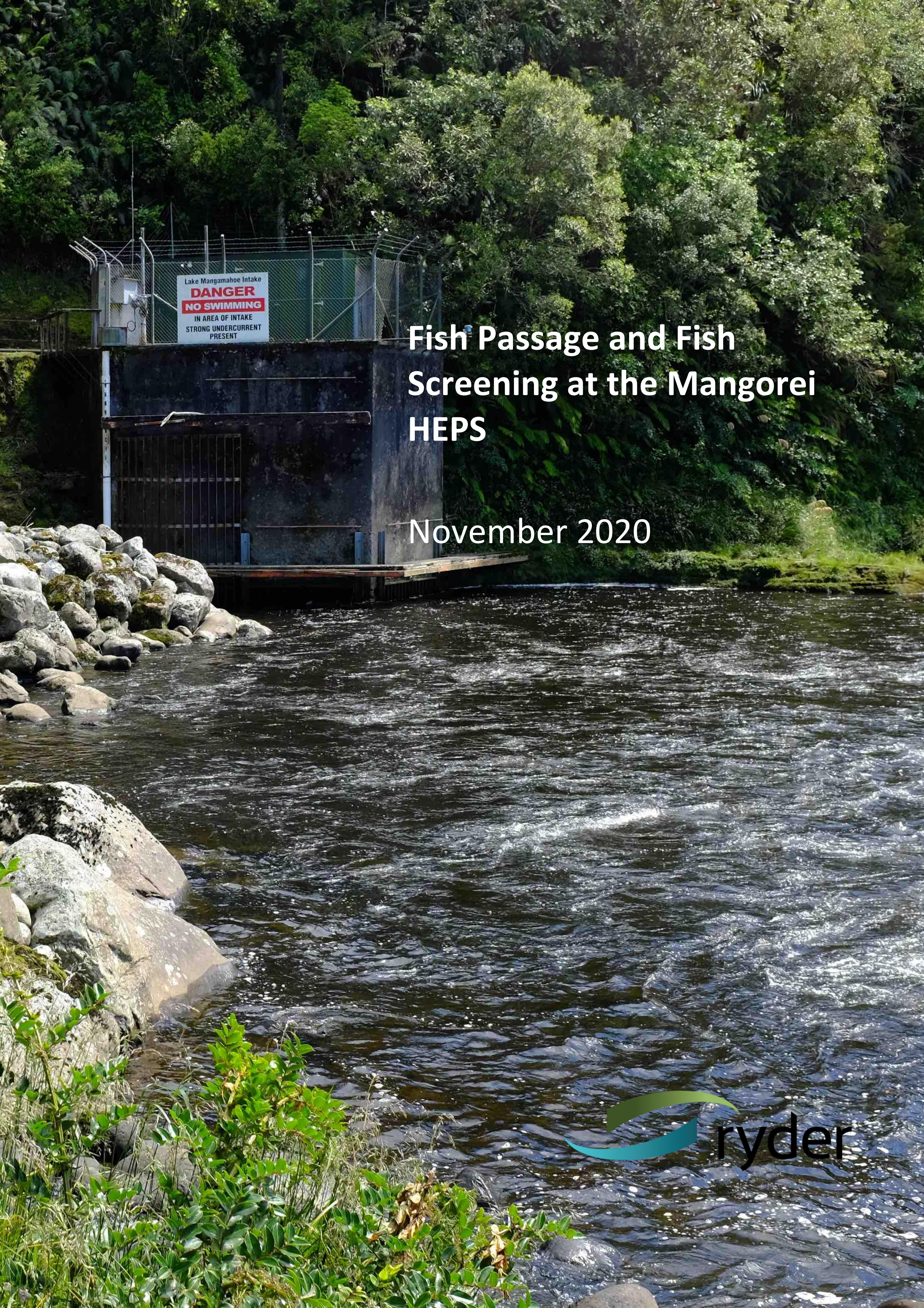
H

APPENDIX H

Fish Passage and Fish Screening Assessment – Ryder Environmental Limited

Fish Passage and Fish Screening at the Mangorei HEPS

November 2020



ryder

Fish Passage and Fish Screening at the Mangorei HEPS

NOVEMBER 2020

Prepared for Trustpower

by

Greg Ryder, PhD.

Ryder Environmental Limited
195 Rattray Street
PO Box 1023
DUNEDIN, 9054
New Zealand
Phone: 03 477 2119

Document version: 17 November 2020 (Final)

Cover page: Mangorei HEPS intake on the Waiwhakaiho River, November 2018 (photo: G. Ryder).

Table of Contents

1 Introduction

1.1 Background

Trustpower has commenced a reconsenting process for the Mangorei Hydro-Electric Power Scheme (the scheme or HEPS) in Taranaki. Currently, information is being gathered to assess potential effects of the scheme on (among other things) aquatic ecology and water quality. Part of this process includes an assessment of the scheme on fish entrainment and fish screening, which is the focus of this report. This report does not address whether it is practicable to retrofit the HEPS with screens to exclude fish species from becoming entrained in the diversion to Lake Mangamahoe or the scheme's penstocks.

1.2 Scheme physical description

The Mangorei scheme is located within the Waiwhakaiho River catchment to the south of New Plymouth (Figure 1). The Waiwhakaiho River catchment covers an area of approximately 13,590 hectares with the upper catchment lying inside Egmont National Park. The river flows in an easterly direction with its mouth situated in the city of New Plymouth (TRC 2019[1]).

The scheme diverts water from the Waiwhakaiho River into man-made Lake Mangamahoe, from where it is directed through an intake to penstocks which carry the water through to the Mangorei Power Station. Generation water from the Mangorei Power Station is returned back to the Waiwhakaiho River, at a site known as the Meeting of the Waters, six kilometres downstream of the original diversion.

There is no dam on the Waiwhakaiho River, rather a low-head concrete weir is situated just downstream of an intake gate (Figure 2). The weir structure includes a fish pass on the true right side of the river. The bulk of residual flow is passed down the fish pass under low flow conditions.

The scheme's Waiwhakaiho River intake is situated on the true left bank (Figure 3). Its location is downstream of a large rapid-run feature (Figure 4) that flows into a section of deeper, slower flowing water created by the weir. The bank immediately upstream of the intake has been armoured with large boulders. The fish pass is located just downstream (below the concrete weir) on the opposite side of the river. The harsh nature of the river (steep gradient, boulder substrate and frequent freshes) has meant the fish pass requires regular maintenance to remove substrate.

Tonkin & Taylor estimate a 7-day MALF of 2.11 m^3/sec at Egmont Village, 2km upstream of the intake (David Leong 2020[2]). The resource consents authorised the scheme to divert up to 10 m^3/sec from the river, and require the maintenance of a residual flow of between 0.4 m^3/sec (1 May - 31 October), 0.6 m^3/sec (1 November-31 December and 1-30 April) and 0.7 m^3/sec (1 January and 31 March) downstream of the intake. No water can be diverted when the flow in the Waiwhakaiho River is greater than or equal to 85 m^3/s. This means any fish species migrating downstream during flood flows greater than 85 m^3/s bypass the scheme's Waiwhakaiho River intake.

The scheme's intake on the Waiwhakaiho River diverts water into Lake Mangamahoe via an approximately 580 m long tunnel (Figure 1). Lake Mangamahoe (Figure 5) was formed by damming the Mangamahoe Stream with an earth dam and associated concrete spillway (Figure 6). The spillway has no residual flow to the lower Mangamahoe Stream although seepage water and spill flows maintain some flow down the spillway most of the time.

The scheme's intake to the Mangorei power station penstocks is located in an arm at the northern end

[1] TRC. 2019. Freshwater Macroinvertebrate Fauna Biological Monitoring Programme Annual State of the Environment Monitoring Report 2017-2018: Technical Report 2018-61 (and Report DS104). Document: 2277172

[2] Leong, D. 2020. Reconsenting of Mangorei Hydroelectric Power Scheme: Hydrology Report. Prepared for Chancery Green on behalf of Trustpower Limited, July 2020.

of Lake Mangamahoe (Figure 1 and Figure 7). The structure consists of four intake gates and a manually operated trash screen.

The penstocks feed into the Mangorei Power Station and generation water from the power station is discharged back to the Waiwhakaiho River via a 250 m long open canal (Figure 8).

Figure 1. *Aerial showing location of structures and surface waters associated with the Mangorei HEPS.*

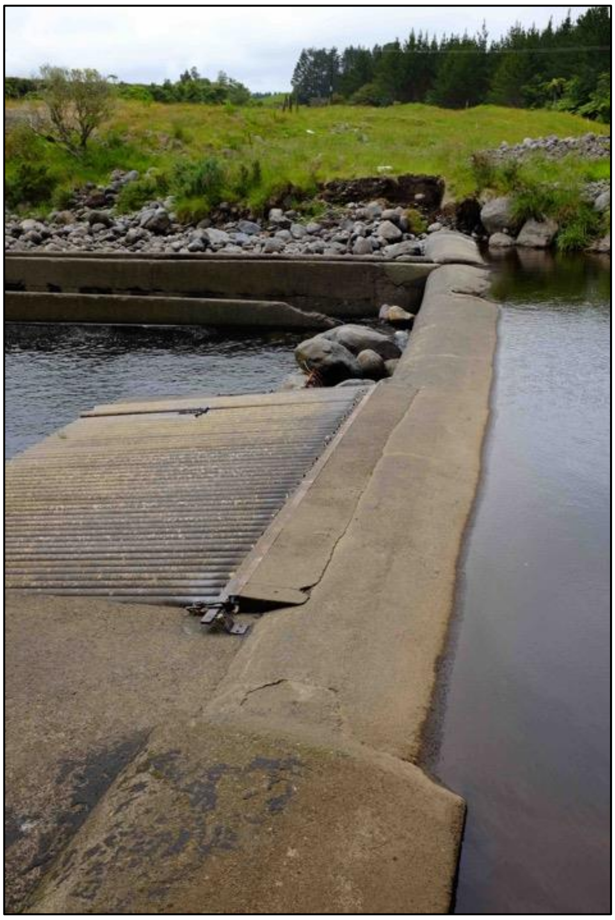


Figure 2. *Mangorei HEPS low-head weir on the Waiwhakaiho River. Part of the fish pass can be seen in the background.*

Figure 3. *Mangorei HEPS intake structure on the Waiwhakaiho River.*

Figure 4. *Waiwhakaiho River upstream of the Mangorei HEPS intake structure.*

Figure 5. *Mangorei HEPS Waiwhakaiho River intake gate trash rack.*

Figure 6. *Lake Mangamahoe looking towards Mount Taranaki.*

Figure 7. *Standing on the Lake Mangamahoe earth dam looking towards the concrete spillway.*

Figure 8. *Mangorei HEPS intake to penstocks at Lake Mangamahoe.*

Figure 9. *Mangorei Power Station with tailrace canal in the foreground. Part of the penstocks can just be seen in the top right of the photo.*

1.3 Report objectives

This report presents an assessment of fish screening considerations for the Mangorei scheme and relies on existing information including:

- the known distribution of fish species in the Waiwhakaiho River catchment;
- ecological values recognised in the Waiwhakaiho River catchment;
- the existing structures associated with the scheme that may influence fish movement and fish mortality;
- any other information that may have relevance with respect to fish screening in Taranaki and New Zealand more generally.

Structures associated with the scheme that may affect fish passage have all been inspected and assessed for potential effects. Further, fish surveys of the river upstream and downstream of the structures, and within Lake Mangamahoe, have recently been undertaken. Tools such as the NZ Fish Passage Assessment Tool provide limited additional information over what has already been gathered on site.

2 Fish distribution and related freshwater ecological values of the Waiwhakaiho River catchment

2.1 General

Existing data and reports were reviewed to gain an understanding of the fisheries of the Waiwhakaiho River catchment and to place these into some context with respect to the issues and values identified in Taranaki Regional Council documents.

2.2 Known fish distribution

The NZ freshwater fisheries database (NZFFD) was interrogated for fish survey records in the Waiwhakaiho River catchment and information extracted from it was used to generate maps of known fish distribution. The data from the database are graphically presented in Appendix 1 and other relevant information is described in the following sections.

Banded, giant and shortjaw kokopu, koaro, lamprey, redfin bully, torrentfish and both longfin and shortfin eel have been recorded upstream of the Waiwhakaiho River intake to Lake Mangamahoe. Longfin eel have also been recorded in Mangamahoe Stream upstream of Lake Mangamahoe along with brown trout (Appendix 1). Brown trout and longfin eel are widely distributed throughout the catchment.

Jowett (2018[3]) summarised fish data for nine Taranaki rivers, including the Waiwhakaiho River. He noted that, generally speaking, rivers with access to the coast are dominated by diadromous fish species, which migrate from the sea as juveniles and spend their adult lives in freshwater. He observed that a similar species assemblage was found in each of the nine rivers, with longfin and shortfin eels, brown trout, common bullies and inanga in most rivers. He also considered that the species list was probably not comprehensive and additional sampling is likely to find that more native fish species are present than currently recorded. Of note is that the Jowett analysis found the Waiwhakaiho River to have the highest fish diversity of the nine rivers assessed.

It is also interesting to note that there are no NZFFD records for Lake Mangamahoe. Taranaki Fish &

[3] Jowett, I.G. 2018. Review of Minimum Flows and Water Allocation in Taranaki. Prepared for Taranaki Regional Council by Jowett Consulting Ltd. Client Report: IJ1702

Game's website states that the lake is the region's most popular lake fishery, holding brown trout up to 2.6 kg and rainbow trout up to 2.25 kg. Modest numbers of adipose fin-clipped hatchery rainbow trout are released annually to maintain the rainbow trout fishery.

2.3 Existing ecological values

A TRC report was prepared in 2016 to inform a review of the Regional Freshwater Plan for Taranaki by assessing, evaluating and identifying freshwater bodies determined to be 'outstanding' (TRC 2016[4]). This report also identified freshwater bodies not otherwise identified as 'outstanding', but still considered to be 'regionally significant' for their natural character, features, and/or amenity, recreational, fishery, ecological, cultural or historical associations. The report identified 52 rivers and lakes in the Taranaki region as having attributes or values that were deemed 'regionally significant'. The Waiwhakaiho River (and tributaries) was deemed regionally significant for:

- Contact recreation (locations: Merrilands Domain, Burgess Park/Meeting of the Waters Scenic Reserve ("power house pool"), Rimu Street extension, Strandon and Adjacent to Lake Rotomanu.
- **Fishery values for trout** (Main stem, Mangorei Stream, Kai Auai Stream, Lake Rotomanu and Lake Mangamahoe) and whitebait.
- **Spawning habitat for trout** (Main stem, Kai Auai Stream, Araheke Stream, Mangamahoe Stream, Mangawarawara Stream, Mangakotutuku Stream, Mangorei Stream) and whitebait habitat (1 km upstream of river mouth).
- **Native fisheries habitat values** (Includes main stem, Araheke Stm, Kai Auahi Stm, Korito Stm, Mangamahoe Stm, Manganaha Stm, Mangaone Stm, Mangaotukutuku Stm, Mangawarawara Stm, Mangorei Stm, Taruawakanga Stm, unnamed wetland) for the following species: Banded kokopu, Giant kokopu, Koaro, Inanga, Lamprey, Longfin eel, Short-jawed kokopu.

The Draft Freshwater and Land Management Plan for Taranaki identified four freshwater management units (FMUs) for the region, including one for 'Outstanding freshwater bodies' (Freshwater Management Unit A). The Waiwhakaiho River catchment is included in the Freshwater Management Unit B: Volcanic ring plain. The draft plan identified the following features for the Volcanic ring plain FMU:

> "*Rivers, reaches, lakes, wetlands and underlying aquifers on the volcanic ring plain (excluding the Hangatahua and Maketawa catchments). Comprises of rivers with short, steep and relatively small catchments in which water levels rise and fall rapidly in response to rainfall. The unit has both shallow unconfined low-yielding aquifers and confined higher yielding aquifers at depth. The unit includes New Plymouth and other urban areas and most of the land use (outside the Egmont National Park) is predominately intensive pastoral farming. The use of surface water supports a wide range of consumptive activities including agriculture, industry, community water supplies, and hydro-electric power generation. Surface water is subjected to higher consumptive and waste assimilation pressures comparative to the eastern hill country (Freshwater Management Unit D).*"

The Draft Freshwater and Land Management Plan for Taranaki contained a schedule of regionally significant freshwater and wetland species (Table 1)[5]. Five (banded, giant and shortjaw kokopu, koaro and lamprey) out of six fish species listed under this schedule have been recorded in the Waiwhakaiho River catchment (brown mudfish have not been recorded), and four of these species have been recorded upstream of the Waiwhakaiho River intake to Lake Mangamahoe.

---

[4] TRC. 2016. Freshwater bodies of outstanding or significant value in the Taranaki region Review of the Regional Fresh Water Plan for Taranaki . Document: 1602585.

[5] Note that assessment of values in the draft plan has not been subject to public scrutiny, as such, whilst being provided here, it is included for context only, and the assessment of significance within it should not be relied upon.

Table 1. *Nationally threatened or regionally distinctive fish species (and freshwater mussels) present in Taranaki rivers, lakes or wetlands. (Source: Schedule 4A: Regionally significant freshwater and wetland species of the 2015 Draft Freshwater and Land Management Plan for Taranaki).**

Indigenous species		
Common name	**Scientific name**	**Significance/Threat classification**
Banded kokopu	*Galaxias fasciatus*	Regionally distinctive, not threatened
Brown mudfish	*Neochanna apoda*	Regionally distinctive, At Risk (Declining)
Freshwater mussel	*Echyridella menziesii*	Regionally distinctive
Giant kokopu	*Galaxias argenteus*	Regionally distinctive, At Risk (Declining)
Koaro	*Galaxias brevipinnis*	Regionally distinctive, At Risk (Declining**)
Lamprey	*Geotria australis*	Threatened (Nationally vulnerable), regionally distinctive
Shortjaw kokopu	*Galaxias postvectis*	Threatened (Nationally vulnerable), regionally distinctive

* Note Table 2 is based primarily on Council officers' experience only, and lacks quantitative data as support.

** Reported as Vulnerable but now classified as Declining.

Although the consent monitoring programme associated with the Mangorei scheme does not include any routine fish monitoring, some surveys have been undertaken in the past. The results of this work were collated and presented in in Appendix II of a 2009 Taranaki Regional Council report (TRC[6]). In summary, the TRC Report survey found:

- the diadromous[7] fish community found upstream of the Mangorei scheme intake weir (Waiwhakaiho River) closely resembled that predicted by the Leathwick *et al*. (2009[8]) model;
- the Waiwhakaiho River fish pass provides adequate passage for those diadromous fish which reach the intake weir;
- there is some evidence suggesting a lack of recruitment of shortjaw kokopu and banded kokopu to the headwaters;
- this lack of recruitment may be due to the absence of an adult population providing attractant pheromones; and
- trout are able to negotiate the fish pass, although whether a significant number do so is uncertain.

The February 2020 fish survey undertaken by Ryder Environmental did not find anything about fish distribution in the catchment that is at odds with the above findings. With respect to instream habitat and fish passage downstream of the Waiwhakaiho River intake, the recently released TRC 2017-2018 annual report[9] on the monitoring programme for the Mangorei scheme states:

> "*The river channel downstream of the weir was inspected and there were no areas noted where fish passage appeared inhibited. It was noted that passage will be better at times when trout are actively migrating, as this often coincides with periods of higher flow. There appeared to be no issue for smaller fish. With regard to condition 5 of consent 2053-3.2, which requires Trustpower to maintain the river channel in the residual flow reach to enhance fish habitat and passage, there were no obvious maintenance works required.*"

[6] TRC. 2018. Trustpower Ltd Mangorei Hydroelectric Power Scheme Monitoring Programme Annual Report, 2016-2017: Technical Report 2017-102. Document: 1978920

[7] Fish that spend portions of their life cycles partially in fresh water and partially in salt water.

[8] Leathwick J, Julian K, Elith J & Rowe D 2009. 'Predicting the distributions of freshwater fish species for all New Zealand's rivers and stream'. Prepared by NIWA for the Department of Conservation. NIWA Client Report: HAM2009-005.

[9] TRC 2019. Mangorei Hydroelectric Power Scheme Monitoring Programme Annual Report 2017-2018: Technical Report 2018-93. Document: 2174298

Another report prepared by the TRC[10] provided a review of native fish in the Taranaki region, including pressures that are affecting the population (Table 2). This report did not rank abstraction as important to regionally distinctive native fish species and fish screening on intakes of hydro schemes or consumptive abstractions was not identified as an issue. Indeed, the report states: "*It is unlikely that these species will be affected by water abstraction, as they either do not occur where large scale water abstraction is common, or utilise habitats that are less affected by water allocation. In addition, the draft proposed policies and rules relating to water abstraction and the retention on ecological flows should adequately protect these species.*"

Table 2. *Pressures that affect populations of threatened or regionally distinctive species in Taranaki (redrawn from TRC 2016).*

Species	Habitat modification						
	Stream modification	Wetland drainage	Loss of passage	Water abstraction	Water quality	Predation	Fishing
Banded kokopu	1	2	3	7	6	4	5
Giant kokopu	2	3	1	6	7	4	5
Shortjaw kokopu	1	7	2	6	4	3	5
Koaro	1	7	2	6	4	3	5
Inanga	2	3	1	6	7	4	5
Longfin eel	1	2	3	6	7	5	4
Lamprey	1	7	2	6	5	4	3
Brown mudfish	2	1	6 =	5	4	3	6 =
Freshwater mussel	1	2	5	4	3	7	6

1 = most important 7 = less important

2.4 Concluding comment

The Waiwhakaiho River catchment is regarded, at least in the reports cited above, as being regionally significant with respect to both native and sport fisheries. However, less is known about the abundance of each fishery relative to other catchments in the region. The Waiwhakaiho catchment has high fish diversity and provides habitat for species that have regional significance and elevated national threat status. It is worth noting, that this status occurs within the existing environment that includes the Mangorei HEPS, which contains no design features for excluding fish from its intakes. However, the scheme does provide for effective fish passage throughout the mainstem of the Waiwhakaiho River and there is no impediment on the river preventing upstream passage for migratory fish species.

Notwithstanding the above, many of the species have life cycles that require access to the estuary or sea, or require safe passage through the river system to access spawning habitat and/or feeding and rearing habitat. Upstream and downstream fish passage in relation to the Mangorei HEPS therefore requires consideration, including whether screening of intake structures is necessary.

3 Fish passage and screening

3.1 General

A number of freshwater fish species in New Zealand are migratory and require passage between inland waters to estuaries or the sea to complete their life cycle (see section 4.3). Safe passage generally requires an adequate depth of surface water, current speeds that don't restrict upstream movement,

[10] TRC. 2016. Native fishery species of significance in the Taranaki region. Review of the Regional Freshwater Plan for Taranaki. Document: 1190381

and structures (natural and man-made) that fish are able to negotiate over (both up and downstream). The diversion of water for abstraction poses another impediment to fish migration if there is no safe passage back to the river.

Water diverted for hydro generation is potentially damaging for fish and lethal in some cases. Fish passing through turbines are subjected to pressure changes, cavitation and shear damage, and mechanical strike. The survival rate during turbine passage is related to fish size, structure height (head), and the type and size of turbine installed.

When reconsenting existing HEPSs in New Zealand, particularly where rivers are dammed, issues around fish passage have typically focused around upstream passage for juvenile eel and other native fish species, and safe downstream passage for adult eel (e.g., Boubeé and Jellyman 2009[11]) rather than the screening of existing intake structures. The issue of safe downstream passage for migrating adult eels is well documented in New Zealand and overseas. Adult longfin eels need to return to the sea in order to spawn (somewhere in the South Pacific near Tonga). As adults, longfin eels are large and can reach well in excess of 1 metre in length, they tend to migrate downstream in autumn, often in association with freshes, although they also move downstream at other times of the year. They tend to be attracted to the greatest flow of water and, in the case of hydroelectric dams, this is typically associated with the intakes to the penstocks and power station. Under these circumstances, most migrant adult eels passing through turbines will be killed (Beentjes *et al*. 2005[12]). Longfin eel are an endemic species in decline, hence the focus on providing safe passage for them at dams and associated structures that may impair migration or cause mortality.

Smaller fish and life stages fair better, and whitebait larvae and even downstream migrating juvenile lamprey most likely survive passage through turbines (Boubeé and Jellyman 2009).

There is a general absence of information on fish screening specific to hydro-electric power schemes in New Zealand. In fact, there are no known examples of highly successful retro-fitting of physical fish screens to an existing large hydro-electric dams in New Zealand. For some existing dams, alternative downstream routes have been trialled and adopted in some instances. For example, the Patea Dam spillway gates are opened deliberately during the downstream eel migration season when eels are observed congregating upstream, and this has achieved considerable success. In 2015, a diverter system was also installed at the Patea HEPS intake at the Patea Dam, allowing migrant eels an alternative way to safely bypass the turbines and continue downstream. This system operates continuously. King Country Energy operates a simple dam bypass (three 100 mm diameter holes) on the Wairere Dam (Mokau River) with some success. Manual trap and transfer programmes for adult eel operate at a number of HEPSs around the country (e.g., Manapouri, Waitaki, Rangitaiki and as discussed below at Mangorei).

Notwithstanding the comments above regarding fish screening at hydro-electricity dams, it is relevant to reflect on the recent Conservation (Indigenous Freshwater Fish) Amendment Act 2019 which provides for regulations to be made "*prohibiting, restricting, or regulating any structure or alteration to a water body that could impede or affect the passage of freshwater fish or specified freshwater fish (see clause 6 of Schedule 1AA)*" (s48A(1)(na)). However, Clause 6 of the 1st Schedule of that Act states that regulations made under s48A(1)(na) do not apply to any hydroelectricity dams constructed before the commencement date of the Act except where those regulations impose requirements that relate to the maintenance of any structure that could impede or affect the passage of freshwater fish or specified freshwater fish. In recommending excluding hydroelectricity dams from fish passage regulations, the Select Committee report on the Bill noted "*the owners of these dams have almost no options to mitigate the effects on the passage of fish*".

---

[11] Boubeé, J. and Jellyman, D. 2009. Facilitating the upstream and downstream passage of indigenous fish at large dams. *In:* McSaveney, E. (ed.) *Dams – Operating in a Regulated Environment.* IPENZ Proceedings of Technical Groups 35/1: 57-63.

[12] Beentjes, M.P.; Boubeé, J.A.T.; Jellyman, D.J. and Graynoth, E. 2005. Non-fishing mortality of freshwater eels (*Anguilla spp*.). New Zealand Fisheries Assessment Report 2005/34. 38 p.

3.2 Existing screening and fish passage associated with the Mangorei Scheme

The Scheme was constructed in 1904, and upgraded in 1931 with a 25 m high dam to form Lake Mangamahoe. Resource consents, which were last granted in 1996, have the following fish passage requirements:

Consent RC 2053-3 (Divert water from Waiwhakaiho River via diversion weir):

- *Maintain the river channel below diversion weir to the 'Meeting of Waters' [for the purpose of enhancing fish passage and habitat].*
- *Taranaki Regional Council will inspect the fish passage device and river channel for compliance after any significant river fresh.*

Consent RC 4887-1 (Erect and maintain structures associated with diversion from Waiwhakaiho River);

- *Maintain fish pass to allow passage of native fish, juvenile and adult trout.*

In 1992 a fish pass was constructed in the Waiwhakaiho River at the Mangorei HEPS diversion weir. The fish pass has been present in its current form since 1998 (Figure 10), when it replaced a smaller pass. The flow through the pass is approximately 0.15 to 0.20 m^3/s and suitable water velocities for fish passage have been provided by an accumulation of rocks, boulders and general debris and the placement of wooden blocks within the pass.

The 2018-19 TRC monitoring report for the Scheme concluded: "*In terms of fish passage, the fish pass is considered adequate to provide for the passage of all fish species expected to migrate up to and beyond the weir. This includes all native migratory species recorded as present in the residual flow reach, and adult trout, which have been shown to be capable of negotiating the pass.*".

Figure 10. *Mangorei HEPS diversion weir with fish pass in the foreground (blocked by boulders due to flooding).*

There is no specific consent requirement relating to the screening of the Scheme's intakes for fish. A trash rack to collect debris is present on the Waiwhakaiho intake (with 180mm spacings), but this is unlikely to prevent fish becoming entrained into the lake. The velocities in the intake tunnel along with its considerable length (540 m) would make it unlikely for fish to be able to make their way back out to the river.

The scheme's intake on Lake Mangamahoe to the Mangorei power station penstocks is shown in Figure 8. The structure consists of four intake gates and a manually operated trash screen with 20mm spacings (Figure 11).

The implications of fish entrainment into Lake Mangamahoe is discussed in the next section.

Figure 11. *Mangorei HEPS intake trash screen on Lake Mangamahoe.*

4 Fish entrainment into Lake Mangamahoe

4.1 Hydrological considerations

The Waiwhakaiho River at Egmont Village has a median flow of 3.89 m^3/sec (Jowett 2018) and a 7-day MALF of 2.11 m^3/sec (Tonkin & Taylor 2020[13]). The typical tunnel flow is about 6.5 m^3/sec. Abstraction must cease at river flows at or above 85 m^3/sec. A residual flow is required below the Waiwhakaiho intake weir of between 0.4 and 0.7 m^3/sec. Therefore, potentially, between river flows of about 10 and 85 m^3/sec, the scheme's intake can divert between 10 and 65% of the flow. Given the proportion of river water diverted into Lake Mangamahoe there is potential for downstream migrating fish to be diverted into the lake.

4.2 Consequences of entrainment

4.2.1 General

Some of the fish species that enter Lake Mangamahoe via the Mangorei scheme intake on the Waiwhakaiho River may be able to reside in the lake for variable lengths of time. Eel and trout in particular are able to thrive in lake environments, and eels in particular can live for decades. Koaro, giant kokopu and shortjaw kokopu are also migratory, with adults of giant and shortjaw kokopu

[13] Tonkin and Taylor. 2020. Reconsenting of Mangorei Hydroelectric Power Scheme: Hydrology Report. Prepared for Chancery Green on behalf of Trustpower Limited, July 2020.

moving downstream to spawn. Koaro and giant kokopu are capable of forming landlocked self-sustaining populations, however, there are no records of the lake being surveyed for these fish using methods suitable for these species, and if may have unsuitable hydraulic characteristics in any event[14]. Notwithstanding the suitability of the lake as habitat for various fish species, there remains a risk that fish with downstream migratory requirements (i.e., adult eel, giant and shortjaw kokopu, larvae of bully and koaro, and juvenile lamprey) may ultimately find their way down to the penstock intake.

The trash screen at the intake structure to the power station (Figure 11) is unlikely to prevent larvae and small fish from entering the penstocks. Velocities in front of trash screen are reportedly sufficiently low for adult eel to avoid impingement. Given this, it is likely that adults of other larger fish species are able to avoid being

4.2.2 Passage back to the river via the power station

If smaller fish and fish larvae can pass through the trash rack at the Lake Mangamahoe intake to the power station, what are their chances of making it safely back to the Waiwhakaiho River via the power station tailrace?

Fish mortality due to passage through 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)[15].

It is possible to estimate fish mortality during passage through turbines using various formulae and information on turbine design. The Mangorei power station has three horizontal Francis turbines (Figure 12).

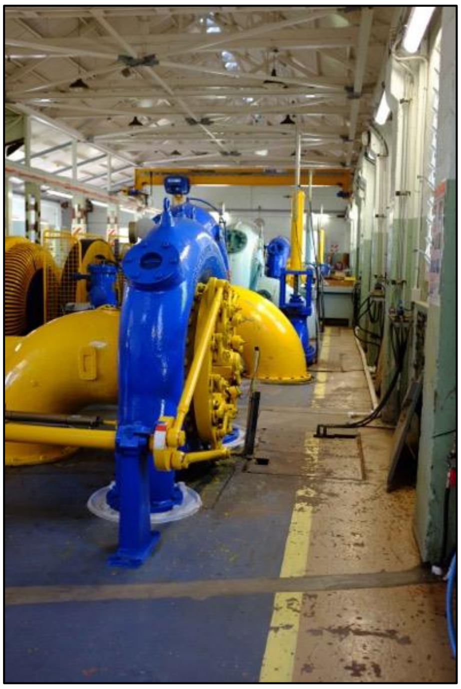


Figure 12. *Mangorei HEPS Francis turbines.*

[14] Richardson and McKerchar (2006) found residence time and volume to be good predictors of whether or not koaro formed land-locked populations. Lakes with koaro were found to have an average residence time of 1073 days while lakes without koaro had an average time of 177 days. If residence time was less than 80 days and the lake volume was less than 10 million cubic metres, then koaro were apparently unable to establish land-locked populations. Richardson, J. and McKerchar, A. 2006. Land-locked fish and lake-residence time. Water & Atmosphere 14(4)

[15] Turnpenny, A.W.H., Clough, S., Hanson, A.P., Ramsay, R., and McEwan, D. 2000. Risk assessment for fish passage through small, low-head turbines. ETSU H/06/00054/REP

For Francis turbines the formula of Larinier and Dartiguelongue (1989[16]) may be used to calculate mortality:

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

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 Mangorei turbines have a gross head of 76.5 m and a maximum flow of 9.17 m^3/s.

Turbine mortality predictions indicate that passage through the Mangorei power station turbines is likely to result in mortality for some fish, particularly for larger individuals, with fish over 20 cm in length having a predicted mortality of at least 50% and fish of around 5 cm in length having a predicted mortality of approximately 23% (Figure 13). The species at greatest risk are migrating adult longfin and shortfin eels due to their long length (assuming they could make it past the intake trash rack), and their mortality is expected to be over 90%.

Larval fish and very small fish have a low predicted mortality rate due to turbines, however mortality of larvae caused by pressure changes may be high.

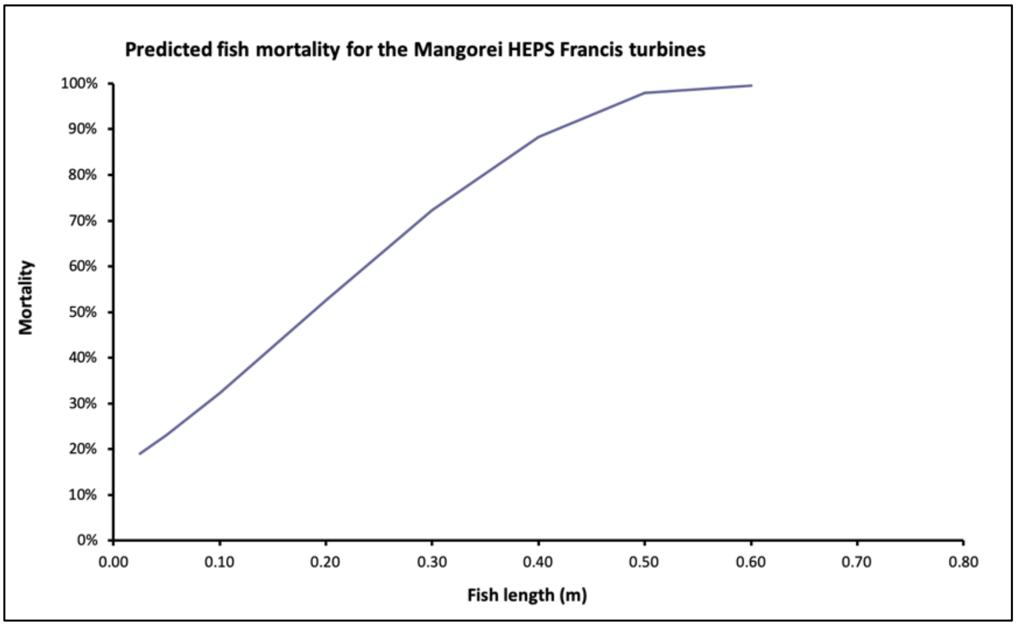


Figure 13. *Predicted risk of mortality for fish of different lengths passing through the Mangorei power station Francis turbines.*

4.3 Effects of entrainment on fish populations

4.3.1 Brown trout

Brown trout are present throughout the catchment (Appendix 1) and it is highly likely that there is sufficient and widespread recruitment of this species from within the Waiwhakaiho catchment such that any mortality associated with entrainment into Lake Mangamahoe and at the intake to the

[16] Larinier M., and Dartiguelongue J., 1989. La circulation de poissons migrateurs: le transit à travers les turbines des installations hydroélectriques (The movements of migratory fish: passage through hydro-electric turbines). Bull. Fr. Pisc., 312-313, 1-90.

penstocks in particular is having only a minor effect on the overall catchment population. Adult trout are strong swimmers with high burst speed, and consequently should be able to avoid impingement against the intake's trash rack and enjoy life in the lake while evading anglers. In any event, as a sport fish, entrainment into the Lake Mangamahoe provides recruitment to the lake fishery.

4.3.2 Lamprey

Lamprey are classified nationally as threatened (Nationally vulnerable)[17]. Adults migrate upstream from the coast and juveniles migrate downstream in autumn/winter. James (2008) reported that rivers in Taranaki and Whanganui were North Island hotspots with respect to historical Maori lamprey fisheries with significant fishing effort[18]. Phillips & Hodgkinson (1922, cited in McDowell 1990[19]) recorded Maori capturing several tons migrating up a river near New Plymouth in June 1921.

There are only two records in the NZFFD of lamprey in the Waiwhakaiho River catchment and one of those is at or about the location of the scheme intake (a 1993 record), with the other being well downstream near the coast. While this could suggest low abundance in the catchment, it may also reflect the amount of (limited) survey effort that has been undertaken, or a lack of effort to target lamprey habitat.

Some research overseas on juvenile lamprey have found them to relatively resilient to effects associated with passage through hydro-electric power turbines (Moser *et al.* 2014[20]). To determine the effects of high-head turbine passage on juvenile lamprey, Colotello *et al.* (2012[21]) conducted laboratory tests using juvenile Western brook and Pacific lamprey exposed to rapid and prolonged decompression in hyper/hypobaric chambers. Lamprey were acclimated for 16–24 hours to pressures equivalent to a depth of 4.6 m (146.2 kPa) and then the pressure was decreased from 146.2 to 13.8 kPa over approximately 3 minutes. Pressure was then maintained at 13.8kPa for ~17 minutes. Following low pressure exposures, lamprey were immediately euthanized, and necropsies were performed to characterize the nature of any barotrauma (e.g., exophthalmia, emboli, haemorrhaging, and hematomas in gills, fins, and other organs). No immediate or delayed mortalities or injuries were observed among either Western brook or Pacific lamprey exposed to this simulation of pressures experiences during turbine passage at a high-head dam. In addition, neither X-rays nor necropsies revealed evidence of barotraumas.

Passage through high-head dam turbines also exposes fish to extreme shear forces. To examine the effects of shear on juvenile lamprey, Neitzel *et al.* (2004[22]) placed individuals 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).

Based on the length of juvenile lamprey (80 - 100 mm), a significant proportion are expected to survive

---

[17] Dunn, N.R.; Allibone, R.M.; Closs, G.P.; Crow, S.K.; David, B.O.; Goodman, J.M.; Griffiths, M.; Jack, D.C.; Ling, N.; Waters, J.M.; Rolfe, J.R. 2018: Conservation status of New Zealand freshwater fishes, 2017. *New Zealand Threat Classification Series 24*. Department of Conservation, Wellington. 11 p.

[18] James, A. 2008. Ecology of the New Zealand Lamprey (*Geotria australis*). ISSN 1179-1659 Te Tai Hauauru - Whanganui Conservancy Fauna Series 2008/1

[19] McDowall R.M. 1990. New Zealand Freshwater Fishes: A Natural History and Guide. Heinemann Reed, Auckland, New Zealand.

[20] Moser, M. L., Jackson, A. D., Lucas, M. C., & Mueller, R. P. (2014). Behavior and potential threats to survival of migrating lamprey ammocoetes and macrophthalmia. Reviews in Fish Biology and Fisheries, 25(1)

[21] Colotello AH, Pflugrath BD, Brown RS, Brauner CJ, Mueller RP, Carlson TJ, Deng ZD, Ahmann ML, Trumbo BA (2012) The effect of rapid and sustained decompression on barotrauma in juvenile brook lamprey and Pacific lamprey: implications for passage at hydroelectric facilities. Fish Res 129–130:17–20

[22] Neitzel D, Dauble DD, Cada G, Richmond M, Guensch G, Mueller RP, Abernethy CS (2004) Survival estimates for juvenile fish subjected to a laboratory-generated shear environment. Trans Am Fish Soc 133:447–454

passage through turbines. Assuming this is the case, the scheme's effect on the population in the catchment can be regarded as minor.

4.3.3 Koaro and bullies

Koaro and bullies typically migrate downstream as small larvae, only a few millimetres long. Mortality of these larvae caused by pressure changes through penstocks and power station is expected to be high (Boubeé 2005[23], Coutant and Whitney 2000[24]).

Koaro are very widespread within New Zealand and its offshore islands, from sea level to extremely high altitudes and distances inland, as well as occurring in south-eastern Australia and Tasmania[25]. Koaro are classified nationally as At Risk (Declining). They have been recorded in the catchment upstream of the intake, but their distribution may be more widespread than the fish database records indicate (Appendix 1). At the catchment scale, the effect of the scheme on the population is probably minor given recruitment of this species is likely to come from populations in surrounding catchments and further afield (via migration of juveniles from the sea).

Bullies are not a threatened species under the Department of Conservation's threat classification system, although one species, bluegill bully is classified as At Risk (Declining). Bluegill bullies are not particularly common in the Taranaki with only six out of 1,227 records in the NZFFD reported from the region. The two Waiwhakaiho River catchment records are located well downstream of the Mangorei scheme intake. Bullies are prolific breeders and population recruitment occurs quickly. Entrainment into the scheme is not likely to be a key threat to the bully populations at a catchment level.

4.3.4 Torrentfish

Torrentfish are a riverine species and adults migrate downstream to spawn in lower reaches in late spring to early autumn. They are classified nationally as At Risk (Declining) and local populations are considered to be particularly vulnerable to large scale abstraction (Warburton 2015[26]). Some may survive passage through the turbines based on their size. However, whether they would be capable of swimming through the stillwater environment of Lake Mangamahoe from the inflow tunnel to the intake structure is unknown.

4.3.5 Banded, giant and shortjaw kokopu

These galaxiid species migrate downstream as adults during autumn and early winter. Giant and shortjaw kokopu are classified nationally as At Risk (Declining) and Threatened (Nationally vulnerable), respectively. Banded kokopu are not threatened. All three species can survive in stillwater environments, although this habitat is not preferred by banded or shortjaw kokopu. All three species have been recorded upstream of the Waiwhakaiho River intake although their numbers and distribution are quite limited (i.e., there is only one record each for banded and giant kokopu upstream of the intake). However, as noted above for lamprey, this may be more of a reflection of the amount of (limited) survey effort that has been undertaken in the catchment.

In 2008, an adult giant kokopu was captured during the adult eel trapping programme in Lake Mangamahoe (Chris England, TPL, pers. comm.). Recent environmental (DNA)[27] survey work at 20 sites undertaken by Freshwater Solutions (Susan McKegg, pers. comm.) has provided strong evidence that another native galaxiid species, koaro, is also present in the lake.

Given low velocities in front of the trash rack at the lake intake to the power station, adults may be

[23] Dr Boubeè in evidence presented at the hearing into reconsenting of the Clutha HEPS. 2005.
[24] Coutant, C.C., and Whitney, R.R. 2000. Fish behaviour in relation to passage through hydropower turbines: A review. *Transactions of the American Fisheries Society* 129: 351–380
[25] New Zealand large galaxiid recovery plan, 2003–13: Shortjaw kokopu, giant kokopu, banded kokopu, and koaro. Threatened Species Recovery Plan 55. Department of Conservation.
[26] Warburton, M.L. 2015. Migratory Movements of Torrentfish (*Cheimarrichthys fosteri*, Haast 1874). PhD. Thesis. University of Otago.
[27] Fish continuously shed tissue such as mucus and scales into the water. This material contains DNA and can be collected from the water and read by scientists to identify the fish present in the water.

able to avoid impingement. As with koaro, at the catchment scale, the effect of the scheme on populations of these species is probably minor given recruitment of these species is likely to come from populations in surrounding catchments and further afield (via migration of juveniles from the sea).

4.3.6 Longfin and shortfin eel

Adult eels migrate downstream mainly in autumn (March to May), with peak migration occurring during autumn flood events (Smith 2014[28]). Floods/freshes in the Waiwhakaiho River are considered to occur when the flow reaches or exceeds 11.7 m^3/sec (which is 3 times the median flow or the 'FRE3[29]' flow) and these occur on average approximately 18 times a year (Jowett 2018). Note that for flood at or above 85 m^3/sec, the scheme's intake is closed and any migrating eels can pass downstream. Notwithstanding, it is possible that when the intake is not closed during the months of eel migration, eel may be entrained into Lake Mangamahoe.

Longfin eel are widely distributed throughout the Waiwhakaiho River catchment including upstream of the scheme's intake. Most shortfin records are located closer to the coast, as expected. Longfin eel are classified nationally as At risk (Declining). Shortfin eel are not threatened and the scheme poses relatively little risk to the shortfin population due to its distance from the coast. As for the diadromous galaxiid species, at the catchment scale, the effect of the scheme on the longfin population is likely to be minor given recruitment of this species comes via migration of juveniles from the sea, however there is the well documented[30] issue of cumulative effects on the wider national population due to multiple stressors (i.e., dams, consumptive abstractions, physical degradation of habitat, water quality degradation, wetland drainage, commercial harvesting). Once eels enter Lake Mangamahoe, they are unable to complete their life cycle unless they can find a safe passage out of the lake and down to the coast, or are captured and released downstream as part of the trap and transfer programme currently operated by Trustpower.

Since 2009, Trustpower has voluntarily operated an adult eel trap and transfer operation in Lake Mangamahoe immediately upstream of the intake structure to the power station supply tunnel and penstocks. The trapping system was developed by Grant Williams, a former eel fisher, in association with local Trustpower staff. The trapping season normally starts from about mid-March, and eel movement is usually triggered by the first significant rain event after summer (Grant Williams, pers. comm.). Migrants are spotted at the lake's station intake, during regular visits to this site by Trustpower staff (at least 3 times per weeks) (Chris England, pers. comm.). Because the migrants are following the flow and are unable get past the intake screens, they tend to circulate in the water in front of these screens. At this point, Trustpower staff capture them using a combination of scoop and set nets. The period of migration can often extend into June, although there appears to no 'real hard and fast' pattern. Trustpower staff consider regular observations are a key to trap and transfer success. Velocities in front of the debris screen are not particularly high and eels that are not captured by the nets swim back into the main body of the lake.

The data show that adult eels (both longfin and shortfin species) are migrating downstream on a regular (annual) basis and find their way into Lake Mangamahoe via the scheme intake on the Waiwhakaiho River (Table 3). The numbers caught can vary widely between years, but this is also the case at the Patea HEPS (Table 3).

---

[28] Smith, J. 2014. Freshwater Fish Spawning and Migration Periods. MPI Technical Paper No: 2015/17

[29] FRE3 flows are considered ecologically important in rivers as they can reduce periphyton accumulation and influence invertebrate abundance and sediment deposition.

[30] Parliamentary Commissioner for the Environment. 2014. Update Report: On a pathway to extinction? An investigation into the status and management of the longfin eel.

Table 3. *Numbers of adult eels trapped and transferred at the Mangorei HEP scheme since 2009, and compared with the transfer programme at Patea HEPS.*

Year	Mangorei HEPS				Patea HEPS
	# of longfin eels transferred	# of shortfin eels transferred	# of unidentified eels transferred	Total # of eels transferred	Total # of eels transferred
2009	-	-	171	171	-
2010	-	-	4	4	-
2011	-	-	7	7	-
2012	-	-	7	7	-
2013	-	-	21	21	594
2014	13	30	44	87	1184
2015	21	8	-	29	614
2016	11	1	-	12	365
2017	40	17	-	57	20
2018	11	10	-	21	60
2019	26	27	-	53	460

The existing trap and transfer programme cannot quantify the proportion of eels that enter the lake relative to the number that bypass the Waiwhakaiho intake and make their way to the coast. It also cannot provide an indication of the number of migrants in the lake that are not captured by the trapping programme, nor those that may subsequently enter the power station penstocks and from there to the power station turbines. Eel surveys of Lake Mangamahoe and indeed the wider Waiwhakaiho catchment would assist in establishing the size of the lake's eel population relative to catchment's population and proportion of migratory-ready adults that become entrained into the lake, but, as discussed in section 5.3.7, such surveys would require considerable effort and resources (over several years) to enable useful estimates. Rather than further survey effort, it is recommended that resources are focused on the existing trap and transfer programme.

The difficulty in estimating the size of adult downstream eel migrations is the lack of knowledge of the current silver eel biomass in the Waiwhakaiho catchment, which may be affected by commercial and recreational fishing, habitat loss or degradation, and also the lack of knowledge of eel biomass in the catchment in the absence of anthropogenic influences. In their review of information for monitoring the status of New Zealand eels, Haro *et al.* (2013[31]) note that escapement of eels is notoriously difficult to measure directly, and usually has to be estimated via systematic sampling. Trustpower monitoring of downstream eel migration at the Patea HEPS spillway and the trapping programme at the Mangorei HEPS intake at Lake Mangamahoe illustrate that eel escapement can be highly variable between years (Table 3).

Ryder Environmental engaged NIWA to estimate the longfin eel biomass of the Waiwhakaiho catchment using a GIS-based generalised additive model (GAM) (Graynoth 2019[32]). The model was originally developed to estimate the current and original biomass (prior to commercial fishing) of longfin eels in rivers throughout New Zealand (Graynoth *et al.* 2008[33]). For the Mangorei HEPS work, the model was used to predict the current and original eel biomass upstream of two locations:

- the Waiwhakaiho River intake to Lake Mangamahoe; and
- the Mangamahoe River above Lake Mangamahoe and its weir (dam).

---

[31] Haro, A., Dekker, W., and N. Bentley. 2013. Independent review of the information available for monitoring trends and assessing the status of New Zealand freshwater eels. Prepared for the Ministry for Primary Industries, November 2013.
[32] Graynoth, E. 2019. Longfin eel biomass estimates for waters upstream of weirs and intakes for lakes Mangamahoe and Ratapiko, Taranaki. Prepared by NIWA for Ryder Environmental.
[33] Graynoth, E., Jellyman, D.J. and Bonnett, M. 2008. Spawning escapement of female longfin eels. New Zealand Fisheries Assessment Report 2008/7.

The modelling approach relies on surveys of longfin eel biomass gathered from several rivers throughout the North and South islands, but not from Taranaki rivers. The model explained 49.5% of the deviance in current biomass and 63.8% of the deviance in original biomass for the sites surveyed (Graynoth *et al.* 2008). There are a number of acknowledged limitations with the Graynoth *et al.* (2008) model. For example, biomass estimates in the Taranaki Rivers assume the elver trap and transport system is effective and that the weirs on the rivers and the Lake Mangamahoe dam do not adversely affect juvenile recruitment (Graynoth 2019).

The model predicts that the Mangamahoe and Waiwhakaiho rivers combined currently support approximately 4.6 tonnes of longfin eels (Table 4). Potential error or bias in these estimates is also incorporated into the estimates in Table 4. If it is assumed the Taranaki rivers are most similar to North Island rivers used to develop the training set (Ruamahanga and Whanganui) then the total tonnage in the Mangamahoe and Waiwhakaiho rivers could be slightly higher and possibly in the region of about 6 to 8 tonnes.

Assuming that approximately 6% of the total eel biomass would be attempting to migrate downstream each year (Bonnet *et al.* 2007[34] in Goldsmith & Ryder[35]), and that migrant eels have an average weight of 4kg, the predicted tonnages in Table 4 equates to approximately 8 migrant eels (between 4 and 12 eels applying a ±50% confidence interval) from the Mangamahoe River and 61 migrant eels (between 30 and 92 eels applying a ±50% confidence interval) from the Waiwhakaiho catchment upstream of the intake to Lake Mangamahoe.

Table 4. *Predicted tonnages in Taranaki Rivers, based on the equations in Graynoth* et al. *(2008) and on GAM's which incorporated the river sampled as a categorical variable (Hoyle 2016[36]).*

Model	Mangamahoe	Waiwhakaiho	Total
Current	0.52	4.08	4.59
Original	0.51	4.45	4.96
Ruamahanga	0.53	5.65	6.18
Whanganui	0.7	7.41	8.11
Buller/Grey	0.20	2.15	2.25
Aparima	0.77	8.24	9.01

Comparing these figures with the reported number of longfin eels trapped at the Lake Mangamahoe intake to the Mangorei Power Station, the average annual efficiency of the trapping programme over the period 2014-2018 (years in which longfin eels were distinguished from shortfin eels) is 28% of the total estimated number of annual longfin eel migrants (18% - 56% using ±50% confidence intervals).

Although this modelling approach is not perfect, the results suggest that the current trap and transfer programme in some years is shifting a significant proportion of adult migrant eels downstream below the HEPS structures. Experienced operators and eel fishers consider that the trapping programme is effective and eels not captured by netting move back into the lake and wait for subsequent flood events or the following year to migrate.

[34] Bonnett, M., Jellyman, D., Graynoth, E., and G. Kelly. 2007a. Updated (March 2007) preliminary assessment of potential impacts of a proposed hydroelectric scheme on fish and fisheries in the Mohaka River. Prepared by NIWA for Meridian Energy Ltd. NIWA Client Report CHC2006-, March 2007.

[35] Goldsmith, R. and Ryder. G. 2017. Matahina Hydroelectric Power Scheme: Upstream and downstream fish passage options. Prepared for Trustpower.

[36] Hoyle, S.D. 2016. Feasibility of longfin eel stock assessment New Zealand Fisheries Assessment Report 2016/29.

5 Fish screening considerations in relation to the Mangorei Scheme

It is understood that the location of the Waiwhakaiho River intake is such that retrofitting infrastructure that would screen the intake effectively and safely (i.e., without impingement or other physical damage) for fish is challenging from both economic and engineering perspectives, as acknowledged by the Select Committee reviewing the Conservation Act Amendment bill. The intake is located in a section on river where movement of debris and large substrate occurs during flood events, and so any infrastructure needs to be of sufficient robustness to withstand considerable forces and debris accumulation while still operating effectively abstract water and screen fish. In order for approach velocities to be sufficiently low to avoid impingement against the screen, the screen surface area would have to be very large and such a structure would be very expensive to build and maintain.

The current trap and transfer programme is minimising the effect of entrainment on the eel population, and the trap and transfer records indicate that in some years a significant number of adults are transferred downstream. The results of eel biomass modelling summarised in section 4 suggests the trap and transfer programme is very effective in some, but not all years, however, the designers and operators of the programme are confident that the programme targets peak eel migration in the lake, and that the risk to eel impingement on the trash screens is minimal. Further, adults are able to return to main body of the lake.

Shortjaw kokopu are a threatened species and catchments of the Taranaki region are a stronghold for it (Figure 14). Giant kokopu, koaro and torrentfish are present in the catchment upstream of the scheme intake and are all ‘at risk’ species. All four species require access to the lower catchment to complete their life cycle.

The risk of entrainment for threatened or at risk fish species recorded upstream of the Mangorei HEPS intake is presented in Table 5 for a range of mesh sizes. As can be expected, entrainment risk is higher for smaller fish. Longfin eel, giant and shortjaw kokopu and torrentfish undertake active downstream migrations as adults and the risk to these species with mesh sizes up to 5 mm is minimal and low for a spacing of 20mm (Table 5).

In some situations, screening of only larger fish may be appropriate and correspondingly a larger mesh size can be effective. Charteris (2006[37]) reported that a 20 mm mesh size is sufficiently small to prevent downstream migrating adult eels from becoming entrained. Information is not available on the risk of entrainment for other species/life history stages encountering a 20 mm mesh screen, so this has been estimated based on fish size and is also shown in Table 5. Along with adult longfin eels, 20 mm spacings should present a low risk of entrainment to downstream migrating adult giant and shortjaw kokopu, and this is the spacing of the trash rack at the Lake Mangamahoe intake.

[37] Charteris, S. 2006. Native fish requirements for water intakes in Canterbury. Department of Conservation, July 2006.

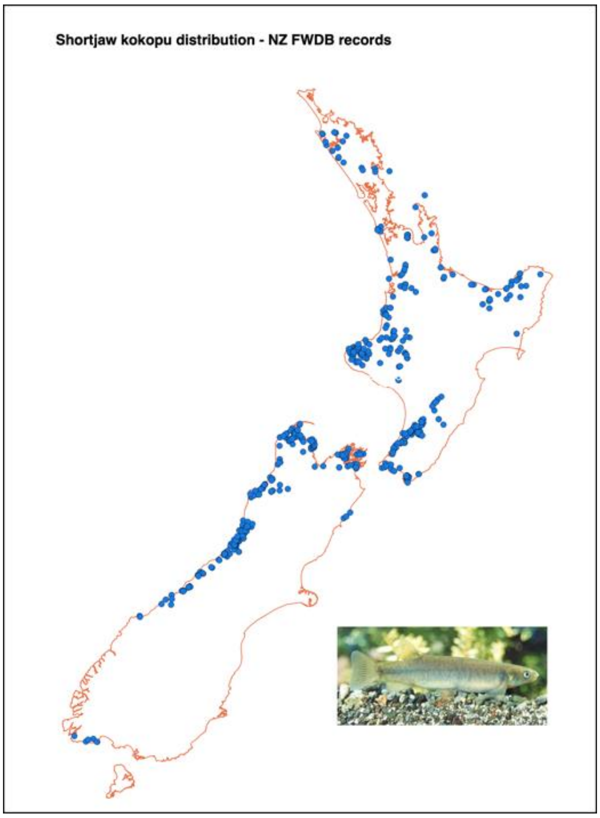


Figure 14. *Distribution of shortjaw kokopu throughout New Zealand. Base data contained within the NZFFD, accessed September 2019.*

Table 5. *Risk of entrainment (minimal risk – blank, low – green highlighting, high - red) for key threatened or at risk freshwater fish species and life history stages recorded in the vicinity of the Mangorei HEPS and migrating downstream. Assessed risk of entrainment information for irrigation intakes screened with 2, 3, 4, or 5 mm side-of-square mesh size is from Jamieson* et al. *(2007)*[38]*. Approximate length ranges from Jamieson* et al. *(2007) and Charteris (2006). Risk of entrainment with a 20 mm spacing from Charteris (2006) for adult eels, and for other species estimated based on length.*

Common name	Life history stage	Direction of migration	Approximate length ranges (mm)	Risk of entrainment in relation to screen spacing				
				2 mm	3 mm	4 mm	5 mm	20 mm
Longfin eel	Adult	Downstream	400-1500	none*	none*	none*	none*	low*
Shortjaw kokopu	Adult	Downstream	70-350	none*	none*	none*	none*	low*
Giant kokopu	Adult	Downstream	70-580	none*	none*	none*	none*	low*
Torrentfish	Adult	Upstream/ Downstream	60-160	none*	none*	none*	low*	high

* assumes other aspects of the fish screen design are appropriate. i.e., approach and sweep velocities.

For migratory fish that become entrained into Lake Mangamahoe and unable to be captured via trapping, an alternative downstream route may be an option, as they would be unable to migrate back

[38] Jamieson, D., Bonnett, M., Jellyman, D., and Unwin, M. 2007. Fish screening: good practice guidelines for Canterbury. Prepared for the Fish Screen Working Party by NIWA. NIWA Client Report: CHC2007-092, October 2007.

through the intake tunnel to the Waiwhakaiho River. The existing spillway down into the Mangamahoe Stream is really the only option for alternative fish passage in this respect, however, and safe passage would be extremely challenging to achieve, given:

- the concrete spillway's steep gradient and length (Figure 15) with no obviously pool at the tail to cushion landing;
- the need for a residual flow sufficient in volume to convey fish safely down it – it is likely that a residual flow would need to be confined with some sort of baffle to concentrate the flow to assist downstream passage and avoid the risk of abrasion; and
- the restriction to passage over the NPDC dam (Figure 16) situated further downstream of the spillway (lower Mangamahoe Stream) before discharging to the Waiwhakaiho River.

Figure 15. *Lake Mangamahoe spillway looking up towards the lake (left) and down towards the Mangamahoe Stream (right).*

Figure 16. *NPDC dam located further downstream of the Lake Mangamahoe spillway on the lower Mangamahoe Stream.*

6 Summary & Conclusion

The Mangorei HEPS diverts flow from the Waiwhakaiho River into Lake Mangamahoe, before discharging the bulk of this water back to the river via the Mangorei Power Station (some of the lake water is abstracted by the NPCC for potable water supply). The trash rack on the Waiwhakaiho River intake has sufficiently wide spacings to enable downstream migrating fish to enter the lake. There are several migratory native fish species in the Waiwhakaiho catchment that have Department of Conservation at risk or threat classifications. Of these, only longfin eel have been recorded as being present in the lake.

To exclude fish from entering the Waiwhakaiho River intake to Lake Mangamahoe, a much larger intake opening, potentially up to 5 times the area of the current opening, would be necessary to be screened to avoid fish impingement given the location of the intake. Even then, the spacings on such a screen could be no closer than approximately 20mm before issues associated with head loss and unacceptably high approach velocities developed. Spacings of 20mm would exclude adults of eel, trout and probably giant and shortjaw kokopu, however small species and life stages may not be able to avoid the screen. It is understood that being able to construct and maintain such a screen would pose significant challenges in this river and there is a high risk of damage due to flooding and debris and boulder movement.

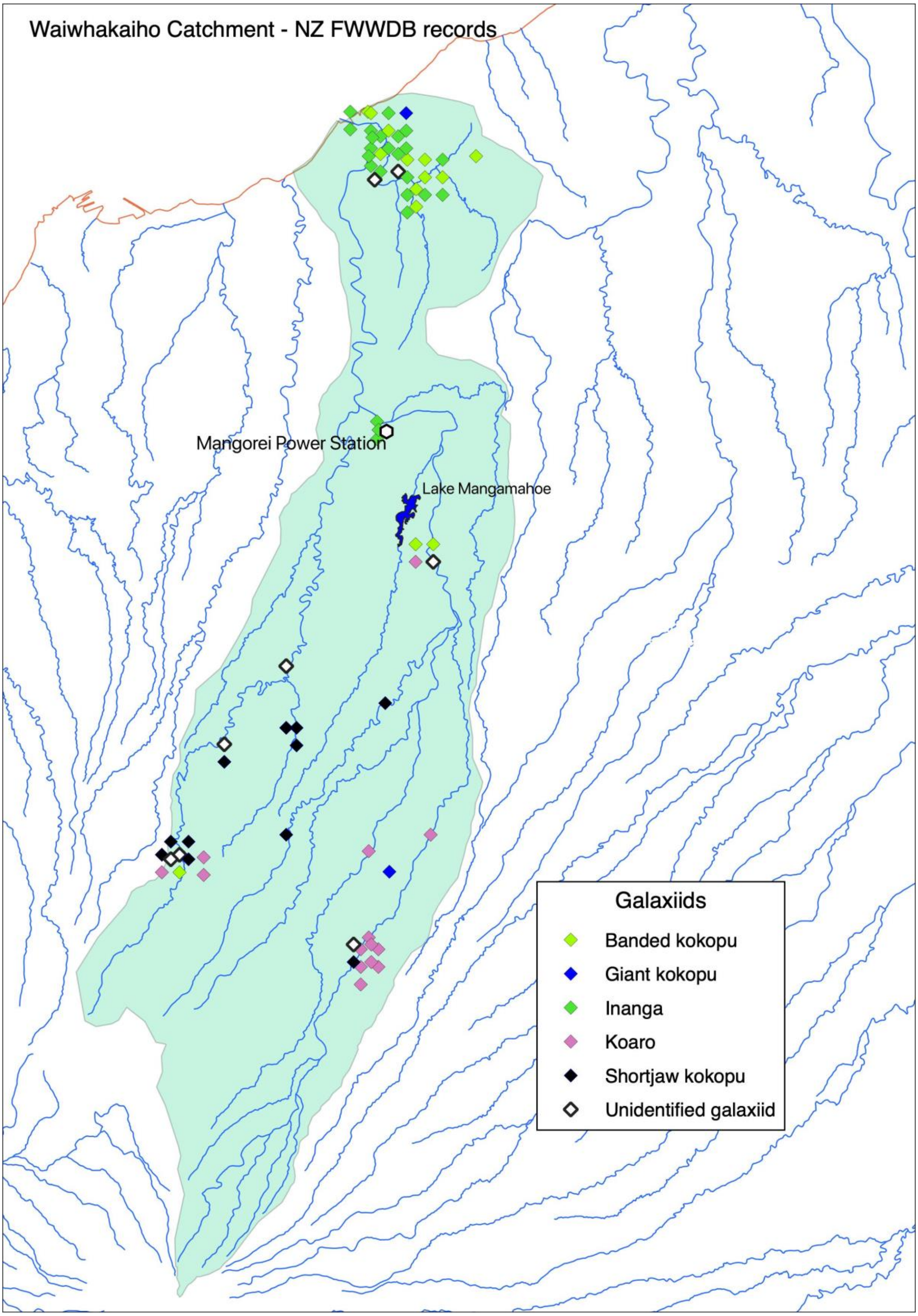
Adult migrating longfin and shortfin eel are successfully caught in the vicinity of the lake’s intake to the Mangorei Power Station by a targeted trap and transfer programme that Trustpower has been operating since 2009. The programme is regarded as working very well and large numbers of adults are caught and transferred in some years. The trash rack in front of the Mangorei Power Station lake intake has 20mm spacings and velocities in front of the rack are considered to be relatively low. Adult eels are unable to pass through these spacings and those not captured by the trapping programme are able to return to the main body of the lake and so can be targeted in future trapping dates. Adults of other at risk or threatened species (giant and shortjaw kokopu) are also likely to be unable to pass through the trash rack and in any event, there are no records of these species being present in Lake Mangamahoe or its catchment tributaries. Small fish that may pass through the trash rack have a higher chance of survival through the station turbines.

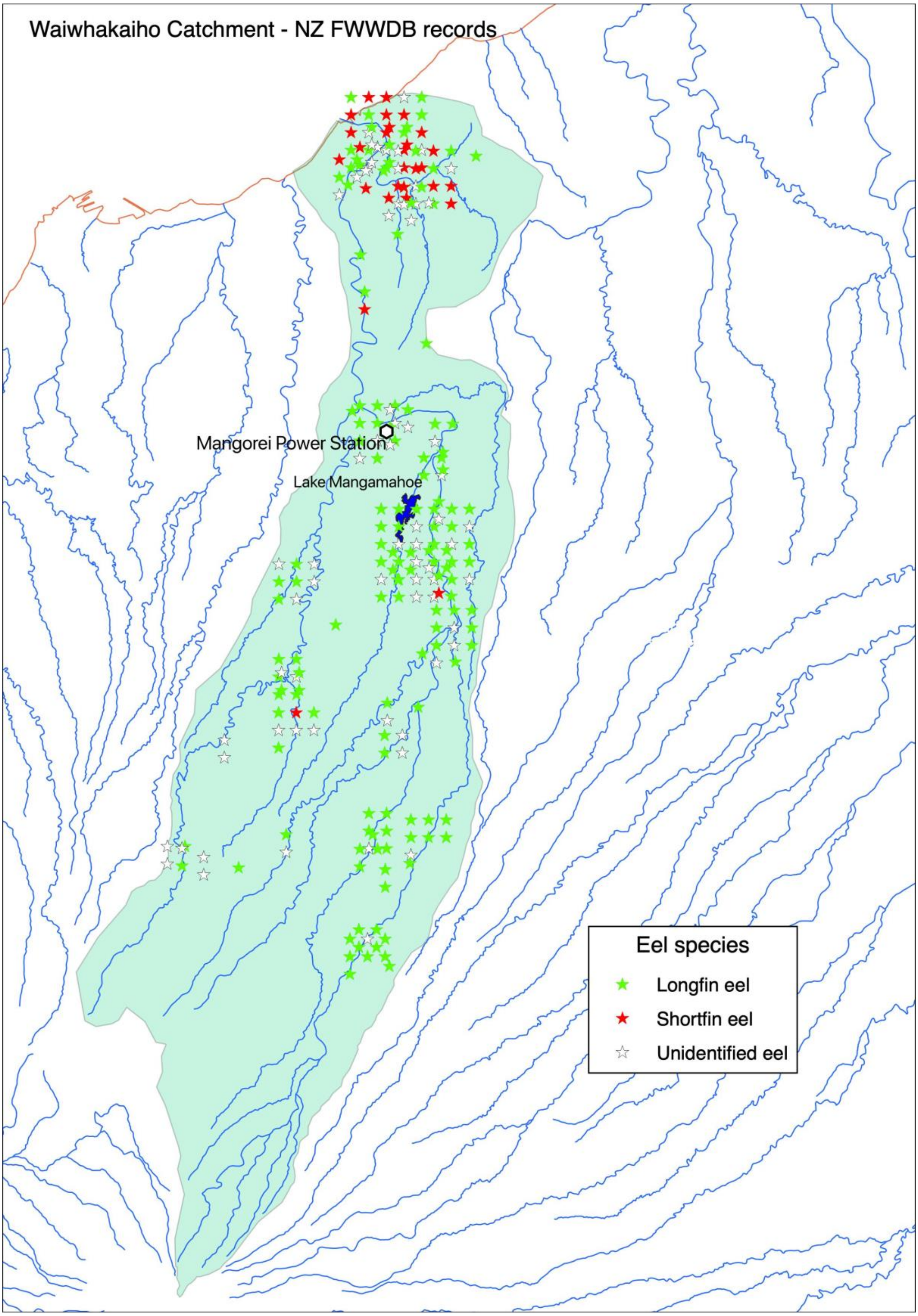
Providing an alternative pathway for downstream migrating fish to leave the lake environment and get back safely to the Waiwhakaiho River would be very difficult to achieve given: the physical nature of the lake's spillway, the need to supply a residual flow of sufficient size and shape to convey fish safely down the spillway, the length of stream environment between the spillway and the Waiwhakaiho River, and the presence of another structure on the lower Mangamahoe Stream that may also impede passage. Again, these factors suggest the chances of successfully providing safe downstream passage for adult fish is relatively low. Given these issues associated with providing alternative route for downstream passage, the following mitigation is recommended:

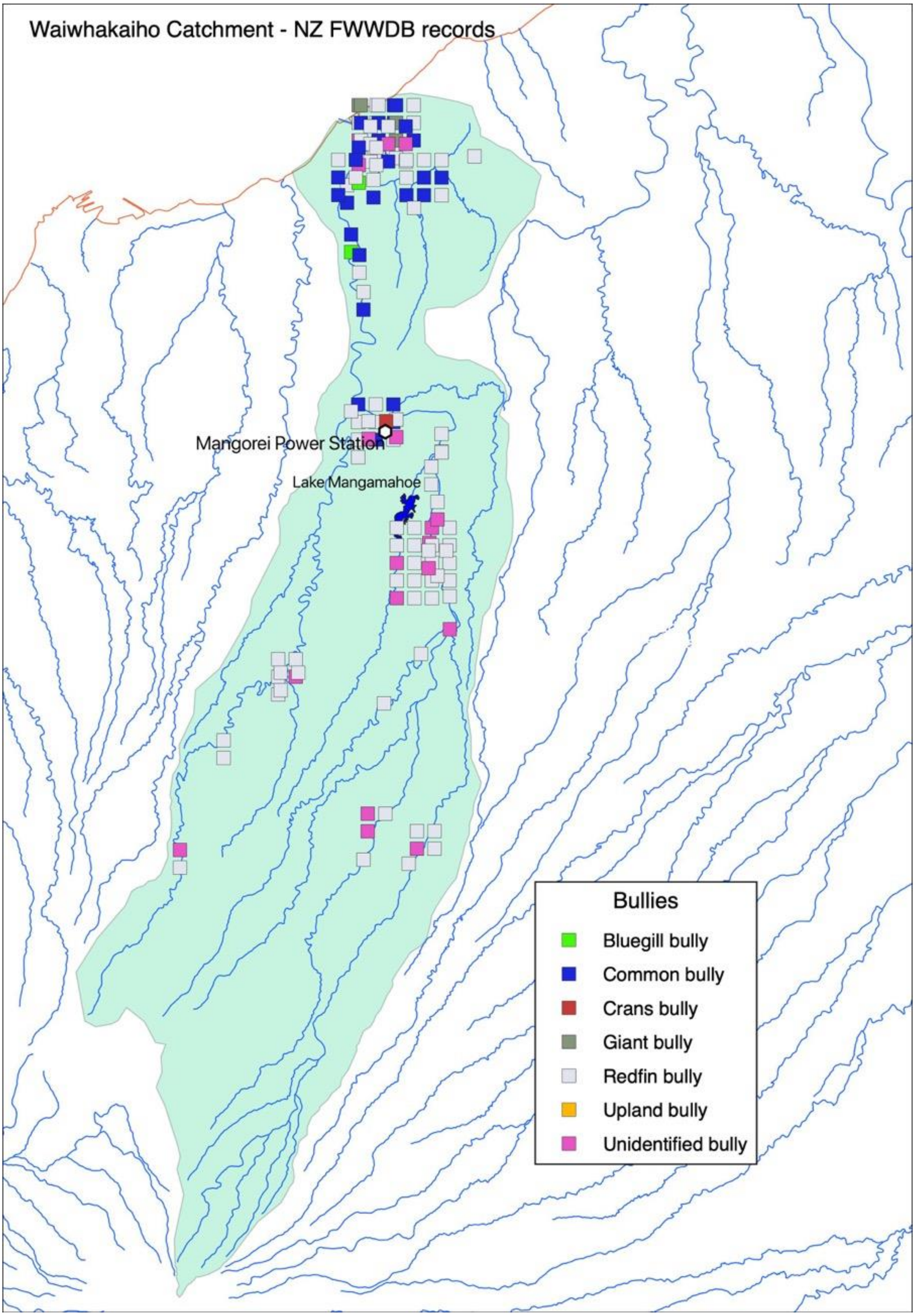
Recommended Mitigation

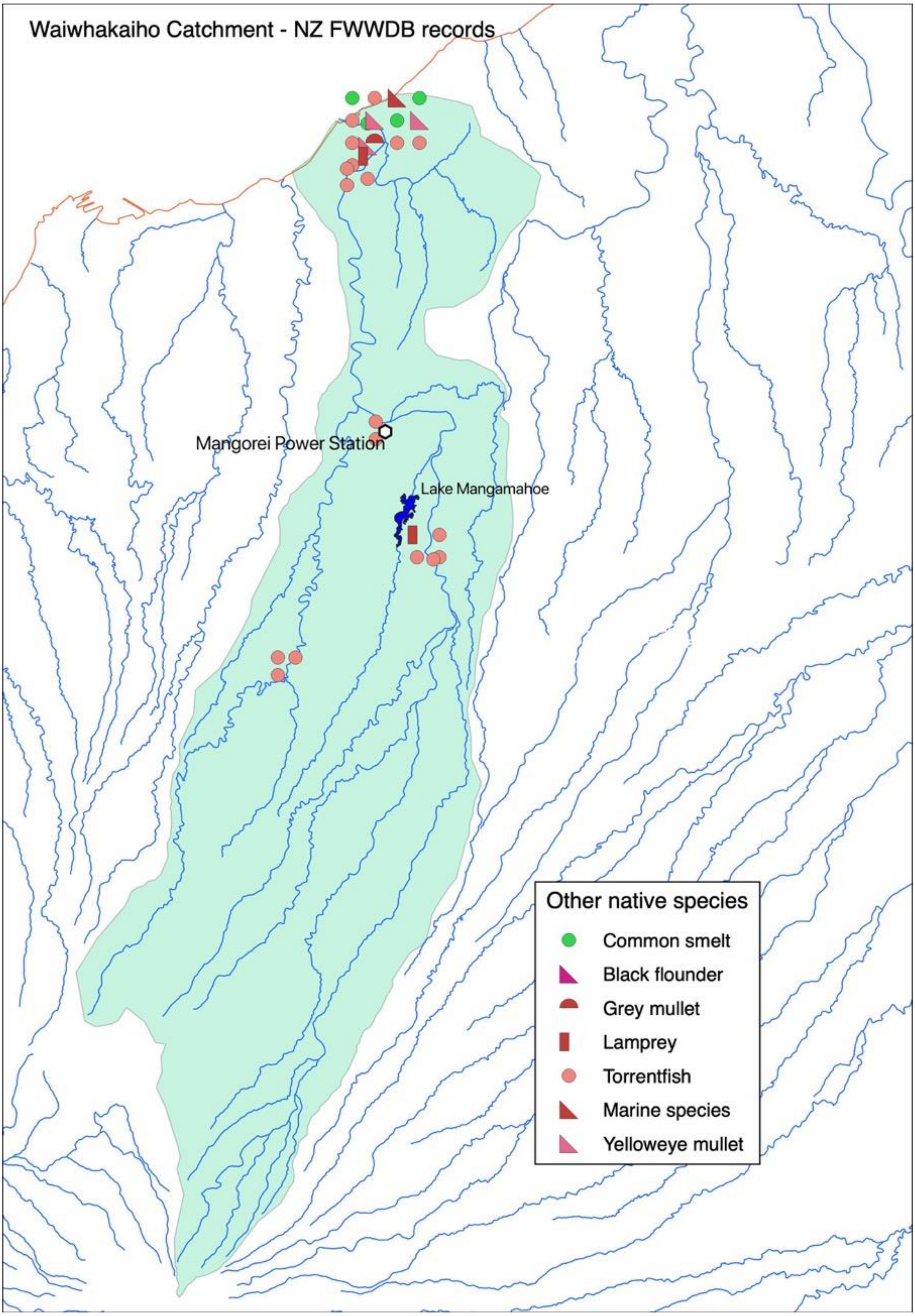
- Improve the existing trap and transfer programme, where practicable. For example, explore options to increase the period of time trapping is undertaken and trapping technique. Transfer other migratory native fish species if captured. Look to develop a collaborate approach with local iwi and other seek input from experts in native fish migration where necessary.
- Relevant authorities (including DOC), in collaboration with other interested parties, to investigate options to restrict commercial eel fishing in Lake Mangamahoe.

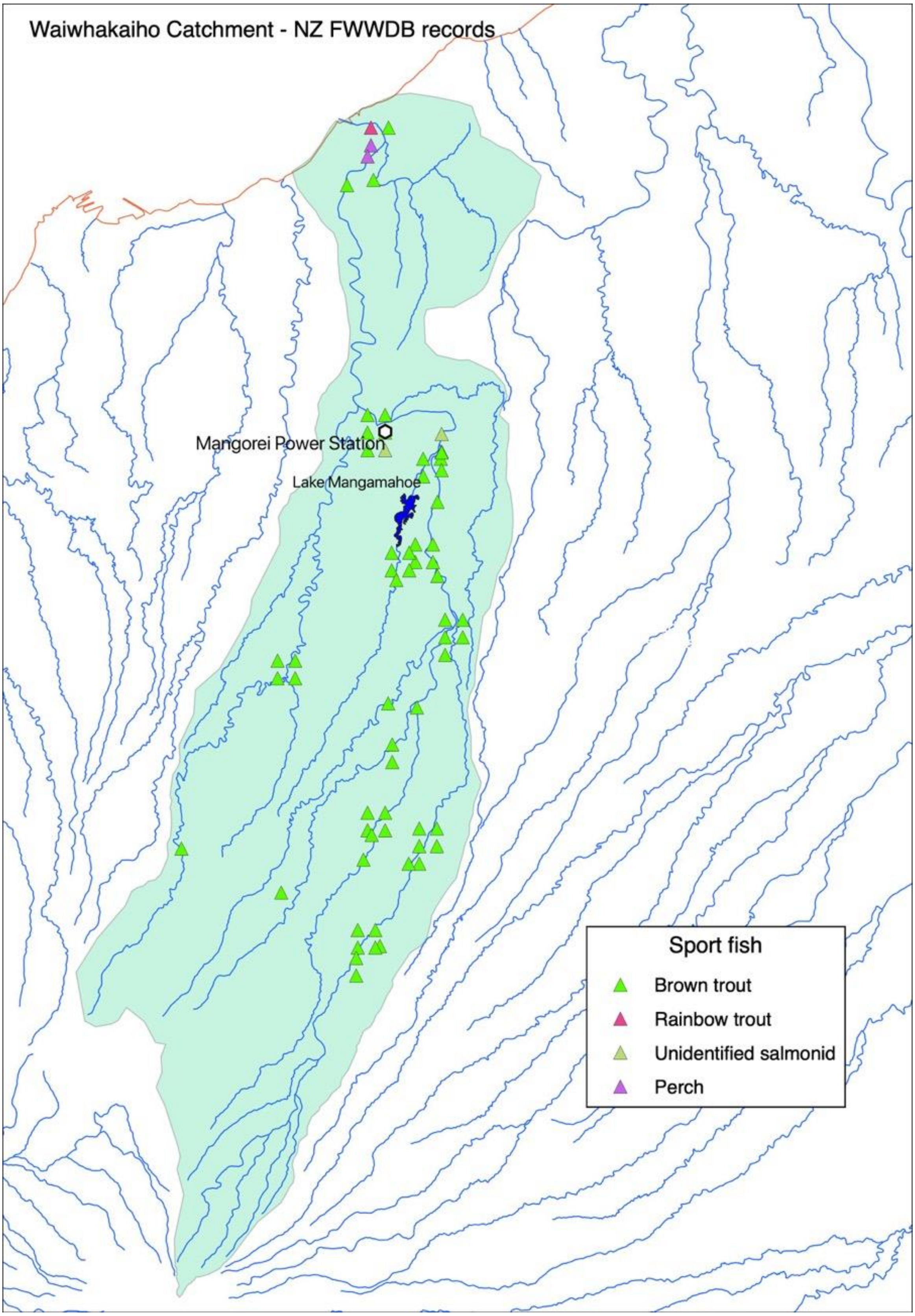
Appendix 1: NZ FFDB data for the Waiwhakaiho River Catchment

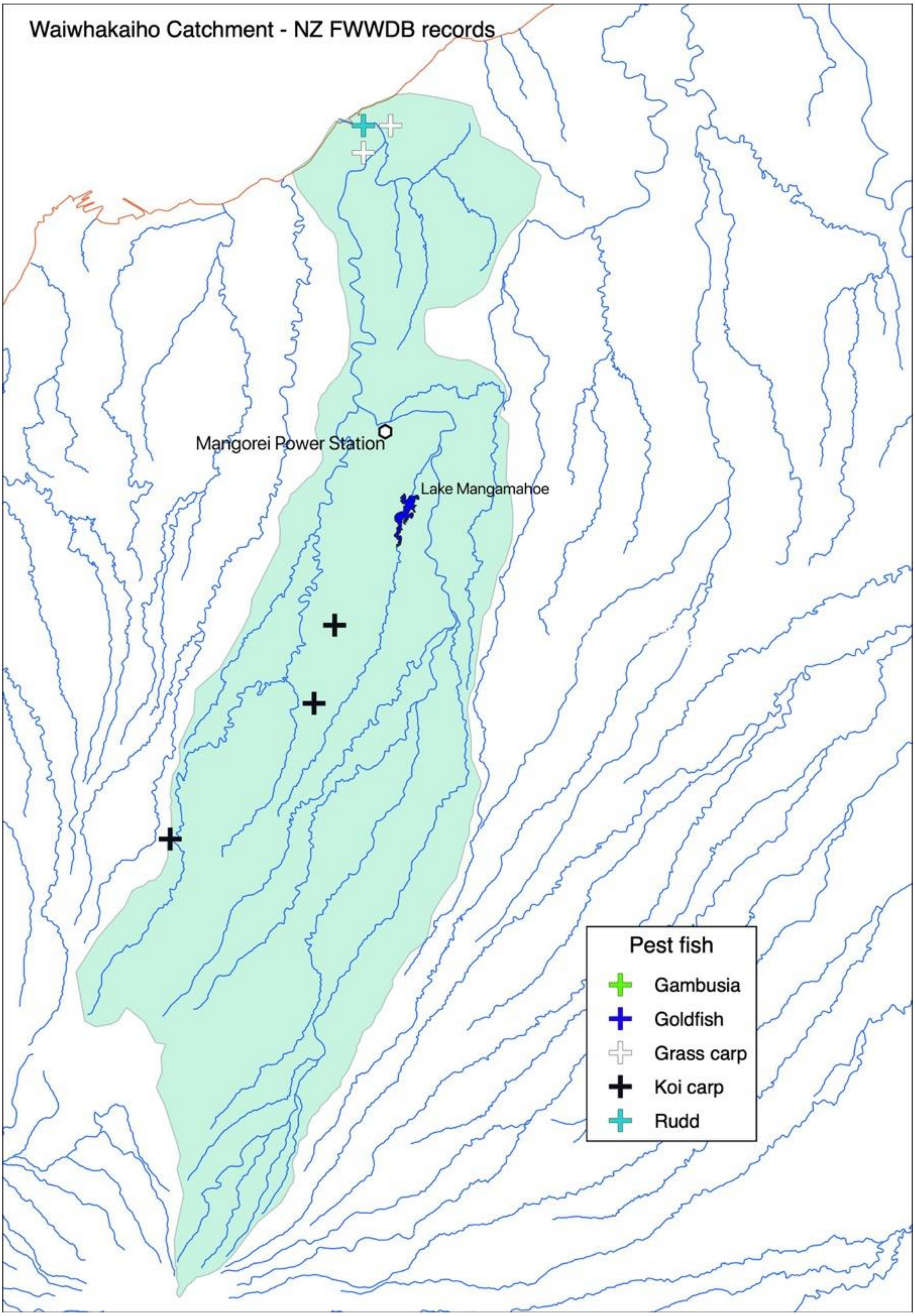



Waiwhakaiho Catchment - NZ FWWDB records
Mangorei Power Station
Lake Mangamahoe
Eel species
Longfin eel
Shortfin eel
Unidentified eel


Waiwhakaiho Catchment - NZ FWWDB records
Mangorei Power Station
Lake Mangamahoe
Bullies
Bluegill bully
Common bully
Crans bully
Giant bully
Redfin bully
Upland bully
Unidentified bully


Waiwhakaiho Catchment - NZ FWWDB records
Mangorei Power Station
Lake Mangamahoe
Other native species
Common smelt
Black flounder
Grey mullet
Lamprey
Torrentfish
Marine species
Yelloweye mullet


Waiwhakaiho Catchment - NZ FWWDB records
Mangorei Power Station
Lake Mangamahoe
Sport fish
Brown trout
Rainbow trout
Unidentified salmonid
Perch


Waiwhakaiho Catchment - NZ FWWDB records
Mangorei Power Station
Lake Mangamahoe
Pest fish
Gambusia
Goldfish
Grass carp
Koi carp
Rudd