Northland Freshwater Fish Monitoring 2021/2022

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Background

New Zealand's freshwater fish fauna is comprised of a relatively low number (i.e., just under 60) of unique, native, and endemic species. Many of these species are migratory, requiring extensive movement within river networks to reproduce with several showing proficient climbing abilities (e.g., eels, kōkopu, and kōaro) allowing them to penetrate farther inland. Additionally, eels and whitebait (i.e., īnanga, the three kōkopu, and common smelt) make up recreationally and culturally important fisheries. Unfortunately, due to a combination of decreased water quality, introduced species, and habitat degradation over half of native species are listed as 'Nationally Threatened' or 'Declining', including species taken in recreational fisheries (e.g., īnanga; Weeks et al., 2016; Dunn et al., 2017). In response to increasing threats on our freshwater fish there has been growing interest in monitoring their communities and populations to gain greater understanding of their management needs.

Monitoring fish to assess the ecological health of rivers and streams has increased in frequency at regional councils across the country in recent decades. The monitoring often follows the methods laid out in Joy et al. (2013), sampling 150m of stream, from December 1st to April 30th, using electrofishing, trapping, or spotlighting methods to increase the likelihood of recovering 95% of species in the area. The National Policy Statement for Freshwater Management (NPS-FM, 2020) included the Fish Index of Biotic Integrity (IBI) as an attribute to inform on ecosystem health. Fish IBI is a score calculated by taking into account a site's elevation and distance to the coast as well as six native species metrics: 1) the total number of species, 2) the number of benthic riffle, 3) the number of benthic pool species, 4) the number of pelagic pool species, 5) the number of degradation tolerant species, and the 6) proportion of native to introduced species. The resulting score is used to estimate the health of the fish community at a site and consequently inform on the state of the local ecosystem. Elevation and the distance to the coast are included as they are strong predictors of fish diversity in New Zealand.

Northland supports at least 23 species of native freshwater fish with more than 50% being endemic to New Zealand, three listed as nationally threatened, and some (i.e., Dune Lake *Galaxias* and Northland mudfish) only found within the region (Table 1). The three threatened species found in the region are the shortjaw kōkopu, pouched lamprey, and Northland mudfish. Shortjaw kōkopu are the most widespread in the region but are still restricted to streams in native bush (e.g., Waipoua Forest), and Northland mudfish are found only in wetlands around Kaikohe and Lake Ōmāpere in the Far North. By contrast, pouched lamprey is considered extremely rare. According to the New Zealand Freshwater Fish Database (NZFFD; Stoffels, 2022), there has been only one physical record of lamprey in Northland since 2000. However, lampreys were detected in the Waipoua Forest with environmental DNA (eDNA) techniques in 2021 by the Northland Regional Council (NRC) reinvigorating efforts to determine the species' range. Northland is also home to unique, land-locked populations of galaxiids inhabiting the Kai Iwi and Poutō dune lakes. Once classified entirely as dwarf īnanga *Galaxias gracilis*, the Kai Iwi populations have been shown to be genetically indistinct from īnanga, but for conservation purposes are treated as a separate species to the Dune Lakes Galaxias (DLG) *Galaxias* "Dune Lakes" (Gee and Franklin, 2017). The Poutō populations are still considered as *G. gracilis* but are listed as "taxonomically indistinct" by Dunn et al. (2017).

Northland Regional Council has been surveying fish diversity and abundance at a subset of River Water Quality Monitoring sites since 2012, but due to resourcing constraints, the number of sites sampled per year has not been consistent. Following the recent Monitoring Network Review at NRC,

twenty-six sites were identified as potentially suitable for sampling in the 2021/2022 season (Northland Regional Council Environmental Monitoring Plan River Water Quality and Ecology).

Table 1: Freshwater fish species found in Northland.

Common Name	Scientific Name	Family	Native Status	Conservation Status	Migratory	Climber	IBI Score
Longfin eel	*Anguilla dieffenbachii*	Anguillidae	Endemic	At Risk - Declining	Yes	Yes	3
Shortfin eel	*Anguilla australis*	Anguillidae	Native	Not Threatened	Yes	Yes	2
Australian Spotted eel	*Anguilla reinhardtii*	Anguillidae	Non-resident Native	Coloniser	Yes	No	N/A
Inanga	*Galaxias maculatus*	Galaxiidae	Native	At Risk - Declining	Yes	No	3
Dune Lake *Galaxias* (Kai Iwi)*	*Galaxias* "dune lakes"	Galaxiidae	Endemic	At Risk – Naturally Uncommon	No	No	3
Dwarf īnanga	*Galaxias gracilis*	Galaxiidae	Endemic	Taxonomically Indistinct	No	No	3
Banded kōkopu	*Galaxias fasciatus*	Galaxiidae	Endemic	Not Threatened	Yes	Yes	4
Shortjaw kōkopu	*Galaxias postvectis*	Galaxiidae	Endemic	Nationally Threatened	Yes	Yes	4
Giant kōkopu	*Galaxias argenteus*	Galaxiidae	Endemic	At Risk - Declining	Yes	Yes	3
Kōaro	*Galaxias brevipinnis*	Galaxiidae	Native	At Risk - Declining	Yes	Yes	4
Northland mudfish*	*Neochanna heleios*	Galaxiidae	Endemic	Nationally Threatened	No	No	3
Black mudfish	*Neochanna diversus*	Galaxiidae	Endemic	At Risk - Declining	No	No	3
Common bully	*Gobiomorphus cotidianus*	Eleotridae	Endemic	Not Threatened	Yes	No	2
Cran's bully	*Gobiomorphus basalis*	Eleotridae	Endemic	Not Threatened	No	No	2
Redfin bully	*Gobiomorphus huttoni*	Eleotridae	Endemic	Not Threatened	Yes	No	3
Bluegill bully	*Gobiomorphus hubbsi*	Eleotridae	Endemic	At Risk - Declining	Yes	No	3
Giant bully	*Gobiomorphug obioides*	Eleotridae	Endemic	At Risk – Naturally Uncommon	Yes	No	3
Common smelt	*Retropinna retropinna*	Retropinnidae	Endemic	Not Threatened	Yes	No	3
Torrentfish	*Cheimarrichthys fosteri*	Cheimarrichthyidae	Endemic	At Risk - Declining	Yes	No	2
Pouched lamprey	*Geotria australis*	Geotriidae	Native	Nationally Threatened	Yes	Yes	3
Grey mullet	*Mugil cephalus*	Mugilidae	Native	Not Threatened	No	No	2
Dart goby	*Parioglossus marginalis*	Gobiidae	Non-resident Native	Coloniser	No	No	2
Black flounder	*Rhombosolea retiaria*	Rhombosoleidae	Endemic	Not Threatened	Yes	No	3

** Indicates species endemic to Northland.*

Methods

Fish monitoring sites, as laid out in the River Water Quality and Ecology Monitoring Plan (RWQEMP), were sampled from December 2021 to April 2022. Four sites were replaced with nearby tributaries (e.g., Waipapa at Forest Ranger to Opaopao Stream at Forest Road, Hakaru at Topuni to Hakaru River UT DS at Topuni, Waipoua at SH12 to Toronui Stream at Waipoua Confluence, and Hatea at Whareora Road to Waikoromiko at Hatea Confluence) because the locations in the RWQEMP were not suitable for sampling due to river width and/or depth. Additionally, 3 sites in the RWQEMP, i.e., Mangonuiowae Stream at Awaroa Road, Waitotoki Stream at Awaroa Road, and Pukekura Stream at No. 2 Arterial Road, were not sampled because iwi and hapū engagement had not been completed in time for the 2021/2022 sampling season. The sampling methods employed were in accordance with Joy et al. (2013). Prior to a monitoring event, each sampling site was assessed for suitability and for the most appropriate sampling methodology that can be applied, either electrofishing (EFM) or trapping/netting. According to Joy et al. (2013), sampling should only occur between the months of December to May at 150m intervals at wadable streams with at least 90% of the river being ≤ 0.6m deep and the mean wetted width of ≤ 12m. Two weeks stand down period was followed in the event of high flow to reduce the impact of streambed movement, thus increasing the success of fish sampling. Data was recorded on a Toughbook laptop using a Microsoft Excel macro system developed for the Waikato Regional Council. At each site, before sampling, physicochemical parameters, including water temperature (°C), dissolved oxygen concentration (DO mg/l), dissolved oxygen percentage (DO %), and conductivity (µS/cm) were recorded using a YSI Pro-DSS water meter.

Electrofishing

Electrofishing monitoring was carried out using a Smith-Root LR-24 Electrofisher. The LR-24 was used preferentially over the other commonly used fishing machine, the NIWA Kainga EFM300, due to the fine-scale tuning (e.g., increase of voltage in increments of 5V vs 100V) of the machine's settings compared to the Kainga. To reduce the impact on the fish, standard settings for all sites were on 12% duty cycle, 30Hz, and pulsed current. Voltage varied from 100 – 300V depending on the conductivity recorded at the site; with lower voltages used at higher conductivities. The intent of electrofishing is to stun fish within the electrical field while keeping the intensity of the field low enough that when the machine is turned off or the fish moves out of the affected area it can swim away immediately.

Monitoring occurred in teams of 3–4, with at least 2 team members being electrofishing certified. Two personnel actively fished, one wearing the electrofisher and other one holding the pole/stop net downstream of the fisher, and the rest of the team members recover fish from the net, measure their size and record data. For each site, 150m of stream was measured and marked with flagging posts at 15m intervals laying out 10 subreaches (Figure 1) prior to fishing each subreach. In each subreach, sampling was conducted from downstream to upstream so that stunned fish would drift into the stop net. Beginning with the net against one bank, the fisher would actively fish an area the width of the stop net beginning 3–5m upstream of the netter and working downstream to the net. After recovering the fish from the net, the netter moved laterally 1 net width across the stream, continuing with the fishing method until the opposite bank was reached. The same procedure was

repeated moving upstream at 3–5m intervals, covering a total distance of 150m. At the end of a subreach, the wetted width (m), depth and middle of channel (m), and total fishing time (min) were recorded. Fishing time is used as a measure of effort to ensure standardisation among sampling teams and seasons.

Fish were identified to species level and total length was measured (TL; mm, length from tip of the nose to tip of the caudal fin) and recorded. The first 50 fish of each species were measured and then the first 10 fish per subreach of that species were measured and the remaining fish were counted. Kōura, freshwater crayfish, *Paranephrops* spp. were not measured but the number of individuals was recorded. Freshwater shrimp *Parataya* spp. and mosquitofish *Gambusia affinis* were counted and placed into 1 of the 5 categories: 0, 1-9, 10-99, 100-1000, or over 1000.

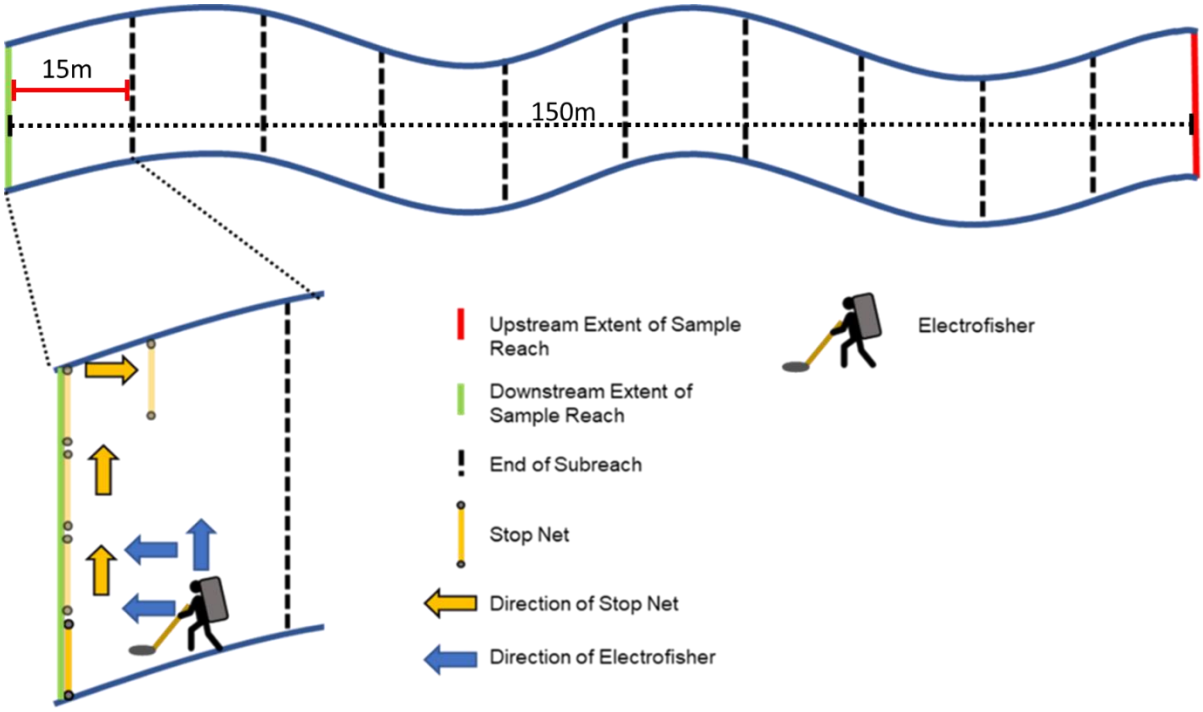

Figure 1: Diagram of electrofishing monitoring methodology. Entire sample reach is 150m separated into 10 subreaches of 15m each.

Netting

The netting method was applied up to 150m of stream using 6 fyke nets and 12 Gee minnow traps (GMTs). The downstream end, upstream end, and midpoint of the sample reach were marked with flagging posts (Figure 2). Three fyke nets were set upstream of the midpoint, three downstream, and two GMTs were set within 5m of each fyke, one up- and one downstream. Fyke nets were set with the open end and wing facing downstream and at an angle to the bank. Stakes were used to anchor either end of the net, with the cod end anchored to the bank, in place. The nets were left out overnight and recovered the next day. Beginning with the most downstream set of nets (i.e., fyke and 2 GMTs) fish were recovered, identified to species level, measured, and released. Fish

measurements and data entry followed the same methodology as Electrofishing. Wetted width and depth were not measured at netting sites due to depth of the stream.

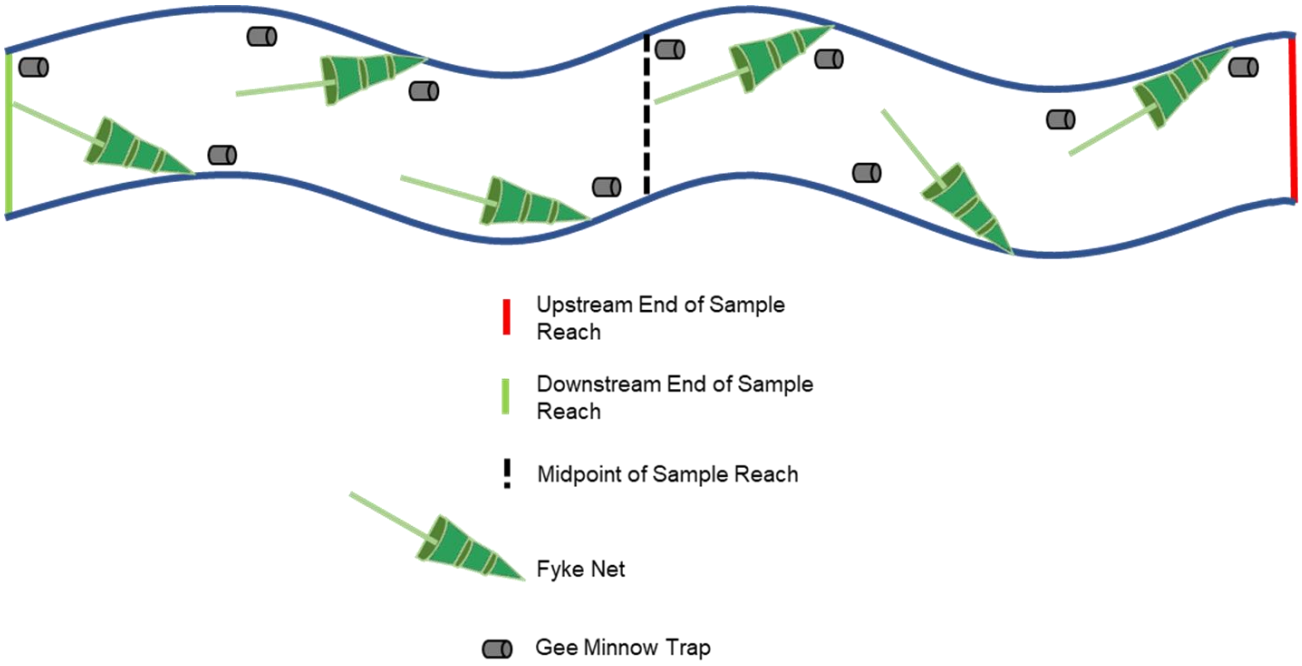

Figure 2: Diagram of net monitoring methodology. Entire sample stream reach is 150m separated into upstream and downstream ends of 75m each.

Analyses

All analyses, except fish IBI, and figures were conducted and generated in R version 4.1.3 using *plyr*, *tidyverse*, *ecodist*, *readxl*, *ggmap*, and *vegan* packages. For each site, mean, median, and 90th percentile values were calculated for wetted width and depth. The abundance of each fish species, climbers' vs poor climbers' (assigned based on comm. with Bruno David – Waikato Regional Council), and species based on threat classification status was counted for each site. Site elevation was calculated using raster tiles via the *elevatr* package. A site's distance to coast was measured by tracing the river from the sample site to the upstream extent of saltwater intrusion using an interactive shiny application and leaflet map.

Fish IBI was calculated for each site using a Microsoft Excel macro developed for NRC. Index values range from 0 to 60, with 0 indicating no fish present and 60 indicating high presence of fish (comparable to situations with little human disturbance; Table 2). A non-multidimensional scaling (NMDS) ordination was run to assess fish community similarity among sites. For the ordination, a species abundance matrix, i.e. the abundance of each species across all sites, was created and run through the *metaMDS()* function from the *vegan* package in R. This function calculates the Bray-Curtis dissimilarity (i.e., a value between 0 and 1 where sites with 0 have all species in common and 1 none in common) for each site and then runs the NMDS ordination by rotating the points through a set number of dimensions over a chosen number of permutations. The resulting ordination values are then plotted in 2D space such that points that are closer together are more similar.

Environmental variables were then fit as vectors to the ordination using the *envfit()* function, also in *vegan*, to show the correlation (i.e. r^2 and P-values are calculated via linear regression) between the

variables and the ordination. Individual species and environmental variables, i.e., distance to sea, elevation, mean wetted width, mean depth, dissolved oxygen, and water temperature, were included in the analysis to show their relative influence on community composition. The NMDS ordination was run over 4 dimensions and 999 permutations.

Table 2: Attributes collected, calculated, and analysed for each site.

Attribute	Measurement	Description
Fish Diversity	Fish IBI	The fish index of biotic integrity is calculated using six metrics (Table 1), the site's elevation (m), and the site's distance to the coast (km) following methods in Joy and Death (2004).
		National Policy Statement for Freshwater Management (2020) quality bands: • A; Excellent - ≥ 34 • B; Good - < 34 and ≥ 28 • C; Fair - < 28 and ≥ 18 • D; Poor - < 18
	Abundance	The number of individuals of each species.
Water Quality	Water Temperature (°C)	
	Dissolved Oxygen	Concentration (mg/L) Percentage (%)
Site Measurements	Wetted Width	Width (m) from wetted edge to wetted edge that end of a subreach.
	Mid-stream Depth	Depth (m) in the middle of stream at the end of the subreach.
	Site Elevation	The site's elevation above sea level (m)
	Site Distance to Coast	The site's river distance to the coast (km)

Results and Discussion

Twenty of 26 sites listed in the River Water Quality and Ecology Monitoring Plan (RWQEMP) were sampled for fish abundance from December 2021 to April 2022 (Table 3; Figure 3). Peria at Honeymoon Valley US Dutton Road was not assessed for sampling method prior to the season, and weather events in April forced a stand down of monitoring, thus preventing the sites from being sampled. Likewise, sampling Victoria at Victoria Valley Road was scheduled for April but due to the stand downs it was not sampled. Kerikeri River at Rainbow Falls was not included in the RWQEMP but was sampled because previous sampling events recorded the presence of bluegill bully *Gobiomorphus hubbsi* – a rare, nationally at-risk species. Unfortunately, no bluegill bullies were encountered and only 5 of 10 subreaches were fished due to width, depth, and flow rate at this site.

Depth and wetted width were recorded at electrofishing sites (n = 15) but not at netting (n = 5) sites. Sites with an average width ≥12m and/or 90% of the stream and depth ≥0.6m are not suitable for electrofishing. All sites except for Opouteke River at Suspension Bridge (mean width = 16.35m) have average wetted widths below 12m, however Kerikeri River at Rainbow Falls and Ngunguru River at Coalhill Lane were close to exceeding the maximum average width of 12m (Table 4; Appendix 1). None of the sites exceeded the depth criteria, however 10 sites had 90th percentiles above 0.6m indicating portions of the stream are deep enough to potentially be unfishable (Table 4; Appendix 1). The average depth over five subreaches for Kerikeri River at Rainbow Falls was 0.61m, so it is possible if sampling was continued for rest of the subreaches, the site would be too deep for the protocols (Table 4).

Table 3: Fish monitoring sites according to the River Water Quality and Ecology Monitoring Plan.

Site	Site Number	FMU	RWQMN Site	Sampled in 2021/2022	Reason Not Sampled	Sampling Method
Pukekura Stream at No2 Arterial Rd	330489	Aupōuri	Yes	No	Method not scoped	
Victoria at Victoria Valley Road	105532	Awanui	Yes	No	Weather events	Electrofishing
Waiharakeke at Stringers Rd	100007	Bay of Islands	Yes	No	Not suitable for fish monitoring.	
Waitangi at Waimate North Road	103178	Bay of Islands	Yes	Yes		Netting
Kerikeri River at Rainbow Falls*	308794	Bay of Islands	Kerikeri at Golfview Rd	Yes; 5 subreaches		Electrofishing
Ruakaka at Flyger Road	105008	Bream Bay	Yes	Yes		Netting
Oruaiti at Windust Road	304641	Doubtless Bay	Yes	Yes		Netting
Peria River at Honeymoon Valley US Dutton Road	330512	Doubtless Bay	Yes	No	Method not scoped	
Oruru at Oruru Road	108979	Doubtless Bay	Yes	Yes		Netting
Mangonuiowae Stream at Awaroa Road	330491	Herekino-Whāngāpē	Yes	No	Iwi engagement ongoing	
Waitotoki Stream at Awaroa Road	330492	Herekino-Whāngāpē	Yes	No	Iwi engagement ongoing	
Tapapa at SH1	313165	Hokianga	Yes	Yes		Electrofishing
Opaopao Stream at Forest Road	331866	Hokianga	Waipapa at Forest Ranger	Yes		Electrofishing
Mangahahuru at Main Road	100237	Northern Wairoa	Yes	Yes		Netting
Tangowahine at Tangowahine Valley Road	322490	Northern Wairoa	Yes	Yes		Electrofishing
Unnamed Tributary at Hakaru at Toponui	332199	Northern Wairoa	Hakaru at Toponui	Yes		Electrofishing
Opouteke at Suspension Bridge	102258	Northern Wairoa	Yes	Yes		Electrofishing
Waimamaku at SH12	109098	Waipoua	Yes	Yes		Electrofishing
Toronui Stream at Waipoua Confluence	332198	Waipoua	Waipoua at SH12	Yes		Electrofishing
Wairau at SH12	313168	Waipoua	Yes	No	Not suitable for fish monitoring	
Ngunguru at Coalhill Lane	110603	Whananaki Coast	Yes	Yes		Electrofishing
Punaruku at Russell Road	313171	Whananaki Coast	Yes	Yes		Electrofishing
Raumanga at Bernard Street	304709	Whangārei	Yes	Yes		Electrofishing
Waiarohia at Second Avenue	108359	Whangārei	Yes	Yes		Electrofishing
Otaika at Otaika Valley Road	110431	Whangārei	Yes	Yes		Electrofishing
Pukenui at Kanehiana Drive	312177	Whangārei	Yes	Yes		Electrofishing
Waikoromiko at Hatea Confluence	331834	Whangārei	Hatea at Whareora Rd	Yes		Electrofishing
**Not in Monitoring Plan*						

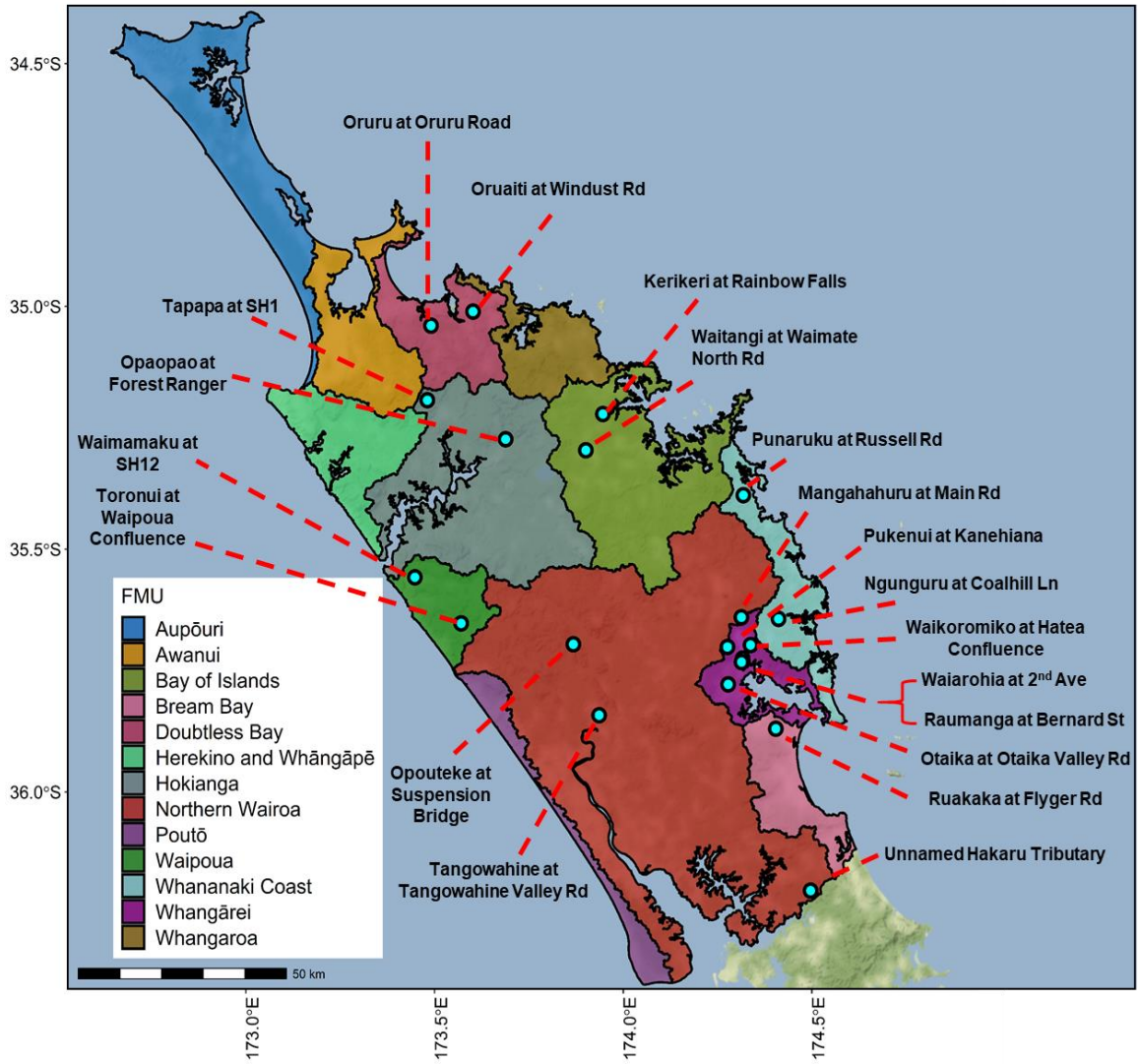

Figure 3: Sites sampled for fish from December 2021 – April 2022 by Freshwater Management Unit (FMU).

We identified 11 native fish species in Northland Regional Council's monitoring network (Figure 4). For IBI, 65% of sites fell into NPS-FM (2020) A band, 20% in B, 10% in C, and 5% (i.e., 1 site, Hakaru River UT DS at Topuni) falling into D (Table 4). Hakaru River UT DS at Topuni contained only eels, both short- and longfin, and was located just upstream of an overhanging culvert, so it is likely the structure impacted fish passage into the tributary. Bullies were the most common species making up 65% of all individuals followed by eels at 18%, galaxiids at 12%, and the remaining 5% was made up of torrentfish and smelt (Figure 6). Opaopao Stream at Forest Road, Waiarohia at 2nd Avenue, and Waikoromiko at Hatea Confluence had the highest IBI scores and species richness among the sites sampled. Conversely, Ngunguru River at Coalhill Lane and Punaruku River at Russel Road had the highest overall abundance of fish collected (Table 4; Figure 7). Four at-risk species, including īnanga and longfin eel, were found at multiple sites throughout the monitoring network but make up only 30.3% of fish found during the season (Figure 5; Figure 6). It is worth noting that the overall percentage of at-risk species found is affected by the large number of īnanga collected at Ruakaka at Flyger Road (Figure 7). No nationally threatened species were found during our standard monitoring, but shortjaw kōkopu and lamprey have been detected via eDNA and traditional sampling methods (e.g., electrofishing and spotlighting) in previous years by NRC and Department of Conservation in the Waipoua catchment (per. comms.; NZFFD, Stoffels, 2022). The majority of our sites are located near the coast (< 10km) and at low elevation (≤ 30m), consequently this results in our network being

overrepresented (81.2%) by species with poor climbing ability (Figure 5; Table 4; Appendix 2). In particular, the climbing galaxiids (e.g., kōaro, banded and shortjaw kōkopu) will be underrepresented by our current monitoring network.

Table 4: Fish diversity and physical data for each site. For IBI, NPS-FM (2020) quality codes are indicated by colour: A = blue, B = green, C = yellow, and D = red. Individuals not identified to species are not included in Richness or Abundance calculations. ** Only 5 of 10 subreaches were fished.

Site		IBI	Fish Species Richness*	Total Fish Abundance	Elevation (m)	Distance to Coast (km)	Temperature (°C)	Dissolved Oxygen (mg/L)	Wetted Width (m)			Mean Depth (m)		
									Mean	Med.	90%	Mean	Med.	90%
Waitangi at Waimate North Road	Netting	24	3	181	79.0	21.9	19.9	10.16	NA	NA	NA	NA	NA	NA
Kerikeri River at Rainbow Falls**	Electrofishing	28	2	17	38.0	3.0	18.3	9.41	11.23	11.37	11.93	0.61	0.60	0.70
Ruakaka at Flyger Road	Netting	52	6	275	17.0	2.0	17.9	7.89	NA	NA	NA	NA	NA	NA
Oruaiti at Windust Road	Netting	44	6	92	19.0	5.6	20.7	8.76	NA	NA	NA	NA	NA	NA
Oruru at Oruru Road	Netting	52	6	71	19.0	0.9	20.0	8.86	NA	NA	NA	NA	NA	NA
Tapapa at SH1	Electrofishing	40	4	73	80.0	12.1	16.6	9.63	5.21	5.21	7.13	0.34	0.28	0.54
Opaopao Stream at Forest Road	Electrofishing	54	7	144	29.0	7.2	16.8	9.08	3.27	2.50	3.36	0.22	0.20	0.39
Mangahahuru at Main Road	Netting	32	4	125	115.0	54.3	18.1	9.13	NA	NA	NA	NA	NA	NA
Tangowahine at Tangowahine Valley Road	Electrofishing	18	2	7	19.0	2.3	21.5	8.01	6.00	6.00	6.63	0.48	0.43	0.71
Hakaru River UT US at Toponui	Electrofishing	14	1	16	26.0	2.2	19.0	7.79	2.19	1.84	3.92	0.39	0.31	0.72
Opouteke at Suspension Bridge	Electrofishing	30	4	120	59.0	62.1	21.6	9.21	16.35	15.30	19.90	0.39	0.39	0.50
Waimamaku at SH12	Electrofishing	44	6	73	19.0	6.2	23.2	9.02	9.96	10.00	11.37	0.47	0.47	0.64
Toronui Stream at Waipoua Confluence	Electrofishing	44	3	20	99.0	12.2	17.2	9.50	7.47	7.70	9.70	0.36	0.31	0.62
Ngunguru at Coalhill Lane	Electrofishing	52	6	510	18.0	2.0	20.1	9.53	10.69	11.00	12.90	0.43	0.30	0.80
Punaruku at Russell Road	Electrofishing	52	6	521	21.0	4.0	17.9	8.90	8.21	8.21	10.00	0.29	0.24	0.50
Raumanga at Bernard Street	Electrofishing	46	6	89	19.0	0.9	17.1	7.75	4.46	4.46	6.00	0.51	0.48	0.77
Waiarohia at Second Avenue	Electrofishing	54	7	147	20.0	0.6	19.3	9.38	4.70	4.40	5.50	0.44	0.44	0.76
Otaika at Otaika Valley Road	Electrofishing	44	5	23	20.0	3.1	18.8	8.48	5.14	5.20	7.20	0.57	0.55	0.83
Pukenui at Kanehiana Drive	Electrofishing	32	1	2	162.0	8.2	15.9	9.64	3.45	3.40	4.00	0.22	0.20	0.26
Waikoromiko at Hatea Confluence	Electrofishing	54	7	74	23.0	2.4	18.1	9.07	5.82	5.50	6.42	0.38	0.32	0.65

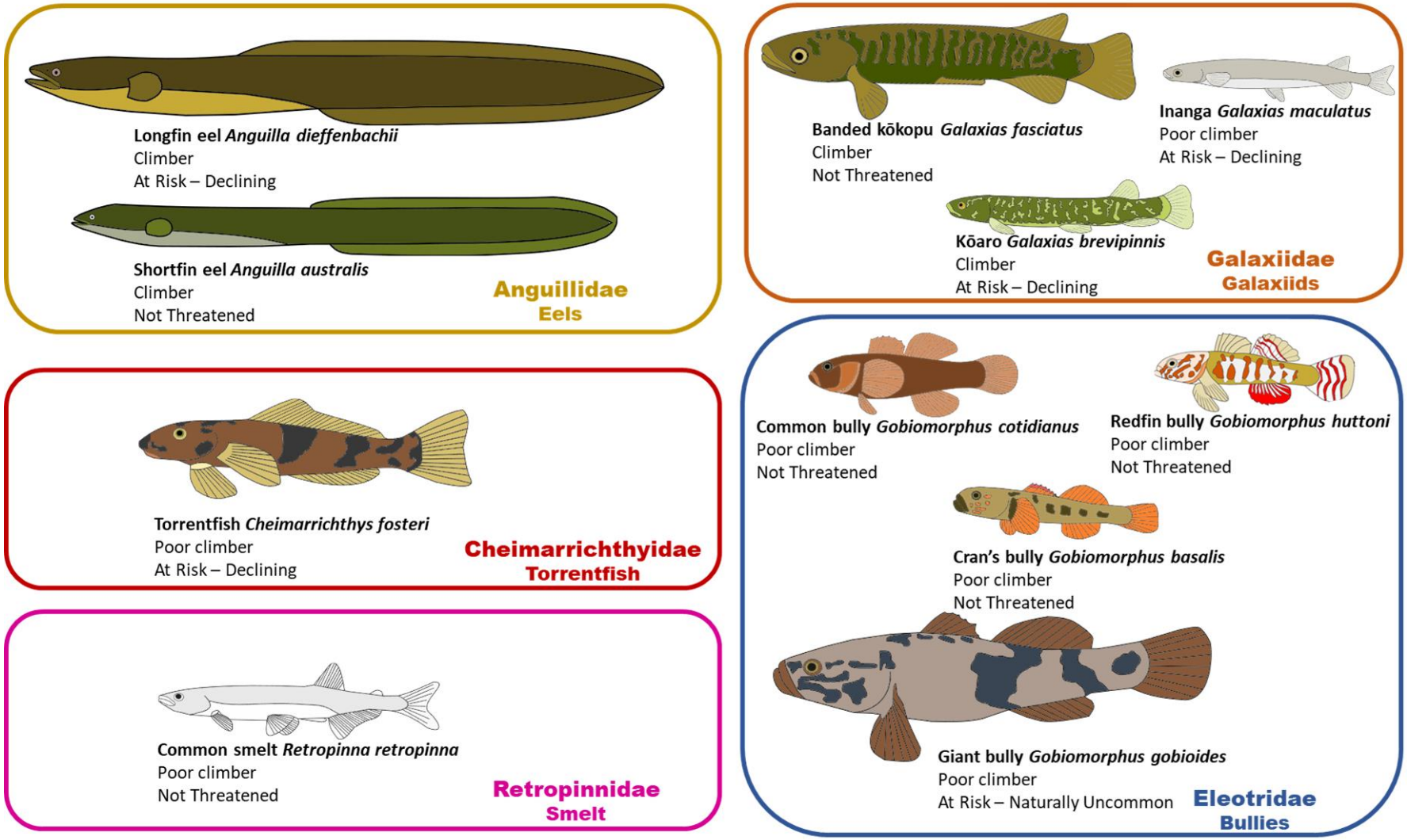

Figure 4: Stylised representations of native fish species and families encountered in the 2021-2022 sampling season.

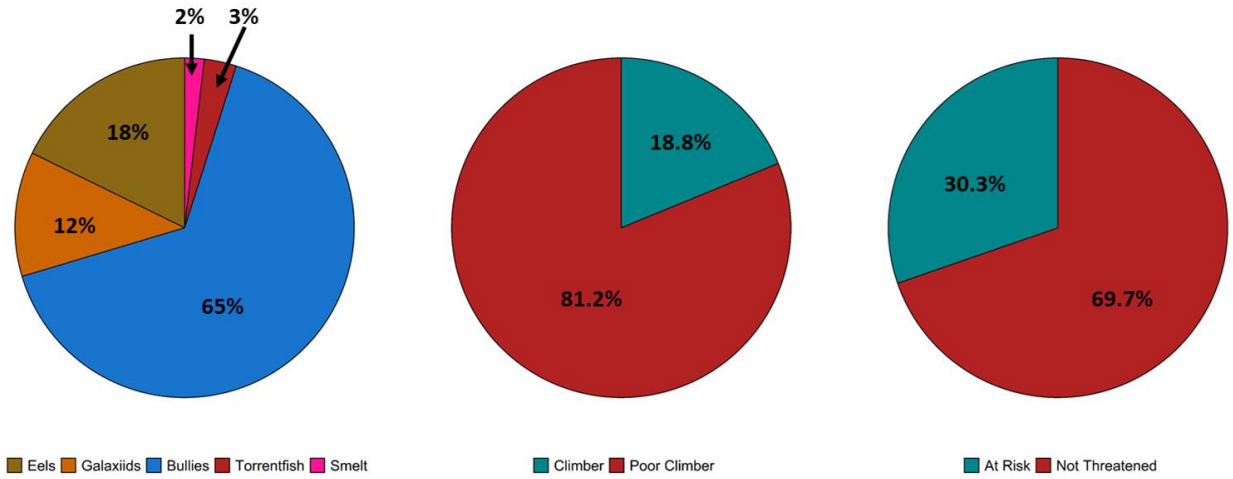

Figure 5: Relative abundance of fish families (left), climbers vs poor climbers (middle), and species by threat classification (right) sampled from December 2021 – April 2022 in the monitoring network.

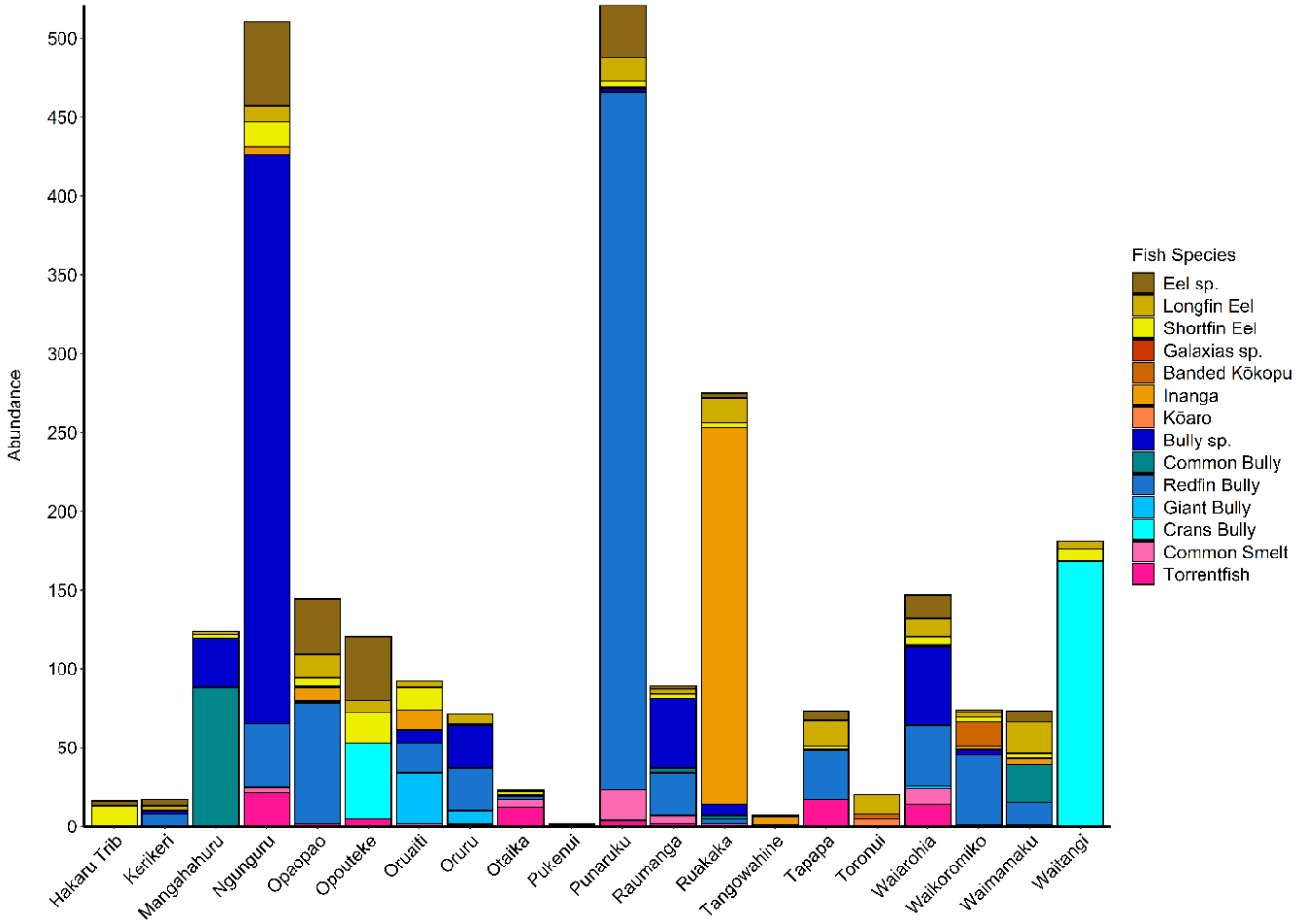

Figure 6: Abundance of each fish species for each site sampled from December 2021 – April 2022.

Fish community similarity among sites was assessed using a non-multidimensional (NMDS) scaling ordination, indicating that sites that are plotted closer together have greater similarity (Stress = 0.0712; Figure 7). Most sites (65%) cluster and are well positioned to assess the presence/absence of bullies, eels, torrentfish, smelt, and īnanga but not the climbing galaxiids (Figure 7). For the environmental/physical variables analysed, only elevation (r^2 = 0.52, P-value = 0.035) and dissolved oxygen (r^2 = 0.38, P-value = 0.049) were shown to significantly explain the variation in community composition (Figure 7; Appendix 3). Interpretation of these results should be cautious as only 1 season of data and 20 sites were included.

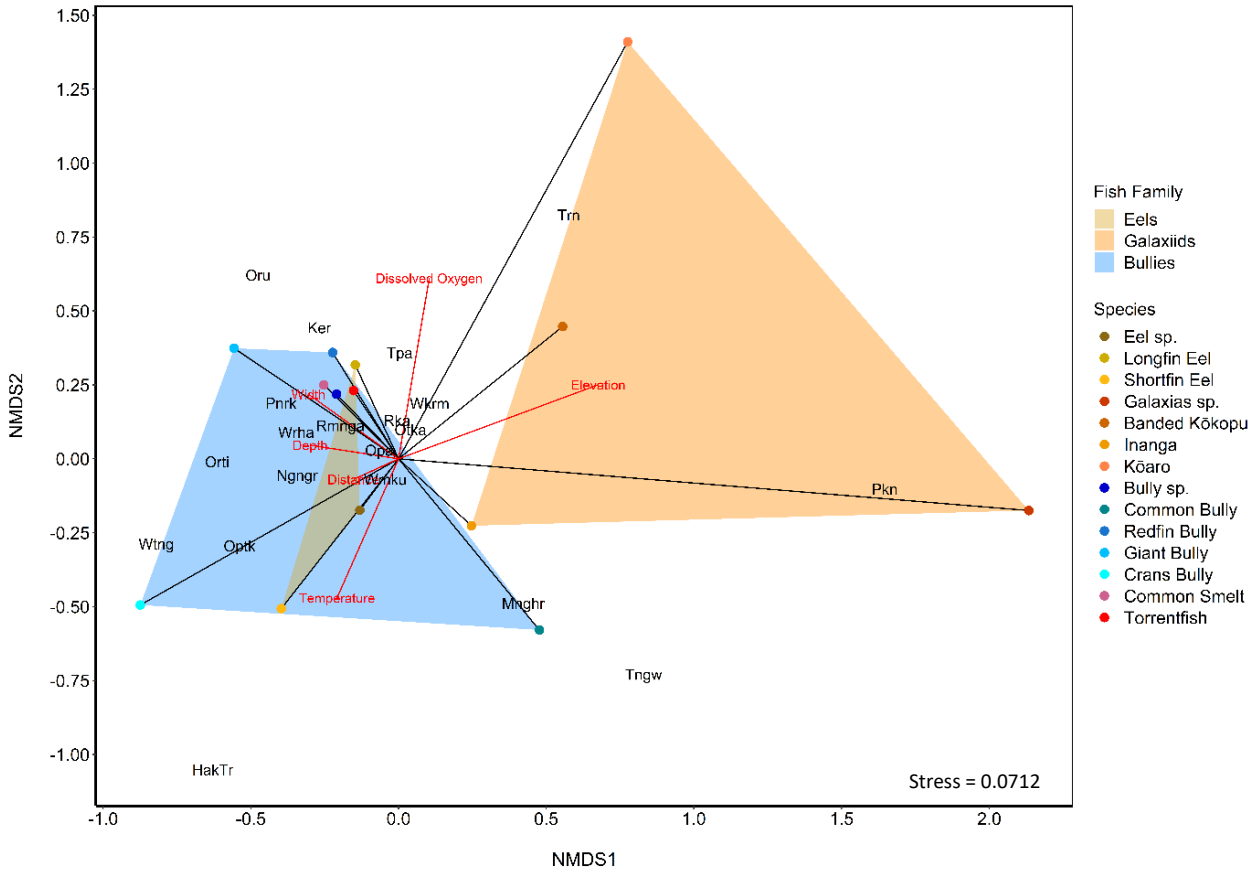

Figure 7: Non-multidimensional scaling (NMDS) ordination showing relationship between fish communities, fish species, and environmental variables with NMDS1 and NMDS2. Points represent individual species and shaded areas connect species within the same taxonomic family. Site names are abbreviated as follows: Ker = Kerikeri River at Rainbow Falls, Mnghr = Mangahahuru at Main Road, Ngngr = Ngunguru at Coalhill Lane, Opa = Opaopao Stream at Forest Road, Optk = Opouteke at Suspension Bridge, Orti = Oruaiti at Windust Road, Oru = Ororu at Ororu Road, Otka = Otaika at Otaika Valley Road, Pkn = Pukenui at Kanehiana Drive, Pnrk = Punaruku at Russell road, Rmnga = Raumanga at Bernard Street, Rka = Ruakaka at Flyger Road, Tngw = Tangowahine at Tangowahine Valley Road, Tpa = Tapapa at SH1, Trn = Toronui Stream at Waipoua Confluence, HakTr = Unnamed Tributary at Hakaru at Toponui, Wrha = Waiarohia at Second Avenue, Wkrm = Waikoromiko at Hatea Confluence, Wmku = Waimamaku at SH12, Wtng = Waitangi at Waimate North Road.

Conclusions and Recommendations

Overall, IBI scores, with the majority in A and only one in D band, as well as species diversity (i.e., 11 species) for NRC's monitoring network are good. However, it should be noted that the IBI has limits and should be interpreted carefully. For instance, the IBI does not take species abundance into consideration, instead it is designed such that sites with high scores have higher species richness or species considered to be sensitive to disturbance. As a result, it is possible for a site to receive an A or B band score with very low abundances if the species are deemed sensitive by the IBI scoring method (see IBI scores in Table 1). For example, Pukenui at Kanehiana Drive, a small, native bush stream at elevation, had an IBI of 32 (B band) but only two fish, both banded kōkopu *Galaxias fasciatus*, were collected. Banded kōkopu are climbing galaxiids with a high IBI species score of 4 (Table 1), so in combination with the sampling location's high elevation the site receives a B-band ("Good") score. Pukenui stream is also located above Whau Valley Dam which acts as a major impediment to fish passage, but this is not reflected by the IBI. Further, rivers and streams at low elevations and near the coast are more likely to have diverse fish communities with high species abundances due to being larger water bodies (i.e., more habitat) and are less likely to be impacted by barriers. So, given the overrepresentation of sites at low elevation and near the coast in NRC's monitoring network, the IBI scores are likely more reflective of sampling location rather than water quality or ecosystem health. For example, Waiarohia at 2nd Ave and Raumanga at Bernard St are urban streams in Whangārei city but have higher IBI scores than Toronui Stream at Waipoua Confluence and Tapapa at SH1 both of which are native bush streams. So, while scores for the network are good overall, interpretation is limited due to the inherent limitations of the IBI calculation and the physical location of sampling sites.

Due to a majority of sites being located at low elevations and near the coast, the network likely underrepresents the distribution of climbing species, particularly galaxiids, and is not able to accurately inform on nationally threatened species (e.g., shortjaw kokopu). Inclusion of smaller streams at higher elevations should help remedy this, however, the current network was designed for the purpose of sampling as many water quality and biological attributes as possible per site. Several network sites were not able to be sampled due to the size of the river (e.g., Waipapa at Forest Ranger) and so smaller tributaries were fished in their place (e.g., Opaopao Stream at Forest Road; Table 3). It is possible this method could be applied to other river network sites to increase the number of smaller streams, farther up in a catchment that get fished. For instance, Opuateke at Suspension Bridge is too wide to sample according to the Joy et al. (2013) methodology and should not be fished in the future, but a nearby tributary could be sampled instead (Appendix 1). Likewise, Kerikeri at Rainbow Falls and Ngunguru at Coalhill Lane should be reconsidered as fishing sites due to width as both are close to not being suitable and Kerikeri comes close for depth as well (Appendix 1). So, both sites could be rescoped for more suitable reaches. Peria at Atkinson's and Pukekura at No.2 Arterial Road are also candidates for removal as they have not been properly scoped for suitability but could help spread out the site distribution.

The number of sites in the Whangārei FMU (i.e., 5) should be reconsidered. This overrepresents one FMU and according to Figure 7 the communities at the sites, with the exception of Pukenui, are similar. Pukenui is upstream of Whau Valley Dam, a major impediment to fish passage and the likely cause for only collecting two galaxiids over 150m (Figure 6); although 1 eel and >40 kōura were seen. The community at Waikoromiko is similar to Opaopao with the later having a higher overall

abundance. So, it is possible one or both could be removed and replaced with more informative sites.

Netting sites also need to be rescoped for suitability as, , it is not possible to sample 150m at two sites. Both Oruru at Oruru Road and Oruaiti at Windust Road had to have the nets set close together over ~75m due to depth (≥1m) at the upstream and downstream ends of the sample reach. This is not good for replicating sampling effort and comparability among sites. Further, Oruru is tidal and nets that the previous night had been submerged were nearly completely dry when they were retrieved the following morning.

December 2021 to April 2022 is the first sampling season in recent years where a majority of sites were sampled solely by NRC staff, mostly due to adequate personnel resourcing – i.e., freshwater ecologist, ecological monitoring officer, and two summer students all electrofishing certified. If a site was not sampled it was due to ongoing community engagement in the area, lack of a proper scope for new sites, weather events, or some combination of the three. Moving forward, site suitability and community engagement need to be completed before the December-May sampling season. In addition, at a minimum the same personnel resourcing should be available to ensure completion with a high level of rigor.

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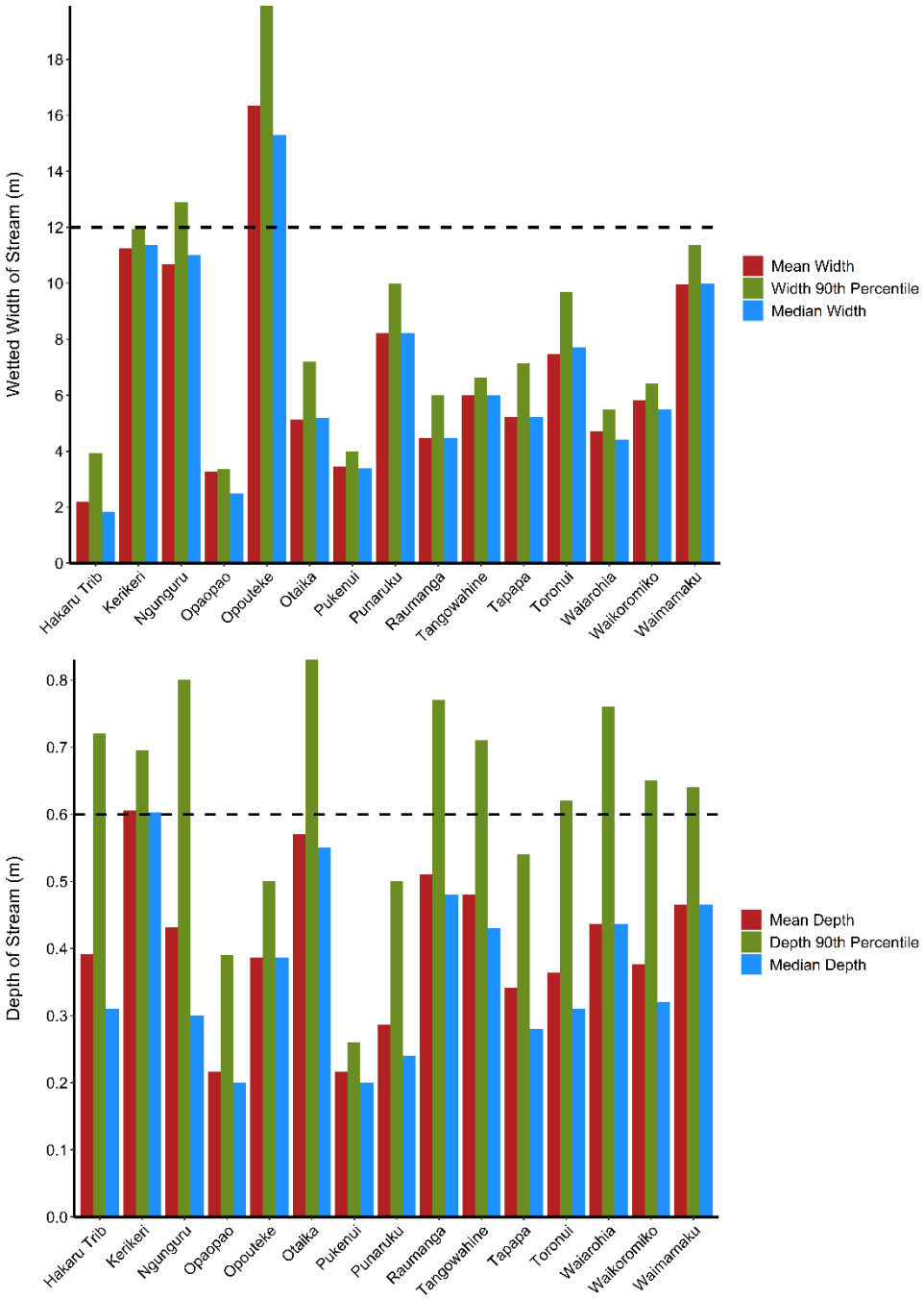
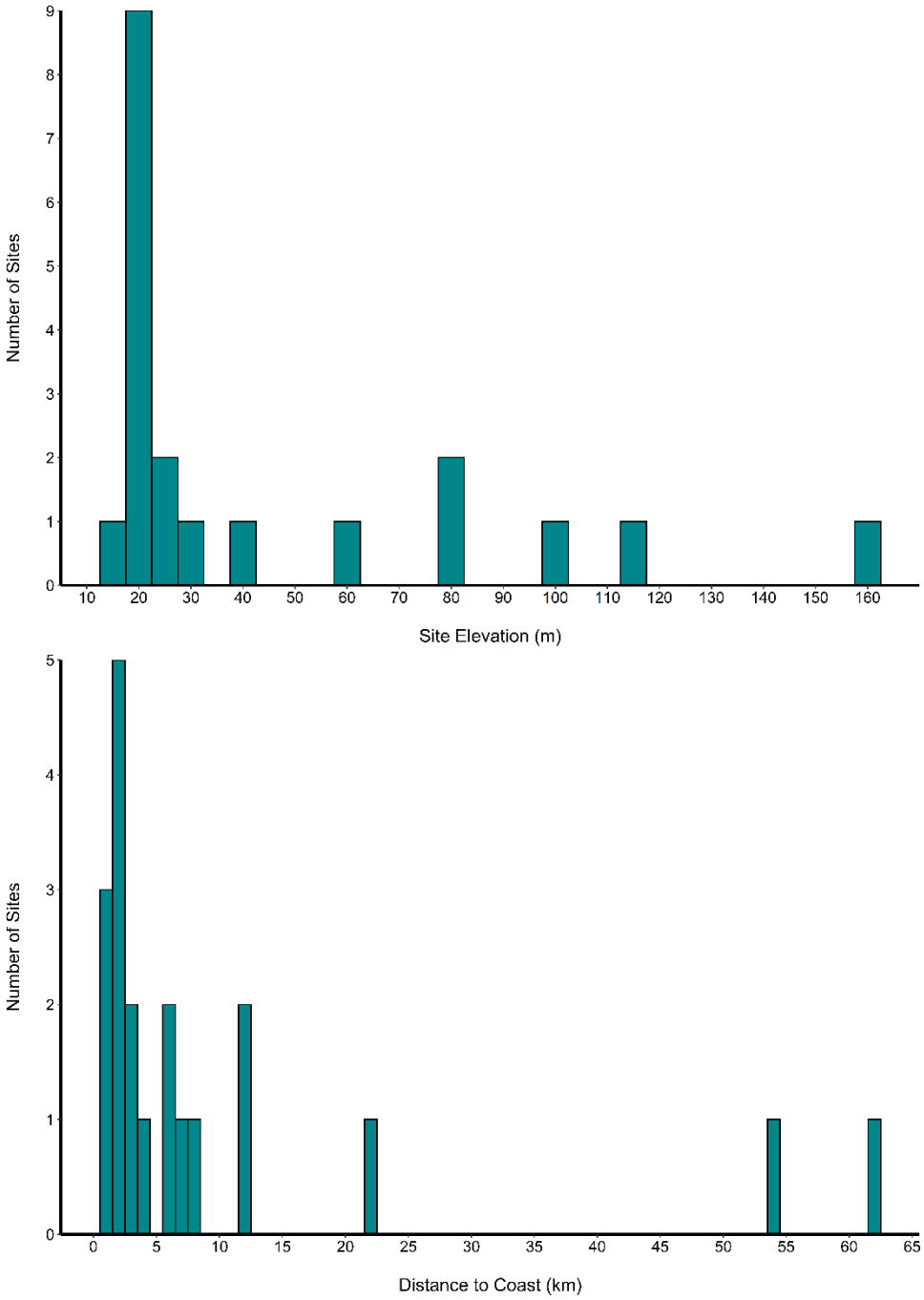
Appendices

Appendix 1: The mean, 90th percentile, and median wetted width (top) and depth (bottom) for electrofishing sites. Dashed line represents the width and depth cut-off for suitability.



Appendix 2: Histograms showing the number of sites sampled by elevation (m; top) and distance to the coast (km; bottom).



Appendix 3: Environmental variable NMDS results. Significant interactions highlighted in bold text.

Measurement	NMDS1	NMDS2	r^2	*P*-value
Elevation	**0.938**	**0.347**	**0.520**	**0.035**
Distance	-0.910	-0.415	0.028	0.668
Temperature	-0.405	-0.914	0.265	0.155
Dissolved Oxygen	**0.168**	**0.986**	**0.384**	**0.049**
Mean Wetted Width	-0.813	0.582	0.140	0.400
Mean Depth	-0.988	0.152	0.092	0.572

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