shown. Figures 4.1 and 4.2 are from February 2020 when the flow was 500 L/s, and the remaining photographs are from February 2021 when the flow was 470 L/s.

Figure 4.1. *Manganui River approximately 0.1 km downstream of the Motukawa HEPS intake weir, approximate flow 500 L/s, February 2020.*

Figure 4.2. *Manganui River approximately 0.3 km downstream of the Motukawa HEPS intake weir, approximate flow 500 L/s, February 2020.*

Figure 4.3. *Manganui River approximately 0.5 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.4. *Manganui River approximately 0.7 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.5. *Manganui River approximately 1.2 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.6. *Manganui River approximately 1.7 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.7. *Manganui River approximately 1.9 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.8. *Manganui River approximately 2.0 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.9. *Manganui River approximately 2.3 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

Figure 4.10. *Manganui River approximately 2.5 km downstream of the Motukawa HEPS intake weir, approximate flow 470 L/s, February 2021.*

With the proposed take of 7,500 L/s, flows in the Manganui River downstream of the take will, at times, decrease relative to those with the currently consented take. Flow reductions downstream of the take will be greatest during the wetter months of May to September (Figure 4.11). There will be no change to median flows downstream of the take in summer (December to February), although mean flows in summer will reduce from approximately 2.3 m^3/s to 2 m^3/s (Figure 4.11). Consequently, as a result of the proposed increased take there could be an increase in the frequency of sustained low flow periods in the river downstream of the intake.

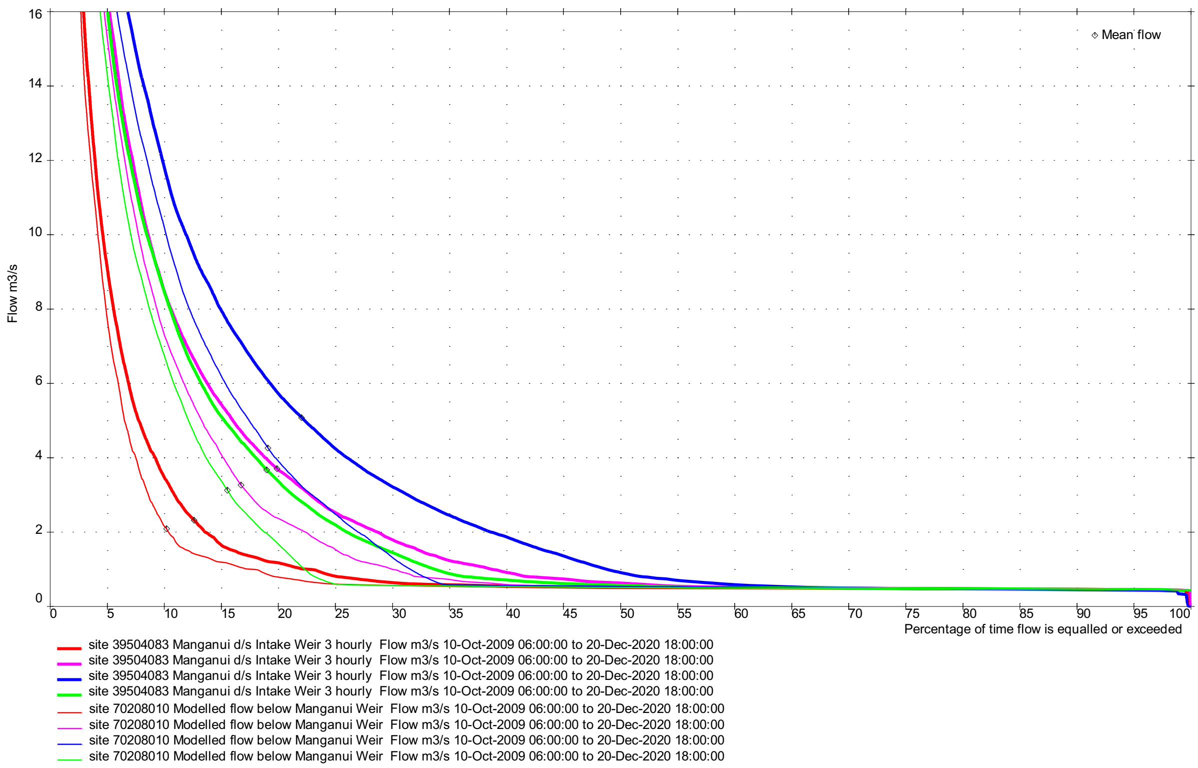


Figure 4.11. *Comparison of seasonal flow duration curves of Manganui River downstream of the intake weir under existing and proposed increased take (from Tonkin and Taylor 2021). Red for summer (D, J, F); magenta for autumn (M, A, M); blue for winter (J, J, A); green for spring (S, O, N). Thick line for historical and thin line for modelled diversion for 7.5 m^3/s race capacity. The diamond marker on each curve indicates the mean flow.*

The minimum residual flow downstream of the intake weir is 400 L/s, however it is consistently higher than this under the existing take with the 7-day MALF being 450 L/s (Table 4.1). Under the proposed take regime, when the maximum of 7,500 L/s is being diverted, the minimum flow downstream of the weir will be 580 L/s (David Leong pers. comm.) Therefore, the frequency of low flow periods, below 580 L/s, will not increase as a result of the proposed increased take. However, at flows above 580

L/s there will be an increase in the number of days each year when flows are towards the lower end of the flow range, relative to existing.

The effect of the proposed residual flow regime on water temperature, nuisance algae growths, macroinvertebrate community health and fish habitat in the Manganui River downstream of the intake are discussed in the following Sections 4.1.1 to 4.1.4.

4.1.1. Effect of abstraction on water temperature

Section 2.2. of Appendix V of the TRC Regional Freshwater Plan (2001) sets out guidelines for surface water quality in the region for the purposes of aquatic ecosystem provision. There are no water quality guidelines that apply to water abstraction, however the temperature guideline for the discharge of contaminants requires that the natural temperature of the water is not to be changed by more than 3 °C as a result of a discharge. The maximum observed increase in mean water temperature downstream of the Motukawa HEPS take on the warmest day over recent summers was only 1.8 °C (Table 3.7), and therefore within the TRC Regional Freshwater Plan (2001) guideline limit for a 3 °C change for discharges.

The proposed abstraction of water from the Manganui River (a maximum of 7,500 L/s) could increase the frequency of sustained low flow periods in the river downstream of the intake. Although there will be no change to the minimum flow of 400 L/s, and the frequency of low flow periods below 580 L/s will not increase, depending on the timing of the diversion, the proposed take regime could potentially result in longer periods of high water temperatures in the river downstream of the take. As discussed in Section 3.2, existing water temperatures downstream of the take during summer are high (Table 3.7) and at times exceed the recommended thermal criteria for brown trout.

The management of water temperatures in the Manganui River downstream of the Motukawa HEPS intake has been considered in accordance with the effects management hierarchy that applies to considering effects on river extent and values in accordance with the NPS-FM (2020). This is documented in the AEE prepared by Mitchell Daysh Limited given the need to consider a broad range of factors in determining what is 'practicable'.

Overall, and in accordance with the effects management hierarchy, it is proposed that a temporary reduction in take be implemented if water temperatures at the Downstream 2.3 km site exceed 25 °C.

The above minimisation measure would be achieved by installing telemetered water temperature loggers (the existing loggers are not telemetered) upstream and downstream of the weir (the exact locations to be determined through consultation with stakeholders) and monitoring to determine if the rolling one hour average temperature exceeds 25°C. It is proposed that a monitoring trial be undertaken during a period of warm water temperatures (e.g. in January/February 2022) to determine the degree of reduction in take necessary to achieve a temperature reduction downstream. If water temperatures upstream of the take also exceed 25 °C then it may not be possible to achieve a temperature reduction below 25 °C downstream.

The implementation of this minimisation measure will ensure that the adverse effects from the proposed increased abstraction of water from the Manganui River on water temperatures downstream, will in the context of its contribution to ecosystem health, be are **no more than minor**.

4.1.2. Effect of abstraction on nuisance algae growths

During summer water temperatures in the Manganui River downstream of the Motukawa HEPS intake are generally higher than upstream, which increases the risk of nuisance algae growths occurring. However, despite the combination at times of stable flows and high water temperatures nuisance algae growths rarely occur in the Manganui River downstream of the Motukawa HEPS intake. Key factors controlling periphyton growth include sunlight, nutrient concentration, temperature, grazing by invertebrates and flow history (i.e. the history of bed disturbance).

The proposed abstraction of water from the Manganui River (7,500 L/s) could increase the frequency of sustained low flow periods and high water temperatures in the river downstream of the intake. Although there will be no change to the minimum flow of 400 L/s, depending on the timing of the increased take, this could potentially increase the risk of nuisance algae growths occurring in the river downstream of the intake.

The frequency of high flow events that are sufficient to cause periphyton flushing is important in understanding how the proposed increased diversion at the Motukawa HEPS intake could influence nuisance periphyton growths in the river downstream. The FRE3 statistic (the number of events per year when the flow exceeds three times the median flow) is used to describe the ‘flashiness’ of a river, and provides an indication of the frequency of events sufficient to flush algae from the riverbed (i.e., the higher the FRE3 statistic the greater the number of flushing events). The number of FRE3 events was calculated for the Manganui River upstream and downstream of the take. The median flow upstream of the take is 4.43 m^3/s (2009 to 2020), so a flow exceeding 13.3 m^3/s is counted as a FRE3 event (David Leong, Tonkin and Taylor, pers. comm.).

At the Upstream site there are an average of 22 FRE3 events per year (range 15 to 31 events per year from 2011 – 2020). Downstream of the intake, under the existing scheme the average number of FRE3 events per year is 15.9, and under the proposed increased take this would reduce to 14.5 events (range 8 to 19 events per year from 2011 – 2020) (Table 4.2). During summer the average number of FRE3 events would reduce from 2.2 under the existing take, to 1.9 under the proposed take (i.e., a 14% reduction) (Table 4.3).

High flows result in periphyton being scoured off the riverbed, with the magnitude of flushing flows required to remove periphyton varying depending on the physical character of the river (e.g. water velocity, substrate size). To understand this process in the Manganui River, instream habitat data was used within SEFA to predict the area of surface and deep riverbed flushing as flows increase (Figure 4.12). Surface flushing occurs at lower flows than deep flushing (as expected), and surface flushing of approximately 70% of the riverbed can be achieved with flows of 27 m^3/s. Above 27 m^3/s the rate of increased surface flushing achieved with increasing flow slows (Figure 4.12).

Table 4.2. *Number of FRE3 events (flows greater than 13.3 m^3/s) per year in the Manganui River at sites upstream and downstream of the Motukawa HEPS intake, 2011 - 2020 (data provide by David Leong, Tonkin and Taylor).*

Year	Number of FRE3 events under existing take of 5,200 L/s		Number of FRE3 events under proposed take of 7,500 L/s	
	Upstream	Downstream	Upstream	Downstream
2011	22	21	22	16
2012	22	15	22	15
2013	16	13	16	12
2014	15	8	15	8
2015	18	13	18	13
2016	31	20	31	18
2017	28	23	28	19
2018	23	15	23	13
2019	24	17	24	17
2020	22	14	22	14
Average	**22.1**	**15.9**	**22.1**	**14.5**

Table 4.3. *Number of FRE3 events (flows greater than 13.3 m^3/s) per summer in the*

Manganui River at sites upstream and downstream of the Motukawa HEPS intake, 2011 - 2020 (data provided by David Leong, Tonkin and Taylor).

Summer (December – February)	**Number of FRE3 events under existing take of 5,200 L/s**		**Number of FRE3 events under proposed take of 7,500 L/s**	
	Upstream	**Downstream**	**Upstream**	**Downstream**
2011-12	5	5	5	5
2012-13	2	1	2	1
2013-14	2	2	2	2
2014-15	0	0	0	0
2015-16	2	2	2	2
2016-17	2	2	2	1
2017-18	5	5	5	3
2018-19	1	0	1	0
2019-20	3	3	3	3
Average	**2.4**	**2.2**	**2.4**	**1.9**

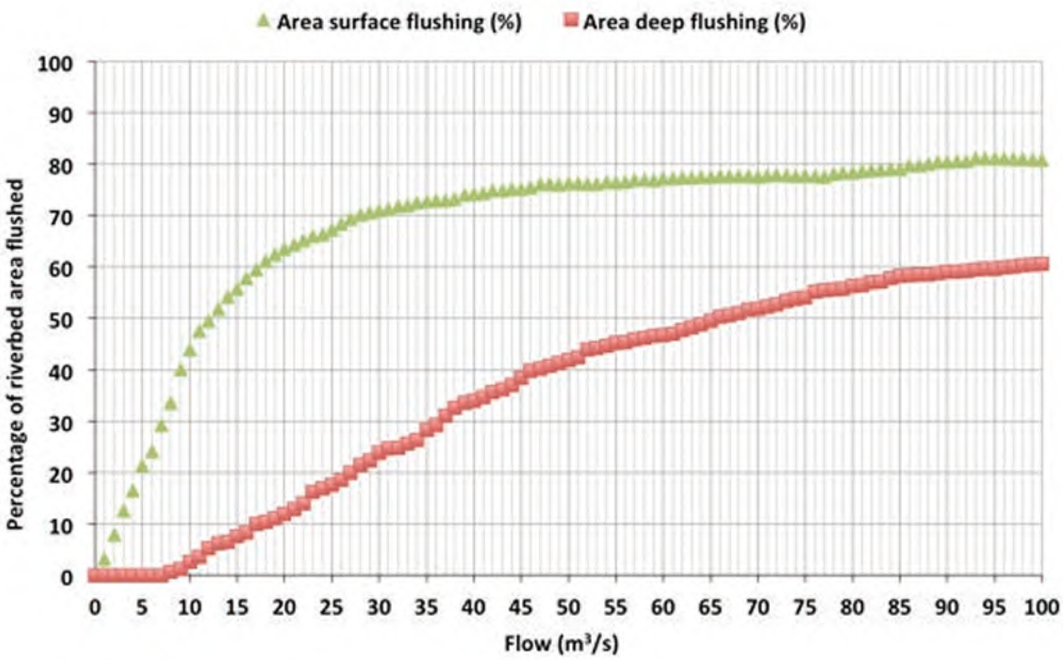


Figure 4.12. *Percentage of riverbed area undergoing surface and deep flushing with increasing flow in the Manganui River.*

The proposed abstraction of water from the Manganui River could increase the frequency of sustained low flow periods and high water temperatures in the river downstream of the intake, which could potentially increase the risk of nuisance algae (periphyton) growths occurring in the river downstream of the intake. Nuisance periphyton growths rarely occur downstream of the intake under the existing conditions.

Overall, and in accordance with the effects management hierarchy, it is proposed that a flushing flow regime be implemented to ensure that the increased take does not contribute to increased periphyton growths downstream.

The above minimisation measure could be achieved by restricting the water take if the flow downstream of the take has not exceeded 13.3 m^3/s (i.e., three times the median flow) for 30 days between 1 November and 31 March. The water take would then be restricted for six hours during the next fresh event to allow a flushing flow of at least 13.3 m^3/s to pass downstream. Based on the instream habitat data this would achieve approximately 52% surface flushing, which would be sufficient to reduce long filamentous periphyton cover (Figure 4.12).

The implementation of this minimisation measure (and the proposed temporary reduction in take if water temperatures downstream exceed 25 °C, as discussed in Section 4.1.1) will ensure that potential risk of nuisance algae growths occurring due to the increased abstraction of water from the Manganui River, will in the context of its contribution to ecosystem health and amenity values, be **no more than minor**.

4.1.3. Effect of abstraction on macroinvertebrate community health

Long-term monitoring by TRC has indicated that sites in the middle and the lower reaches of rivers in the Taranaki region generally have lower macroinvertebrate health in summer than spring. This difference has been related to summer warmer water temperatures, increased periphyton cover, and lower flows, resulting in additional less 'sensitive' taxa being present and/or increases in the abundance of lower scoring 'tolerant' taxa, combined with lifecycle patterns. Increased summer water temperatures in the Manganui River downstream of the Motukawa HEPS intake could potentially have adverse effects on macroinvertebrate communities. However, monitoring of invertebrate communities indicates that they are similar upstream and downstream of the intake, and are overall indicative of 'good' health.

In its most recent annual compliance report for the Motukawa HEPS TRC concluded that the invertebrate community supported by the residual flow of 400 L/s, with regards to presence/absence of taxa, and their respective abundances, is not significantly different to that supported by natural flows. Although they noted that under more sustained drier weather conditions, any differences become more prominent (TRC 2020b).

The proposed abstraction of water from the Manganui River could increase the frequency of sustained low flow periods and high water temperatures in the river downstream of the intake, which could potentially increase the risk of nuisance algae (periphyton) growths occurring in the river downstream of the intake. Nuisance periphyton growths and high water temperatures can have adverse effects on macroinvertebrate community health.

The management of macroinvertebrate community health in the Manganui River downstream of the Motukawa HEPS intake has been considered in accordance with the effects management hierarchy that applies to considering effects on river extent and values in accordance with the NPS-FM (2020). This is documented in the AEE given the need to consider a broad range of factors in determining what is 'practicable'.

Overall, and in accordance with the effects management hierarchy, it is proposed that a temporary reduction in take be implemented if water temperatures downstream exceed 25 °C (Section 4.1.1), and that a flushing flow regime be implemented to ensure that the increased take does not contribute to increased periphyton growths downstream. The implementation of these minimisation measures will ensure that potential risk of adverse effects on macroinvertebrate community health occurring due to the increased abstraction of water from the Manganui River, will in the context of its contribution to ecosystem health, be **no more than minor**.

4.1.4. Effect of abstraction on fish habitat

The proposed abstraction of water from the Manganui River could increase the frequency of sustained low flow periods and high water temperatures in the river downstream of the intake. High water temperatures can have adverse effects on fish habitat.

The management of fish habitat in the Manganui River downstream of the Motukawa HEPS intake has been considered in accordance with the effects management hierarchy that applies to considering effects on river extent and values in accordance with the NPS-FM (2020). This is documented in the AEE given the need to consider a broad range of factors in determining what is 'practicable'.

Overall, and in accordance with the effects management hierarchy, it is proposed that the existing residual flow and the Condition 5 requirement for artificial freshes be maintained. The implementation of these minimisation measures (and the proposed temporary reduction in take if water temperatures downstream exceed 25 °C, as discussed in Section 4.1.1) will ensure that the potential risk of adverse effects on fish habitat occurring due to the increased abstraction of water from the Manganui River, will in the context of its contribution to ecosystem health, indigenous biodiversity and amenity values, is **no more than minor**.

4.2. Effect on Lake Ratapiko environment

Lake Ratapiko is an artificial lake formed to provide power generation. In addition to this primary function, the lake has developed ecosystem services over time and now supports a limited native fish community and a trout fishery (sustained by stocking). Due to the need for the Motukawa HEPS to store and use water from the lake in order to operate efficiently it is not possible to avoid temporary losses of habitat for some species, as the lake level fluctuates within a typical operating range of 2 m. Seasonal lowering of the lake for weed control and other maintenance work reduces the level by approximately 2 m lower than typical and results in large areas of lake bed being exposed for one to two weeks. In order to avoid or minimise the risk of fish stranding, existing consent conditions require that lake level draw down for maintenance occurs gradually over a 7-day period. Lake lowering in autumn reduces the risk of high temperatures impacting aquatic communities (noting that emergency lowering could still be required during summer). The implementation of these measures ensures that the potential risk of adverse effects on the existing aquatic community occurring due to the operation of Lake Ratapiko is **no more than minor**.

4.3. Effect of discharge from the Motukawa HEPS tailrace to Makara Stream

When the Power Station is generating, nutrient levels (nitrogen and phosphorus) are elevated in the Makara Stream downstream of the Motukawa HEPS tailrace discharge. Based on the available data, nutrient levels in the Makara Stream downstream of the discharge are, however, well within relevant NOF bottom lines (i.e. nitrate and ammonia (toxicity)) (NPS-FM 2020). Elevated nutrient levels are not apparent further downstream in the Waitara River.

Water temperatures in the Makara Stream downstream of the tailrace increase with generation flow, although they typically remain within the range of thermal preferences for the fish species present (i.e., common/Cran's bullies and eels). Dissolved oxygen monitoring in the Makara Stream downstream of the Motukawa HEPS tailrace discharge found that oxygen concentrations were above guideline levels.

The management of water quality in the Makara Stream downstream of the Motukawa HEPS discharge has been considered in accordance with the effects management hierarchy that applies to considering effects on river extent and values in accordance with the NPS-FM (2020). This is documented in the AEE given the need to consider a broad range of factors in determining what is 'practicable'.

Overall, and in accordance with the effects management hierarchy, the risk of adverse effects on water quality in Makara Stream occurring due to the discharge of water from the Motukawa HEPS, will in the context of its contribution to ecosystem health, be **no more than minor**.

4.4. Fish passage

As noted in Section 3.6, 20 species of freshwater fish have been identified in the Waitara River catchment, and of the native species that are present in the catchment in the vicinity of the Motukawa HEPS, all other than Cran's bullies have migratory life cycles that require safe passage to and from the sea or estuary to complete their life cycle (i.e. are diadromous).

Most diadromous species that require access back to sea to breed move with the downstream flow of water and, with hydroelectric schemes, this typically means that this water passes through a hydroelectric power station (in this case, the Motukawa Power Station).

There are a number of aspects associated with the Motukawa HEPS that have potential influence on fish passage. These are summarised in the table below along with existing mitigation measures.

Fish Passage Aspect	Existing Mitigation
The residual reach in the Manganui River below the intake.	Residual flow of 400 L/s. An additional 400 L/s must be passed over the intake weir (for three hours daily) if the weir is not naturally overtopped by flows of 400 L/s or higher for a continuous period of 30 days (Consent 3369-2 Condition 5).
The Manganui River intake weir.	Fish passes on both sides of the weir.
The Manganui River intake race entrance and associated trash rack.	Trash rack has spacings of 150mm which assist fish in not becoming impinged against the rack under high intake conditions. An electrical field device has been operating on these trash racks for at least 15 years to help deter fish from entering the intake race. Intake gates closed during large flood events.

Fish Passage Aspect	Existing Mitigation
Leakage from the race into the return channel associated with the old sluice gate.	
Screening associated with the in-race generator located on the race between the settling pond and Lake Ratapiko.	Existing Kaplan turbines likely to cause only minor damage to small fish (see section 4.4.4). A bypass valve is located at the base of the canal immediately upstream of the in-race generator. Condition 5 of consent 6390-1 requires generation to cease on three occasions during November to February each year, and for the bypass valve to be open for 12 hours.
The potential abstraction of water from the Mangaotea Stream into the race.	This abstraction has been discontinued.
The damming of the Mako Stream to form Lake Ratapiko.	An upstream elver pass is located around the concrete spillway to the Mako Stream.
Trash racks / weed screen in front of the penstock intake at Lake Ratapiko that feeds the Motukawa Power Station.	An electrical field device to deter fish away from the entrance to the penstocks is installed in the forebay of the penstocks and has been in place for at least 15 years. An annual adult eel trap and transfer programme operates in the same area in autumn.
Downstream passage through the Motukawa Power Station turbines.	See above.
The Motukawa Power Station as a barrier to upstream migration for fish (particularly elver) in the Makara Stream catchment.	An elver trap has been operating at the Motukawa Power Station since 2001. Recently, a nearby competing attractant flow was diverted so that it now discharges at the same point as the discharge from the elver trap.

4.4.1. Manganui River

(i) Residual reach

The current consent requires a residual flow of 400 L/s to be maintained below the intake weir. As noted in Section 1.2, this residual flow is conveyed below the weir via two fish pass that are located on opposite sides of the river. The residual flow is augmented by contributions from several tributaries that enter the river downstream of the intake weir (see figures 4.1 to 4.10). In addition to maintaining a minimum flow in the reach downstream of the intake, flow variability is maintained by natural floods and freshes which are frequent in the Manganui River. For example, even after taking Motukawa HEPS's existing abstraction into account, the average number of FRE3 flow events per year is almost 16, and on average, 2.2 FRE3 events occur over the summer months. Such flow variability is important for migratory fish as they often use freshes as cues to move upstream or downstream, depending on life cycle stage.

Information on fish distribution in the Manganui River catchment indicates all migratory fish species present in the catchment are found at least as far upstream as the intake weir, indicating that passage is being provided through the residual reach.

The proposed take regime for the Motukawa HEPS will not compromise the current 400 L/s residual flow downstream of the Manganui River intake weir. Information on fish distribution in the Manganui River catchment indicates all migratory fish species present in the catchment are found at least as far upstream as the intake weir, indicating that passage is being provided through the residual reach.

There is a predicted slight decrease in the average number of FRE3 events per annum downstream of the intake (from 15.9 per year to 14.5 per year, and, for the summer months, the average number of FRE3 events would reduce slightly to 1.9 per year, see tables 4.2 and 4.3). Adult eels migrate downstream on freshes, therefore, it is recommended that reducing the number of FRE3 events from about mid-March to mid-June is avoided, as this coincides with the bulk of the adult eel migration season (based on observations associated with the Lake Mangamahoe adult eel trapping programme, and elsewhere around New Zealand).

(ii) Manganui River intake weir and fish passes

Passage upstream of the weir is provided by the two fish passes. Longfin and shortfin eels, common/Cran's and redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout have all been recorded upstream of the weir. Lamprey have been recorded within the true right bank fish pass (the main fish pass) and also within the Motukawa HEPS settling pond in 2021. Torrentfish have been recorded in the Manganui River at the bottom of the main fish pass, but not further upstream.

The Manganui River fish passes appear to be effective at providing upstream fish passage for all species, with the possible exception of torrentfish (based on upstream fish records, although juvenile torrentfish are reasonably good climbers). The true right bank fish pass (horse-shoe shaped) was constructed in 2002 and was designed to provide a more 'natural' stream-like environment with a series of riffles and pools. Some concern has been raised in TRC compliance reports and by Taranaki Fish & Game in recent discussions about the state of some of the rock weirs within the pass possibly creating barriers for some species due to high water velocities and steep drop-offs, although extensive overhanging vegetation cover along the banks may still provide passage for those species that find the drop-offs challenging.

Ongoing maintenance of the true right bank fish pass is recommended to address these potential barriers.

The older fish pass on the true left bank of the weir provides an alternative pathway for fish passage. Its location on the opposite side to the river from the scheme intake has some potential advantages for fish migrating upstream and avoiding the potential risk of being swept into the intake after negotiating passage up the true right bank fish pass. Similarly, this pass provides a downstream pathway away from the HEPS intake.

Fish passage downstream of the weir is provided by the two fish passes all year round, while freshes and floods that spill over the weir itself will provide an additional pathway likely to be important for passage of out-migrating adult eels in autumn.

It is worth noting that other structures in the Manganui River system may also be affecting fish passage and so the distribution of fish in the catchment may not be influenced by just the Motukawa HEPS. For example, there is a weir in the Manganui River at SH3 near Midhurst, approximately 13 km upstream of the Motukawa HEPS intake weir (Figure 4.13). Although the vertical drop on this weir is not as great as the one associated with the Motukawa HEPS weir, it could affect upstream fish passage for some species (e.g., adult galaxiids, bully and torrentfish) under low flow conditions.

Figure 4.13. *Weir in the Manganui River at SH3 near Midhurst, approximately 13 km upstream of the Motukawa HEPS intake weir, February 2021.*

The Manganui River fish passes appear to be effective at providing upstream fish passage for all species, with the possible exception of torrentfish. Under low flow conditions, the bulk, if not all, of the river flow moves down these passes. As there is no proposal to change the residual flow, the fish passes will continue to operate as they currently do and, as such, there is unlikely to be any change to the effectiveness of the passes.

(iii) HEPS intake and associated trash rack

A significant proportion of the river's flow can at times be diverted into the scheme's intake. The intake is located on the true right bank immediately upstream of the upstream end of the true right bank fish pass. Given the proximity of the scheme's intake to this fish pass, and the proportion of flow that can be abstracted from the river, both upstream and downstream migrating fish run the risk of being entrained into the intake and conveyed further downstream in the scheme's infrastructure.

Trash racks, situated just several metres down from the river intake (Figure 4.14), is the first obstacle encountered by fish. There is a risk that larger fish could become impinged on them, particularly under high flow conditions. However, the spacing between the vertical bars is quite wide (150mm), and as such the risk is considered to be relatively low.

Figure 4.14. *Motukawa HEPS trash rack on the Manganui River intake, November 2018.*

No changes are proposed to the infrastructure associated with the HEPS intake and associated trash rack. The only material physical change that can be anticipated with a maximum take of 5,200 L/s7,500 L/s is an increase in the average water velocity through the trash rack and intake gates. However, the trash rack bar spacing of 150mm is such that it is unlikely to result in any impingement of larger fish under anticipated higher flow intake rates.

(iv) Sluice gates

Sluice gates (Figure 4.15), situated approximately 80 m downstream of the intake trash racks, have an associated return channel to the Manganui River, which discharges at a point approximately 675 m downstream of the scheme's intake (Figure 4.16). The sluice gates do not seal tight, and leak water into the return channel, and in doing so provide an attractant flow of water for fish, koura and shrimp upstream from the river. The channel is effectively a dead-end as there is no ability to enter the race via the sluice gate. TRC has reported this as an issue and a limited survey found a number of elver in the return channel. It is recommended that the potential for fish and other migrant species to access the channel be limited by installing a barrier on the vertical wall at the channel's outlet to the Manganui River (right photo in Figure 4.16). This would restrict the ability of elvers and other species to climb into the dead-end channel.

Figure 4.15. *Sluice gate channel, November 2018. Motukawa HEPS sluice gates.*

The proposed increase in the maximum rate of take will not materially affect the operation of the sluice gates. If more water was to leak through the gates and back to the Manganui River via the sluice channel, the recommended barrier on the vertical wall at the channel's outlet will prevent fish from gaining access.

Figure 4.16. *Sluice gate channel, February 2020. Left: Looking up channel towards sluice gate. Right: Downstream end of the channel at the Manganui River.*

4.4.2. In-race generator

An in-race generator, constructed in 2006, is situated in the scheme's race between the settling pond and Lake Ratapiko (Figure 1.6). The structure has a trash screen with 75 mm spacing (Figure 4.17) that is unlikely to exclude large and small fish which would pass through to the Kaplan turbine (Figure 4.17). Further, the screen is positioned in such a way that does not provide fish any opportunity to swim away from the screen, should they not pass through it. The rationale behind the current screen spacing was related to the need to reduce the scale of clogging by debris that was occurring with the original screen design (which had 13 mm spacing).

When not running, water in the race is shut out from the entrance to the generator and does not pass through the screen. Under such circumstances, fish are able to pass unimpeded down the race towards Lake Ratapiko. There is also a bypass pipe that has an entrance on the bed of the race on the upstream side of a weir associated with the generator structure. The bypass pipe exits downstream of the generator (Figure 4.17) and so provides an unimpeded pathway for fish. Condition 5 of consent 6390-1 requires generation to cease on three occasions during November to February each year, and for the bypass valve to be open for 12 hours in order to enable trout to pass through the dam. Although the generator is shut down more frequently than required under condition 5, for the purposes of this assessment, it is assumed that it operates more or less continuously.

Figure 4.17. *Top left: Trash screen on the Motukawa HEPS in-race generator. Top right: The Kaplan turbine. November 2018 (note, flow not being diverted and generator not operating). Bottom: Bypass pipe outlet at bottom of weir.*

Kaplan turbines are generally regarded as providing safe passage for small fish, due to their low head and slow rotation. Boubée (2003), in assessing Kaplan turbines proposed for the Project Aqua hydroelectric scheme on the Waitaki River, estimated trout fry (30 mm length) mortality at 3–6% during each turbine transit and 5–7% for fingerlings (115 mm length). Larger fish (adult eel and adult trout) would be more susceptible to damage and even mortality if they pass through the screen and into the turbine. Despite the wide spacing, there is also some risk that large eels could become impinged on the screen given it is aligned more or less perpendicular to the oncoming water and the lack of a bypass route.

Under an increased rate of flow into the HEPS, the in-race generator will potentially pass more water through the turbines. No changes are proposed to the infrastructure associated with the generator and therefore, when operating, the effects of fish reaching the generator's trash screen and passing through the turbine blades are the same as the current situation.

4.4.3. Mako Stream

The damming of the Mako Stream to form Lake Ratapiko resulted in a physical barrier to upstream passage for fish (Figure 1.9). An elver pass (a small pipe with a small water supply from a hose) for the upstream migration was constructed around the concrete spillway to the Mako Stream (Figure 4.18). The most recent TRC compliance report (2019-2020) noted that "*Inspections in the 2019-2020 period found the fish pass to be inadequate to provide passage for all the species likely to be present in the small stream*". Bullies (common/Cran's), longfin eel and brown trout have all been recorded in the Mako Stream further downstream, and based on these surveys, it is considered that provision for elver passage is sufficient, given bullies and brown trout do not require migration to complete their life stages. No fish have been found immediately downstream of the spillway.

The are no identified changes to the effects of the HEPS on fish passage in the Mako Stream as a result of an increase in the rate of take from the Manganui River.

Figure 4.18. *Elver pass at Lake Ratapiko spillway, August 2019 (pass not operating at the time).*

Trustpower has recently made improvements to the elver passage at the Ratapiko spillway. The path of the attractant flow for the elver pass was deepened and better defined, and low lying areas containing water were drained, leaving the pathway to the elver trap as the only viable route for elver to use (Chris England, pers. comm.).

4.4.4. Lake Ratapiko and Motukawa Power Station

Water in Lake Ratapiko is piped through a penstock to the Motukawa Power Station (Figures 1.10 and 1.11). The intake to the penstock is screened for trash and the structure has a mechanical cleaner (Figure 4.19).

Lake Ratapiko is essentially a dead-end for adult eel that are ready to return to the sea to complete their life cycle. When ready to migrate, adult eel follow the flow of water downstream and, in this case, that is through the penstock screens to the Motukawa Power Station. The spacing between the screen bars is mostly 40 mm with some at 37 mm. This spacing is unlikely to keep out all adult eels. A monitoring inspection of the Motukawa HEPS undertaken by TRC during the 2008-2010 reporting period confirms this, with an eel observed that appeared to have passed through the turbines. Although there have been no other reports of eels trapped in this location, a trap and transfer programme has since been intensified (see below) and an electrical field device has recently been reinstalled to help deter fish from entering the forebay.

In 2019, Trustpower hydrologists surveyed water depths and velocities 0.5 m in front of the screens to the Motukawa Power Station penstocks using an acoustic Doppler current profiler (ADCP). At an intake rate on the day of 4.4 m^3/s, the average velocity

0.5 m in front of the screens was 0.11 m/s, which is within the 0.12 m/s guideline value for fish screening to reduce the risk of impingement. Based on information collated from studies of swimming velocity preferences of native fish, Charteris (2006) concluded that velocities <0.3 m/s approaching water intakes would minimise involuntary entrainment of most juvenile and adult native fish by intake structures. This conclusion is in line with conclusions from Mitchell (1989) and Boubée *et al*. (1999) in their native fish swimming investigations.

Figure 4.19. *Trash screen at Lake Ratapiko intake to the Motukawa Power Station penstocks, February 2021.*

The above information suggests that fish may be able to avoid impingement against the trash screen, however they may be able to swim through the screen and down to the Power Station.

Fish mortality due to turbines has been well documented, as have results from impact (or 'strike'), pressure changes (associated with passing through high, then low pressure zones across the runner) and high shear stresses (close to fixed and moving surfaces and in the turbulent wake of the blade and in the draft tube) (Turnpenny *et al*. 2000). It is possible to estimate fish mortality during passage through turbines using various formulae and information on turbine design. The Motukawa Power Station has three horizontal Francis turbines (pers. comm. Thomas Fritz, Trustpower). For Francis turbines, the formula of Larinier and Dartiguelongue (1989) may be used to calculate mortality:

$$P = [SIN(6.54 + 0.218\ H + 118\ TL - 3.88\ D1m + 0.0078\ N)]2\ (R = 0.85)$$

Where, P is the mortality rate (between 0 and 1), H is the net head (in m), D1m the entrance diameter of the wheel measured at mid-height (in m), N (in rpm) is the speed of rotation, and TL (in m) is the length of the fish.

The Motukawa turbines have a gross head of 98 m and a maximum flow of 7 m^3/s. Turbine mortality predictions indicate that passage through the Motukawa Power Station turbines is likely to result in mortality for some fish, particularly for larger individuals, with fish over 200 mm long having a predicted mortality of at least 50%. In contrast, predicated mortality for fish less than 100 mm long is 36% or less. The species at greatest risk are downstream migrating adult longfin and shortfin eels due to their long length, and their mortality is expected to be over 90%.

The above assessment indicates that preventing adult eels from entering the penstocks is necessary to minimise effects. In autumn, Trustpower operate an annual trap and transfer programme for adult eels in the Ratapiko arm where the penstock intake is located and at the Ratapiko Dam at the Mako Stream spillway (the facilitation of passage for adult eels over the Ratapiko Dam is required under special condition 7 of consent 3373). The latest results (2019-2020) show that 18 longfin eel were transferred[17]. This compares to 26 longfin eel and 27 shortfin eel transferred in the previous period, and 7 longfin eel and 3 shortfin eel in the season previous to that. TRC report that commercial eeling occurs within Lake Ratapiko and that this likely influences the number of migrating adult eels caught within the lake from year to year, however, no further details on commercial eeling are available.

Further evaluation of adult eel trapping from Lake Ratapiko is recommended. A fyke-net trapping programme around the edges of the lake in autumn would assist in reducing the potential number of adults that migrate down towards the penstock intake. Rising lake levels in autumn are thought to provide a stimulus for mature adults to migrate, therefore, undertaking this programme prior to (or in association with) the annual autumn lake drawdown may be advantageous.

In addition to Lake Ratapiko, trialling an autumn trapping operation in the settling pond is recommended with the aim of transferring adult eels out of the race system before they encounter the in-race generator and the intake to the Power Station penstock at Lake Ratapiko.

With respect to other species that may be drawn into the Motukawa Power Station penstock intake, smaller fish and life stages fair better, and most likely survive passage through turbines (Boubeé and Jellyman 2009). Some research overseas on juvenile lamprey have found them to be relatively resilient to effects associated with passage through hydro-electric power turbines (Moser *et al.* 2014). Neitzel *et al.*

[17] Eels are relocated to the Manganui River downstream of the weir.

(2004) placed juvenile lamprey directly into the shear zone in an experimental test tank that replicated specific velocities within the turbine environment. Lamprey did not suffer any ill effects of exposure to jet velocities (equivalent to rates of strain 1,220 to 1,830 cm/s/cm). There were no immediate deaths and no immediate gross injuries. Possible reasons for the hardiness of juvenile lamprey may include their flexibility, lack of a swim bladder, and the reduced size of vulnerable structures (Moser *et al.* 2014).

The are no identified changes to the effects of the HEPS on fish passage in Lake Ratapiko and entrainment into the Motukawa Power Station penstocks. The mitigation measures proposed for the current operation are equally applicable to this scenario. This conclusion assumes that the rate of take into the penstocks does not increase materially (and, as such, will not increase velocities through the trash racks).

One potential effect of the increased rate of take under higher river flow conditions is the risk of more fish becoming entrained within the scheme, in particular, adult eels migrating downstream in autumn. This issue has been addressed in section 5.2.1(i). However, if it was determined that a greater number of migrants were finding their way into Lake Ratapiko due to the increased flow, this would be justification to intensify the trap and transfer programme even more so.

4.4.5. Motukawa Power Station tailrace

An elver trap was installed at the Motukawa Power Station late in the 2001-2002 summer (Figure 4.20). TRC report that, following modifications, this trap has operated successfully since the 2002-2003 elver migration period, with elvers transferred to either the Manganui River upstream of the weir or into Lake Ratapiko. The total weight of elvers transferred each year is presented in Figure 4.21. Based on weight and elver weights, the average number of elver transferred each year is estimated to range between about 30,000 and 47,000 individuals. Based on data from the 2005-2006 trapping season, approximately 25% of the elver are longfin eel.

Figure 4.20. *Left: Motukawa HEPS elver trap inspection. Right: Elvers in the fish trap, February 2020.*

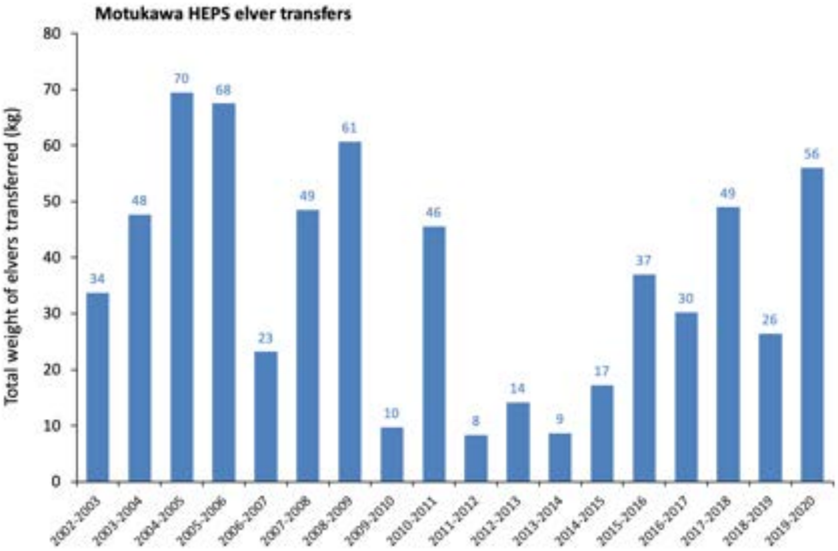


Figure 4.21. *Elver transfer data for the monitoring years to date (from TRC 2020b). Numbers above each bar is the numerical value (kg) of elver transferred.*

There are other inflows of water to the Power Station tailrace that could attract elver away from the elver trap. These alternative attractant flows have been previously identified by TRC, and are shown in Figure 4.22. Elvers were found climbing a concrete wall adjacent to the piped watercourse in February 2021 (Figure 4.23). Recently, Trustpower have piped the attractant flow so that it now discharges at the same point as the discharge from the elver trap (i.e. providing additional attractant flow to the trap). No modification is required to the natural watercourse.

Figure 4.22. *Watercourses entering from the true left of the Motukawa HEPS tailrace discharge, February 2021. The flow on the right of the photograph is from a natural watercourse. The flow on the left is piped.*

Figure 4.23. *Elvers climbing a concrete wall adjacent to a piped watercourse on the true left of the Motukawa HEPS tailrace discharge, February 2021.*

The Motukawa Power Station elver trap works well and consistently traps a large number of elver most years. Further refinements to the operation can be made through:

- Improvements to address access to the trap under station closures;
- The introduction of some cover within the fish trap to reduce stress on elvers (it can be seen in Figure 4.26 that elvers are congregating inside the pipe to the trap);
- The release of trapped elvers to the Waitara River (upstream of the Makara

Stream confluence) as that is where they have come from;

- That elvers are not transferred into Lake Ratapiko.

The are no identified changes to the effects of the HEPS on upstream fish passage at the Motukawa Power Station tailrace. It is difficult to determine whether a more regular discharge of water from the Power Station would attract more fish into the Makara Stream. Regardless of that, the continued regular and efficient operation of the fish trap in the tailrace is recommended along with the recommendations identified above.

4.4.6. Summary of effects of existing operation on fish passage

The table presented at the start of this section on fish passage has been updated below to show recommended additional mitigation measures to enhance fish passage.

Fish passage aspect associated with the Motukawa HEPS	Existing mitigation	Recommended additional mitigation
The residual reach in the Manganui River below the intake.	Residual flow of 400 L/s.	
The Manganui River intake weir.	Fish passes on both sides of the weir.	Ongoing maintenance of the true right bank fish pass to address erosion of banks and drop structures that may impede fish passage.
The Manganui River intake race entrance and associated trash rack.	Trash rack has spacings of 150mm which assist fish in not becoming impinged against the rack under high intake conditions. An electrical field device is currently operating on these trash racks to help deter fish from entering the intake race. Intake gates closed during large flood events.	
Leakage from the race into the return channel associated with the old sluice gate.		Install a barrier on the vertical wall at the return channel's outlet to the Manganui River

Fish passage aspect associated with the Motukawa HEPS	Existing mitigation	Recommended additional mitigation
		to prevent upstream access for climbing species.
Screening associated with the in-race generator located on the race between the settling pond and Lake Ratapiko.	Kaplan turbines likely to cause only minor damage to small fish. A bypass valve is located at the base of the canal immediately upstream of the in-race generator. Condition 5 of consent 6390-1 requires generation to cease on three occasions during November to February each year, and for the bypass valve to be open for 12 hours.	Instigate an annual adult eel trapping programme for Lake Ratapiko, including a fyke-netting around the edges of the lake in autumn to assist in reducing the potential number of adults that migrate down towards the penstock intake. Review after three years pending the effectiveness of trapping in the settling pond (see below). Undertaking this programme prior to (or in association with) the annual autumn lake drawdown for spraying and maintenance. Trial an autumn trapping operation in the settling pond with the aim of transferring adult eels out of the race system before they encounter the in-race generator and the intake to the Power Station penstock at Lake Ratapiko.
The potential abstraction of water from the Mangaotea Stream into the race.	This abstraction has been discontinued.	
The damming of the Mako Stream to form Lake Ratapiko.	An upstream elver pass is located around the concrete spillway to the Mako Stream.	Regular inspection of the elver pass to ensure it is fit for purpose.
Trash racks / weed screen in front of the penstock intake at Lake Ratapiko that feeds the Motukawa Power Station.	An electrical field device to deter fish away from the entrance to the penstocks has been reinstalled in the forebay of the penstocks. An annual adult eel trap and transfer programme operates in the same area in autumn.	
Downstream passage through the Motukawa Power Station turbines.	See above.	
The Motukawa Power Station as a barrier to upstream migration for fish (particularly elver) in the Makara Stream catchment.	An elver trap has been operating at the Motukawa Power Station since 2001.	Introduce some cover into the fish trap to reduce stress on elvers.

Fish passage aspect associated with the Motukawa HEPS	Existing mitigation	Recommended additional mitigation
	Recently, a nearby competing attractant flow was diverted so that it now discharges at the same point as the discharge from the elver trap.	Trapped elvers be released to the Waitara River (upstream of the Makara Stream confluence). Cease transferring elvers into Lake Ratapiko.

5. Summary and conclusion

The Motukawa HEPS is located within the Waitara River catchment to the south-east of New Plymouth. The scheme diverts water from the Manganui River via an approximately 5 km long water race into Lake Ratapiko. Lake Ratapiko is an artificial storage lake resulting from the damming of the Mako Stream in 1927. From the lake, water is directed through an intake to penstocks that carry it through to the Motukawa Power Station. Generation water from the Power Station is discharged to the Makara Stream, which then enters the Waitara River approximately 1.7 km downstream.

The Motukawa HEPS can currently divert up to 5,200 L/s of water from the weir intake on the Manganui River, and must maintain a residual flow of 400 L/s in the river below the weir. Trustpower are proposing to increase the diversion to 7,500 L/s, while maintaining the existing residual flow. In order to determine the effects of the proposed increased water abstraction on water quality and aquatic communities downstream, existing information on aquatic communities were reviewed, and additional monitoring was undertaken in the catchment during 2019 to 2021.

A diverse fish community is present upstream and downstream of the Manganui River intake weir, which incorporates two fish passes. Recent surveys have confirmed that longfin and shortfin eels, common/Cran's and redfin bullies, inanga, koaro, shortjaw kokopu, and brown trout are all present upstream of the weir. Lamprey have been recorded in the intake weir fish pass, and the presence of juvenile lamprey within the Motukawa HEPS settling pond in March 2021 indicates that adult lamprey have successfully spawned upstream of the weir. Torrentfish have been recorded in the river at the bottom of the fish pass, but have never been recorded upstream of the weir. A trap and downstream transfer system is also operated for eels near the penstock intake in Lake Ratapiko, and a trap and upstream transfer system is operated for elvers at the Motukawa HEPS tailrace.

During summer water temperatures in the Manganui River downstream of the intake are generally higher than upstream, and can exceed thermal criteria for brown trout. Temperatures are however typically within the range of thermal preferences for native fish species. Although very high water temperatures can be detrimental, warm water temperature can increase productivity in aquatic communities. Fish are also able to respond to water temperatures above their thermal preferences by temporarily moving to cooler locations (e.g. where a tributary or groundwater inflow enters). However, in order to ensure that water temperatures downstream of the intake do not remain at very high temperatures for an extended period, it is recommended that a temporary reduction in take be implemented when temperatures are high. The implementation of this minimisation measure will ensure that the adverse effects from the abstraction of water from the Manganui River on water temperatures downstream under proposed increased take are **no more than minor**.

Periphyton is essential for the functioning of healthy ecosystems, but when it proliferates it can become a nuisance by degrading instream values. Key factors controlling periphyton growth include sunlight, nutrient concentration, temperature, grazing by invertebrates and flow history (i.e. the history of bed disturbance). Despite the combination at times of stable flows and high water temperatures, nuisance algae growths rarely occur downstream of the intake. The proposed increased diversion of water from the river could increase the frequency of sustained low flow periods and high water temperatures in the river downstream of the intake, which could potentially increase the risk of nuisance algae (periphyton) growths occurring. It is proposed that a flushing flow regime be implemented to ensure that the increased take does not contribute to increased periphyton growths downstream. The implementation of flushing flows (and the proposed temperature minimisation measure) will ensure that potential risk of nuisance algae growths occurring due to the increased abstraction of water from the Manganui River is **no more than minor**.

Warm summer water temperatures, increased periphyton cover, and low flows (combined with lifecycle patterns) can result in less 'sensitive' macroinvertebrate taxa being present and/or increases in the abundance of lower scoring 'tolerant' taxa. The abstraction of water from the Manganui River (and the associated increases in water temperature) could potentially have adverse effects on macroinvertebrate communities downstream of the Motukawa HEPS take. Invertebrate communities downstream of the intake are similar to upstream and indicative of 'good' health under the existing conditions. The implementation of the temperature minimisation measure will ensure that the potential risk of adverse effects on macroinvertebrate community health occurring due to high water temperatures related to the proposed increased abstraction of water from the Manganui River is **no more than minor**.

The abstraction of water from the Manganui River could potentially have adverse effects on fish communities downstream of the Motukawa HEPS take through habitat loss and disruption to upstream passage. The existing scheme operation supports a diverse native fish community and passage is provided for brown trout and migratory native fish to the weir fish pass. It is proposed that the existing residual flow of 400 L/s and the Condition 5 requirement for artificial freshes be maintained. The continued implementation of these minimisation measures (and the proposed temperature minimisation measure) will ensure that potential risk of adverse effects on fish habitat occurring due to the proposed increased abstraction of water from the Manganui River is **no more than minor**.

Lake Ratapiko is an artificial lake formed to support power generation. In addition to this primary function, the lake has developed ecosystem services over time and now supports a limited native fish community and a trout fishery (sustained by stocking). Due to the need for the Motukawa HEPS to store and use water from the lake in order to operate efficiently it is not possible to avoid temporary losses of habitat for some species, as the lake level fluctuates within a typical operating range of 2 m. Seasonal lowering of the lake for weed control and other maintenance work reduces the level by a further approximately 2 m, and results in large areas of lake bed being exposed for one to two weeks. It is unlikely that any fish or mussels stranded as the water levels recedes will survive until the water level is restored. In order to avoid or minimise the risk of stranding, existing consent conditions require that lake level draw down for maintenance occurs gradually over a 7-day period. Lake lowering in autumn reduces the risk of high temperatures impacting aquatic communities (noting that emergency lowering could still be required during summer). The implementation of these measures ensures that the potential risk of adverse effects on the existing aquatic community occurring due to the operation of Lake Ratapiko is **no more than minor**.

When the Motukawa HEPS Power Station is generating, water from Lake Ratapiko is discharged to the Makara Stream downstream of the Motukawa HEPS tailrace. Monitoring in the Makara Stream upstream and downstream of the tailrace discharge indicates that when the Power Station is generating, downstream nutrient levels (nitrogen and phosphorus) are elevated, and dissolved oxygen levels reduced at times. However, all are still well within the NPS-FM (2020) bottom lines. Water temperatures in the stream are also elevated at times when the Power Station is generating, however temperatures are typically within the range of thermal preferences for the fish species present. Overall, the risk of adverse effects on water quality in the Makara Stream occurring due to the discharge of water from the Motukawa HEPS with the proposed increased take is **no more than minor**.

The current residual flow of 400 L/s below the intake weir on the Manganui River provides for fish passage in that reach of the river. Flow variability is also maintained by natural floods and freshes, which are frequent in the Manganui River. Increasing the maximum rate of take to 7,500 L/s may result in a slight decrease in the average number of FRE3 events per annum downstream of the intake. Because adult eels migrate downstream on freshes, it is recommended that reducing the number of FRE3 events from about mid-March to mid-June is avoided, as this coincides with the bulk of the adult eel migration season.

Passage upstream of the intake weir is provided by the two fish passes and these appear to be effective at providing upstream fish passage for all species, with the possible exception of torrentfish. Ongoing maintenance of the true right bank fish pass is recommended to address potential barriers created by erosion of rock weirs within the pass. Fish passage in the Manganui River downstream of the intake weir is provided by the two fish passes all year round, while spills over the weir associated with freshes and floods provide an additional pathway.

The proximity of the scheme's intake to the true right bank fish means that both upstream and downstream migrating fish run the risk of being entrained into the scheme's intake and conveyed further downstream in the scheme's infrastructure. Trash racks on the intake have vertical bar spacing of 150mm, and these present a low risk of impingement, regardless of the rate of abstraction.

Sluice gates situated approximately 80 m downstream of the intake trash racks leak water into a channel that returns flow back to the Manganui River. This leaking water provides an attractant flow of water for fish, koura and shrimp into what is effectively a dead-end channel. It is recommended that the potential for fish and other migrant species to access this channel be limited by installing a barrier on the vertical wall at the channel's outlet to the Manganui River.

An in-race generator, situated in the scheme's race between the settling pond and Lake Ratapiko, is unlikely to exclude large and small fish which would pass through the existing trash screen and to the Kaplan turbine. Most small fish are likely to pass safely through this turbine, however larger fish would be more susceptible to damage and even mortality. There is also some risk that large eels could become impinged on the trash screen.

Under an increased rate of flow into the HEPS, the in-race generator will potentially pass more water through this turbine. No changes are proposed to the infrastructure associated with the generator and therefore, when operating, the effects of fish reaching the generator's trash screen and passing through the turbine blades are the same as the current situation.

The damming of the Mako Stream to form Lake Ratapiko has resulted in a physical barrier (Ratapiko spillway) to upstream fish passage. This structure has an elver pass for upstream migration and Trustpower has recently made improvements to elver passage at the spillway. The are no identified changes to the effects of the HEPS on fish passage in the Mako Stream as a result of an increase in the rate of take from the Manganui River.

Because the water in Lake Ratapiko is piped through a screened penstock to the Motukawa Power Station, Lake Ratapiko is essentially a dead-end for adult eel that are ready to return to the sea to complete their life cycle. If adult eels could get through the screens they would almost certainly perish when encountering the station's turbines. A trap and transfer programme operates at the intake to the penstocks and an electrical field device operates to help deter fish from entering the forebay. Further evaluation of adult eel trapping from Lake Ratapiko is recommended, including establishing a fyke-net trapping programme around the edges of the lake in autumn to assist in reducing the potential number of adults that migrate down towards the penstock intake. Trialling an autumn trapping operation in the settling pond is also recommended to remove adult eels out of the race system before they encounter the in-race generator and the intake to the Power Station penstock at Lake Ratapiko.

An elver trap is located in the tailrace of the Motukawa Power Station. This trap has operated successfully since 2002 and has recently been subjected to some improvements to attract elvers to the trap. A number of other minor improvements have been recommended to further enhance the effectiveness of the trapping programme.

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7. Appendix One: Monitoring methods

7.1. Monitoring site map

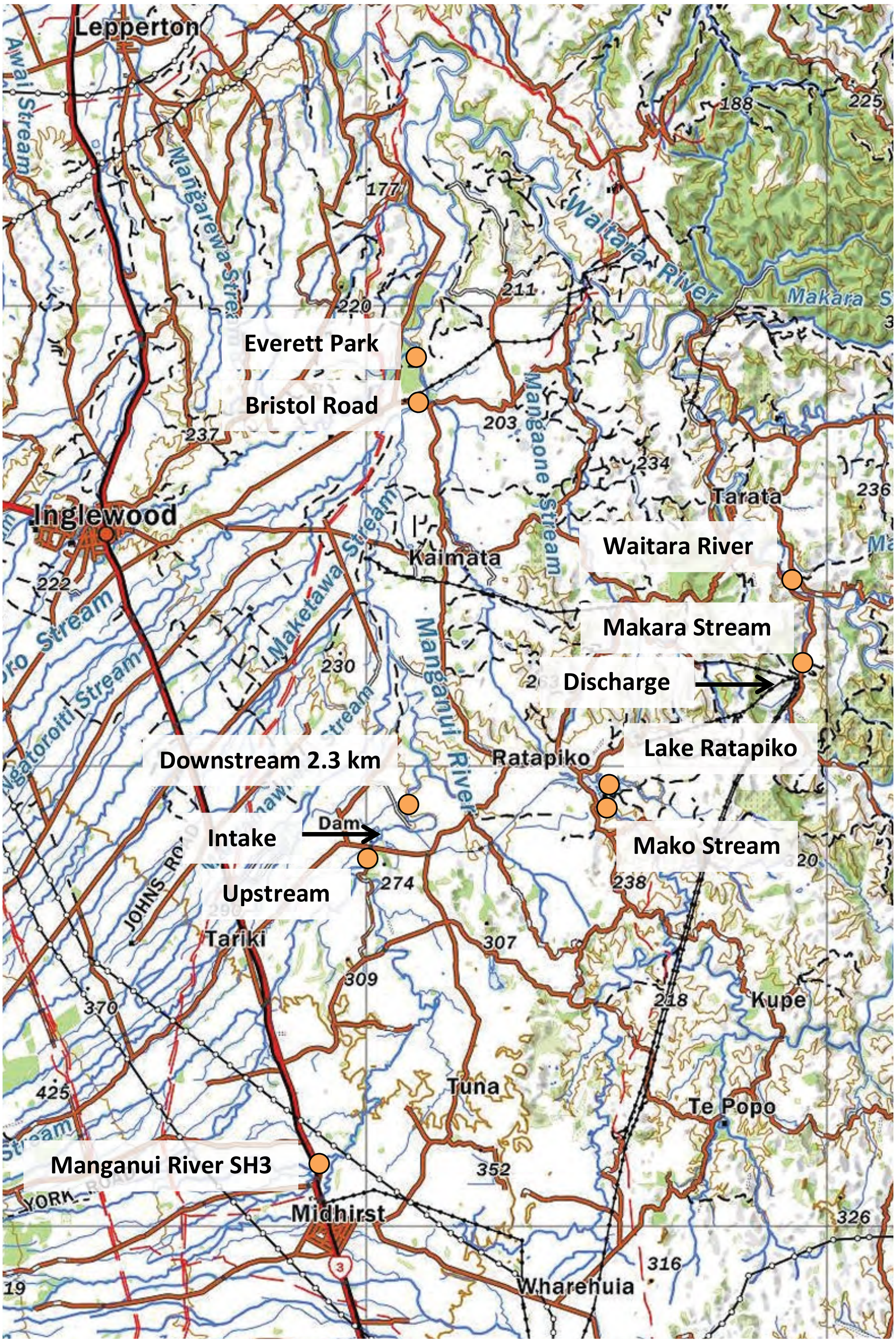


Figure A1.1. *Map of key monitoring locations (note that not all sites are shown, refer to Section 8.2 for a complete list).*

7.2. Monitoring site location information

Watercourse	Site name	Organisation	Site code	Type	Easting	Northing
Manganui River	SH3	TRC	MGN000195	River flow	1708871	5651282
Manganui River	SH3	NIWA	MGN000195	Water quality	1708871	5651282
Manganui River	SH3	TRC	MGN000195	Benthic macroinvertebrates	1708871	5651282
Manganui River	SH3	TRC	MGN000195	Periphyton	1708871	5651282
Manganui River	Upstream Manganui HEPS intake	Ryder/TPL and TRC compliance	REL MGN 01	Benthic macroinvertebrates	1710000	5657822
Manganui River	Upstream Manganui HEPS intake	TRC	MGN000300	Water temperature logger	1710000	5657822
Manganui River	300m downstream Manganui HEPS intake	TRC compliance	MGN000320	Benthic macroinvertebrates	1710221	5658490
Manganui River	1.7km downstream Manganui HEPS intake	TRC compliance	MGN000360	Benthic macroinvertebrates	1711505	5658773
Manganui River	2.3km downstream Manganui HEPS intake	Ryder	REL MGN 02	Water quality	1710896	5658942
Manganui River	2.3km downstream Manganui HEPS intake	Ryder	REL MGN 02	Periphyton	1710896	5658942
Manganui River	2.3km downstream Manganui HEPS intake	TRC compliance	MGN000375	Benthic macroinvertebrates	1710896	5658942
Manganui River	2.3km downstream Manganui HEPS intake	TRC compliance	MGN000375	Water temperature logger	1710896	5658942
Manganui River	Everett Park	TRC	MGN000435	River flow	1711149	5669127
Manganui River	Everett Park	TRC	MGN000435	Water temperature logger	1711149	5669127
Manganui River	Everett Park	TRC	MGN000435	*E. coli*	1711149	5669127
Manganui River	Everett Park	TRC	MGN000435	Benthic cyanobacteria	1711149	5669127
Manganui River	Bristol Road	TRC	MGN000427	Benthic macroinvertebrates	1711210	5667887
Manganui River	Bristol Road	TRC	MGN000427	Periphyton	1711210	5667887
Lake Ratapiko	Boatramp	TRC	LRP000050	*E. coli*	1714913	5659488
Lake Ratapiko	Boatramp	TRC	LRP000050	Planktonic cyanobacteria	1714913	5659488
Lake Ratapiko	Ratapiko Road	Ryder/TPL	REL LRP 01	Water quality	1714653	5659689
Mako Stream	Lake Ratapiko spillway	Ryder/TPL	REL MKO 01	Water temperature logger	1715163	5659158
Makara Stream	Upstream Motukawa HEPS tailrace	Ryder/TPL	REL MKR 01	Water quality	1719399	5661891
Makara Stream	Upstream Motukawa HEPS tailrace	Ryder/TPL	REL MKR 01	Periphyton	1719399	5661891
Makara Stream	Downstream Motukawa HEPS tailrace	Ryder/TPL	REL MKR 02	Water quality	1719361	5662162
Makara Stream	Downstream Motukawa HEPS tailrace	Ryder/TPL	REL MKR 02	Water temperature/DO logger	1719361	5662162
Waitara River	Upstream of Makara Stream/Motukawa HEPS tailrace	TRC	WTR000540	Water quality	1720693	5663779
Waitara River	Downstream of Makara Stream/Motukawa HEPS tailrace	Ryder/TPL	REL WTR 01	Water quality	1719268	5663819

7.3. Monitoring site photographs

Figure A1.2. *Manganui River at SH3, February 2021.*

Figure A1.3. *Manganui River Upstream, February 2020.*

Figure A1.4. *Manganui River Downstream 2.3 km, February 2021.*

Figure A1.5. *Manganui River at Bristol Road, August 2019.*

Figure A1.6. *Waitara River downstream of Makara Stream/Motukawa HEPS tailrace, February 2020.*

7.4. Macroinvertebrates

Benthic macroinvertebrates were sampled using a kicknet with 500 µm diameter mesh, following Ministry for the Environment's 'Protocols for sampling macroinvertebrates in wadeable streams' (Stark *et al.* 2001). Macroinvertebrate samples were processed for macroinvertebrate taxa identification and their relative abundance using the semi-quantitative protocols outlined in the Ministry for the Environment's 'Protocols for sampling macroinvertebrates in wadeable streams' (Stark *et al.* 2001). Protocol 'P1: Coded abundance' was used, which is summarised briefly below.

In the laboratory, samples were passed through a 500 µm sieve to remove fine material and residual ethanol. Contents of the sieve were then placed in a white tray. Each taxon present in the sample was assigned to one of five coded abundance categories using the codes established by Stark (1998) (Table A1.1). Up to 20 individuals representative of each taxon were removed from each sample to confirm identifications under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006).

Table A1.1. *Coded abundance scores used to summarise macroinvertebrate data (after Stark 1998).*

Abundance	Coded abundance	Weighting factor
1 - 4	Rare (R)	1
5 - 19	Common (C)	5
20 - 99	Abundant (A)	20
100 - 499	Very abundant (VA)	100
> 500	Very very abundant (VVA)	500

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: A measurement of the number of taxa present.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, and percentage of the total number of taxa comprising EPT taxa (% EPT taxa): These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table A1.2). For example, a low site score (e.g., 40) represents 'poor' conditions and a high score (e.g., 140) represents 'excellent' conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}}\right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Abundance of all taxa is recorded using a five-point scale (Table A1.1). As for MCI, SQMCI scores can be interpreted in the context of national standards (Table A1.2).

$$SQMCI = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Table A1.2. *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI	SQMCI
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

8. Appendix Two: Water quality data summary

8.1. Manganui River

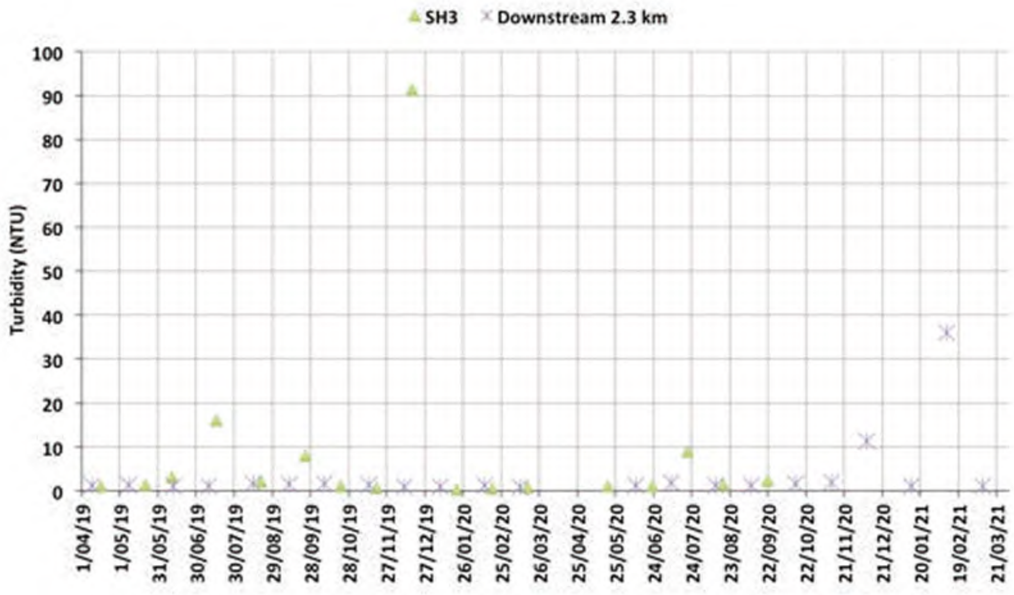


Figure A2.1. *Turbidity level (NTU) at Manganui River sites, April 2019 – March 2021.*

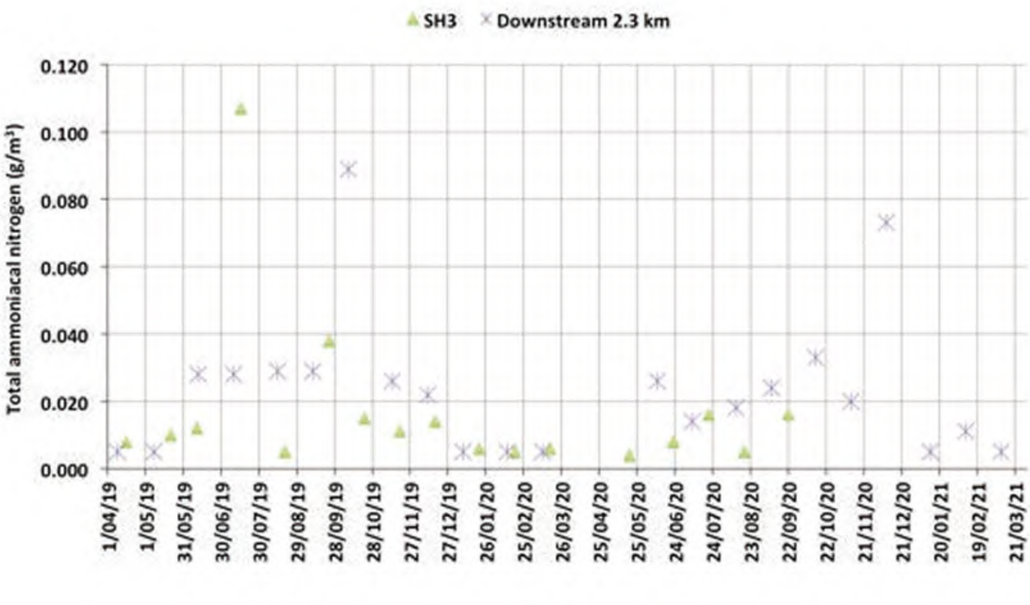


Figure A2.2. *Total ammoniacal nitrogen concentration (g/m^3) at Manganui River sites, April 2019 – March 2021.*

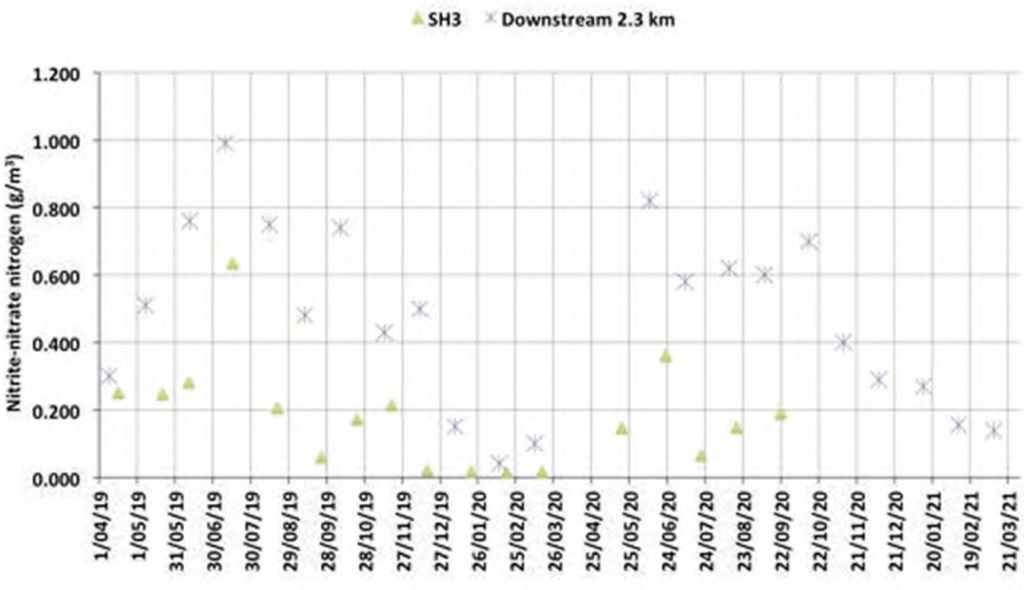


Figure A2.3. *Total nitrite-nitrate nitrogen concentration (g/m^3) at Manganui River sites, April 2019 – March 2021.*

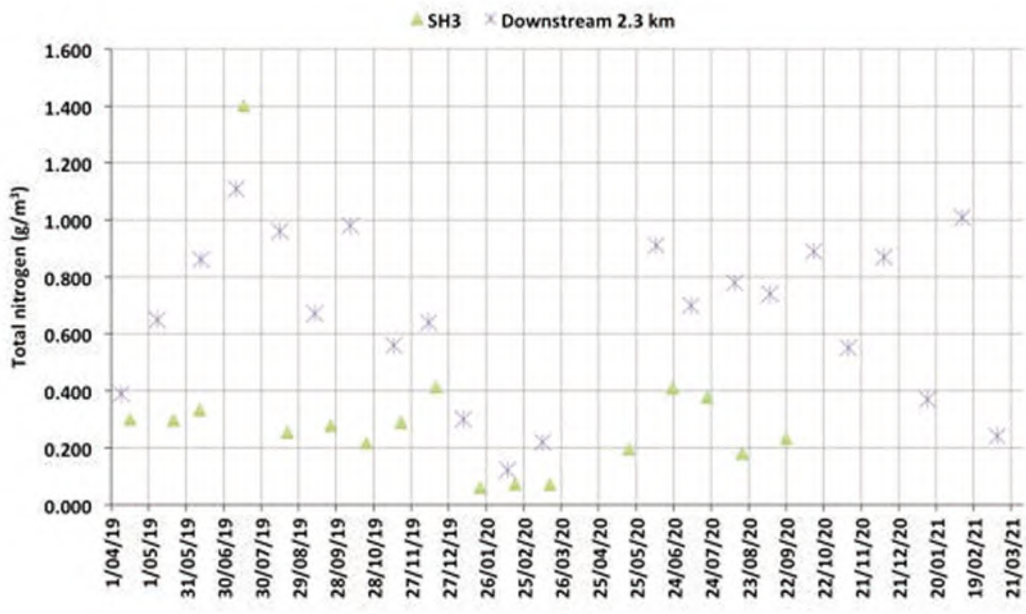


Figure A2.4. *Total nitrogen concentration (g/m^3) at Manganui River sites, April 2019 – March 2021.*

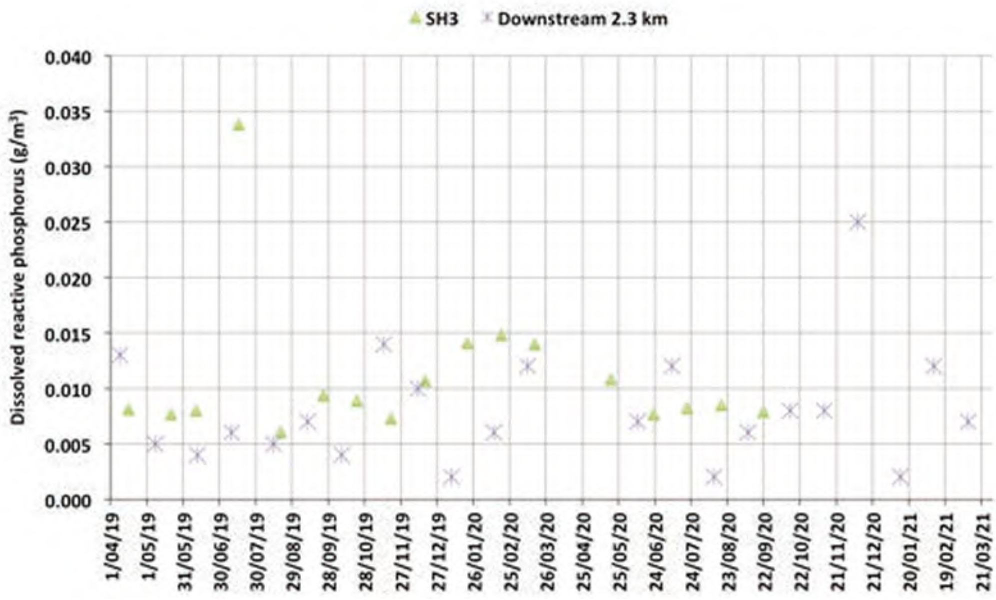


Figure A2.5. *Dissolved reactive phosphorus concentration (g/m^3) at Manganui River sites, April 2019 – March 2021.*

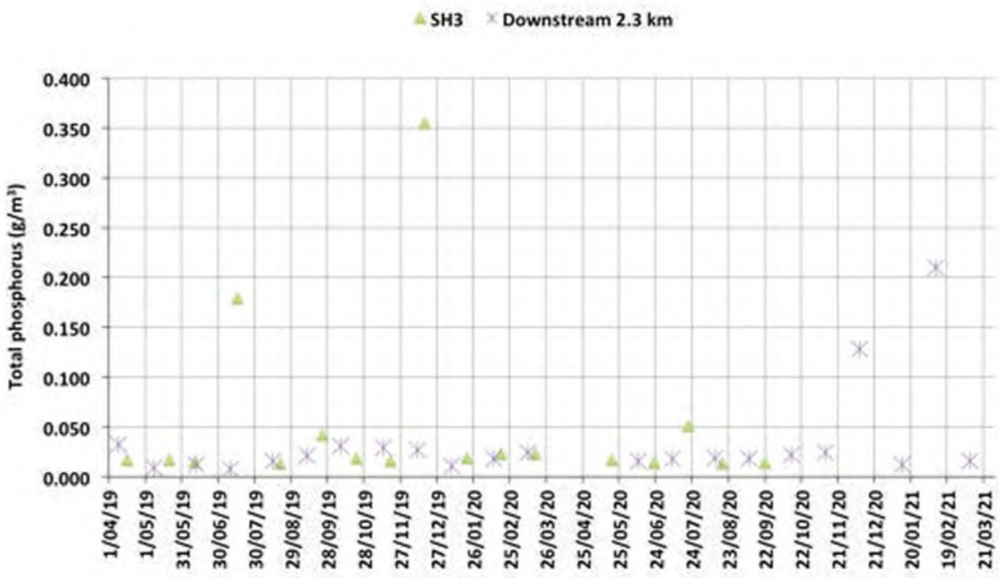


Figure A2.6. *Total phosphorus concentration (g/m^3) at Manganui River sites, April 2019 – March 2021.*

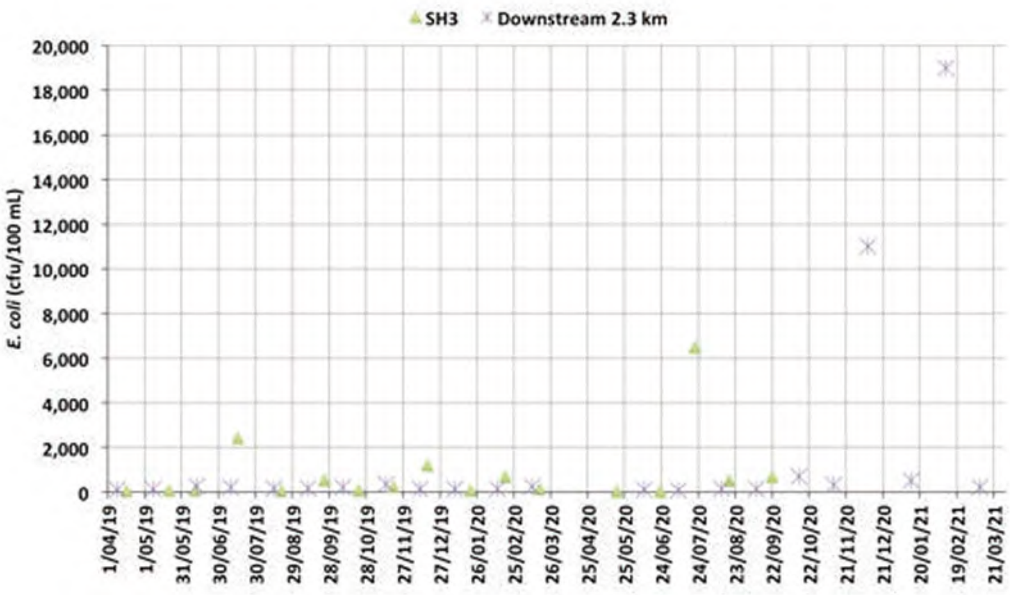


Figure A2.7. E. coli *concentration (cfu/100 mL) at Manganui River sites, April 2019 – March 2021.*

8.2. Makara Stream

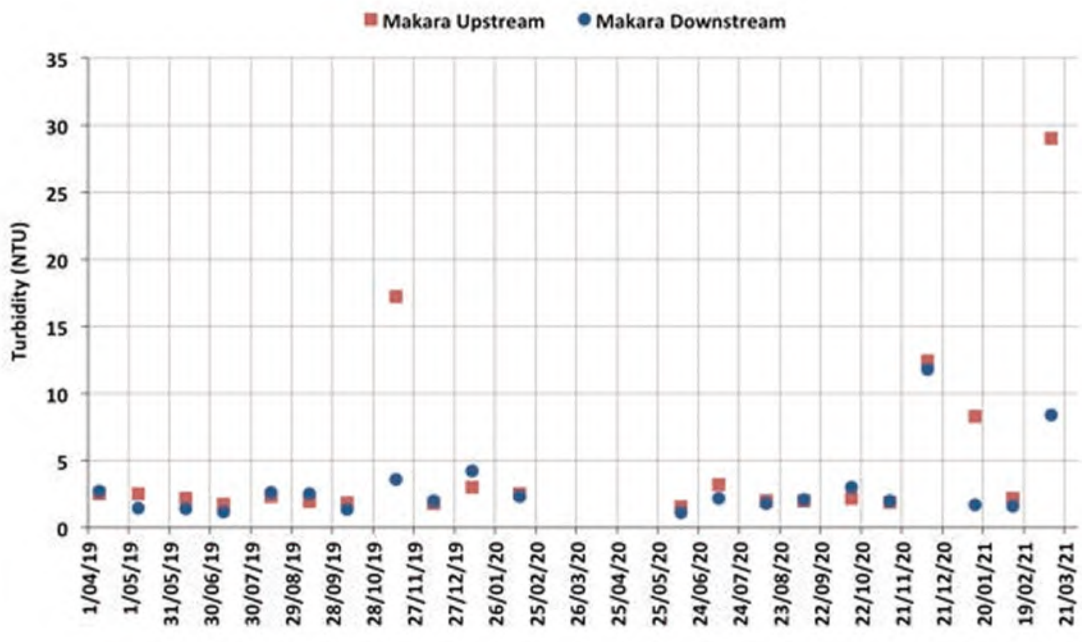


Figure A2.8. *Turbidity level (NTU) at Makara Stream sites, April 2019 – March 2021.*

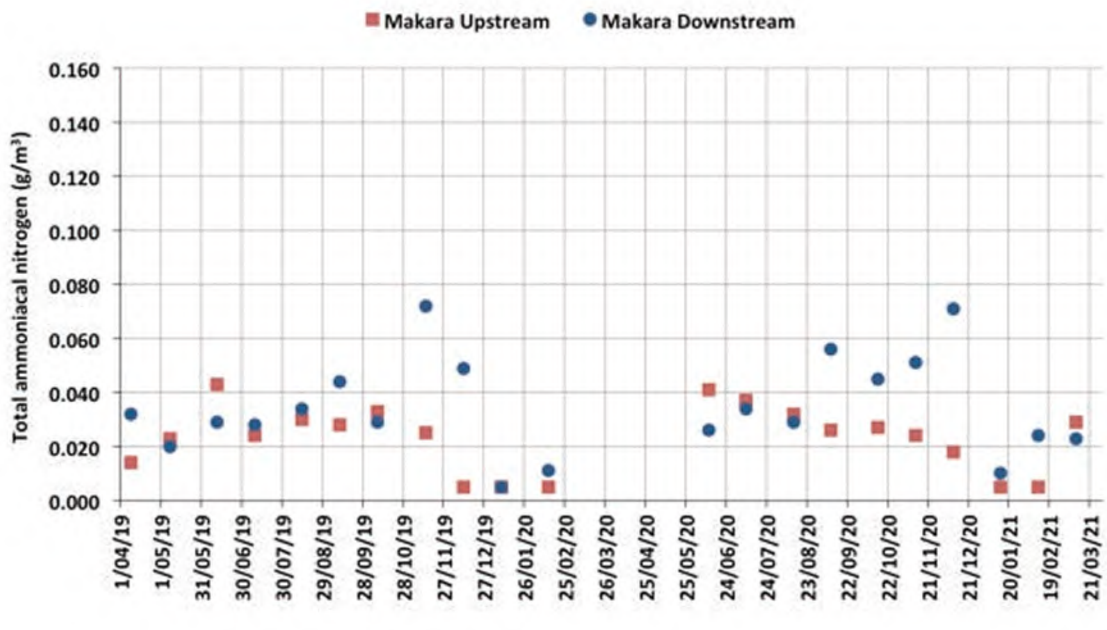


Figure A2.9. *Total ammoniacal nitrogen concentration (g/m^3) at Makara Stream sites, April 2019 – March 2021.*

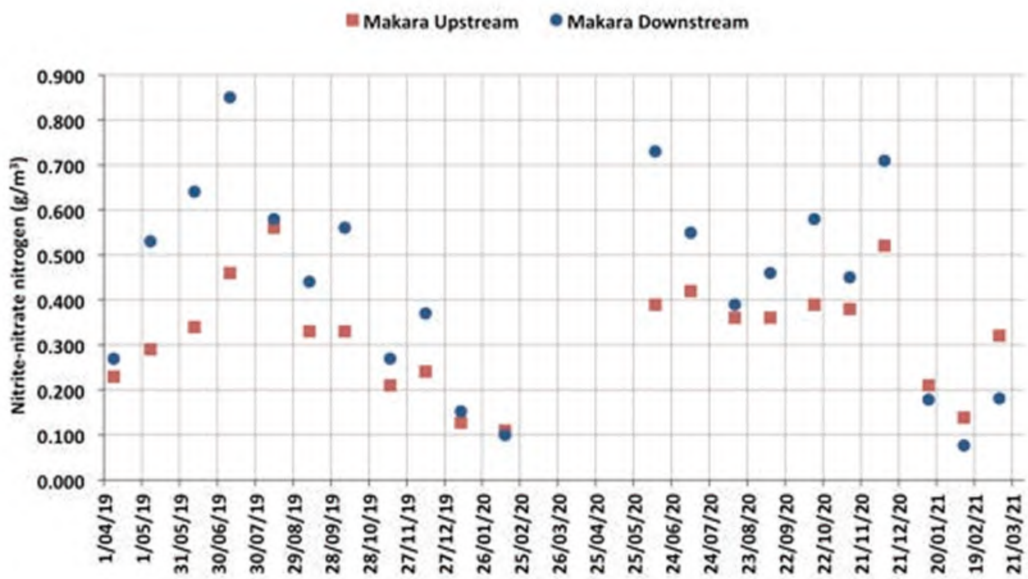


Figure A2.10. *Total nitrite-nitrate nitrogen concentration (g/m^3) at Makara Stream sites, April 2019 – March 2021.*

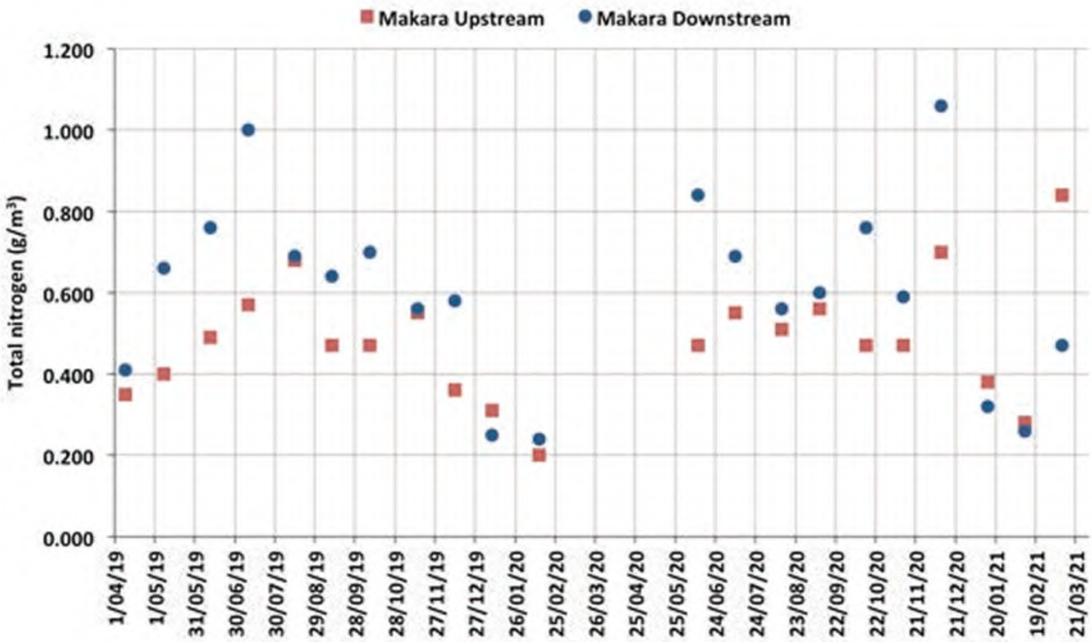


Figure A2.11. *Total nitrogen concentration (g/m^3) at Makara Stream sites, April 2019 – March 2021.*

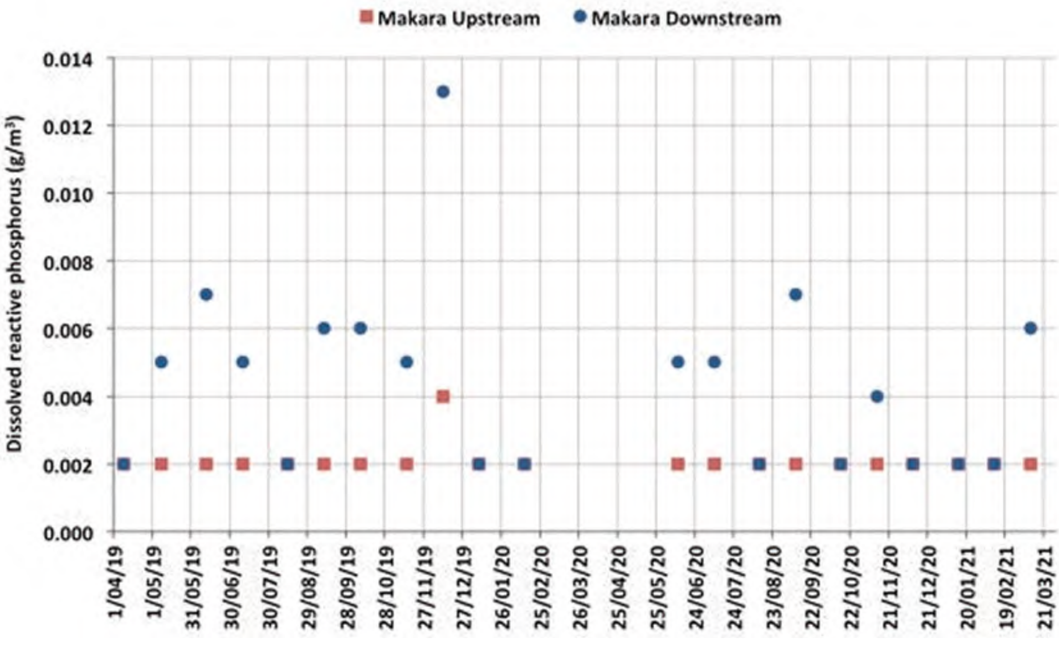


Figure A2.12. *Dissolved reactive phosphorus concentration (g/m^3) at Makara Stream sites, April 2019 – March 2021.*

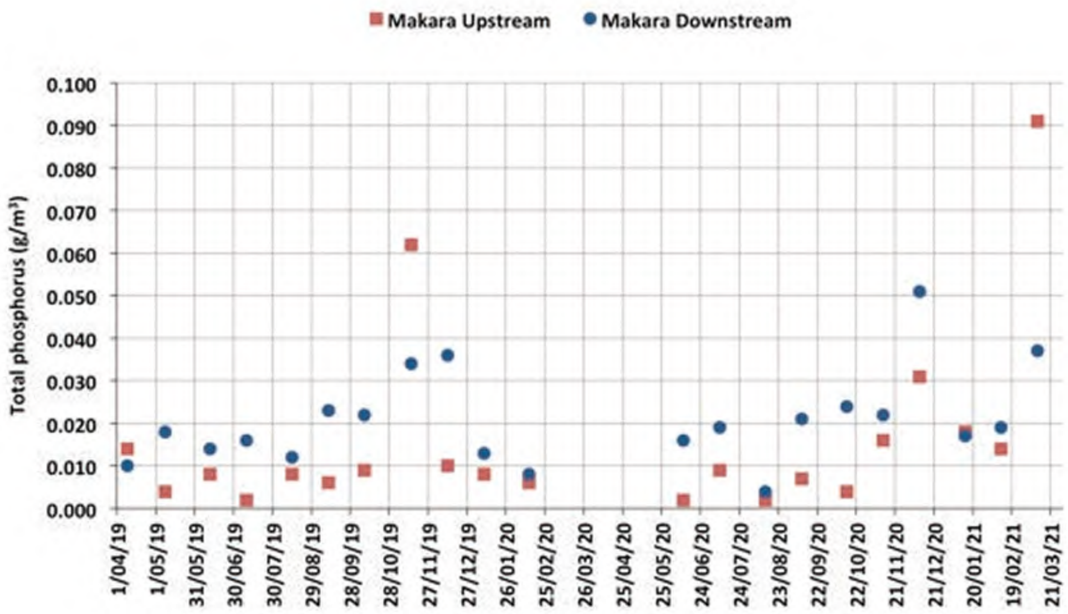


Figure A2.13. *Total phosphorus concentration (g/m³) at Makara Stream sites, April 2019 – March 2021.*

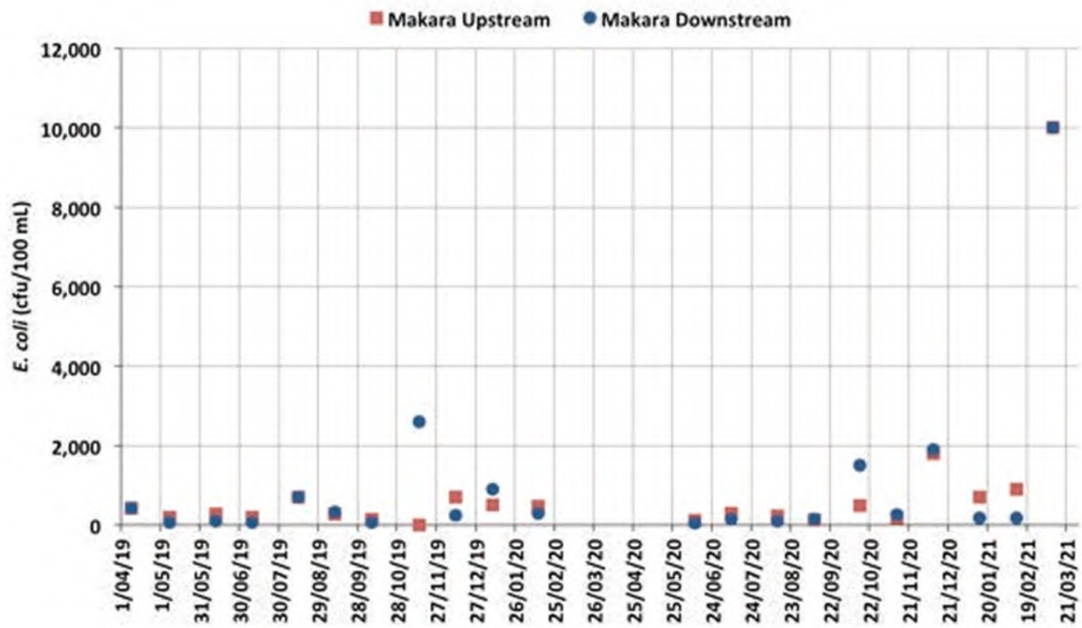


Figure A2.14. E. coli *concentration (cfu/100 mL) at Makara Stream sites, April 2019 – March 2021.*

8.3. Waitara River

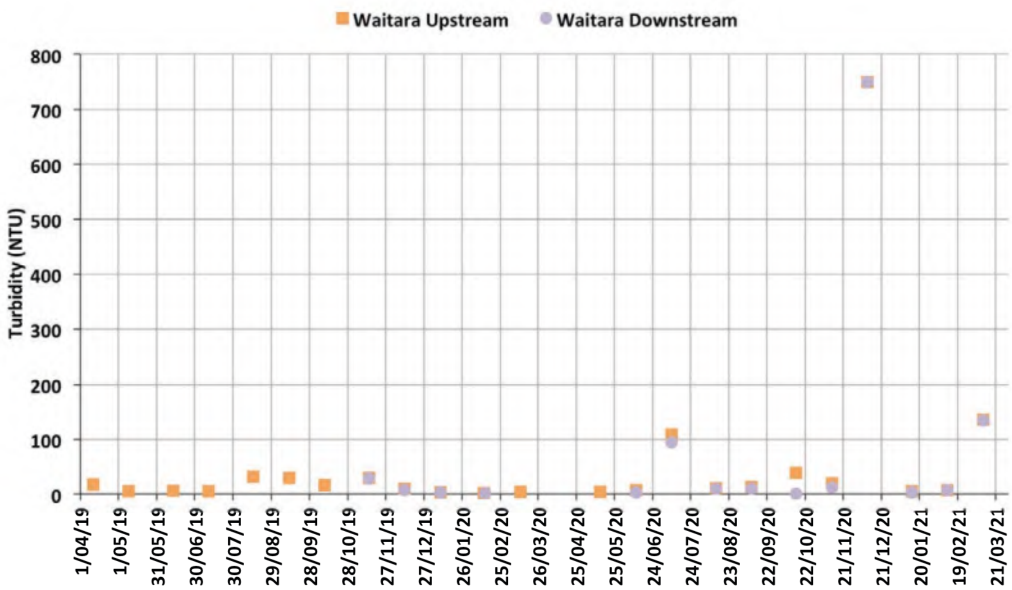


Figure A2.15. *Turbidity level (NTU) at Waitara River sites, April 2019 – March 2021.*

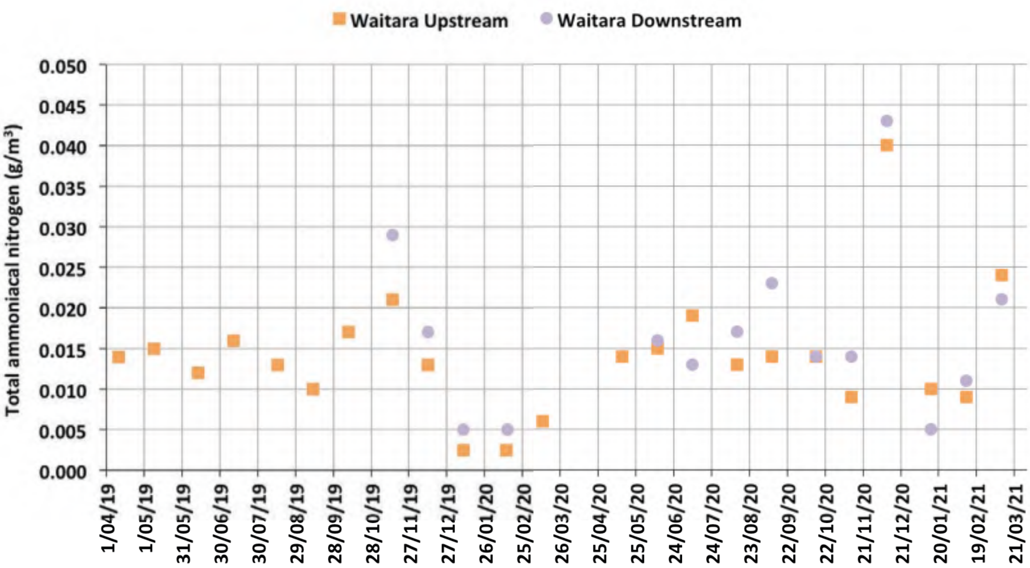


Figure A2.16. *Total ammoniacal nitrogen concentration (g/m^3) at Waitara River sites, April 2019 – March 2021.*

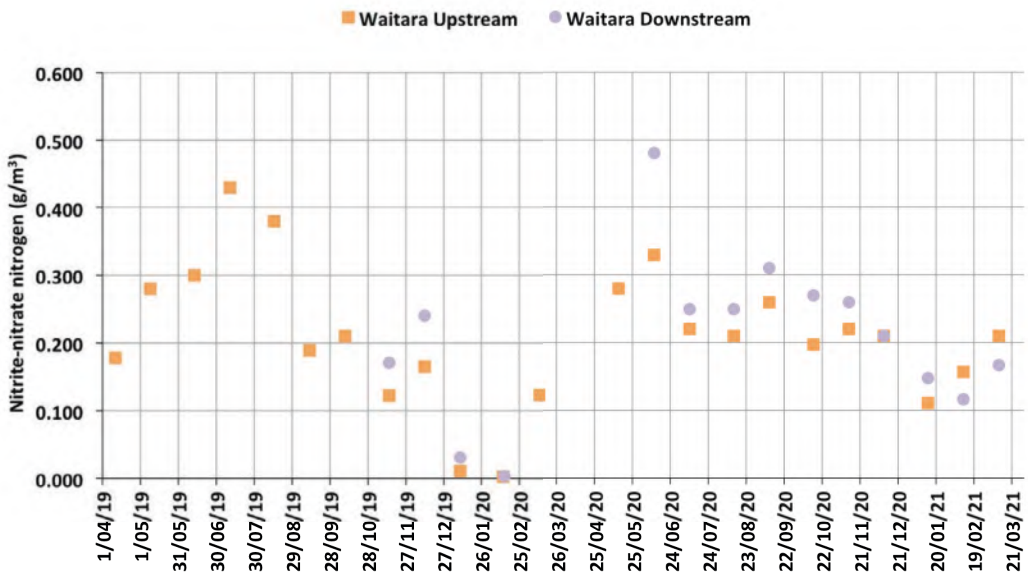


Figure A2.17. *Nitrite-nitrate nitrogen concentration (g/m^3) at Waitara River sites, April 2019 – March 2021.*

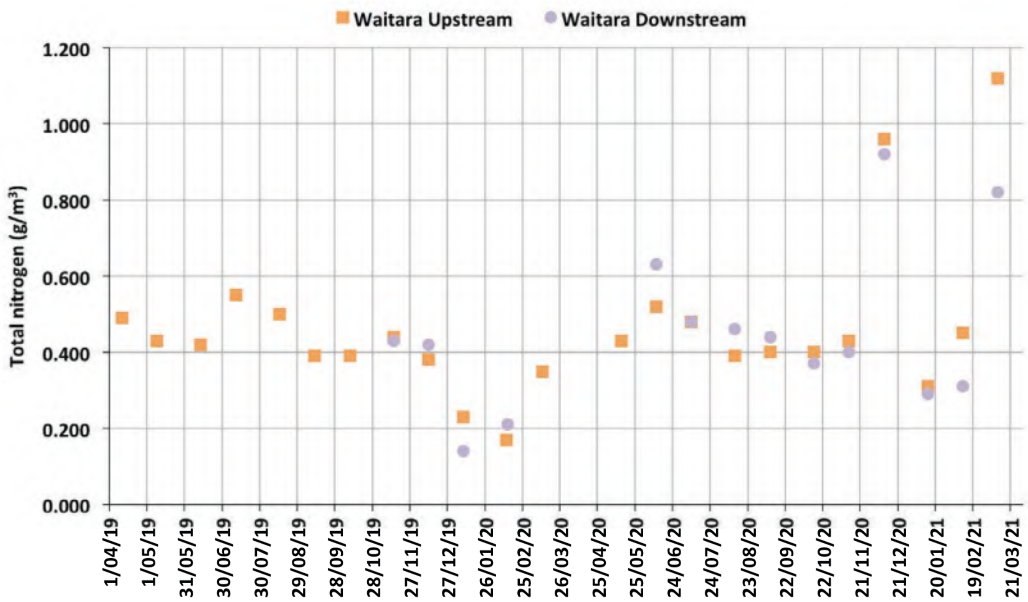


Figure A2.18. *Total nitrogen concentration (g/m^3) at Waitara River sites, April 2019 – March 2021.*

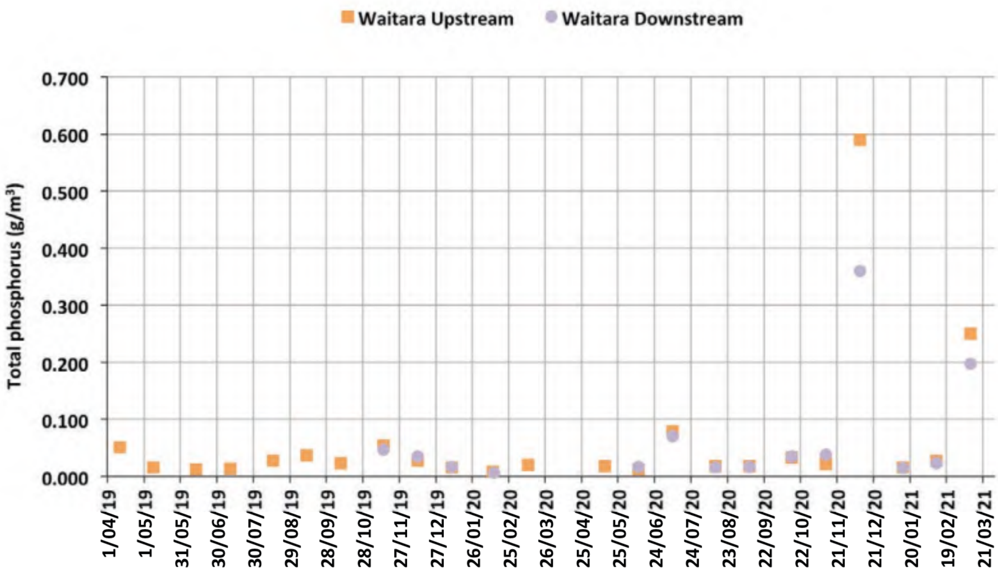


Figure A2.19. *Total phosphorus concentration (g/m^3) at Waitara River sites, April 2019 – March 2021.*

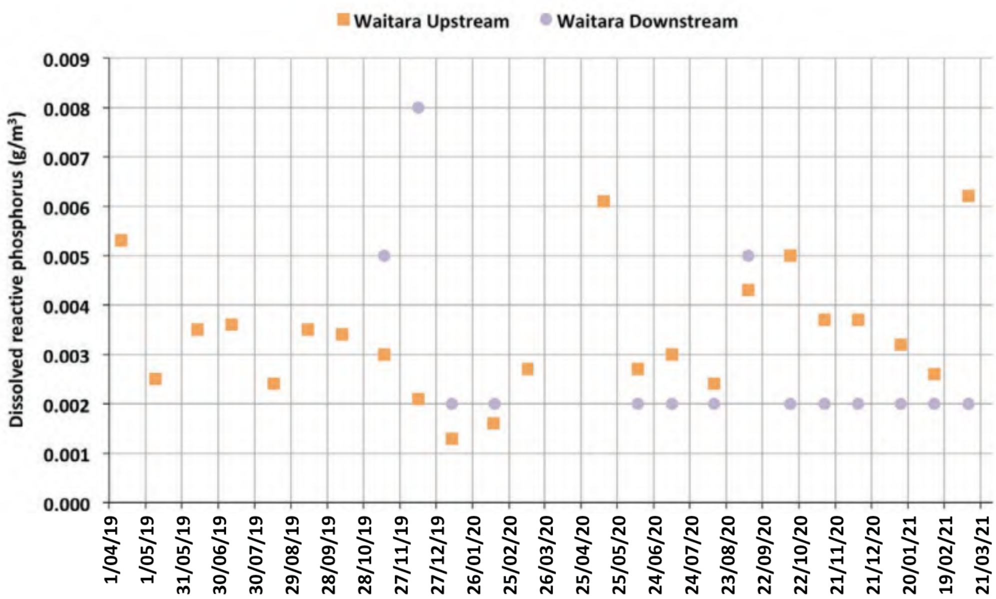


Figure A2.20. *Dissolved reactive phosphorus concentration (g/m^3) at Waitara River sites, April 2019 – March 2021.*

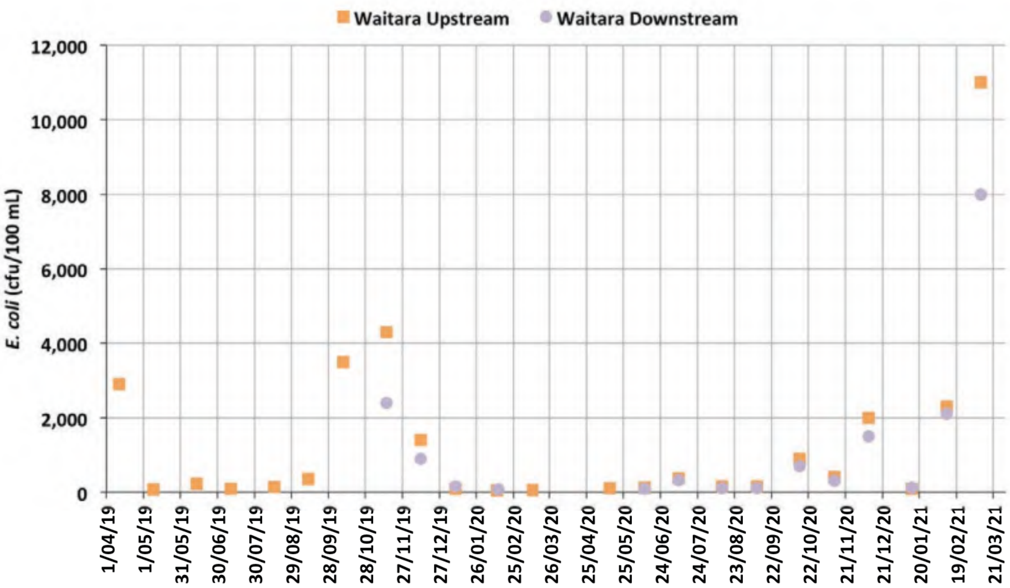


Figure A2.21. E. coli *concentration (cfu/100 mL) at Waitara River sites, April 2019 – March 2021.*

9. Appendix Three: Manganui River benthic macroinvertebrate data

9.1. Manganui River Manganui benthic macroinvertebrate data summary, 2010-2020

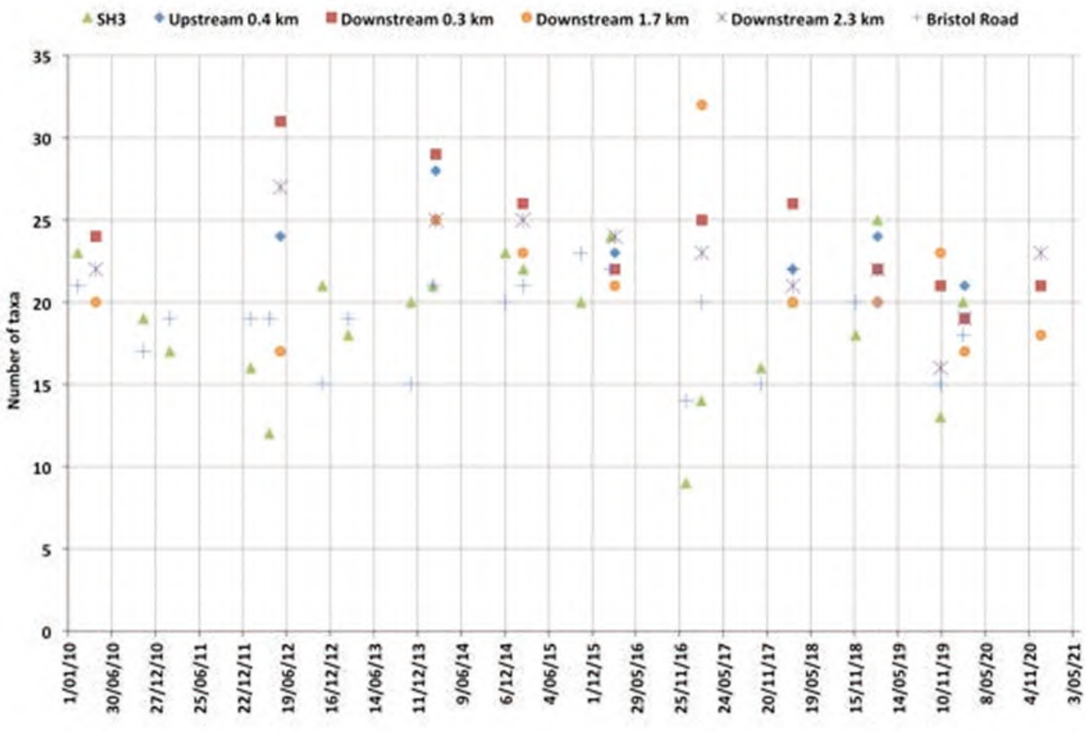


Figure A3.1. *Number of taxa at Manganui River sites, February 2010 – February 2020.*

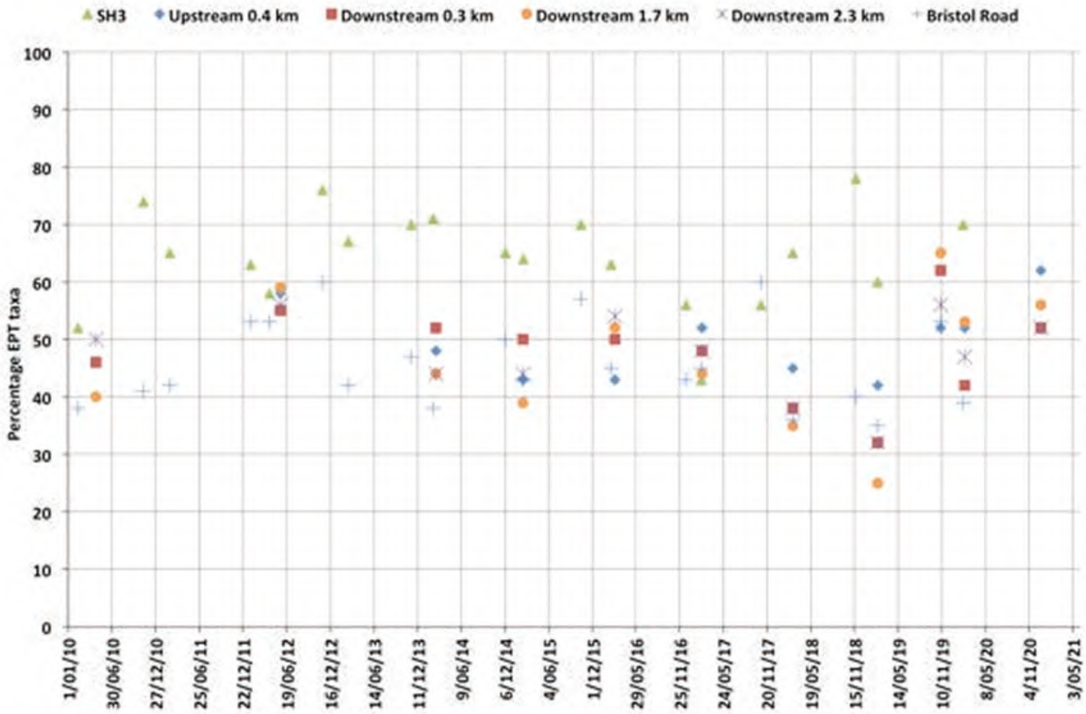


Figure A3.2. *Percentage of EPT taxa at Manganui River sites, March 2010 – February 2020.*

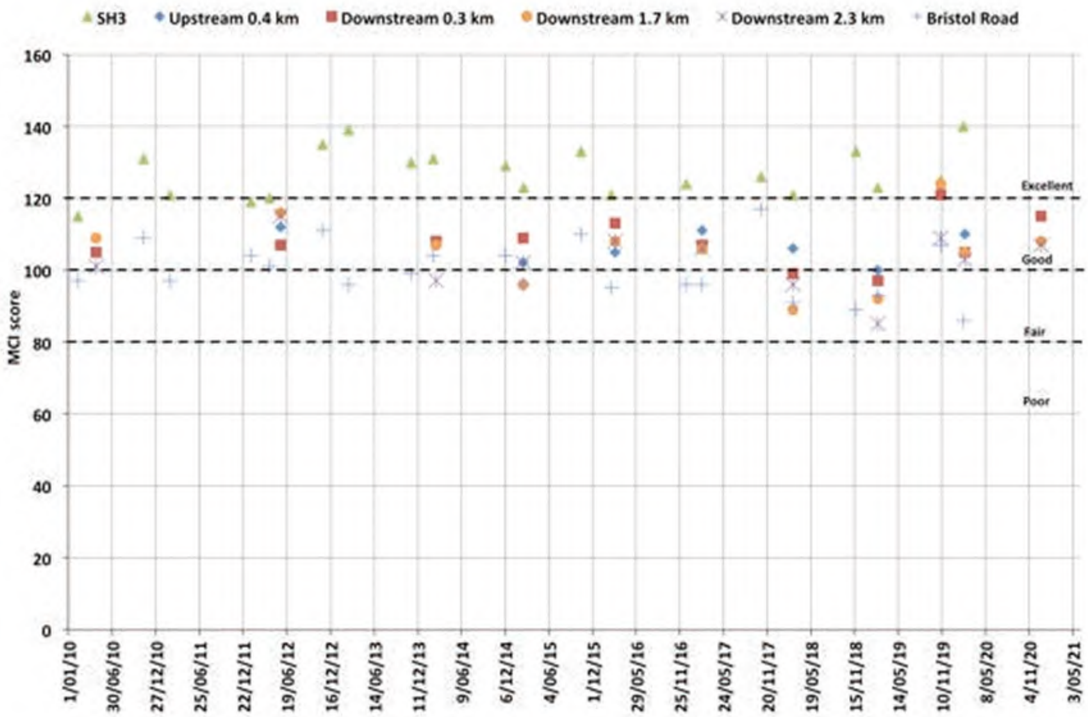


Figure A3.3. *MCI scores at Manganui River sites, March 2010 – February 2020. Interpretations for macroinvertebrate community health based on MCI scores are also shown.*

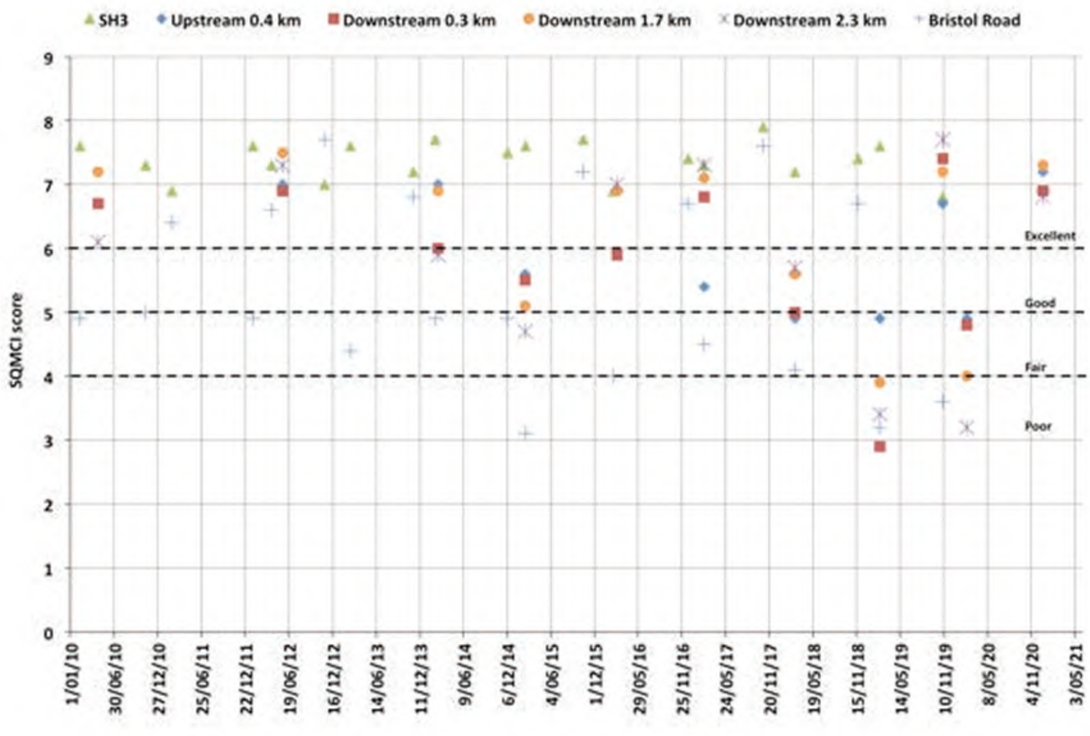


Figure A3.4. *SQMCI scores at Manganui River sites, March 2010 – February 2020. Interpretations for macroinvertebrate community health based on SMCI scores are also shown.*

9.2. Manganui River benthic macroinvertebrate data, November 2019 and December 2020

6 November 2019

Taxa List	Site Code / Sample Number	MCI score	Upstream 0.4 km	Downstream 0.3 km	Downstream 1.7 km	Downstream 2.3 km
			RWC19007	RWC19008	RWC19009	RWC19010
ANNELIDA (WORMS)	Oligochaeta	1	-	-	R	-
	Lumbricidae	5	R	-	-	-
MOLLUSCA	*Potamopyrgus*	4	R	R	A	-
EPHEMEROPTERA (MAYFLIES)	*Ameletopsis*	10	-	-	R	-
	Austroclima	7	R	C	C	-
	Coloburiscus	7	VA	A	A	A
	Deleatidium	8	XA	XA	XA	XA
	Nesameletus	9	C	A	C	A
	Zephlebia group	7	R	R	-	-
PLECOPTERA (STONEFLIES)	*Austroperla*	9	-	R	-	-
	Megaleptoperla	9	R	-	R	-
	Zelandobius	5	-	C	R	C
	Zelandoperla	8	C	R	R	-
COLEOPTERA (BEETLES)	Elmidae	6	A	C	A	C
	Hydraenidae	8	R	C	R	-
	Ptilodactylidae	8	R	-	-	-
MEGALOPTERA	*Archichauliodes*	7	C	A	A	C
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	C	C	A	C
	Costachorema	7	A	C	A	C
	Hydrobiosis	5	C	C	C	R
	Neurochorema	6	-	-	R	-
	Beraeoptera	8	A	A	C	C
	Olinga	9	-	-	R	-
	Pycnocentrodes	5	VA	A	VA	A
DIPTERA (TRUE FLIES)	*Aphrophila*	5	A	A	C	C
	Eriopterini	5	R	-	-	-
	Maoridiamesa	3	VA	A	R	C
	Orthocladiinae	2	A	A	C	C
	Tanytarsini	3	-	R	-	R
	Empididae	3	-	-	-	R
	Austrosimulium	3	R	-	-	-
		Number of Taxa	23	21	23	16
		MCI	122	121	124	109
		SQMCIs	6.7	7.4	7.2	7.7
		EPT (taxa)	12	13	15	9
		% EPT (taxa)	52	62	65	56

'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

22 December 2020

Taxa List	Site Code / Sample Number	MCI score	Upstream 0.4 km RWC20004	Downstream 0.3 km RWC20005	Downstream 1.7 km RWC20006	Downstream 2.3 km RWC20007
ANNELIDA (WORMS)	Oligochaeta	1	-	-	C	R
MOLLUSCA	*Potamopyrgus*	4	R	-	C	R
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	R	C	R	R
	Coloburiscus	7	C	VA	A	VA
	Deleatidium	8	XA	XA	XA	XA
	Nesameletus	9	C	A	C	A
PLECOPTERA (STONEFLIES)	*Zelandobius*	5	R	-	R	R
	Zelandoperla	8	R	R	-	-
COLEOPTERA (BEETLES)	Elmidae	6	A	A	VA	A
	Hydraenidae	8	-	R	-	R
	Staphylinidae	5	-	R	-	-
MEGALOPTERA (DOBSONFLIES)	*Archichauliodes*	7	R	C	A	C
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	A	VA	A	VA
	Costachorema	7	C	A	C	C
	Hydrobiosis	5	C	C	C	C
	Neurochorema	6	R	R	R	R
	Beraeoptera	8	R	R	-	R
	Olinga	9	R	-	-	R
	Pycnocentrodes	5	VA	VA	A	VA
DIPTERA (TRUE FLIES)	*Aphrophila*	5	C	A	R	C
	Eriopterini	5	-	R	-	-
	Limonia	6	-	-	-	-
	Maoridiamesa	3	C	C	-	C
	Orthocladiinae	2	C	C	R	A
	Tanypodinae	5	-	-	R	-
	Tanytarsini	3	R	R	-	R
	Empididae	3	-	-	-	-
	Psychodidae	1	-	-	-	R
	Austrosimulium	3	R	R	-	C
	Tanyderidae	4	-	-	R	-
		Number of Taxa	21	21	18	23
		MCI	115	115	108	107
		SQMCIs	7.2	6.9	7.3	6.8
		EPT (taxa)	13	11	10	12
		% EPT (taxa)	62	52	56	52

'Tolerant' taxa | 'Moderately sensitive' taxa | 'Highly sensitive' taxa

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

10. Appendix Four: NZFFD records for longfin eel

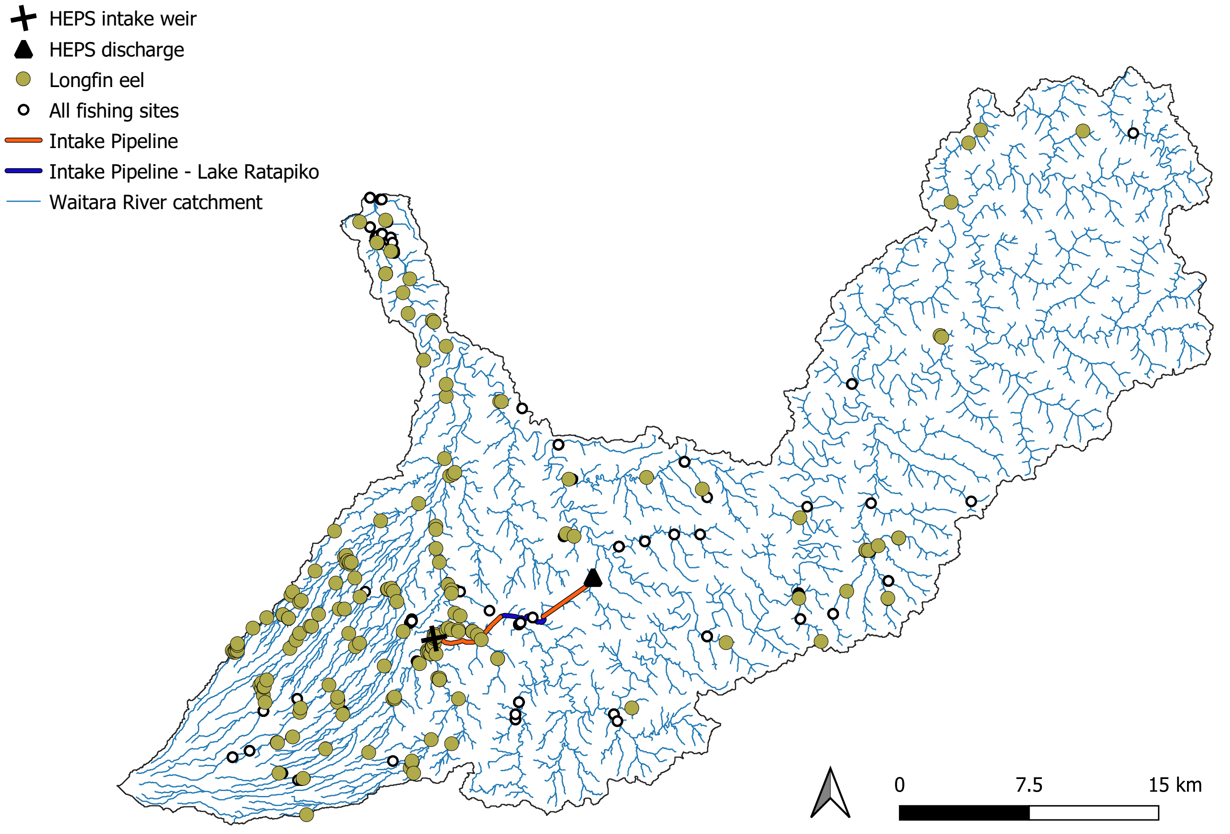


Figure A4.1. *NZFFD records for longfin eel in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

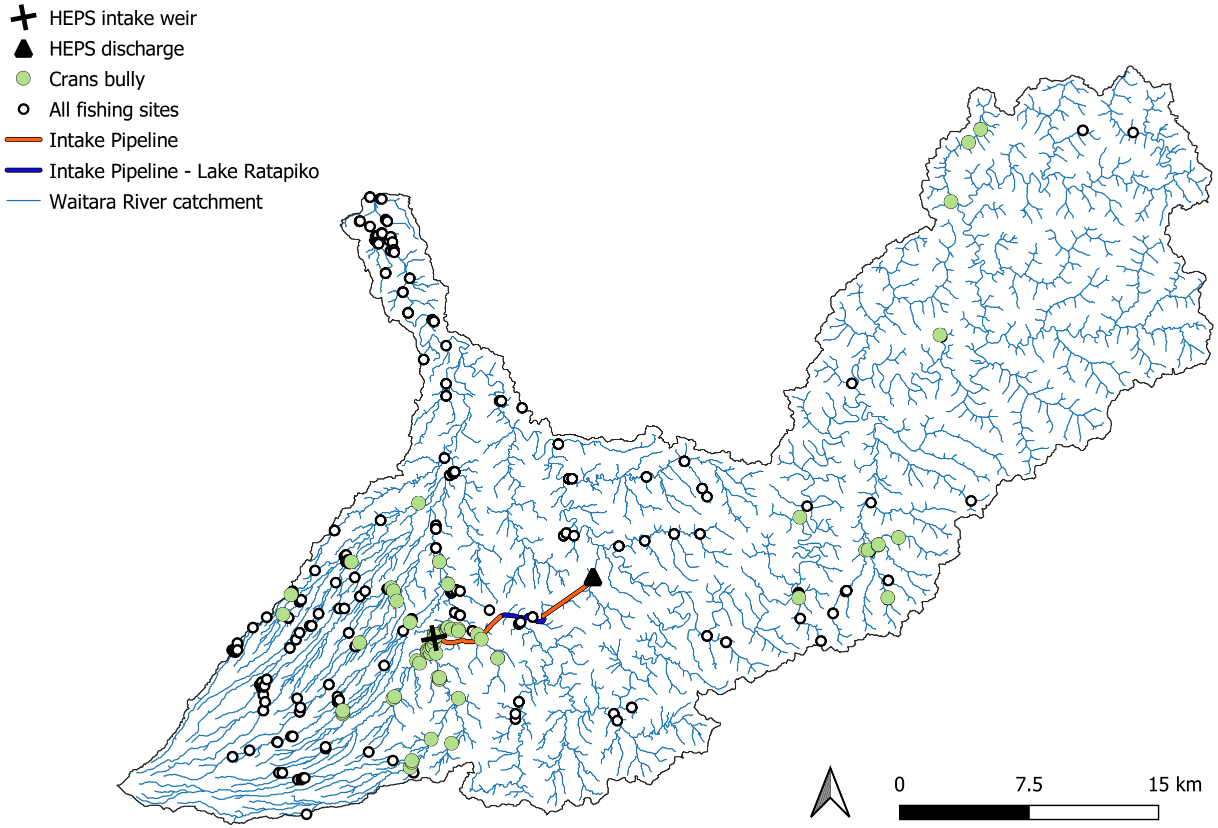


Figure A4.2. *NZFFD records for Cran's bully in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

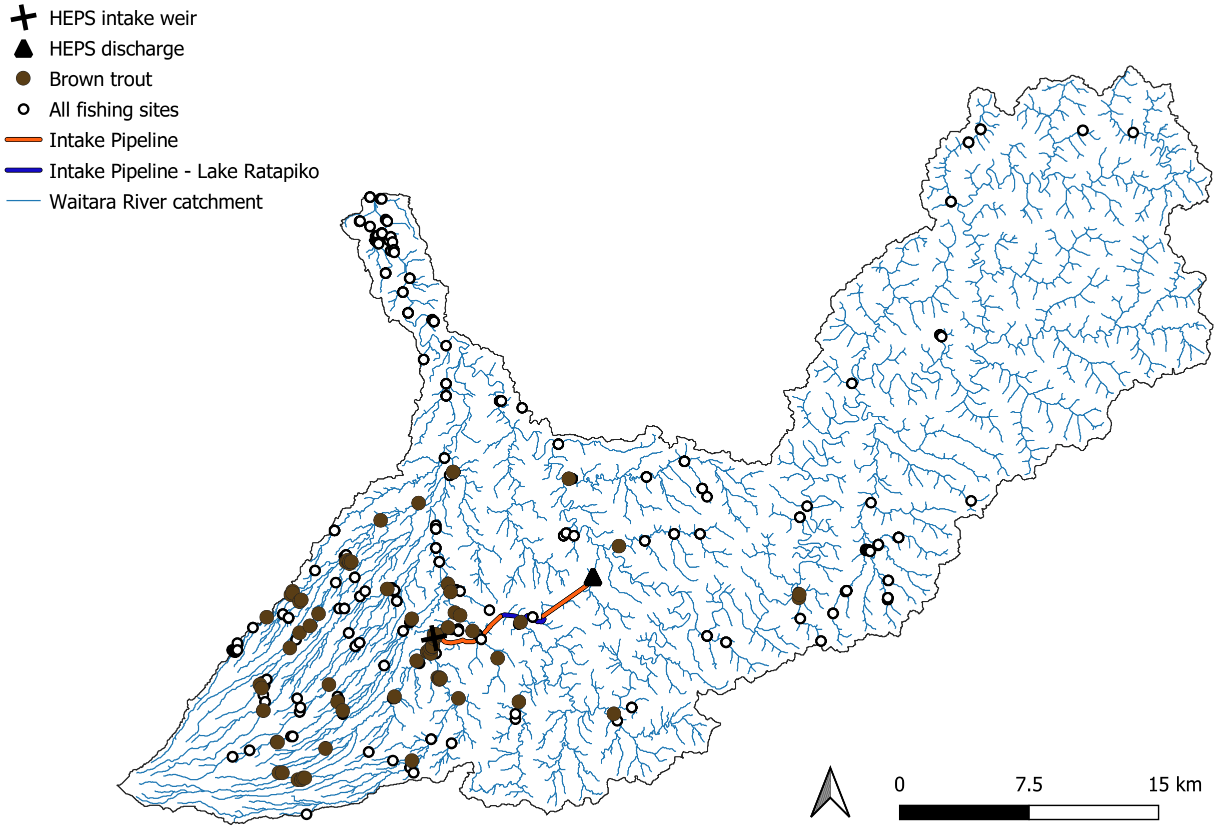


Figure A4.3. *NZFFD records for <u>brown trout</u> in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

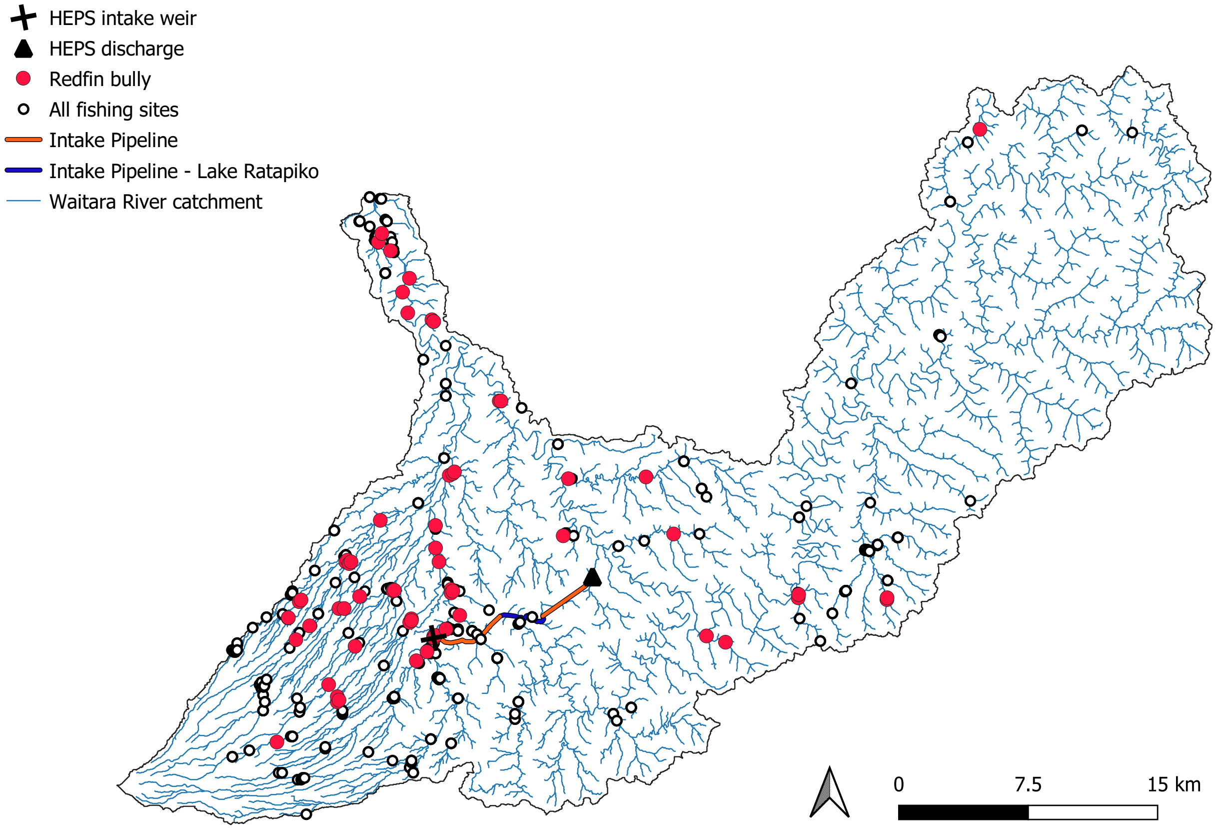


Figure A4.4. *NZFFD records for redfin bully in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

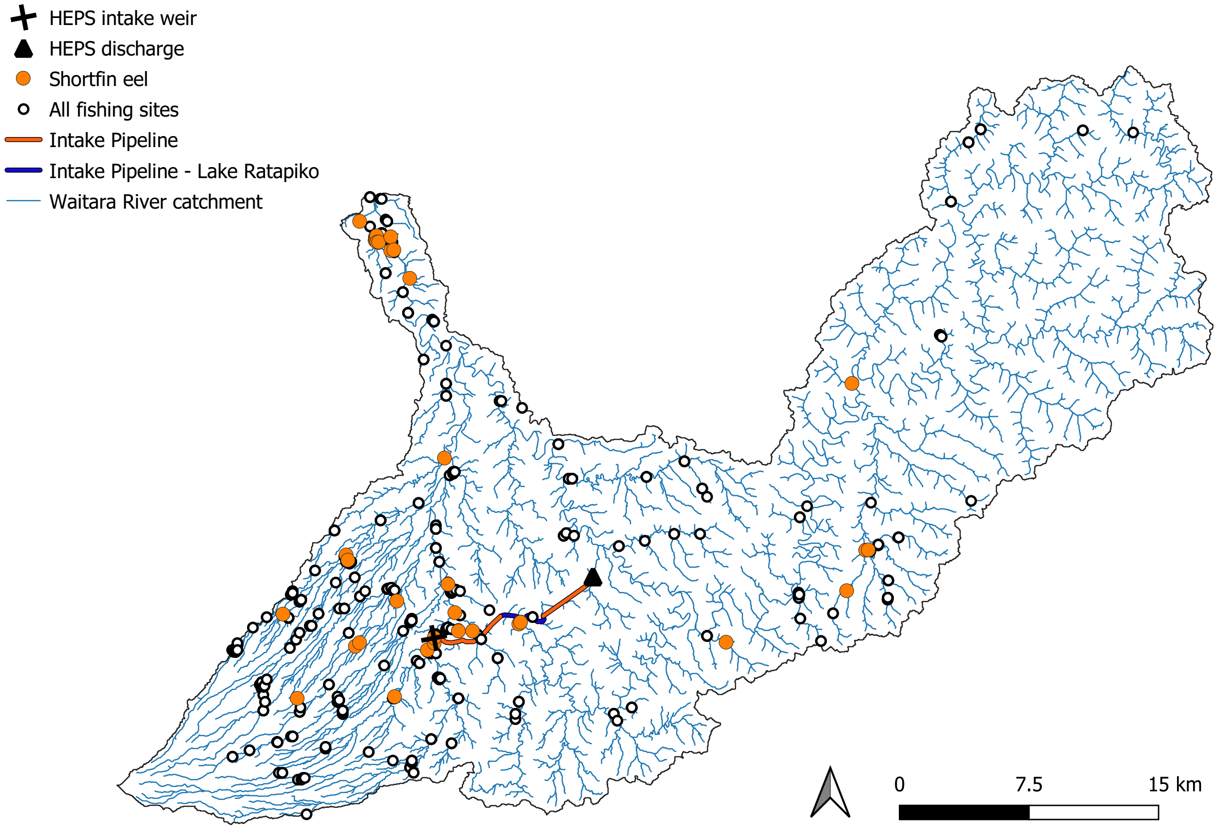


Figure A4.5. *NZFFD records for* <u>*shortfin eel*</u> *in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

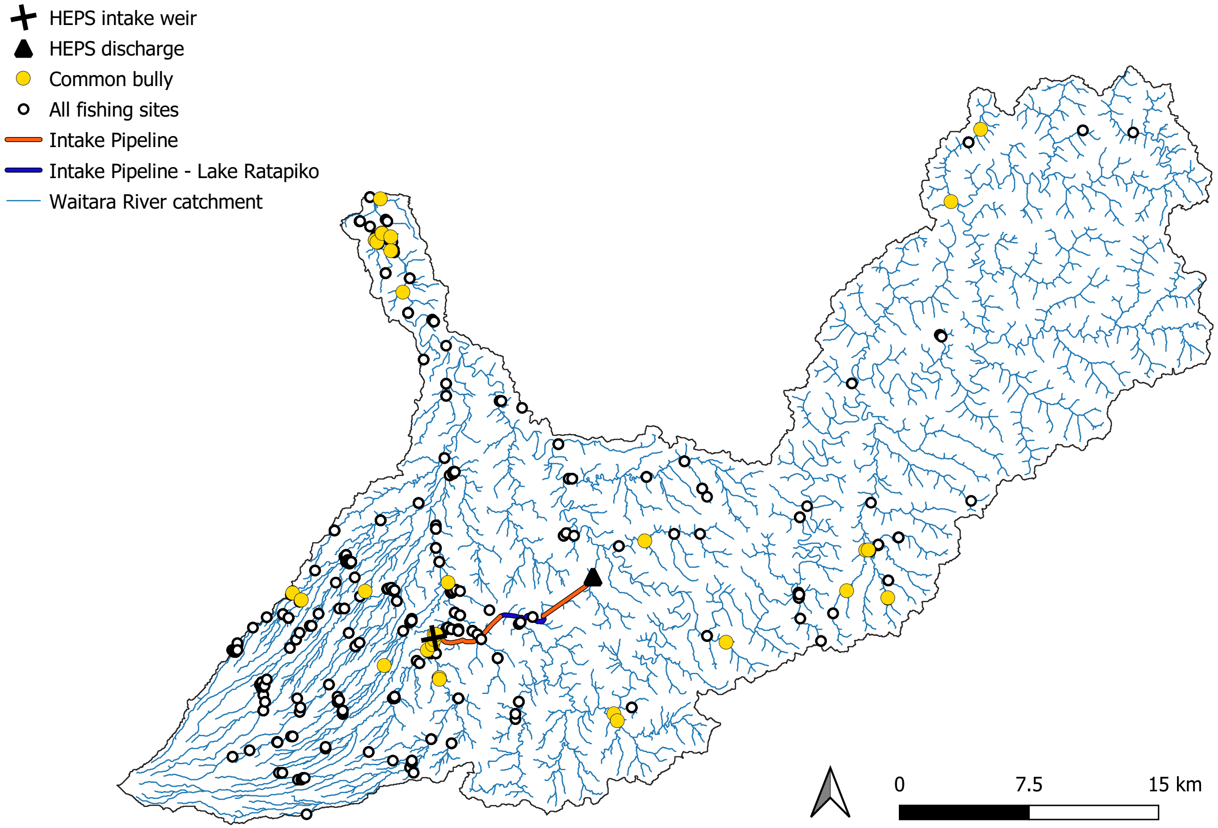


Figure A4.6. *NZFFD records for* <u>*common bully*</u> *in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

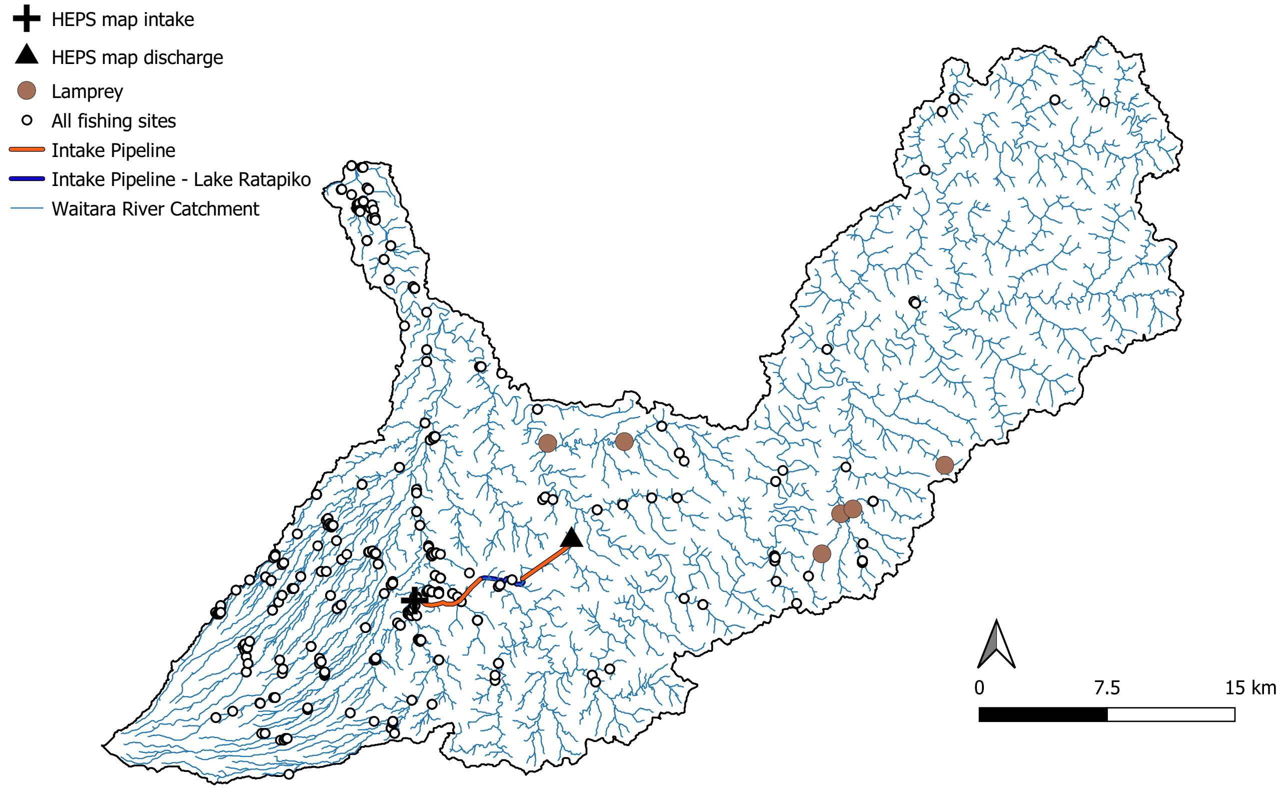


Figure A4.7. *NZFFD records for <u>lamprey</u> in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

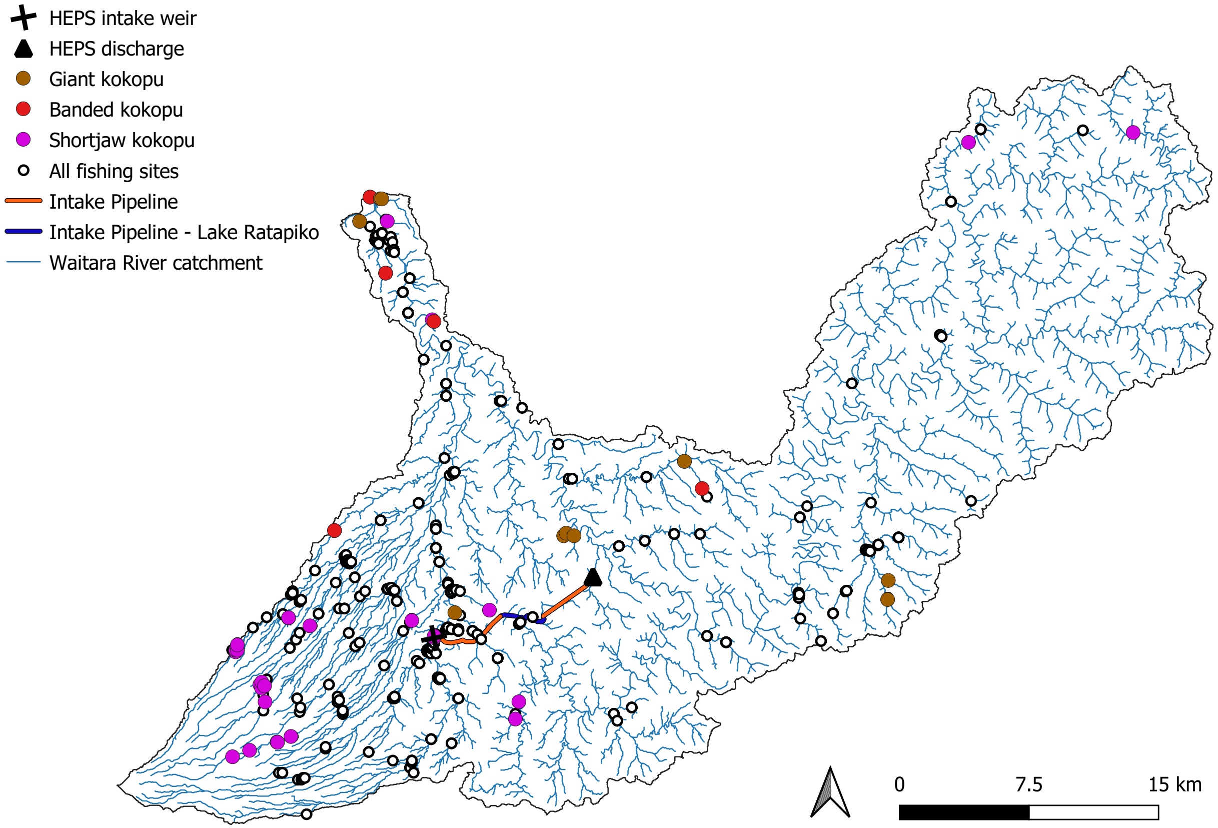


Figure A4.8. *NZFFD records for* *<u>kokopu species</u>* *in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

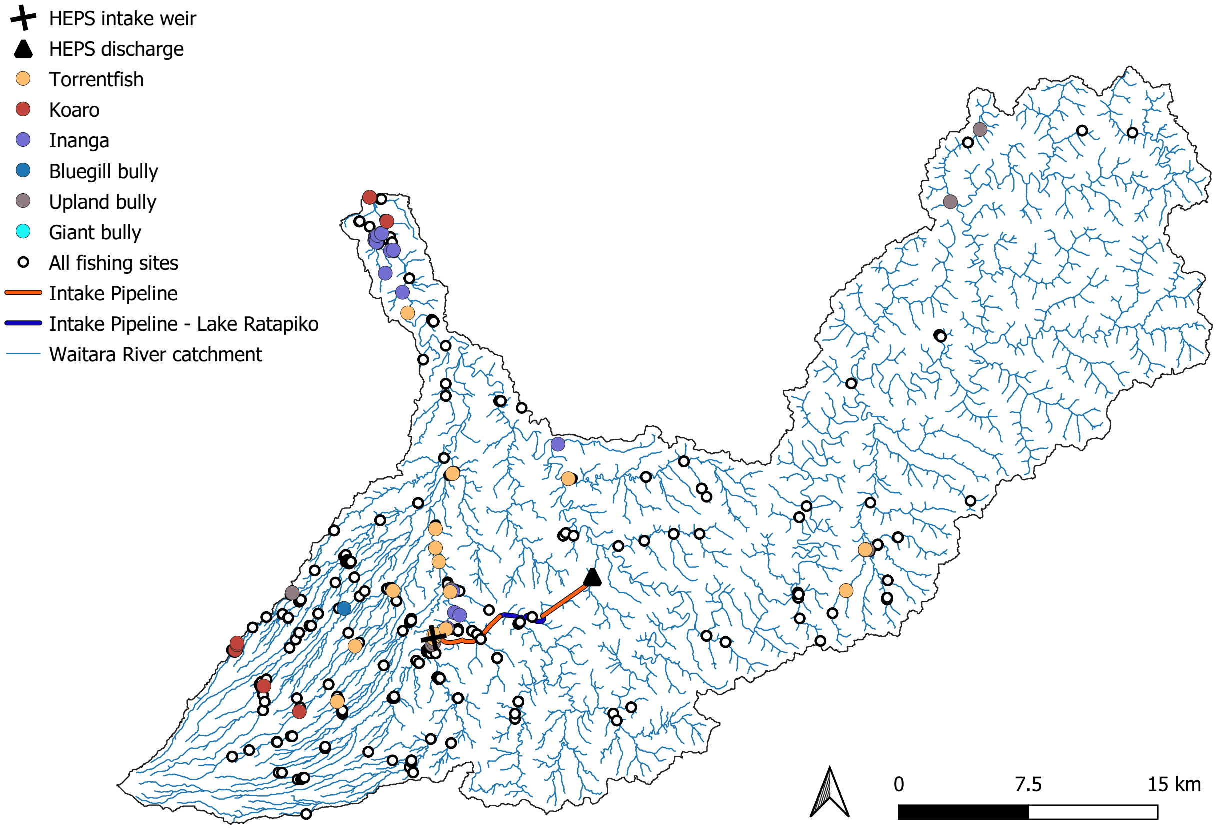


Figure A4.9. *NZFFD records for <u>low occurrence native species</u> in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

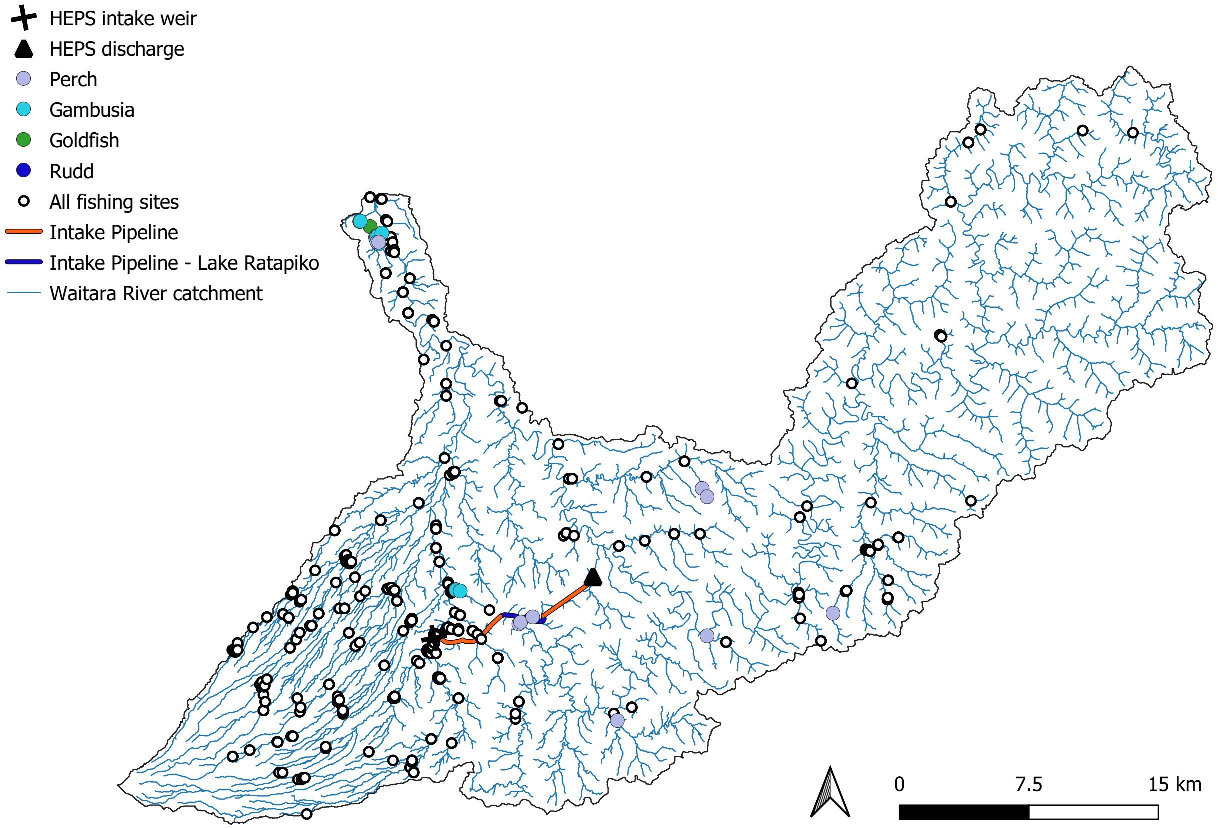


Figure A4.10. *NZFFD records for <u>low occurrence non-native species</u> in the Waitara River catchment (including the Manganui River). Open circles show the location of all sites with NZFFD records.*

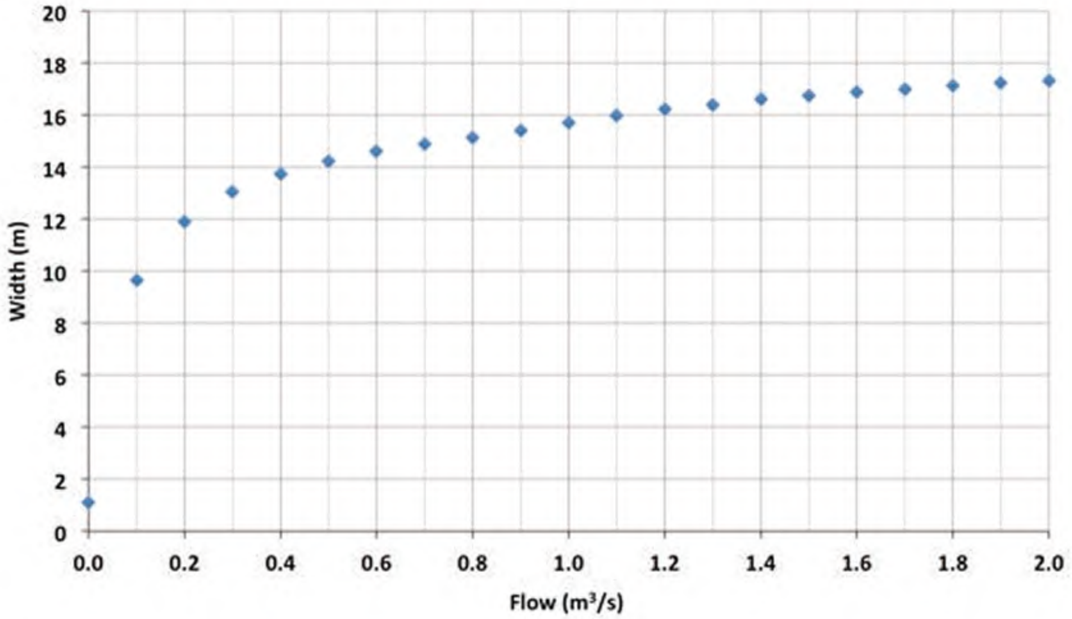
Table A4.1. *February 2020 and February 2021 fish survey methodology information for the Manganui and Waitara River catchments. Note that the range of habitats present at each site were surveyed. The 'habitat' column provides a general indication of the type of habitat present. All nets were baited and set overnight. Three eDNA samples were collected from the Manganui River: 400 m upstream site. At all other eDNA sampling sites one sample was collected.*

Site	Reference	Electric fishing		Minnow trapping		Spotlighting	eDNA
		Electrode live time (minutes)	Habitat	Number of traps set	Habitat		
Te Popo Stream: at Pembroke Road	E1698863 N5647950					✓	
Te Popo Stream: at SH3	E1708965 N5650543	13	Medium-fast riffle, slow-medium run				✓
Unnamed true right tributary of Manganui River: at Kaiapoi Road	E1711145 N5652240			3	Slow run/pool		
Manganui River: at Croydon Road	E1710432 N5655993	8	Fast-very fast riffle, slow-medium run				✓
Manganui River: 400 m upstream of HEPS intake	E1710005 N5657893	12	Fast-very fast riffle				✓ 3 samples
Manganui River: weir fish pass	E1710132 N5658363	10	Fast riffle, medium run	6	Slow run		
Manganui River: 750 m downstream of HEPS intake	E1710352 N5658447	5	Medium-fast riffle				
Manganui River: 3 km downstream of HEPS intake	E1711008 N5658793						✓
Manganui River: at Bristol Road	E1711125 N5667840						✓
Mako Stream: upstream of Lake Ratapiko	E1716418 N5659863	4	Slow run				
Mako Stream: downstream of Lake Ratapiko spillway	E1715158 N5659159			3	Slow run		
Mako Stream: at Mana Road	E1715808 N5658756			3	Slow run		
Mako Stream: at Makara Road	E1716449 N5656644	2	Medium riffle, slow-medium run				
Makara Stream: upstream of tailrace confluence	E1719272 N5660957						✓
Unnamed true left tributary of Makara Stream: upstream of tailrace confluence	E1719319 N5661857					✓	✓
Motukawa HEPS tailrace	E1719365 N5661913					✓	
Motukawa HEPS tailrace fish trap	E1719365 N5661913					✓	

11. Appendix Five: Instream habitat model

Table A5.1. *Habitat suitability curves used in IFIM analysis.*

Common name	Life history stage	Habitat suitability curve
Benthic invertebrate density		Jowett (2019)
Food producing habitat		Waters (1976)
Brown trout	Adult (> 400 mm)	Hayes and Jowett (1994)
	Juvenile (7-170 mm)	Thomas and Bovee (1993)
	Yearling (< 100 mm)	Raleigh *et al.* (1986)
Cran's bully		Jowett and Richardson (2008)
Inanga	Feeding	Jowett (2002)
Lamprey		Jowett and Richardson (2008)
Longfin eel	< 300 mm	Jowett and Richardson (2008)
	> 300 mm	Jowett and Richardson (2008)
Redfin bully		Jowett and Richardson (2008)
Shortfin eel	< 300 mm	Jowett and Richardson (2008)
	> 300 mm	Jowett and Richardson (2008)
Shortjaw kokopu		McDowall *et al.* (1996)
Torrentfish		Jowett and Richardson (2008)



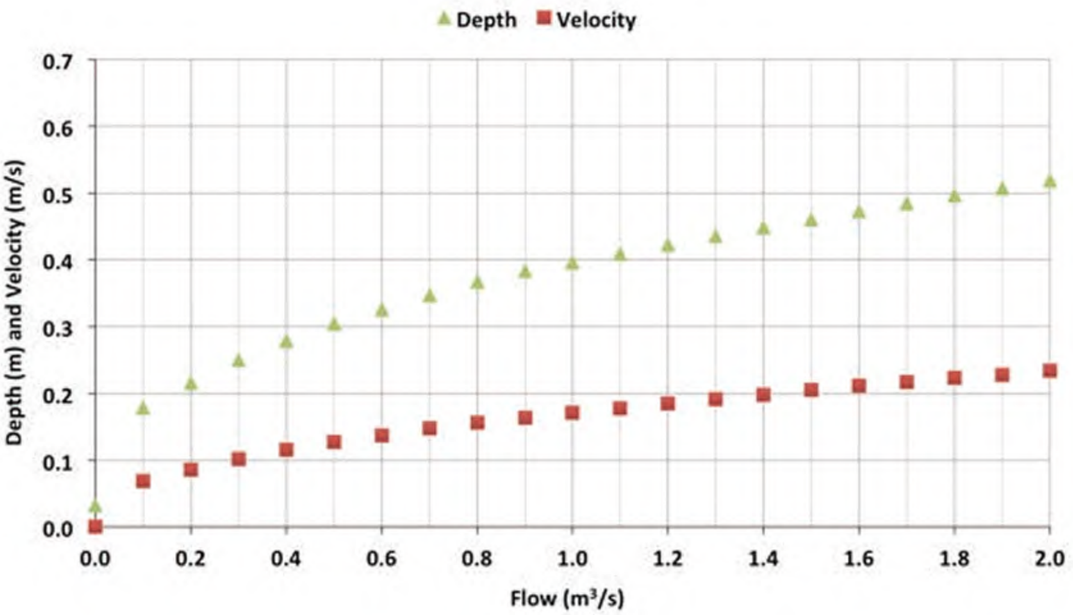


Figure A5.1. *Variation in average width (m), depth (m), and velocity (m/s) with flow in the Manganui River upstream and downstream of the Motukawa HEPS (combined Jowett (1993) and Kingett Mitchell (2005) models).*