Kopurererua Wetland: a study of native fish in the Kopurererua Stream and potential habitat enhancements.

University of Waikato Summer Scholarship Student Report – June 2021

*Figure 1. Male redfin bully (*Gobiomorphus huttoni*). Endemic to New Zealand. Image: McQueen (2008).*

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Abstract

During the summer of 2020/2021, research into the presence and biodiversity of native fish in the Kopurererua Valley Reserve was undertaken for the Kopurererua Valley Rotary Centennial Trust and the People, Cities & Nature MBIE contract with the University of Waikato. Methods used were fish with fyke nets and minnow traps, literature research, DNA testing and use of the NIWA freshwater fish database. It was found that the stream has a relatively poor representation of native fish, with ellow-eyed mullet (*Aldrichetta fosteri*), shortfin eel (*Anguilla australis*), longfin eel (*Anguilla dieffenbachii*), torrentfish (*Cheimarrichthys fosteri*), giant kōkopu (*Galaxias argenteus*), banded kōkopu (*Galaxias fasciatus*), inanga (*Galaxias maculatus*), common bully (*Gobiomorphus cotidianus*), giant bully (*Gobiomorphus gobioides*), redfin bully (*Gobiomorphus huttoni*), common smelt (*Retropinna retropinna*) and black flounder (Rhombosolea retiaria) recorded as present. Native fish that were not present but could potentially inhabit the stream due to presence in other local streams were kōaro (Galaxias *brevipinnis*), lamprey (*Geotria australis*), shortjaw kōkopu (*Galaxias postvectis*) and black mudfish (*Neochanna diversus*). Reasons for the absence of those particular fish are most likely due to the degraded state of the water, substrate and riparian vegetation. Recommendations for enhancing the wetland ecosystem include prioritising the restoration and enhancement of riparian vegetation, and further investigation is recommended to include research into the Kopurererua Stream hydrology and riparian conditions to understand what the most appropriate mitigation techniques might be for habitat and inanga spawning area restoration. Identification of the tidal wedge to predict the likely hydrological optimum area for inanga spawning would be an important first step to enhancing inanga recruitment in the stream.

Introduction

Wetlands are areas that are situated where land meets water and are either permanently or intermittently wet (Johnson & Gerbeaux, 2004). These areas support specialised ecosystems that have evolved to sustain life in wet conditions (New Zealand Government Resource Management Act, 1991). Wetlands play a large and vital role as an ecosystem services provider, including flood control, water filtration, carbon sequestration and habitat provision for many species (Myers, Clarkson, Reeves & Clarkson, 2013). Despite the positive environmental impact wetlands create, the majority of the world's wetlands have been progressively drained to make way for pasture and urbanisation (Myers, Clarkson, Reeves & Clarkson, 2013). New Zealand for example, has only 10% of its pre-anthropogenic wetland cover remaining. The Ramsar Convention on Wetlands, and the Convention on Biological Diversity place obligations on New Zealand to protect and restore public wetlands (Myers, Clarkson, Reeves & Clarkson, 2013), but wetland areas on private land are continuing to degrade because of land-use intensification (Belliss, Shepherd, Newsome & Dymond, 2017).

The largest urban wetland restoration project in the Southern Hemisphere is being undertaken in the Kopurererua Valley Reserve, Tauranga (Canham, 2020). The 360 ha reserve sits at the northern end of the Kopurererua sub-catchment, and within Tauranga City surrounds. The elongated catchment is made of just over 7400 ha and runs north from the Mamaku Plateau to the Tauranga Harbour (Bay of Plenty Regional Council, 2012) (Fig 2a). Dry stock, dairy farming and lifestyle blocks make up over 50% of the catchment land, while native forest also has substantial representation in the upper catchment (Bay of Plenty Regional Council, 2019). The main waterway within the catchment is Kopurererua Stream which flows through the wetland before encountering the industrial estate in Judea, and then enters the Waikareao Estuary (Bay of Plenty Regional Council, 2019) (Fig 2b).

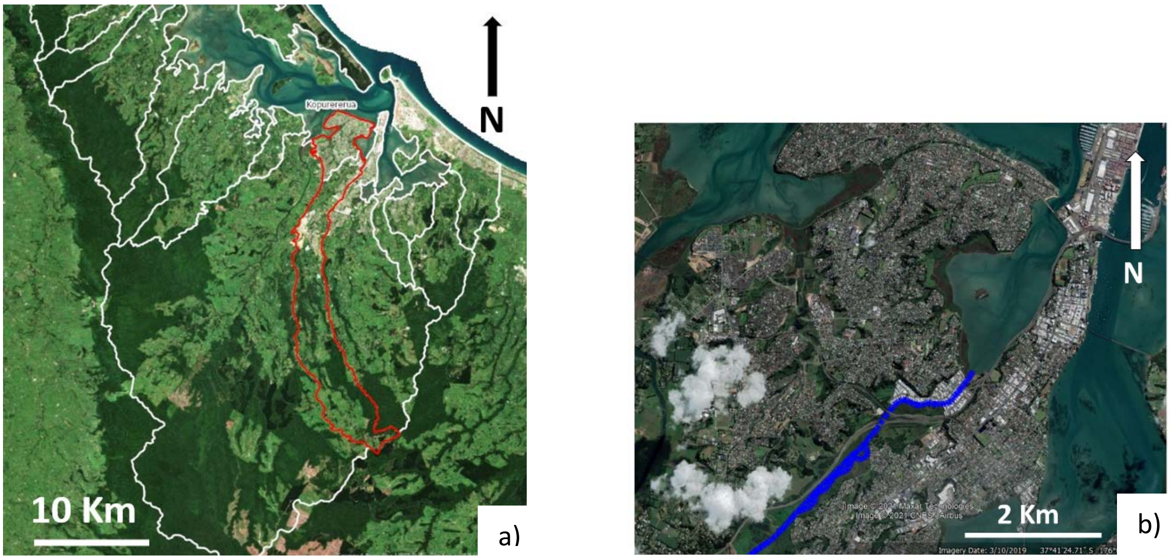

Figure 2. a) Map showing the elongated Kopurererua sub-catchment in red. (Image supplied by Bay of Plenty Regional Council). b) Kopurererua Stream (channelised and re-aligned section) flowing through Tauranga City and into Waikareao Estuary, depicted with blue line. Image: GoogleEarth Pro.

As with most wetlands Kopurererua was modified by settlers, first by Maori to a lesser extent, and then by the European settlers who worked to have the land cleared and drained for failed attempts at farming, and later, the laying of utility pipelines (Canham, 2020). The land became a ‘wasteland’ where around 200 tonnes of inorganic rubbish including cars, steel and whiteware were dumped over many years (Canham, 2020). The misuse of the land was damaging to the relationship tangata whenua had with area which has special historical and cultural value and affected the wetland’s mauri (lifeforce) (Canham, 2020). In 1996, a collaboration between Ngai Tamarawaho (the mana whenua), Tauranga’s city and regional councils and the Kopurererua Valley Rotary Trust was created with the vision to restore the wetland and the relationship between mana whenua and the land (Canham, 2020). Ongoing goals included restoring the aquatic and terrestrial habitats, creating an enjoyable and natural space for the community to enjoy and realigning the Kopurererua Stream to be similar to its original course (Canham, 2020).

Recent studies have found water quality of the Kopurererua Steam to be poor and likely degrading, with sediments, nitrates and phosphates entering the stream from inadequately managed catchment areas (Land, Air, Water Aotearoa, n.d; Bay of Plenty Regional Council, 2019). The steep and agricultural parts of the catchment, along with stock access and a lack of sufficient riparian vegetation, cause nutrients (including faecal matter and phosphates) and sediments to enter the Waikareao Estuary via the stream (Bay of Plenty Regional Council, 2019). Nitrate accumulations are elevated in the stream as it flows through the industrial area of Judea (Bay of Plenty Regional Council, 2019). Low water quality due to catchment use and lack of appropriate riparian vegetation is directly linked to the biota that can inhabit streams (Hanchet, 1990; Swales & West, 1991). Research (Personal observation, 2021; NIWA Freshwater Fish Database, n.d) has shown that certain fish species are absent in the Kopurererua river but are present in other rivers in the Bay of Plenty including threatened/endangered species like Lamprey, Black mudfish, Kōaro, and Shortjaw Kōkopu (Appendix 1). This could be because of water quality and/or lack of suitable spawning vegetation, habitat or migration passages

Aim

The aim of this research was to compile information on the biodiversity of the fish in Kopurererua Reserve. Methods used were fyke nets and minnow traps, the NIWA freshwater fish database, DNA extrapolation from the Kopurererua Stream, and existing literature. Current riparian vegetation was assessed for suitable spawning habitat of native and endemic fish species, and certain potential habitat enhancements were assessed for viability. This research will help in the future planning of the wetland enhancements, as well as providing a baseline of fish species found in the Kopurererua Stream.

Methods

Sites for fyke and minnow net fishing.

Site 1 - Lat 37°42'1.26"S Long 176° 8'53.40"E

Site 1 is situated at the eastern boundary of Kopurererua Reserve (Fig 3). Access to the stream was from Koromiko Street, Tauranga. The surrounding land is industrial and urban to the North and East, and regenerating wetland to the South and West. There are two historical hospital sewage ponds adjacent to the stream. The stream is 11m wide, 600m from the Waikareao Estuary. Riparian vegetation is made up primarily of a mixture of grasses including Floating sweetgrass (*Glyceria maxima*) with a few sparce Tī Kōuka/Cabbage tree (*Cordyline australis*) and Harakeke/flax (*Phormium tenax*).

Site 2 - Lat 37°42'26.55"S Long 176° 8'12.10"E

Site 2 is situated at the wooden footbridge within Kopurererua Reserve, accessed from Faulkner Street, Tauranga (Fig 3). The stream is five meters wide and approximately 2000m from the Waikareao Estuary. The immediate surrounding land is regenerating wetland, flanked by urban settlement and a major toll road (Takitimu Drive). The riparian vegetation is primarily comprised of *Glyceria maxima* with no taller plants to offer shade to the stream.

Site 3 - Lat 37°43'2.52"S Long 176° 7'37.03"E

Site 3 is situated at the metal footbridge within the Kopurererua Reserve, accessed from Jones Street, Tauranga (Fig 3). The stream is five meters wide and approximately 3700m from the Waikareao Estuary. The surrounding land is regenerating wetland, within an urban and pastural setting. The riparian vegetation is comprised mostly of *Glyceria maxima*, with little to no shade available to the stream.

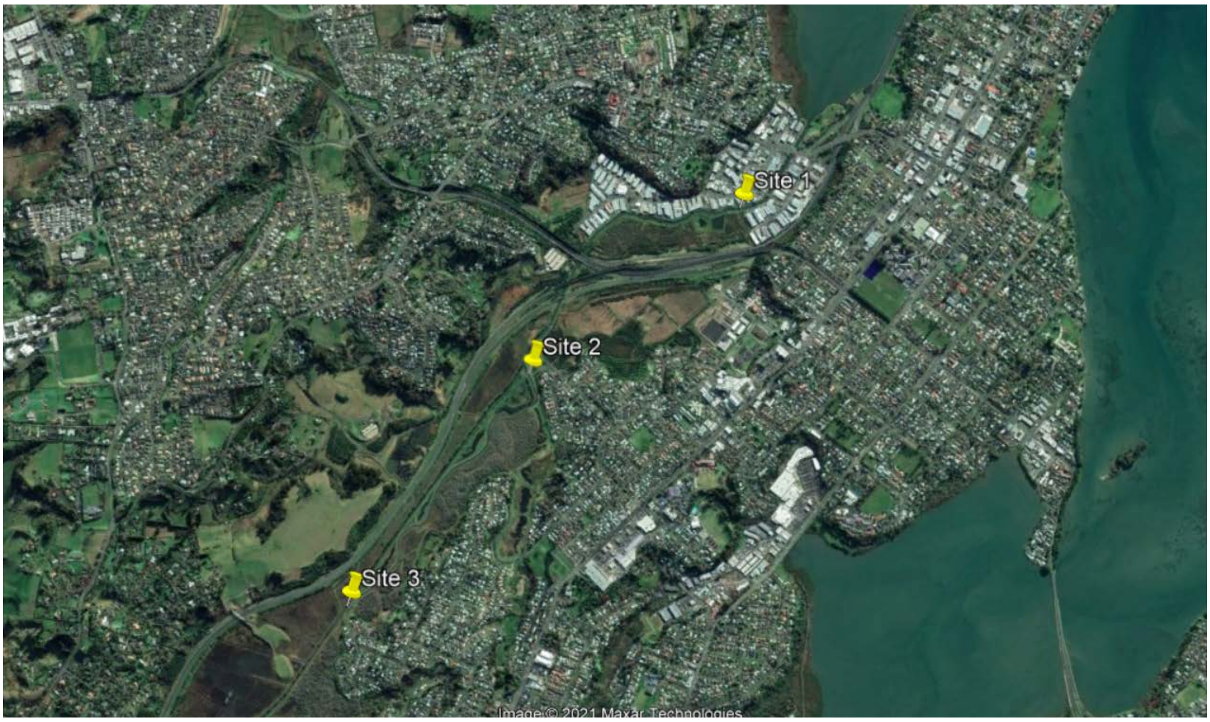

Figure 3. Site 1, 2 and 3 for fyke nets and minnow traps set along Kopurererua Stream. Image: GoogleEarth Pro.

Research methods

Minnow and Fyke net fishing

At each site, one fyke net was set by securing the wing end to the bank with a 2500mm stake and throwing the weighted cod end into the stream (Fig 4a). At site one and two, three minnow traps were set approximately 50m apart and, thrown into the stream, attached to a rope which was secured to the bank by tying to vegetation (Fig 4b). At site three, four minnow traps were deployed. All sites were entered into the GPS.

Net/trap time in the water was calculated for catch per unit effort data. Fish were identified to species level, measured and released.

Figure 4. a) Fyke net being thrown into the stream and secured to a metal stake at site 1. b) Minnow net being thrown into the stream and tied to vegetation at site 1. Images taken by author.

At site 3, a water sample was taken and filtered as per instructions to send to Wilderlab in Wellington to get analysed for fish DNA (Multi species NGS test) (Fig 5).

Figure 5. eDNA sampling equipment, ready to be sent to Wilderlab. Image taken by Brendan Hicks.

NIWA Freshwater Fish Database

NIWA Freshwater fish database assistant was located on the NIWA website and downloaded. Fish records from specific catchments and rivers/streams were downloaded from the same website and accessed via the freshwater database assistant. The database assistant was then able to present a map with all fish records in the chosen areas, detailing fish species, date and location.

eDNA

An environmental DNA (eDNA) kit was obtained from Wilderlab and 300 ml of stream water from Site 3 (Lat 37°43'2.52"S Long 176° 7'37.03"E) was collected and passed through a filter using gloves and sterile equipment, as per instructions. These kits identify DNA in the water for up to two days after the presence of a fish (Wilkinson, 2021) using qPCR (quantitative polymerase chain reaction). The sample was labelled and sent to Wilderlab for analysis, and the data returned in a Microsoft Excel spreadsheet.

Literature research

Literature research was undertaken to access and extrapolate data from reports on the Kopurererua catchment, reserve and stream for native fish diversity and abundance. Searches included the University of Waikato online library, Google Scholar, Department of Conservation and the Tauranga Library. Other streams and rivers within the wider vicinity were also briefly researched for comparisons.

Salt wedge

Research and personal communication were undertaken to ascertain the salt wedge range of the Kopurererua Stream. Research is lacking in this area and one of the reasons may be the physical barriers for boats (low bridges and estuary depths) to navigate at very specific times.

Results

Fyke nets and minnow traps

Fish caught in the minnow traps were common bully and inanga. The fyke nets caught fish that were identified as triplefin, redfin bully, common smelt, inanga and freshwater shrimp (Table 1)

NIWA Freshwater Fish Database

The NIWA Freshwater Fish Database proved to have the most species accounted for. The species noted in the database were: yellow-eyed mullet, shortfin eel, longfin eel, giant kōkopu, banded kōkopu, inanga, gambusia (pest fish), common bully, giant bully, redfin bully, rainbow trout, common smelt and black flounder (Table 1)

eDNA

The results from the eDNA testing of the Kopurererua Stream showed that there was DNA from shortfin eel, longfin eel, torrentfish (which has not been recorded in the Kopurererua Stream before), freshwater mussel, banded kōkopu, inanga, gambusia, common bully, redfin bully, rainbow trout and common smelt (Table 1). Some galaxiids, smelt and bullies were identified only to genus level, and at the time of writing this report, no conclusions on the species were made.

Note: Triplefin was not in the DNA results the same day the fish were identified in the stream, so was most likely mis-identified. Therefore triplefin is not investigated further in this report.

Literature research

Information on fish species in the Kopurererua Stream have been reported on very rarely, and only one piece of literature was found to have adequate information. Hicks, Bell & Ring (2005) reported shortfin eels, common smelt, rainbow trout, inanga, yelloweye mullet, juvenile black flounder, giant bullies, and freshwater crayfish. Kōaro, torrentfish, lamprey, black mudfish and shortjaw kōkopu were not reported as present in Kopurererua Stream up till this research but are found in other rivers in the Bay of Plenty (Hicks, Bell & Powrie, 2014; Boubée & Baker, 2005; NIWA Freshwater Database n.d.).

Table 1. Fish and crustacean species noted as present in the Kopurererua Stream by each method, marked with a dot. Triple fin (*) was most likely mis-identified due to eDNA results having contradicting evidence.

	eDNA sample	NIWA FFDB	Net/Trap
Fish			
Yelloweye mullet		•	
Shortfin eel	•	•	
Longfin eel	•	•	
Torrentfish	•		
Giant kōkopu		•	
Banded kōkopu	•	•	
Inanga		•	•
Common bully	•	•	•
Giant bully		•	
Redfin bully	•	•	•
Common smelt	•	•	•
Black flounder		•	

Triplefin			•*
Rainbow trout	•		
Crustacea			
Kōura		•	
Shrimp		•	

Salt wedge

A computer modelling program was created and used in 2021 to determine the likely upper salt wedge limits of particular rivers and streams in the Bay of Plenty (Suren, 2021), and therefore the spawning area for Inanga. Although Kopurererua Stream is not included in that particular report, the author supplied a map to indicate the upper limit of the salt wedge in both the channelised and realigned sections of the stream, using the model. The salt wedge limit is located west of Scott St (re-aligned section) and at the bridge off Wylie St on the channelised section of the stream (Fig 6)

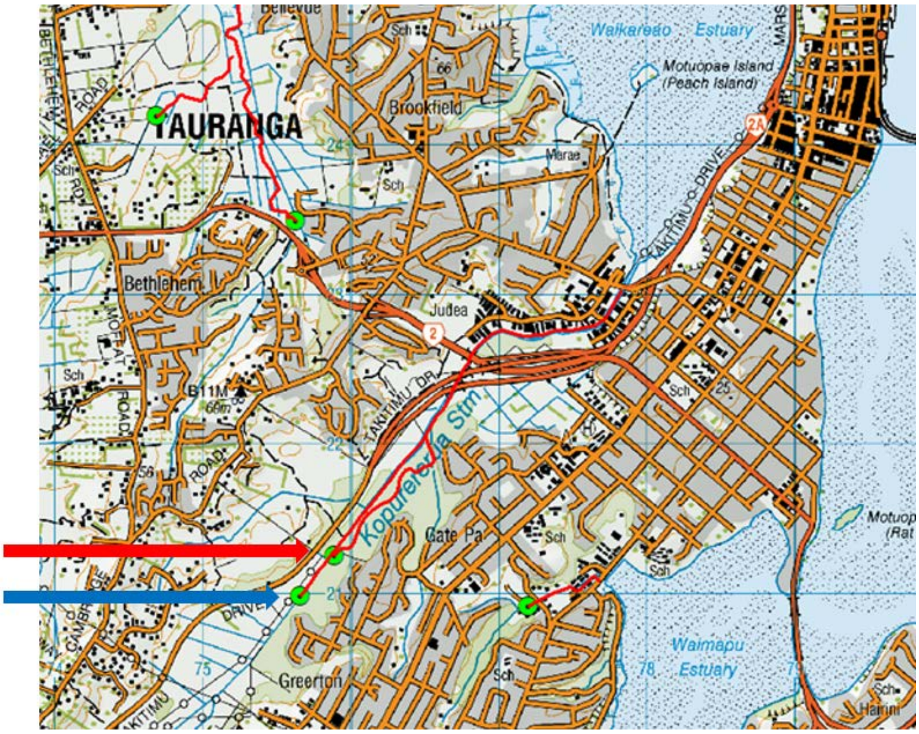

Figure 6. Map of Tauranga showing the salt wedge upstream limits with green dots, as per the model data (Suren, 2021). *Red arrow indicates the realigned stream section salt wedge limit, the blue arrow indicates the channelised stream section salt wedge limit.*

Discussion

Kopurererua Stream has a relatively poor representation of native fish for the Bay of Plenty. There are most likely many reasons for this. Water quality has a major impact on what fish are able to inhabit waterways (Hanchet, 1990; Swales & West, 1991). Land, Air and Water Aotearoa (LAWA) have cautioned that Kopurererua Stream is not safe to swim in, and notes that the stream is in the worst 25% of rivers for black disc, turbidity, total nitrogen, total oxidised nitrogen, ammoniacal nitrogen and total phosphorous, with most of these variables in even further decline (Land, Air and Water Aotearoa, n.d.). Organisms have an optimal range within each environmental variable (Vannote, Minshall, Cummins, Sedell, & Gushing, 1980) which means Kopurererua Stream must be able to provide habitats that comply with the individual needs of the fish for at least part of the diel cycle.

Water temperature plays a big role in fish biodiversity either directly, for example, temperature affects metabolism (Khan, Pether, Bruce, Walker & Herbert, 2014), or indirectly, for example, nutrient toxicity increases when water temperature increase (Ficke, Myrick & Hansen, 2007). Waterways that run through pasture or land with no canopy cover are warmer due to the lack of shade (Roth et al., 2010). Within the Kopurererua Valley Reserve, the stream has very little riparian vegetation that offers shade, and certainly not enough to make a significant difference in water temperature. Hicks, Bell & Ring (2005) measured the lower Kopurererua Stream temperature in June (winter), with a reading of 10.4^{o}C which was classified as cold, but in a report by the BOPRC (2009) a maximum temperature of 18.1^{o}C was recorded (Scholes & McIntosh, 2009). One of the habitat requirements for threatened fish Kōaro is cold water and the lack of appropriate riparian vegetation for shade may be part of the reason for its absence. Another effect warmer water has on the biodiversity of Kopurererua Stream is the presence of the predatory pest fish gambusia/mosquitofish (*Gambusia affinis*). Gambusia prey on juvenile fish and fry, and nip the fins of adult fish, which can render them unable to swim properly and causes death (Rowe, Smith & Baker, 2007). Gambusia have been found to display this aggressive behaviour in waters >15^{o}C and avoid streams than contain water colder than 10^{o}C (Rowe, Smith & Baker, 2007). Lowering the temperature could make Kopurererua Stream less desirable to Gambusia and therefore decrease the predation rate of native fish.

The turbidity of Kopurererua has been shown to be poor in recent reports (Hicks, Bell & Ring, 2005; Scholes & McIntosh, 2009;) with Scholes & McIntosh (2009) reporting that Kopurererua Stream has the highest turbidity reading out of all the Bay of Plenty rivers, and one of the four worst rivers for black disc readings. This is most likely due to the high sediment input from the catchment because of the steepness, land usage and poor riparian vegetation. Kōaro and black mudfish are especially intolerant to turbidity, as are longfin eels to a lesser degree (McEwan & Joy, 2013; Hicks & Barrier, 1996; Kearney, Jeffs & Lee, 2008). As well as negatively impacting the native fish, sedimentation loads can also affect the receiving environment, in this case the Waikareao Estuary.

Most of New Zealand's native fish are diadromous (NIWA, n.d.), including the short and long-fin eel, yelloweye mullet, kōkopu (giant, banded, shortjaw), inanga, bullies (common, giant, redfin), common smelt, torrentfish, kōaro and lamprey. As such, a clear and safe passage from the ocean and estuary to their river habitats are imperative. Kopurererua Stream has been assessed for impedance by Boffa Miskell (2014) during a city-wide assessment of stormwater structures. Nine structures documented in the Kopurererua Stream could not be found, and three structures were deemed to be medium priority for remediation. Part of the strategy for prioritising the remediation was to categorise the habitat upstream from the structure. The poorer the habitat, the lower the priority. Further ecological restoration of the wetland would increase the health of the stream habitat and therefore increase the priority of any remediation required for fish passage.

Other factors that will affect the presence or abundance of native fish include substrate materials, pool and riffle sequences, cover and spawning habitat (See appendix 2). Lamprey, kōaro, redfin bully and shortjaw kōkopu all require habitat that contains large substrate particles/boulders, turbulence and pool and riffle sequences. Giant bully, giant kōkopu and banded kōkopu require in-stream cover such as debris dams and logs, and shortjaw kōkopu require forest cover at the stream edge. McQueen (2013) states that the loss of forest cover is a leading cause of the decline in shortjaw kōkopu numbers. Spawning site habitats are another vital aspect of freshwater fish biodiversity and these sites are under pressure from degradation and loss due to human activities (Taylor et al., 2019). Inanga spawn in stream edge vegetation in or just above the salt wedge during tidal events (McDowall 1988; Hamer 2007). Banded kōkopu and shortjaw kōkopu also use stream-side vegetation to spawn

(Charteris, Allibone & Death, 2003). Lamprey, kōaro and redfin bully all spawn specifically within the substrate (Under large boulders, in cobbles below riffles and under rocks, respectively).

Kopurererua Stream has not been studied well in its entirety, and better knowledge of the barriers, substrates, pool and riffle sequences and vegetation is needed to fully understand what mitigation is needed to increase abundance, diversity and recruitment of native freshwater fish. At a minimum, due to previous investigations that report the poor water quality, further planting and managing appropriate riparian vegetation should be prioritised. This will decrease sedimentation and nutrient input, as well as providing shade for temperature management and enhance and expand spawning sites. If further realignment of Kopurererua Stream is undertaken, it may be a good use of resources to create extra spawning areas off the main waterway and investigate the possibility of improving the substrate material.

Conclusion

Kopurererua Wetland is a taonga of Tauranga and has the potential and the opportunity to be a highly diverse and functioning ecosystem that other restoration projects look to as a case study for inspiration and methodology. The four methods of data collection give a good outline of the fish present in the stream. The native fish present are for the most part tolerant to variable conditions and it is reasonably obvious that the native fish that are absent require a higher quality habitat. The science is clear: Kopurererua Stream has high sedimentation, high nutrient input and high turbidity, all which are detrimental to the biodiversity of native freshwater fish. Restoring, enhancing and extending riparian vegetation and forest cover along the Kopurererua Stream should be implemented as soon as possible. Further investigation into the geology and geography of the stream substrate and catchment is recommended to determine what mitigation techniques are going to be appropriate for in-stream restoration.

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Appendices

Appendix 1

Threatened and at risk freshwater fish absent from Kopurererua Stream, but present in other waterways in surrounding areas.

Common name	Scientific name	Example of locations	Reference
Lamprey	*Geotria australis*	Wairapukao Stream, Waiari Stream, Awakaponga Stream, Mangaone Stream, Waimapu Stream	(NIWA n.d.; "Schedule 1 – Aquatic Ecosystem Areas", 2021)
Black mudfish	*Neochanna diversus*	Piako River, Topehaehae Stream, Ohinemuri River	(NIWA, n.d.)
Kōaro	*Galaxias brevipinnis*	Te Puna River, Kaiate Stream, Romanga Stream, Waitao Stream	(Boubée & Baker, 2005; NIWA n.d.))
Shortjaw kōkopu	*Galaxias postvectis*	Opuiaki Stream, Mangokarengorengo River, Kaiate Stream	(NIWA, n.d.)

Appendix 2

Native fish descriptions for fish that are present in Kopurererua Stream, or absent but present in other waterways in surrounding areas.

Yelloweye mullet, *Aldrichetta forsteri*

Yelloweye mullet, *Aldrichetta forsteri*. (Gomon & Bray n.d.).

Non-diadromous

Not threatened

Physical attributes Commonly 200-300mm long, although they have been measured at 500mm long at the maximum age of 7 years. Elongated body, slightly arched back, with a deeper belly. They are grey-green on top with silver sides, and slight yellow underneath. Bright yellow or golden coloured eyes, which are a distinguishing feature. Head is broad, with a pointed snout, more-so as an adult. Small mouth. Two dorsal fins. Slightly forked tail. **Distribution and behaviour** Found in the South West Pacific, including throughout New Zealand, and East, South and West Australia. Their diet is wide ranging, including algae, crustaceans, diatoms, molluscs, insect larvae, fish, polychaetes, coelenterates, fish eggs and detritus. They inhabit marine and brackish waters and will go upriver into freshwater for feeding but cannot stay in freshwater for prolonged periods. Most commonly found in salt water, estuaries and salt wedge areas. Spawn in summer and autumn, in coastal waters including estuaries. The eggs are pelagic and free floating.

(Gomon & Bray, n.d.; McQueen & Morris, 2013)

Shortfin eel, *Anguilla australis*

Shortfin eel*, Anguilla australis.* (Gomon & Bray, 2018).

Catadromous

Not threatened

Physical attributes Up to 1200mm long (female) and 600mm (male). Elongated. Usually light brown or olive. Small mouth, cleft reaches eye. Dorsal fin extends only a little past the length of the anal fin. **Distribution and behaviour** Found in coastal drainages of New Zealand, south-eastern Australia and the western Pacific Islands. They are hardy and tolerates a large range of temperature and salinity. Inhabits estuarine waters, lowland lakes, swamps and low velocity streams and rivers. Eggs are laid and hatched in the Pacific Ocean, Glass eels migrate from ocean to estuary during winter and spring. Juvenile eels migrate upstream during summer. Adult eels migrate to the ocean for spawning and death in autumn.

(Beumer 1996; Richardson, Boubee & West 1994; McQueen & Morris, 2013)

Longfin eel, *Anguilla dieffenbachii*

Longfin eel, *Anguilla dieffenbachia*. (Lau, 2020).

Catadromous

At risk, declining

Physical attributes up to 2000mm long (females) and 700mm long (males). Elongated, dark brown or black body. They have a large mouth, with the cleft reaching well past the eye. The dorsal fin extends further along the body than the anal fin. Big loose wrinkles appear when the body is bent. **Distribution and behaviour** Found throughout New Zealand rivers and lakes but higher upstream than Shortfin eels. Hardy, adults tolerate large ranges of temp and salinity but relatively intolerant to pollution. They prefer faster moving water and penetrate further inland than Shortfin eels. Often found in waterways with stony substrates. Eggs are laid and hatched in the Pacific Ocean. Glass eels migrate from ocean to estuary during winter and spring. Juvenile eels migrate upstream to mature in summer. Adult eels migrate to the ocean for spawning in autumn and die afterwards.

(McQueen & Morris, 2013; Paulin, Roberts, Steward & McMillan, 2001; Kearney, Jeffs and Lee, 2008; McDowall 1990)

Torrentfish, *Cheimarrichthys fosteri*

Torrentfish, *Cheimarrichthys fosteri.* (Blueether, 2012).

Amphidromous

At risk, declining

Physical attributes 100-130mm long with a wedge shaped body. They have a broad head, narrowing all the way to the tail. They are pale brown with three vertical dark brown bands, decreasing in width as they go along the body, and a slim band over the head and across the eyes. The dorsal and anal fins have a long base and there are some short spines in the first dorsal fin. **Distribution and behaviour** They are found throughout New Zealand, but more concentrated in the North Island. They prefer rivers that go directly to the sea, and not via estuaries. They use riffles during the day, and feed at night in slower water. Adult male sand females live separately, with females inhabiting areas upstream to the males. Spawning occurs in freshwater close to the coast in summer.

(McQueen & Morris, 2013; Hamer, 2007)

Giant kōkopu, *Galaxias argenteus*

Giant kōkopu, *Galaxias argenteus*. (Miles, 2019).

Amphidromous

At risk, declining

Physical attributes Usually between 300-450mm long with a stocky and broad body. Olive-dark brown base colour, with gold circles and crescent shape markings along body. Short, round snout. Fins are thick, rounded and fleshy. **Distribution and behaviour** Widespread, but not abundant on the east coast of New Zealand. Generalist feeders, acquiring nutrition from both aquatic and terrestrial sources. They can tolerate drains and pastural areas. They prefer waterways with pools and in-river cover (debris dams), undercut banks and riparian veg. They use areas adjacent to riffles for feeding. Spawning habits are largely unknown, but they probably spawn in autumn and winter in mid-low reaches.

(McQueen & Morris, 2013; Bonnet & Lambert, 2002; David & Stoffels, 2003)

Kōaro, *Galaxias brevipinnis*

Kōaro, *Galaxias brevipinnis*. (Walrond, n.d.).

Amphidromous

At risk, declining

Physical attributes 160-180mm long but can be as long as 280mm. Their body is a tubular shape with a broad head but pointed profile. They are silver/grey with dark conjoined markings over the body - marks become speckles as fish ages. Pectoral and anal fins are large and strong, used for climbing and 'walking' when migrating upstream. **Distribution and behaviour** Juveniles are very strong climbers, even against strong currents. They are found throughout New Zealand, from low coastal areas to high altitudes inland. They prefer cold, clear, fast flowing water that has depth and turbulence. They inhabit streams that have large substrate particles and gaps, at higher altitudes. They spawn in cobbles at the stream edge below riffles, during summer and autumn. Spawning information is lacking, and the first confirmed New Zealand spawning site of Kōaro was only found in 1999 in Taranaki.

(McQueen & Morris, 2013; Baker & Hicks, 2003; McEwan & Joy, 2013; Allibone & Caskey, 2000).

Banded kōkopu, *Galaxias fasciatus*

Banded kōkopu, *Galaxias fasciatus.* (Blueether, 2013).

Amphidromous

Not threatened

Physical attributes 200-300mm long with a stocky and broad body. They are brown with vertical amber stripes. There is a small silver/white vertical line behind the operculum. Short, rounded snout. Fins are thick and fleshy. **Distribution and behaviour** Excellent climbers and therefore are found throughout New Zealand, in low to high altitudes. They have a preference to terrestrial drift prey, including crickets and cockroaches. In stream debris (debris dams) and pools are their highest preference for habitat. The streams they inhabit are higher in altitude, narrower, and higher abundance of native riparian vegetation than Giant Kōkopu. Native canopy is imperative for their presence. They spawn in stream-margin vegetation and debris during mid-autumn to mid-winter, when the waterway is at flood.

(McQueen & Morris, 2013; West, Jowett & Richardson, 2005; Baker & Smith, 2007; Hamer, 2007)

Inanga, *Galaxias maculatus*

Inanga, *Galaxias maculatus*. (Gomon & Bray, n.d.)

Amphidromous

At risk, declining

Physical attributes 80-110mm long, with a long and slim body. Pale olive/brown with tiny black spots along the length of body. They have silver eyes and abdomen. Some have a green stripe along the back. The head has a round profile, with large eyes. Tail is slightly forked. **Distribution and behaviour** Not found further than 200km upstream, and less than 230m in elevation as they cannot climb. Commonly inhabit lowland areas and can tolerate a range of water conditions. Not highly selective of habitat and lives in a wide range of temperature and ground cover and can be found in clear to tannin stained water. They migrate to estuaries to spawn among reeds and grasses at the water margin during autumn and winter.

(McQueen & Morris, 2013; Glova, 2003; McDowall, 1990; McDowall 1988; Hamer, 2007)

Shortjaw kōkopu, *Galaxias postvectis*

Shortjaw kōkopu, *Galaxias postvectis.* ("Aquatic life – Manawatu River", 2021).

Amphidromous

Threatened, nationally vulnerable

Physical attributes 100-300mm long with a stocky and broad body. Mottled markings of brown/grey/pink. There is a dark patch behind the operculum. Bluish eyes, with an undercut lower jaw. Fins are thick, rounded and fleshy. **Distribution and behaviour** Mostly found in the North Island of New Zealand but are scarce on the east coast of the North Island, and north and west South Island. Their diet is benthic and terrestrial drift. They inhabit streams and rivers with large substrate particles and gaps, turbulence, and riffles and pool sequences, within forest cover. They spawn late during autumn and early winter, in stream bank rocks, debris and vegetation during flood.

(McQueen & Morris, 2013; West, Jowett & Richardson, 2005; McEwan & Joy, 2013; Hamer, 2007)

Lamprey, *Geotria australis*

Lamprey*, Geotria australis.* (Gomon & Bray, 2018).

Anadromous

Threatened, nationally vulnerable

Physical attributes 450-750mm long. They are elongated and eel-like. They have seven gill holes in a line behind the eyes. They are grey and brown in freshwater, but blue when returning from the ocean. Their mouth is a round sucker-like opening lined with rasping teeth. Males have a large pouch of skin behind the mouth. They have two small rear dorsal fins and a tail fin, but lack pectoral, pelvic and anal fins. They are primitive fish that evolved before bones, jaws or swim bladders evolved. **Distribution and behaviour** They can climb vertically, using their mouth to suction onto surfaces. They are scattered throughout New Zealand but scarce on the east coast of the North Island. They are also found in Australia, Chile, and Argentina. They utilise small to medium rivers and streams that provide riffles and runs, pools and backwaters, and boulders. Adults migrate upstream in winter. Eggs are laid in coagulated masses, adhering to the underside of large boulders during spring. Spawning sites have been found in narrow, shallow second order streams, with native canopy.

(McQueen & Morris, 2013; McDowall 1990; Jellyman, Glova & Sykes, 2002; Baker et al., 2017; Hamer, 2007)

Common bully, *Gobiomorphus cotidianus*

Common bully, *Gobiomorphus cotidianus*. (Bendle, 2014)

Facultatively amphidromous

Not threatened

Physical attributes up to 120mm long, with a solid body and tapered profile. Some have a hump directly behind the head. Pale brown/grey with dark patches along the body. A few dark, horizontal lines on cheek under eyes. They have a pale vertical line at the base of the pectoral fins **Distribution and behaviour** They are generalist and found throughout New Zealand including Rakiura (Stewart Island) and landlocked lakes. Their diet consists of zooplankton, gastropods and chironomid larvae. They prefer slow flowing water. They spawn in spring and summer, beneath stones or among aquatic weeds.

(McDowall, 1990; McQueen & Morris, 2013; Jarvis & Closs, 2015; Ingram, Dutoit, Mikheev, Khan & Schallenberg, 2020; Bleackley, Landman & Ling, 2009; Hamer, 2007)

Giant bully, *Gobiomorphus gobioides*

Giant bully, *Gobiomorphus gobioides.* ("Giant Bully | The Styx", 2021).

Amphidromous

At risk, naturally uncommon

Physical attributes Up to 240mm long. They are dark brown/grey with light or gold markings in short horizonal lines or patches, along the body. They have a tapered head, large mouth and a protruding lower jaw. The finds are rounded, with 6 spines on first dorsal fin. **Distribution and behaviour** They are found in the lower reaches of waterways, usually <10km inland. Their preferred habitat is tidal areas that include instream cover of logs, and vegetation. They are at least partly piscivorous. Giant Bully's spawning and migration habits are not well understood, but it is believed that they spawn during spring and summer in estuaries.

(McQueen & Morris, 2013; Jellyman, Sagar, Glova & Sykes, 2000, Hamer, 2007)

Redfin bully, *Gobiomorphus huttoni*

Redfin bully, *Gobiomorphus huttoni*. (McQueen, 2008).

Amphidromous

Not threatened

Physical attributes Up to 120mm long with a solid, with a blunt profile. They are light brown with dark rectangle patches along body and have diagonal stripes on their cheeks. Males have bright red patterns on dorsal, anal and tail fins. Females have brown patterns. Fins are rounded, with 6 spines on first dorsal fin. **Distribution and behaviour** They are found throughout New Zealand coastal areas, although they can penetrate quite far inland. Scarce on the Kaikoura and Canterbury coasts. Habitat specialists and needs both large substrate particles and interstitial spaces, shallow pools and sand substrate. They need areas of low sedimentation) Spawns in winter and spring, underneath rocks in flowing water.

(McQueen & Morris, 2013; McEwan & Joy, 2013; Vanderpham, Nakagawa & Closs, 2013; McDowall, 1990; Hamer, 2007)

Black mudfish, *Neochanna diversus*

Black mudfish, *Neochanna diversus*. ("New Zealand mudfishes: A guide", n.d.).

Non-diadromous

At risk, declining

Physical attributes 90mm long. Their body is of tubular shape with a short, blunt head and small mouth and eyes. They are very dark brown/grey, with darker spots mottling over the body and distal fins. The fins and tail have a thick, fleshy base. **Distribution and behaviour** They are only found between Kaitaia and northern Taranaki in New Zealand. They do not tolerate high turbidity. The inhabit swampy streams and wetlands that have emergent and overhanging vegetation. Black mudfish needs areas that dry up over summer and have low human impact. They can survive out of water for a few months using aestivation if they are kept damp in mud, leaf litter or under tree roots. Areas where they are found have an absence of Inanga and Common Bullies. They spawn in wetlands in winter, at the start of the wet season.

(McQueen, 2013; Hicks & Barrier, 1996; Hamer, 2007)

Common smelt, *Retropinna retropinna*

Common smelt, *Retropinna retropinna.* (Moore, 2007).

Facultatively amphidromous

Not threatened

Physical attributes 90-110mm in length, long and slender with slight depth to the body but slim from above. They have a keel on their abdomen between the pelvic and anal fins. They have a silver body, with slight olive colouring on the top. They do not have a lateral line. They have a pointed head with large eyes and mouth. Their tail is forked. **Distribution and behaviour** They are found throughout New Zealand but are most prevalent in the North Island. They can penetrate far inland as long as the land gradient is low, and also inhabit landlocked lakes. They are generalist feeders. They prefer low water velocity, low elevation and low gradient rivers and streams. The diadromous populations spawn in sandy riverine substrates during summer to early winter, peaking during autumn.

(McQueen & Morris, 2013; Boubée & Ward, 1997; Ward, Northcote & Boubée, 2005)

Black flounder, *Rhombosolea retiaria*

Black flounder, *Rhombosolea retiaria.*
(Milicich, 2018).

Catadromous

Not threatened

Physical attributes 200-250mm long but can get up to 450mm long. They are distinctively flat, with a slightly oval shaped body. They lie on the left side, with both eyes on the right side. The eyes face opposite directions enabling a very wide angle of vision. They are grey, olive or brown, with spots and halos of orange, cream and black. They are able to change their colour intensity to help with camouflage against the substrate. The dorsal and anal fins are based along the entire length of the body, with short but thick rays. **Distribution and behaviour** They are found throughout New Zealand, but patchy. They inhabit estuaries and low reaches of low gradient rivers. They are scarce in Northland and the west coast of both main islands. Black flounder are predatory carnivores that ambush their prey from sandy substrates (McQueen & Morris, 2013).

(McQueen & Morris, 2013) (McEwan, 2013)