REPORT NO. 3973

NGĀ AWA MONITORING PROGRAMME: WAIPOUA CATCHMENT REPORTING 2021–23

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Prepared for Department of Conservation

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EXECUTIVE SUMMARY

This report provides the Department of Conservation (DOC) with an analysis of the data collected from the Waipoua catchment over the 2020/21 to 2022/23 monitoring seasons as part of the Ngā Awa river restoration programme being implemented by DOC in partnership with other organisations.

The data comprised indicators and measures of freshwater ecological integrity collected from 20 sites within the Waipoua catchment between April 2021 and March 2023. Sites were located on both public conservation land (PCL) and private land. The indicators and measures were classed into three high-level categories:

- aquatic life (including fish, macroinvertebrates, megainvertebrates, aquatic plants and periphyton)
- habitat (including habitat types, discharge, substrate stability and deposited sediment)
- water quality (including nutrients, other water chemistry data and visual clarity / suspended sediment).

Where possible, the data were analysed with respect to guideline values or attribute bands from the New Zealand National Policy Statement for Freshwater Management (NPS-FM) and compared with data from other Ngā Awa catchments and DOC's National Freshwater Monitoring Programme (NFMP). Interpretation of results relative to NPS-FM attribute bands has been included to provide context, although the sampling regime used does not allow attribute bands to be designated for each metric. In addition to various environmental metrics, threat classifications and species distributions were determined for selected aquatic life data. The relationships between metric scores and covariates from other metrics and the River Environment Classification variables were explored to investigate potential drivers of the observed results. The analytical approach closely follows the process taken by Kelly et al. (2023) for analysing data from the NFMP.

Across the attributes measured at the 20 sites surveyed in 2020/21, 2021/22 and 2022/23, the results indicate a mix of water quality and ecosystem health. Aquatic life scores suggest there is high biodiversity at most sites, although some sites had poor macroinvertebrate community metrics that appear unrelated to organic enrichment. Similarly, the habitat and water quality measures were somewhat variable, with generally high habitat diversity, although some sites had elevated nutrient concentrations. There was some evidence to suggest that land cover may be having an impact on instream biotic communities and habitat characteristics; however, only one site was under exotic forestry and the patterns among pastoral-dominated and indigenous forest-dominated sites were not consistent. The results presented here provide an overview of the water quality conditions within the catchment and will be invaluable as baseline data to support restoration efforts that are underway.

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GLOSSARY

Average score per metric (ASPM)	The average score obtained from the MCI, EPT taxa richness and %EPT results for macroinvertebrates.
Backpack electric fishing	A fishing method where a backpack machine is used to create an electric current, which temporarily stuns fish and enables their capture for identification and measurement.
Ecological integrity	The degree to which the physical, chemical and biological components (including composition, structure and process) of an ecosystem and their relationships are present, functioning and maintained.
Fish index of biotic integrity (F-IBI)	A measure of the overall health of a fish community, taking into account factors such as species richness and diversity of taxa with varied habitat preferences and pollution tolerance.
Hard-bottomed	Freshwater environments with more than 50% hard substrates, such as rocks or gravel, as opposed to soft substrates like mud or sand.
Macroinvertebrate Community Index (MCI)	A biotic index used to determine stream or river health based on the presence (or absence) of different macroinvertebrate taxa.
Megainvertebrates	Very large invertebrates, such as crayfish (kōura), mussels (kākahi), shrimp and crabs.
Meso-habitat	Habitat types determined by channel and flow characteristics, such as runs, riffles and pools.
National Environmental Monitoring Standards (NEMS)	A set of technical standards used to ensure national consistency in environmental monitoring in Aotearoa New Zealand.
New Zealand Freshwater Fish Database (NZFFD)	A database containing information on the distribution of freshwater fish species in Aotearoa New Zealand.
New Zealand National Policy Statement for Freshwater Management (NPS-FM)	A government policy aimed at ensuring the sustainable management of freshwater resources, approved in 2020 and updated in 2023. See MfE (2023).
New Zealand River Environment Classification (REC) system	A system used to classify freshwater environments in Aotearoa New Zealand, based on physical characteristics and land cover.
New Zealand Threat Classification System (NZTCS)	A system that classifies species in New Zealand based on their risk of extinction. NZTCS category is the category into which the species is placed, and NZTCS status is the overall conservation status of a species, taking into account factors such as population size, habitat quality and threats.
Percent EPT (%EPT)	The percentage of distinct Ephemeroptera, Plecoptera and Trichoptera taxa present. These groups of insects are commonly used as indicators of water quality and ecological integrity because they are sensitive to pollution.
Periphyton	Micro-organisms, including algae, fungi and bacteria, that are attached to the river substrate.

Physico-chemical factors	Physical and chemical factors that can affect the health and quality of freshwater environments, such as temperature, dissolved oxygen levels and nutrient levels.
Primary production	The production of energy by primary producers, such as periphyton, in an ecosystem
Public conservation land and waters (PCL)	Areas of land (and waters) managed by the Department of Conservation.
Quantitative Macroinvertebrate Community Index (QMCI)	A quantitative variant of the MCI based on both the number and relative abundance of different taxa present in a macroinvertebrate sample.
Soft-bottomed	Freshwater environments with more than 50% soft substrates, such as mud or sand, as opposed to hard substrates such as cobbles, boulders and bedrock.
Taxon-Independent Community Index (TICI)	An environmental DNA-based taxon-free, biotic index of riverine ecological health recently developed by Wilderlab NZ Ltd.

1. INTRODUCTION

1.1. Background

The Ngā Awa river restoration programme is being implemented by the Department of Conservation (DOC) in partnership with other organisations. The aim of the programme is to restore the biodiversity of 14 rivers from mountains to sea, and freshwater monitoring is being carried out to establish a baseline ecological state. This monitoring collects data on plant and animal communities and habitat characteristics at a range of monitoring locations throughout the catchments being restored. The objective of this programme is to provide data to enable a robust status and trend assessment of the ecological integrity of focus catchments to aid in directing and assessing the effectiveness of restoration actions.

As part of this programme, DOC has engaged Cawthron Institute (Cawthron) to analyse the initial data collected in three of the catchments included in the Ngā Awa programme. The analysis of these data will enable DOC to realise the intent of the monitoring programme by providing outputs of the field-collected data and interpretation with reference to additional national-scale datasets. Data manipulation and analysis scripts generated for this report are also provided to facilitate future analysis.

This report is one of a series of three reports, each focusing on a different catchment (Waipoua, Waikanae and Te Hoiere / Pelorus River), and outlines the results of monitoring undertaken in the Waipoua catchment at 20 sites between April 2021 and March 2023. Four of these sites were monitored in both 2021 and 2022, but for the purposes of this report, only state data (i.e. not trend) are presented, with a brief commentary on any notable differences between sampling occasions. These metrics have been organised by their overarching theme (aquatic life, habitat and water quality) to facilitate analysis, grouping and discussion.

This report and accompanying R-code for data analysis aim to:

- report on state and, in future years, trends in components of ecological integrity in rivers and streams within each catchment
- demonstrate the utility and value of the data collected.

1.2. Catchment and monitoring programme description

The Waipoua River is a large fifth-order river flowing into the west coast between Dargaville and the Hokianga Harbour in Northland. It is considered to be one of the better condition rivers in Northland, which is largely due to the fact that approximately 74% of the Waipoua catchment is within public conservation lands (PCL) or QEII National trust covenants. The PCL within the catchment has been managed by DOC since 1987, with the Waipoua Forest forming part of the Northland Conservation Park. In the remaining catchment, approximately 5% of headwaters are in private ownership and approximately 21% of the lower catchment is in iwi and whānau ownership. The impact of both historical and current land use on private land within the catchment is of concern, although early restoration actions have focused on reducing mammalian predators and forest health, particularly following the discovery of kauri dieback disease in the forest. Mana whenua Te Roroa regained ownership of large areas of the watershed through Treaty settlement and have initiated restoration projects such as Te Toa Whenua (West et al. 2022).

Monitoring of the Ngā Awa catchments was based on the monitoring protocols developed for DOC's National Freshwater Monitoring Programme (NFMP; see Kelly et al. 2023). For the Waipoua catchment, the primary objective of the monitoring programme is to 'Measure the state and trend in component of ecological integrity of the Waipoua River and its tributaries'. Monitoring objectives and site selection were determined through collaboration with DOC and Te Roroa. Site locations were determined using Halton iterative partitioning to generate an ordered list of randomised sample locations that were spatially balanced across the study area using the New Zealand River Environment Classification (REC) river network, and then stratified by stream order (Larsen et al. 2008; Snelder et al. 2010). An important consideration for monitoring the Waipoua catchment was the presence of kauri dieback, so monitoring sites avoided known disease hotspots.

As established in the NFMP, the environmental indicators and metrics were chosen to enable assessment of the broad categories of aquatic life, habitat and water quality. A range of parameters were measured at each site, encompassing stream metrics for sediment and sedimentation, primary production, waterway biological function, water chemistry and physico-chemical factors, and assessments of habitat availability. Environmental DNA (eDNA) samples were collected using Wilderlab kits, with three replicates collected per site at sites monitored in the 2020/21 monitoring season and six replicates collected per site at sites monitored in the 2021/22 and 2022/23 monitoring seasons.

1.3. Description of ecological indicators measured

1.3.1. Aquatic life

The presence and abundance of different functional groups at different trophic levels is one indicator of ecological integrity (Schallenberg et al. 2011). Key groups for which metrics have been developed are macroinvertebrates and fish. The metrics of waterway biological condition are the Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI), macroinvertebrate taxonomic richness and diversity (including %EPT by taxa richness), fish index of biotic integrity (F-IBI), and presence / absence of key taxa, including freshwater crayfish, shrimp and mussels.

There are few metrics associated with aquatic plants in relation to waterway health. Thus, the primary metric associated with macrophytes and bryophytes (hornworts, liverworts and mosses) is diversity and the presence of taxa classified as At Risk or Threatened (de Lange et al. 2020).

Primary production can provide an indication of the trophic state of a waterway. Primary production is typically assessed using periphyton cover and chlorophyll-*a* concentrations. The NPS-FM separates sites into productive and default periphyton classes, reflecting that some sites by virtue of their climate and geological attributes naturally have higher primary production (MfE 2023, appendix 2C). The productive classes are defined as having a dry climate (either warm-dry or cool-dry) and geological categories with higher levels of nutrient enrichment: soft-sedimentary, volcanic-basic and volcanic-acidic. All other REC class combinations are considered to belong to the default category.

The guideline values specified in the NPS-FM are intended for sites that are monitored regularly, and the numeric attribute states for most metrics relate to the percentage of times the site exceeds this state or to long-term means or medians for the site. As sites from the Ngā Awa monitoring programme are unlikely to be monitored with the intended frequency outlined in these guidelines, the values are provided only for context, and metrics cannot be classed into an attribute band.

1.3.2. Habitat

The suite of metrics associated with stream habitat provides information on the presence and diversity of habitat components that can support a range of species typical of unmodified habitats. For these analyses, metrics used consisted of those characterising hydrological diversity (the presence of habitat types such as pools, riffles, runs, rapids and gravel beds), along with specific characteristics (such as bank vegetation and woody debris) that provide habitat for fish and other species such as *Hymenolaimus malacorhynchos* (blue duck / whio).

Discharge can provide an indication of the size of the streams that is separate to stream order and can be considered as a covariate that helps to explain patterns observed in other data. For example, deposited sediment can be associated with flow rates, as can fish species that have differing flow preferences.

Broadly, the substrate metrics assessed include an evaluation of the overall geological stability of each site (Pfankuch 1975), the composition and broad size distribution of the fine sediment (sediment assessment methods 1, 3 and 6; Clapcott et al. 2011), and the presence of non-nutrient contaminants (herbicides and pesticides).

1.3.3. *Water quality*

The metrics collected in this section are necessary both for identifying and monitoring sites subject to human-derived stressors, and also to provide background information for unmodified sites in relation to the other ecological integrity indicators. To aid interpretation, monitoring results were compared to guideline values from ANZECC (1992) and attribute band values from the NPS-FM. Water quality data were divided into nutrient-related data (dissolved reactive phosphorus, nitrogen and ammonia), other water chemistry data (pH, dissolved oxygen, conductivity and the presence of other ions) and water clarity (black disc, turbidity).

1.4. Overview of sites

Twenty sites were monitored over the 2020/21, 2021/22 and 2022/23 monitoring seasons. Twelve sites were monitored in the 2020/21 season, with four of these revisited and remeasured in 2021/22. A further eight sites were monitored in the 2022/23 season (Figure 1). Apart from the four sites that were revisited, each site was monitored once. Sites spanned first to fifth order, including six first-order, six second-order, five third-order, one fourth-order and two fifth-order sites. Monitoring was conducted by DOC in conjunction with mana whenua.

It should be noted that some land in the headwaters of the Waipoua is in private ownership, with some farming taking place. Sites were located on both PCL and private land. Riparian fencing of the tributaries passing through farmland is one of the restoration actions that has been implemented since 2019. Fish passage improvements have also taken place, with fish passage structures added to a ford in the lower catchment in 2017 and further modifications to this in September 2019 and February 2020 (DOC [date unknown]).

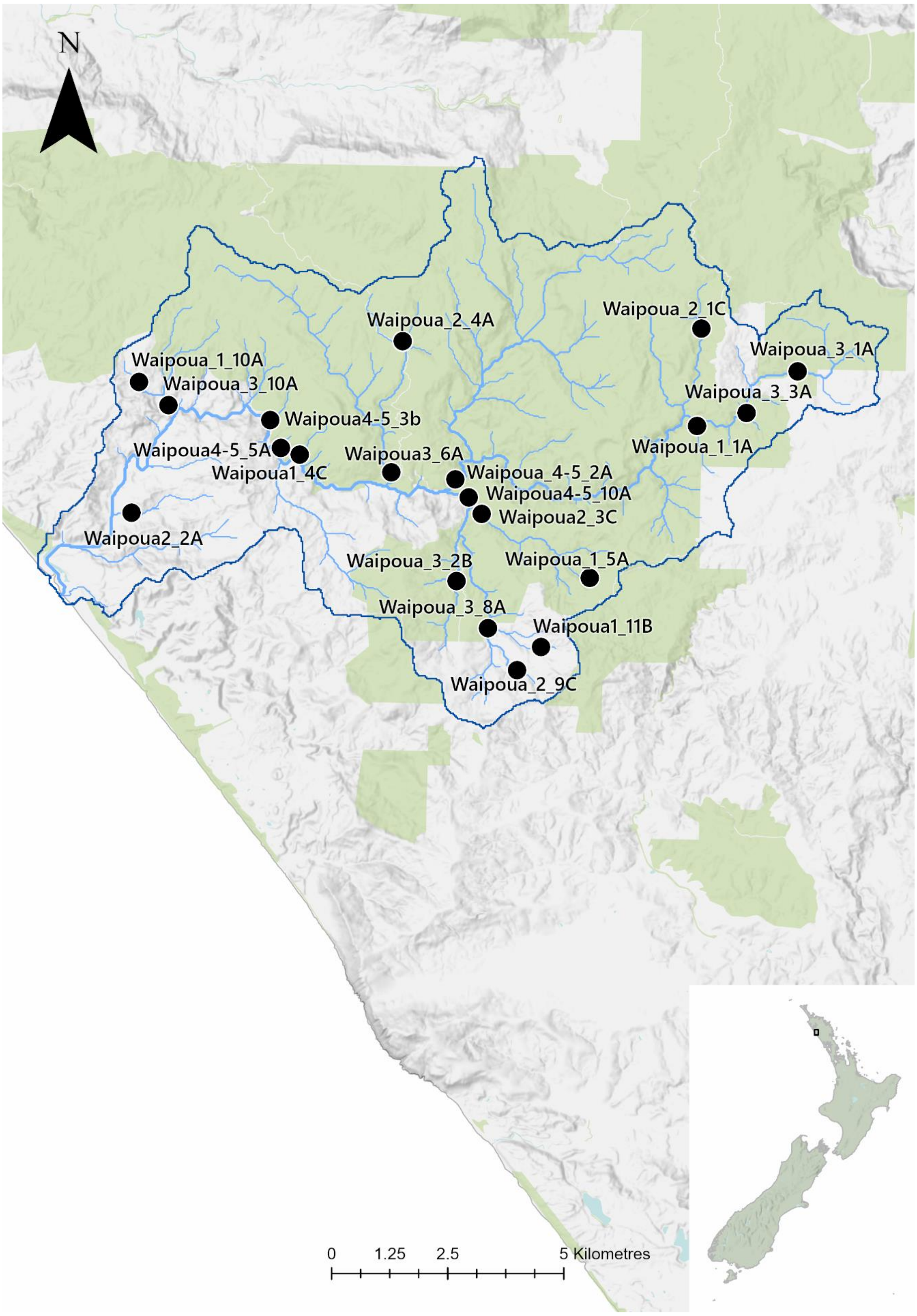


Figure 1. Map of sampling locations within the Waipoua catchment. Green areas are those within public conservation land. Basemaps generated by Eagle Technologies (2023), sourced from LINZ Data Service (2023) and licensed for reuse under CC BY 4.0.

2. ANALYTICAL APPROACH AND RESULTS

The analytical approach used closely followed the process taken by Kelly et al. (2023) for analysing data from NFMP, involving three phases of aggregating and curating of the dataset, calculation of the relevant metrics and values, and analysis and plotting of the data. All data analysis steps were undertaken using the R programming language in the RStudio graphical user interface and coding was scripted using R-markdown. A summary of the information flow between stages is illustrated in Figure 2, and the specific package versions used are included in Appendix 2. The full outline of the analytical process followed is presented in Kelly et al. (2023). Where sites were repeated, metrics were calculated and are presented for both sampling occasions, but no analyses of temporal changes were carried out due to the small number of repeated sites. Any notable changes in metrics between sampling occasions are detailed in the results. Individual sampling occasions are distinguished by a sampling unique identifier (UID), combining the site identifier and monitoring season, with 2020 referring to the 2020/21 monitoring season and so on.

ArcGIS Pro was used to create all maps in this report, using the datasets exported from the analytical pipeline outlined above.

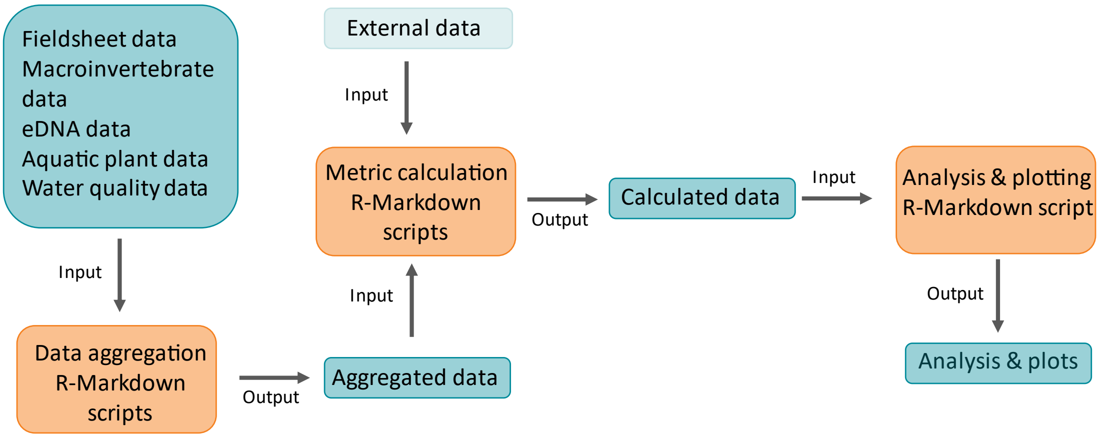


Figure 2. A conceptual overview of the flow of information and relationship between data files and analysis scripts.

3. AQUATIC LIFE

3.1. Fish

3.1.1. Metric calculation

Fish index of biotic integrity (F-IBI)

The F-IBI is one metric used to assess the overall fish communities in Aotearoa New Zealand (Joy and Death 2004). The F-IBI uses six attributes to assess the integrity of fish communities: number of native taxa present, number of native benthic pool-dwelling taxa, number of native benthic riffle-dwelling taxa, number of native pelagic pool-dwelling taxa, number of native intolerant taxa and proportion of native to non-native taxa. Low scores for the F-IBI indicate the absence (or lower diversity) of taxa that belong to these attributes, reflecting loss of biological integrity of the fish communities. This can be interpreted as the consequence of a lack of suitable habitat for those species or pollution reducing the number of pollution-intolerant taxa. For the purposes of the F-IBI calculations, trout are considered as ‘native’ species as they are indicators of good water quality.

Data from the Ministry for the Environment (MfE) F-IBI dataset (MfE 2019), including data from the New Zealand Freshwater Fish Database (NZFFD) on fish records nationally from 1998 to 2018, was downloaded for the construction of quantiles against which to score metrics. As distance inland and elevation are known variables that affect the composition of native fish communities, the reference dataset was used to regress each of the first five metrics against both distance inland and elevation (giving 10 regressions). Quantiles were calculated for each of the 10 regressions at the 33rd and 66th percentiles. Although the methods followed were those outlined by MfE (2019), some quantiles fell to zero for two of the metrics: number of pelagic pool species (both 33rd and 66th percentiles were zero) and number of intolerant species (33rd percentile was zero). This matches the experience of the Bay of Plenty Regional Council (BOPRC 2016), which similarly could not calculate quantiles using national-level data from the NZFFD, and previous experience with data from the NFMP (Kelly et al. 2023). Cross-checking the results of the calculations with the scores output from the MfE data indicated that the outcome was the same using their dataset, indicating the method may need refinement. The result is that the presence of any pelagic pool species results in the maximum score of 5, while for the intolerant species, scores were either 3 or 5.

To ensure consistency in scores and enable future comparison with new data, the dataset used to generate the species richness lines and subsequent quantiles was the same as that used by Statistics New Zealand in the 2018 update to the national picture of F-IBI scores. In addition, the same R script used to calculate F-IBI for the NFMP analyses (Kelly et al. 2023) was used here. The authors are aware that MfE has recently released an online F-IBI calculator through an R Shiny app.[1] However, there is potential that differences in how sites with no fish are treated could introduce artificial variation, thus we used the same method as the NFMP to ensure consistency among datasets.

Threat classes

For each individual fish recorded to species level, the New Zealand Threat Classification System (NZTCS) status and category were assigned. The proportion of individuals belonging to each of the NZTCS threat classes (Dunn et al. 2018) was then determined for the national dataset, and for each site. These data included both fish that were measured, and those identified to species level but not measured in the field data.

Environmental DNA (eDNA)

Environmental DNA metabarcoding is the term used for a method of collecting DNA from an environmental sample rather than from the organism itself. This DNA is then amplified and the resulting sequences are attributed to specific organisms based on their similarity to reference sequences. Environmental DNA metabarcoding data consisted of taxon names and read numbers for replicate samples collected per site at the time of sampling. Environmental DNA metabarcoding can be prone to sequencing error, contamination and tag-jumping, which may result in sequences appearing in samples erroneously. Generally, such errors result in sporadic detections of sequences with low read numbers. To reduce the risk of this, all eDNA data were subject to a data-filtering step commonly undertaken when working with eDNA metabarcoding data to reduce the potential for errors in the final data (Pearman et al. 2023). The filtering steps required a taxon to be present in at least two replicate samples and with a minimum of 20 reads in each of those to be recorded as present, or, if a taxon was present in a single sample, it needed at least 100 reads to be considered present. These are very permissive rules in the context of typical bioinformatic data-filtering protocols.

Environmental DNA glossary

Amplicons are short pieces of an organism's genome that have been amplified to a measurable amount by PCR.

Metabarcoding is using PCR to amplify a region of the genome to produce amplicons that will distinguish each taxon in a community.

Multiplexing is when a unique sequence (tag) is added to the PCR and then multiple samples are combined and sequenced together.

PCR is polymerase chain reaction, a method of multiplying a piece of an organism's genome to a measurable amount.

Reads / read numbers are the number of times a sequence is detected in a sample.

Sequencing errors are mistakes in the sequence that occur during the laboratory PCR and sequencing steps of eDNA metabarcoding.

Tag-jumping is the process when the unique identifying tag in a multiplexed reaction is incorporated onto a sequence from a different sample.

[1] https://mfenz.shinyapps.io/fish-ibi-calculator

Following the filtering steps, the presence of the fish taxa for both electric fishing data and eDNA data was filtered to remove genus-level results if a species for that genus was recorded at that site. If no species-level results were recorded for the site, then the genus-level result was retained in the dataset. This was to avoid artificially inflating species richness estimates due to missed fish in the case of electric fishing, or insufficient taxonomic resolution in the case of eDNA data.

Finally, the fish communities found at each site by each method were compared to generate lists of taxa found only with electric fishing and only with eDNA, and taxa found with both methods.

3.1.2. Catchment state

Species present

Seven native fish taxa were physically caught and identified in the Waipoua catchment. Six fish taxa were caught using electric fishing and identified to species level, including banded kōkopu (*Galaxias fasciatus*), kōaro (*Galaxias brevipinnis*), longfin eel (*Anguilla dieffenbachii*), redfin bully (*Gobiomorphus huttoni*), shortfin eel (*Anguilla australis*) and torrentfish (*Cheimarrichthys fosteri*). Further individuals of *Anguilla* spp. were missed during fishing and could not be identified to species level. Banded kōkopu, īnanga (*Galaxias maculatus*) and redfin bully were caught by spotlighting, with *Anguilla* sp. and *Galaxias* sp. also recorded with this method. In addition, īnanga were caught during trapping at Waipoua4-5_3b. In general, the number of species detected at each site decreased with distance from the coast (Figure 4).

In addition, brown bullhead catfish (*Ameiurus nebulosus*), common bully (*Gobiomorphus cotidianus*), common smelt (*Retropinna retropinna*), lamprey (*Geotria australis*) and shortjaw kōkopu (*Galaxias postvectis*) were detected using eDNA. A full table of the fish found at each site using all methods is presented in Appendix 3. For the sites sampled in both 2020/21 and 2021/22, there were differences in the fish species detected on each sampling occasion (Table 1). This highlights that fish communities may vary over time or that a single sampling event may not detect all species present at a site, even when single-pass electric fishing is combined with eDNA.

Fish lengths

For fish taxa where more than 15 individuals were caught across all sites, fish length distribution was plotted and compared with the national records from the NZFFD. No lengths outside of the minimum and maximum lengths recorded for each species in the NZFFD were observed. Plots showing the distribution of data compared with the NZFFD are presented in Appendix 4.

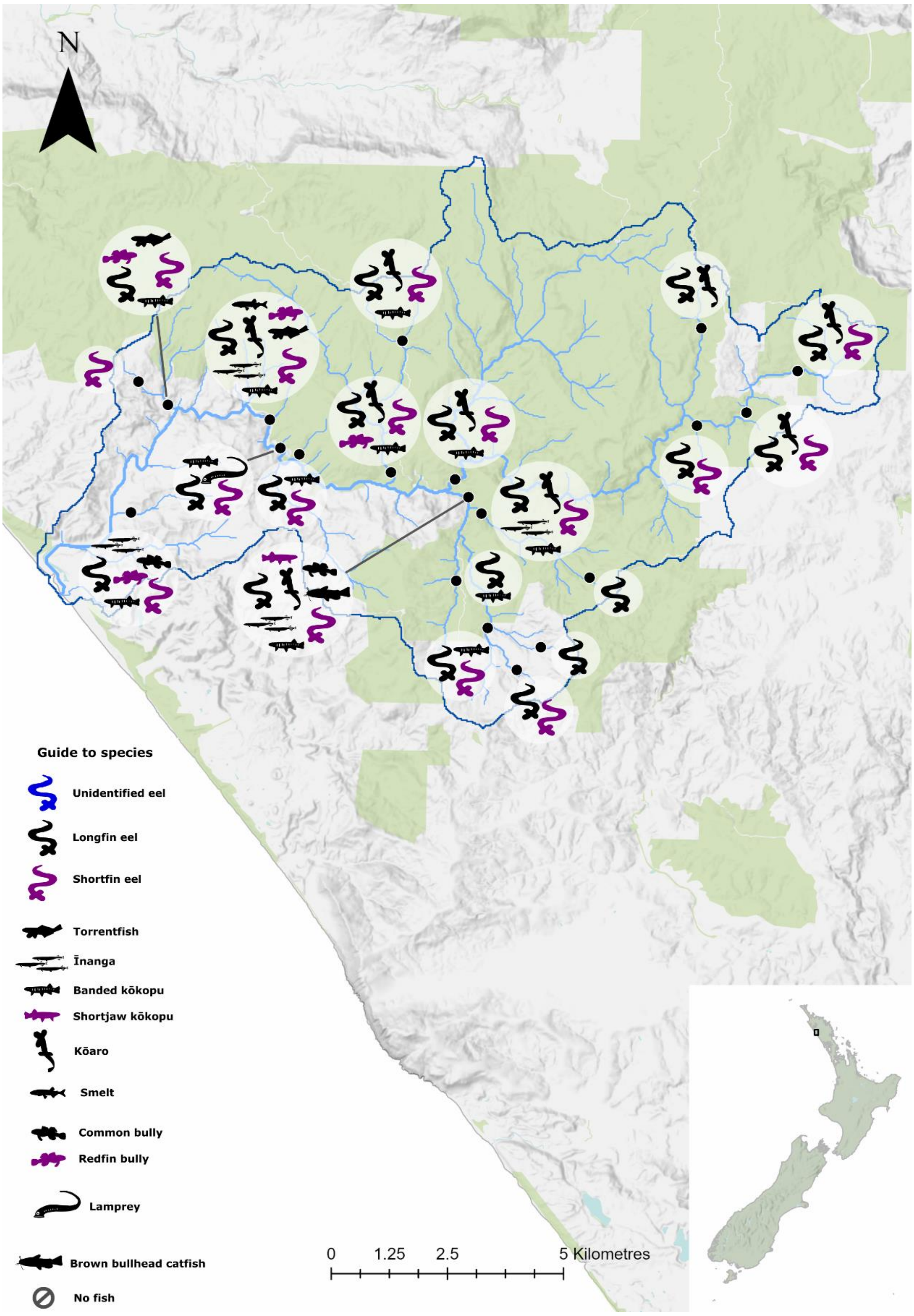


Figure 3. Sites where fish species were found within the Waipoua catchment (all detection methods). For repeated site, all fish species detected over both sampling occasions are shown. See Appendix 3 for a full table of the species found at each site. Basemaps generated by Eagle Technologies (2023), sourced from LINZ Data Service (2023) and licensed for reuse under CC BY 4.0.

Table 1. Fish species detected at each sampling occasion for the sites sampled in both 2020/21 and 2021/22 using both electric fishing and eDNA. Species in **bold** were detected on only one occasion.

Site	Detected in 2020/21	Detected in 2021/22
Waipoua_2_4A	Banded kōkopu **Kōaro** Longfin eel Unidentified eel	Banded kōkopu Longfin eel **Shortfin eel** Unidentified eel
Waipoua_3_1A	**Kōaro** Longfin eel Unidentified eel	Longfin eel Shortfin eel
Waipoua_3_10A	Banded kōkopu Longfin eel Redfin bully Shortfin eel **Torrentfish** Unidentified bully Unidentified eel	Banded kōkopu Longfin eel Redfin bully Shortfin eel Unidentified eel
Waipoua_3_3A	Kōaro Longfin eel Shortfin eel Unidentified eel	Kōaro Longfin eel Shortfin eel Unidentified eel

Threat classes

Of the fish detected in the Waipoua catchment, lamprey and shortjaw kōkopu are classified as Threatened: Nationally Vulnerable. Īnanga, kōaro, longfin eel, and torrentfish are classified as At Risk: Declining. All other fish species found are listed as Not Threatened.

Pest species

Brown bullhead was detected using eDNA at Waipoua4-5_10A in the 2022/23 monitoring season, although no individuals were caught using electric fishing. This is potentially the first detection of brown bullhead within the Waipoua catchment as no previous records of it here have been entered in the NZFFD. We recommend that the presence of brown bullhead in Waipoua is confirmed through physically capturing and identifying a specimen as it is an invasive species in Aotearoa New Zealand (NIWA 2020) and is included within the sustained control programme for freshwater pests in the Northland Regional Pest and Marine Pathway Management Plan 2017–2027 (NRC 2017).

F-IBI

While fish at most sites were sampled using electric fishing, one site (Waipoua2_2A) was sampled using spotlighting and one site was sampled using a combination of fyke nets and Gee's minnow traps (Waipoua4-5_3b). As spotlighting is an acceptable sampling method for assessing F-IBI following the requirements of the NPS-FM and all sub-reaches were sampled, an F-IBI score was calculated for Waipoua2_2A. However, while trapping is also an acceptable fish sampling method, it was unclear if the entire reach was sampled at Waipoua4-5_3b and the fish data provided were incomplete, so no F-IBI score was calculated. Likewise, no fishing was carried out at Waipoua_3_2B due to deep pools and kauri dieback protocols preventing movement around the site, nor at Waipoua_2_1C due to an electric fishing machine malfunction. No fish were caught at Waipoua_1_10A, which may have been due to the limited effectiveness of electric fishing through reduced visibility resulting from the site's soft-bottomed nature. Fishing effort was also reduced at the four sites monitored in the 2021/22 monitoring season due to time constraints, as iwi monitoring teams were also trained on sampling occasions.

At 16 of the 20 sites where F-IBI could be calculated, F-IBI scores ranged from a maximum of 56 to a minimum of 20 (out of a possible maximum score of 60), spanning from the NPS-FM A band through to C band (Figure 3). The five sites that fell within C band were low-order sites or high up in the catchment, suggesting that the reduction in F-IBI may be related to fish passage or habitat preferences.

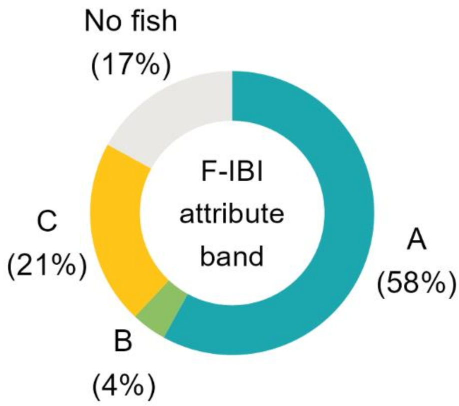


Figure 4. Proportion of sites in each NPS-FM attribute band for the Fish Index of Biotic Integrity (F-IBI).

3.2. Macroinvertebrates

3.2.1. Metric calculation

Metrics calculated to assess macroinvertebrate diversity and communities included the Macroinvertebrate Community Index (MCI), Quantitative MCI (QMCI), percentage of Ephemeroptera, Plecoptera and Trichoptera by taxa richness (%EPT), and average score per metric (ASPM). The calculation of MCI, QMCI and ASPM followed the methods set out in the NEMS Macroinvertebrates (National Environmental Monitoring Standards Working Group 2022), with tolerance scores taken solely from Clapcott et al. (2017) to align with the requirements of the NPS-FM 2020 and follow nationally consistent practices. This ensures that MCI, QMCI and ASPM calculations use the same reference values employed nationally and so are comparable to other datasets. As specified by the field sheets, hard-bottomed tolerance scores for metric calculations were used for 18 of the 20 sites, and soft-bottomed tolerance scores used for Waipoua_1_10A and Waipoua2_2A.

In calculating MCI and QMCI, multiple macroinvertebrate taxa could not be assigned tolerance scores. This was primarily because the taxa could not be identified to a high enough taxonomic resolution, likely due to early-instar individuals being collected in macroinvertebrate samples. For hard-bottomed sites, the taxa that could not to assigned tolerance scores were *Austroclima* and *Mauiulus* (two genera of mayfly with contrasting scores that cannot be distinguished at early instars); Leptophlebiidae (a mayfly family); Hydrobiosidae, Hydropsychinae and Leptoceridae (all caddisfly families); and Zygoptera (a suborder of Odonata). For soft-bottomed sites, tolerance scores could not be assigned to Polycentropodidae (a caddisfly family) or *Stictocladius* (a chironomid genus without a soft-bottom tolerance score). The omission of this taxon may have affected metric values, but there is no suitable method to allocate tolerance scores where specimens cannot be identified to a sufficient resolution or no tolerance scores exist. The approach taken follows national convention for calculating macroinvertebrate metrics.

Other metrics calculated were taxa richness, the number of taxa found, the proportion of exotic species and the proportion of taxa within each conservation category / status. The number of taxa included the total number of taxa present at each site, irrespective of the identification level reached. Information on macroinvertebrate conservation category / status was taken from the NZTCS database,[2] primarily based on the Grainger et al. (2018) assessment. The presence of any potential pest macroinvertebrate species was assessed by comparing the taxon found to species designated as pest species by NIWA (2020).

3.2.2. Catchment state

Macroinvertebrate diversity metrics

A total of 235 individual taxa were identified across the 20 sites sampled, and macroinvertebrate diversity metrics could be calculated for all sites. The taxon count for each site ranged from 16 to 55 taxa, while MCI values ranged from 89 to 138, QMCI values ranged from 3.62 to 8.41, ASPM ranged from 0.44 to 0.69, and %EPT ranged from 0.0% to 66.7% (Table 2, Figure 5). The variation in macroinvertebrate scores differed between metrics, and lower diversity at some sites did not result in lower MCI / QMCI scores. While metrics are related, each indicates different characteristics of macroinvertebrate communities – e.g. taxa richness indicates the

[2] https://nztcs.org.nz

diversity present at a site, while MCI / QMCI score indicates the tolerance of the macroinvertebrate community present.

Table 2. Macroinvertebrate metrics calculated for all monitoring sites. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in, with repeated sites shaded in grey. Changes between the 2020/21 and 2021/22 monitoring seasons for each repeated site are indicated in brackets. Average score per metric (ASPM) is the normalised average of MCI, %EPT and EPT richness.

UID	Monitoring season	MCI score	QMCI score	Number of EPT taxa	Percentage of EPT taxa	ASPM	Number of taxa
Waipoua_1_10A_2020	2020	121	6.06	3	17.65	0.61	19
Waipoua_1_1A_2020	2020	133	5.07	17	48.57	0.66	39
Waipoua_1_5A_2020	2020	125	4.76	22	48.89	0.63	50
Waipoua_2_1C_2020	2020	138	6.68	28	66.67	0.69	55
Waipoua_2_4A_2020	2020	133	5.02	25	60.98	0.66	48
Waipoua2_4A_2021	2021	121 (-12)	6.45 (+1.43)	17 (-8)	54.84 (-6.14)	0.61 (-0.05)	41 (-7)
Waipoua_2_9C_2020	2020	127	4.82	25	54.35	0.63	53
Waipoua_3_10A_2020	2020	116	6.17	23	53.49	0.58	51
Waipoua3_10A_2021	2021	124 (+8)	4.92 (-1.25)	17 (-6)	47.22 (-6.27)	0.62 (+0.04)	36 (-15)
Waipoua_3_1A_2020	2020	132	7.21	16	48.48	0.66	40
Waipoua3_1A_2021	2021	130 (-2)	7.34 (+0.13)	16 (no change)	55.17 (+6.69)	0.65 (-0.01)	31 (-9)
Waipoua_3_2B_2020	2020	127	5.13	11	47.83	0.63	29
Waipoua_3_3A_2020	2020	133	7.34	22	66.67	0.66	41
Waipoua3_3A_2021	2021	124 (-9)	6.66 (-0.68)	15 (-7)	55.56 (-11.11)	0.62 (-0.04)	30 (-11)
Waipoua_3_8A_2020	2020	124	5.52	23	53.49	0.62	51
Waipoua_4-5_2A_2020	2020	129	8.41	15	62.50	0.65	28
Waipoua1_11B_2022	2022	130	5.30	20	62.50	0.65	36
Waipoua1_4C_2022	2022	134	6.09	20	62.50	0.67	36
Waipoua2_2A_2022	2022	89	3.62	0	0.00	0.44	16
Waipoua2_3C_2022	2022	128	6.71	23	60.53	0.64	46
Waipoua3_6A_2022	2022	101	4.03	12	42.86	0.51	33
Waipoua4-5_10A_2022	2022	124	5.46	22	61.11	0.62	40
Waipoua4-5_3B_2022	2022	101	4.48	8	38.10	0.50	23
Waipoua4-5_5A_2022	2022	108	4.20	12	46.15	0.54	28

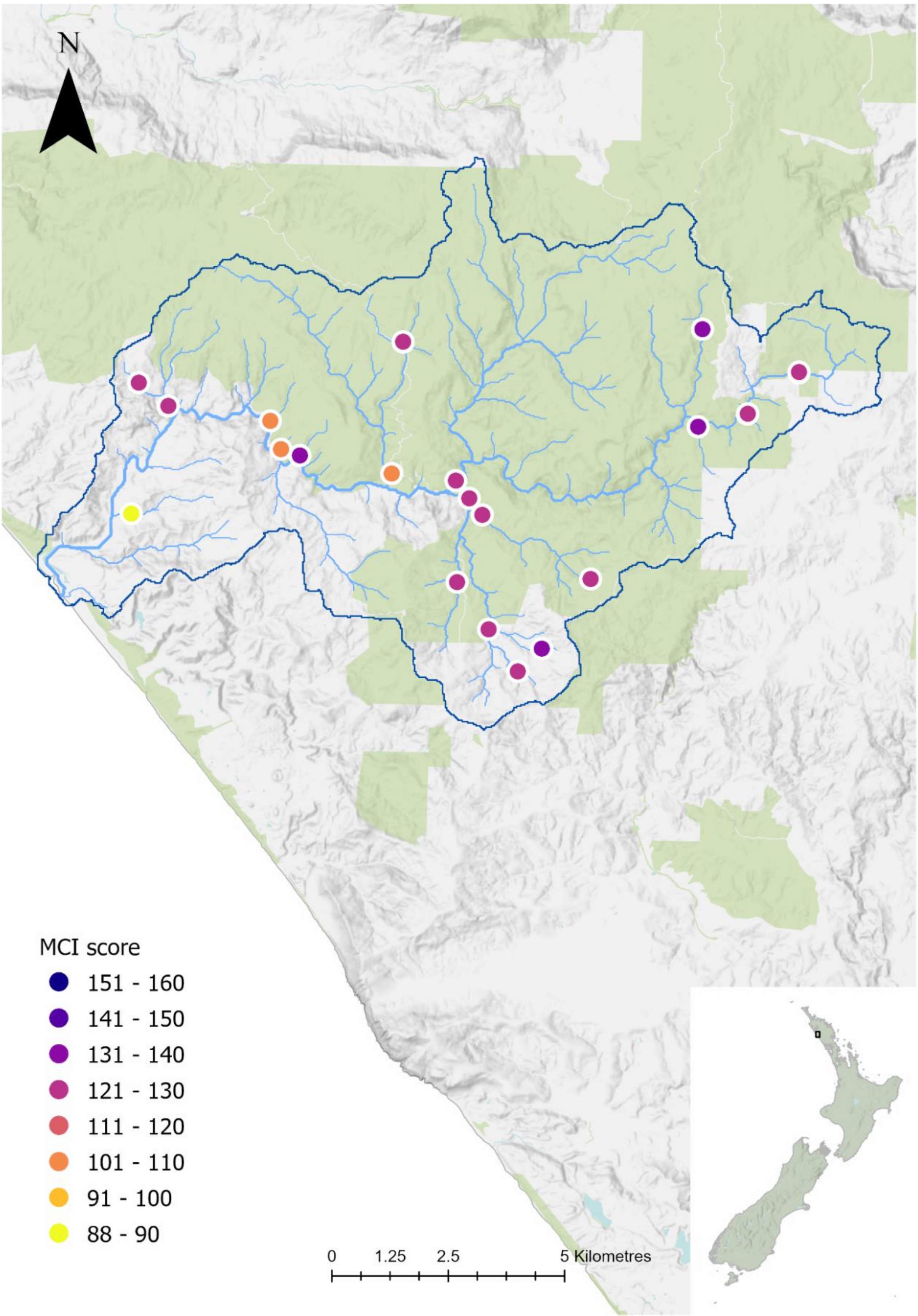


Figure 5. Map of MCI values across the Waipoua catchment. For repeated sites, the most recent data are shown. Basemaps generated by Eagle Technologies (2023), sourced from LINZ Data Service (2023) and licensed for reuse under CC BY 4.0.

When interpreted using the NPS-FM attribute bands to relate macroinvertebrate diversity metrics to ecological conditions, seven samples met the MCI threshold of 130 for A band, indicative of pristine or reference conditions; 13 samples fell into B band, indicating good conditions; and three samples were in C band, indicating moderate degradation. One sample fell into D band (below the national bottom line). A similar spread of results was observed for QMCI, with seven samples exceeding the threshold for A band, six samples falling in B band, seven in C band and four below the national bottom line in D band. Conversely, for ASPM, 19 samples met the threshold for A band, while the remaining five met the requirements for B band (Figure 6). For the sites sampled in both 2020/21 and 2021/22, there was some variability in macroinvertebrate metric scores. Most changes were inconsistent in direction with both increases and decreases for individual metrics at each site, although Waipoua3_3A had a decrease across all metrics in 2021/22 compared with 2020/21 (Table 2). For the NPS-FM, a 5-year median is used to assign band scores, and year-to-year variation may be the result of local drivers, climate and the timing of the surveys, so is not unexpected.

A potential driver of the observed differences in macroinvertebrate community condition is land cover. The two sites in exotic forestry displayed lower values for MCI and QMCI (Figure 7). However, sites in indigenous forest spanned a wide range of MCI and QMCI values, and sites in pastoral land exhibited high values for both MCI and QMCI, suggesting that other factors may also be influencing macroinvertebrate communities. It is possible that habitat availability and sedimentation are contributing to the observed patterns. The MCI was developed to respond to organic enrichment; however, the sites with low MCI and QMCI scores did not have markedly different nitrate or phosphorus concentrations compared with other sites within the catchment. It is probable that the scores are related to different levels of deposited or interstitial fine sediment, which is also known to be correlated with MCI scores. Further investigation into the relationships between macroinvertebrates and environmental conditions within this catchment would be worthwhile.

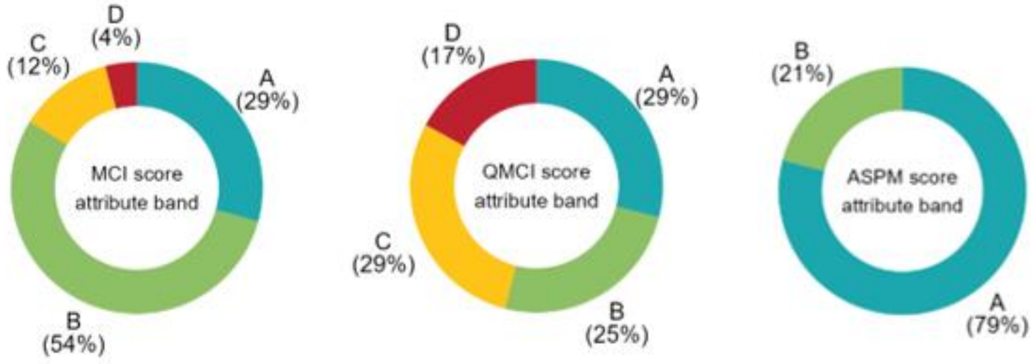


Figure 6. Proportion of samples in each NPS-FM attribute band for Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI) and average score per metric (ASPM).

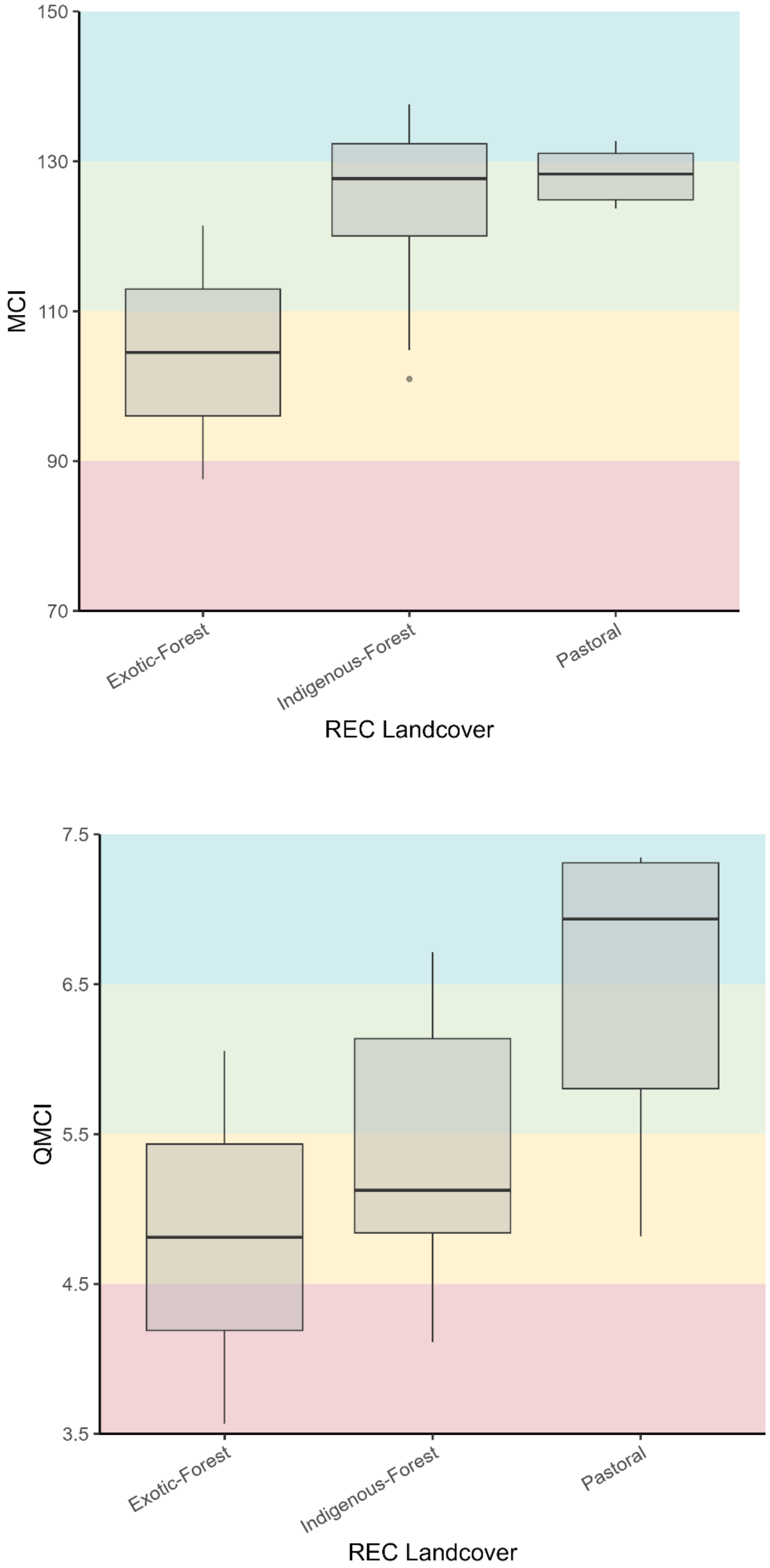


Figure 7. Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores for each REC land cover (two sites in exotic forest, 22 in indigenous forest and nine in pastoral land). Colours represent NPS-FM bands, with A = blue; B = green, C = yellow and D = red.

Threat category and status

Only 42% of taxa found could be assigned to an NZTCS threat category and status. Of the taxa that could be assigned, seven At Risk taxa were found. Of these, the mayfly species *Isothraulus abditus* and *Siphlaenigma janae* were listed as At Risk: Declining. Five species were At Risk: Naturally Uncommon, including the caddisfly *Ecnomina zealandica,* the dragonfly *Antipodochlora braueri*, the mayflies *Mauiulus aquilus* and *Zephlebia nebulosa*, and the stonefly *Stenoperla helsoni.* In addition, the amphipod *Phreatogammarus waipoua* was found and is listed as Data Deficient (Table 3).

Table 3. Sites where At Risk or Data Deficient macroinvertebrate taxa were found in the Waipoua catchment.

NZTCS category	NZTCS status	Order	Species	Sites found at
At Risk	Declining	Ephemeroptera	*Isothraulus abditus*	Waipoua_1_1A
			Siphlaenigma janae	Waipoua_1_1A
	Naturally Uncommon	Ephemeroptera	*Mauiulus aquilus*	Waipoua1_4C Waipoua3_6A Waipoua_3_10A Waipoua_4-5_2A Waipoua4-5_10A
			Zephlebia nebulosa	Waipoua_3_2B
		Odonata	*Antipodochlora braueri*	Waipoua_1_1A Waipoua_1_5A Waipoua_2_4A Waipoua_2_9C Waipoua3_10A
		Plecoptera	*Stenoperla helsoni*	Waipoua3_3A
		Trichoptera	*Ecnomina zealandica*	Waipoua_1_5A
Data Deficient		Amphipoda	*Phreatogammarus waipoua*	Waipoua1_4C Waipoua2_3C Waipoua3_10A Waipoua4-5_10A

Pest species

The only pest macroinvertebrate species found was the snail *Physa acuta*, which was recorded at Waipoua2_2A in the 2022/23 monitoring season.

3.3. Megainvertebrates

3.3.1. Metric calculation

The data relating to the detection of megainvertebrates were collated to determine where crabs, kōura, mussels or shrimp were present. These data comprised information from mussel surveys, electric fishing and records of megainvertebrates removed from macroinvertebrate samples.

As with the analyses of the NFMP data (Kelly et al. 2023), we note that information about the presence of megainvertebrates at a site is compiled from information gathered during multiple protocols. Given the potential for inconsistencies in the recording of megainvertebrates in the field data sheets and among field teams, it would be beneficial to apply a specific megainvertebrate protocol if information on megainvertebrate presence or abundance is of interest.

3.3.2. Catchment state

Mussel surveys were conducted on six occasions, with the mussel species *Echyridella menziesii* detected at one site (Waipoua4-5_3b). No record was made of abundance, but it was noted that *E. menziesii* was present all along one bank.

Kōura and the shrimp *Paratya curvirostris* were found at 13 and three sites, respectively, with 103 kōura and 15 shrimps caught during electric fishing.

3.4. Aquatic plants

Aquatic plants sampled as part of the Ngā Awa monitoring programme included macrophytes and bryophytes (liverworts, hornworts and mosses). Where these plants were present in the periphyton transects, samples were collected to enable taxonomic identification.

3.4.1. Metric calculation

Results for bryophytes are presented as presence–absence data, with accompanying threat classifications from the NZTCS, primarily based on the de Lange et al. (2020) assessment.

There are presently no national standards for macrophytes or bryophytes in Aotearoa New Zealand rivers. Matheson et al. (2012) suggested that, in the absence of guidelines for aquatic plants in rivers, percentage cover of the streambed by surface-growing plants and percentage cross-sectional area volume (CAV) of macrophytes should be less than 50% to avoid adverse ecological effects.

3.4.2. Catchment state

Presence of bryophytes and macrophytes

Bryophytes were recorded at seven sites within the Waipoua catchment (Table 4), while no macrophytes were found. Cover was highest at Waipoua_2_4A in the 2021/22 monitoring season, with 39% bryophyte cover observed in periphyton transects, while only 0.5% cover was recorded at Waipoua_1_1A and Waipoua_1_10A in the 2020/21 monitoring season. Two of the sites with bryophytes were repeated, with a small increase in bryophyte cover observed for both. As no macrophytes were present, CAV was not calculated.

Table 4. Bryophyte cover and species present within the Waipoua catchment. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in, with repeated sites shaded in grey. Changes in bryophyte cover between the 2020/21 and 2021/22 monitoring seasons for each repeated site are indicated in brackets, with taxa found in only one of the years given in **bold**. Sites not listed had no bryophyte cover recorded within the periphyton transects.

UID	Total bryophyte cover	Species present
Waipoua_1_10A_2020	0.5	*Hypnodendron spininervium*
Waipoua_1_1A_2020	0.5	*Hepatostolonophora paucistipula* *Hypnodendron spininervium*
Waipoua_2_1C_2020	23.55	*Lobatiriccardia* sp. *Radula demissa*
Waipoua_2_4A_2020	35.35	***Dinckleria fruticella*** *Echinodium hispidum* ***Lobatiriccardia* sp.** ***Ptychomnion aciculare*** ***Radula demissa*** ***Thuidiopsis furfurosa***
Waipoua_2_4A_2021	39 (+3.65)	*Echinodium hispidum* ***Fissidens strictus*** ***Megaceros* sp.** ***Radula strangulata*** ***Rhynchostegium tenuifolium***
Waipoua_3_1A_2020	6.35	***Hypnodendron spininervium*** *Psilosiphon* sp.
Waipoua_3_1A_2021	12.25 (+5.90)	*Psilosiphon* sp. ***Radula plicata*** ***Stolonivector waipouensis*** ***Trichomanes elongatum***
Waipoua_3_3A_2021	12.5	*Echinodium hispidum* *Megaceros* sp.
Waipoua_3_8A_2020	20.75	*Hepatostolonophora paucistipula* *Lobatiriccardia* sp.

Endemicity and threat classification

From specimens collected at the seven sites where bryophytes were recorded, 16 species were identified by Manaaki Whenua – Landcare Research (Table 4). Endemicity or threat classification could not be assigned for all species, but *Trichomanes elongatum* and *Stolonivector waipouensis* were the only endemic species identified as present in the Waipoua catchment. The only At Risk species found were *Fissidens strictus* and *Stolonivector waipouensis*, which both have a status of Naturally Uncommon. All other species that could be assigned a threat classification were classed as Not Threatened.

3.5. Periphyton

3.5.1. *Metric calculation*

The periphyton cover was calculated as the average cover of each periphyton type across all the views in the periphyton surveys. Periphyton biomass was assessed at all 18 hard-bottomed sites on all sampling occasions and was supplied in the Hills Laboratory data files as chlorophyll-*a* per square metre sampled, calculated from the analyses of rock scrapings.

3.5.2. *Catchment state*

Periphyton cover

One site exceeded 30% of long filament (> 2 cm) cover or more than 60% of thick (> 3 mm) benthic mats (Figure 8), which are thresholds associated with adverse effects on benthic macroinvertebrate communities (Biggs 2000). The site with high cover of filamentous algae was Waipoua4-5_5A, with 49% cover. Bare substrate comprised a large proportion of the benthos at many sites, although four sites were dominated by thin films.

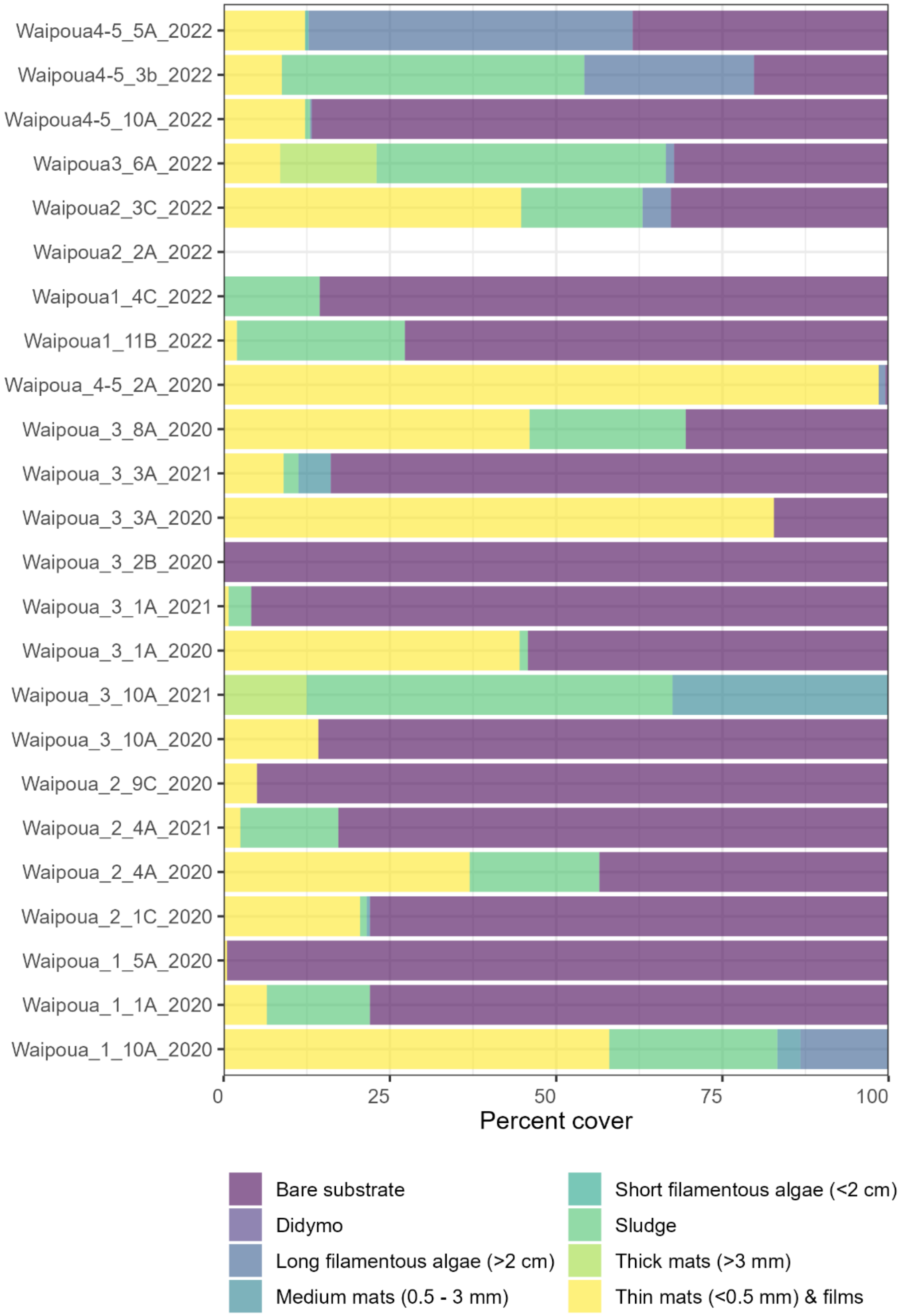


Figure 8. Periphyton cover by type for each site. Mats included green, brown, diatom and cyanobacterial mats. No periphyton transects were carried out at Waipoua2_2A.

Periphyton biomass

The periphyton biomass at all sites where samples were collected was low (mean = 8.77 mg/m^2, minimum = 0.6 mg/m^2, maximum = 41 mg/m^2), indicating low growth rates and accumulation within the catchment. All results were below the A band threshold in the NPS-FM and the chlorophyll-*a* concentrations estimated to adversely affect benthic communities (Biggs 2000; Biggs and Kilroy 2000). Generally, these results indicate that the sampled streams had low primary production or high grazing activity by macroinvertebrates.

3.6. Taxon-Independent Community Index

The Taxon-Independent Community Index (TICI) is an ecosystem health metric developed by Wilderlab NZ Ltd (Wellington, Aotearoa New Zealand). The TICI was developed by relating eDNA metabarcoding data from 40 rivers to MCI scores for those sites.[3] The Wilderlab website notes, 'The TICI is still in development and should be interpreted as an experimental tool at this stage'. The Ngā Awa samples were assessed using the Riverine V1 version of the TICI index.

In the Waipoua catchment, three sites yielded a TICI score with the Wilderlab rating of 'Pristine', 10 sites were 'Excellent', five were 'Good' and one was 'Average' (Table 5). There was no change in the TICI rating between sampling occasions for the four sites that were sampled twice. No TICI was calculated for site Waipoua_1_10A. A number of sites were given a rating of 'Good' or 'Excellent' when the MCI score would indicate an expected result of 'Pristine' (samples below the regression line in Figure 9). The TICI index result provided is solely numeric (with a text qualifier for the state) and based on scores related to the presence of certain amplicon sequence variants (ASV). As the scores associated with each ASV are unknown, the index operates like a black box, making it impossible for users of the data to investigate why sites have been given unexpectedly low scores that are not explained by any other variables at those sites.

[3] https://www.wilderlab.co.nz/tici

Table 5. Median Taxon-Independent Community Index (TICI) values for all monitoring sites. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in, with repeated sites shaded in grey. Changes between the 2020/21 and 2021/22 monitoring seasons for each repeated site are indicated in brackets. Scores from individual replicates, the number of sequences included and the degree of reliability stated by Wilderlab are included in Appendix 4.

UID	Monitoring season	Median TICI value	TICI rating
Waipoua_1_1A_2020	2020	112	Excellent
Waipoua_1_5A_2020	2020	122	Pristine
Waipoua_2_1C_2020	2020	125	Pristine
Waipoua_2_4A_2020	2020	116	Excellent
Waipoua_2_4A_2021	2021	117 (+1)	Excellent
Waipoua_2_9C_2020	2020	117	Excellent
Waipoua_3_10A_2020	2020	117	Excellent
Waipoua_3_10A_2021	2021	111 (-6)	Excellent
Waipoua_3_1A_2020	2020	102	Good
Waipoua_3_1A_2021	2021	105 (+3)	Good
Waipoua_3_2B_2020	2020	110	Excellent
Waipoua_3_3A_2020	2020	110	Excellent
Waipoua_3_3A_2021	2021	114 (+4)	Excellent
Waipoua_3_8A_2020	2020	112	Excellent
Waipoua_4-5_2A_2020	2020	110	Excellent
Waipoua1_11B_2022	2022	120	Pristine
Waipoua1_4C_2022	2022	119	Excellent
Waipoua2_2A_2022	2022	97	Average
Waipoua2_3C_2022	2022	119	Excellent
Waipoua3_6A_2022	2022	109	Good
Waipoua4-5_10A_2022	2022	109	Good
Waipoua4-5_3b_2022	2022	106	Good
Waipoua4-5_5A_2022	2022	107	Good

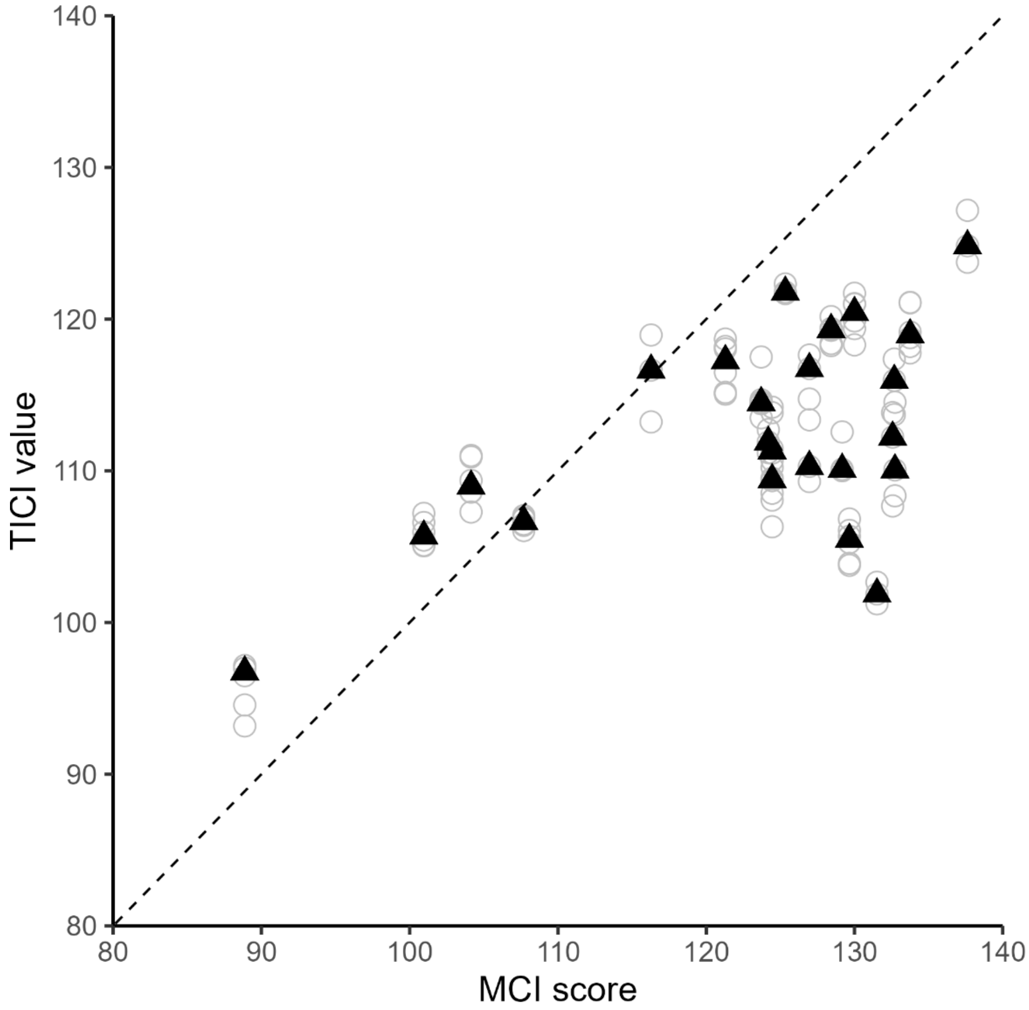


Figure 9. Taxon-Independent Community Index (TICI) scores plotted against Macroinvertebrate Community Index (MCI) scores for each site. Filled triangles are median TICI values for each site, while open circles are individual TICI values from each replicate. The dashed line is a 1-to-1 regression line to provide context when interpreting the plot.

Although there is a strong linear relationship between the TICI and 5-year median MCI score for the sites used in the development of the TICI, this relationship was not as clear in the samples from Waipoua, with the relationship breaking down particularly at high MCI values (Figure 9). The interpretation of the MCI metric is aided by its long history of use (> 30 years) and that it was developed specifically to reflect pressures from organic enrichment on macroinvertebrate communities (Stark 1985; Stark and Maxted 2007). As the TICI has, to the best of our knowledge, been developed by calibrating the scores to MCI scores rather than drivers or pressures, it cannot be considered equivalent for the purpose of interpretation. In addition, although the TICI is taxon-independent in its development, the presence of non-aquatic taxa in the indicator dataset means that the index conflates instream responses with potential drivers (e.g. from land use) and the implication of this on interpreting the results requires more investigation. A further consideration is that sampling approaches used for eDNA rely on water samples. The eDNA in these water samples could have originated many kilometres upstream and may not reflect the conditions at the site. In contrast, the macroinvertebrates collected for the MCI are presumed to mostly live at the site.

Across all the samples, a reliability score is assigned by Wilderlab (Appendix 5). A threshold of 250 sequences is used by Wilderlab to denote a ‘highly reliable’ score. This is an extremely low number of sequences in contrast with other eDNA metabarcoding-based indices available in Aotearoa New Zealand – for example, the Lake Health Index (Pearman et al. 2022) and Benthic Fish Farm Index (Pochon et al. 2020; Pochon et al. 2021) – and raises questions about the robustness of the method. This is likely the result of the degree of multiplexing by Wilderlab to include a broad range of different taxonomic groups in a single sequencing run. To enable robust assessment of the reliability of the index score and to aid interpretation of the results, both the number of indicator ASVs and the total number of sequences belonging to those ASVs need to be included.

4. HABITAT

4.1. Meso-habitat

Hydrological diversity provides an indication of the variety of flow habitats available at a site (referred to here as meso-habitats). Generally, the greater the meso-habitat heterogeneity (the more habitat types), the more potential for species diversity because differing habitat preferences are catered for. A wide variety of meso-habitat types were available across sites, with all but two having three or more meso-habitat types (Figures 10 and 11). Runs and riffles featured as the most common dominant habitat type; however, cascades and pools were also notable habitat at some sites.

For the four sites sampled in both the 2020/21 and 2021/22 monitoring seasons, all sites had no change in the meso-habitat types present, although the area of habitat described as pool increased at two sites. Note that a change in field procedures between the 2021/22 and 2022/23 monitoring seasons the meant that step pools were distinguished as a separate meso-habitat type. As a result, meso-habitat data from the 2022/23 monitoring season is not directly comparable with earlier data. No meso-habitat information was collected from Waipoua_3_2B, as sampling was restricted to a small number of sub-reaches due to deep pools and because kauri dieback protocols limited movement.

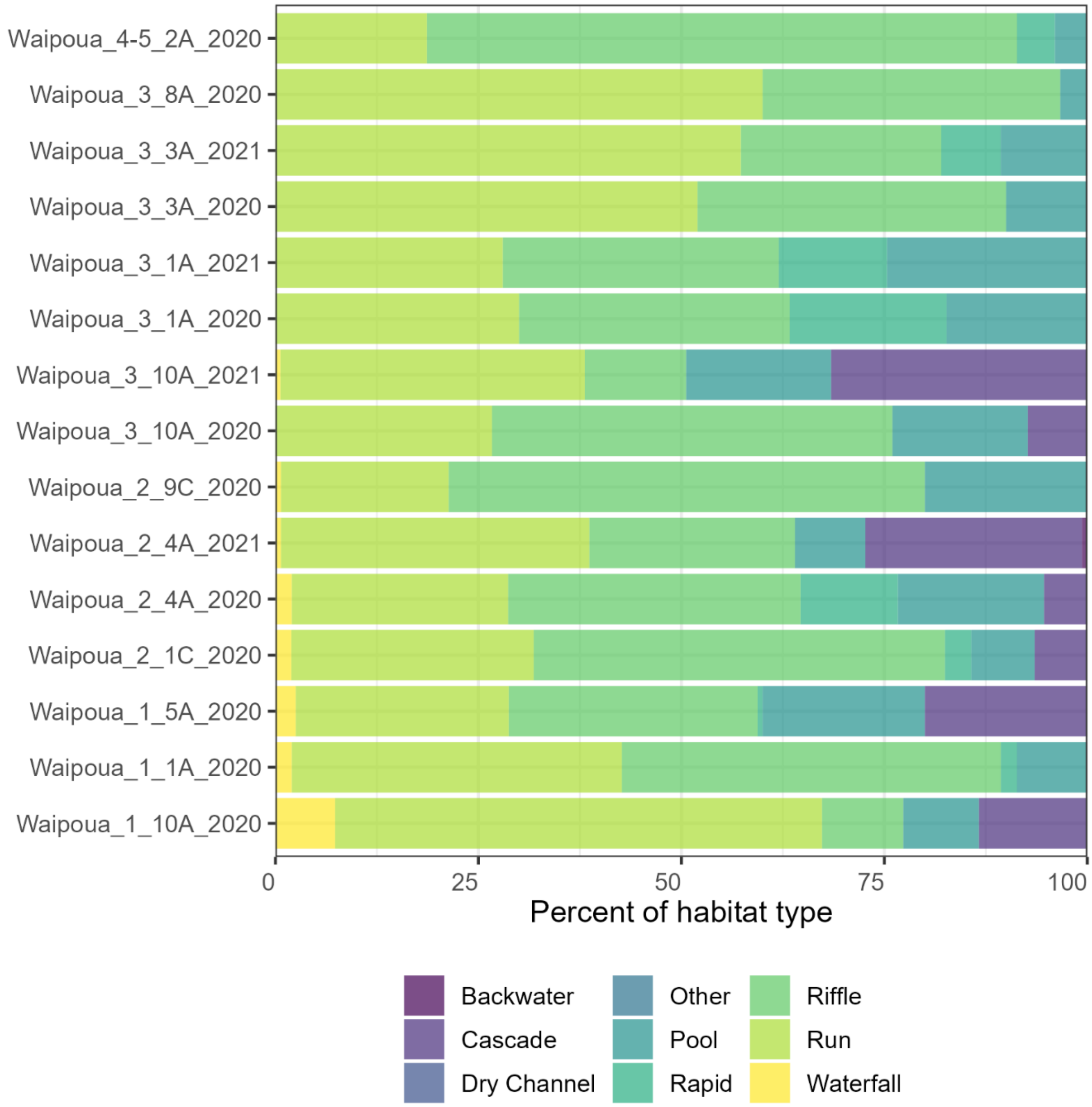


Figure 10. Meso-habitat diversity as a percentage of the 150 m stream reach at each site sampled in the 2020/21 and 2021/22 monitoring seasons.

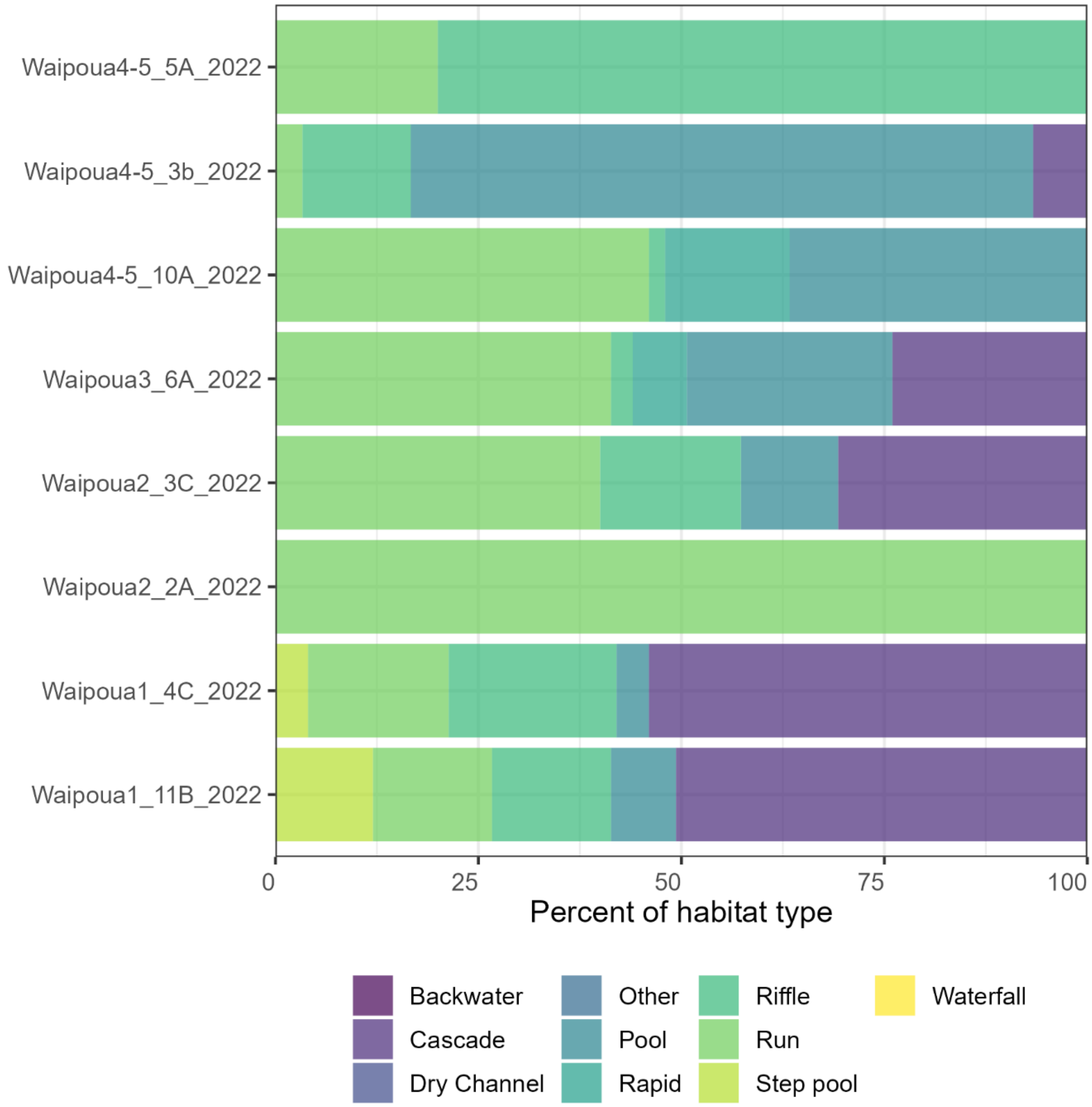


Figure 11. Meso-habitat diversity as a percentage of the 150 m stream length sampled for the sites sampled in the 2022/23 monitoring season. The higher the number of types represented, the more diverse the habitat at the site.

4.2. Discharge

The stream discharge is calculated from the cross-sectional area of the stream and the mean velocity measurement (taken at 0.6 × the water depth). Taken by itself, this is a descriptive measure of the site at the time of sampling and will be highly influenced by preceding rainfall conditions in the catchment.

The survey sites had low discharge at the time of sampling, with most sites below 1 m^3/s. The greatest recorded discharge was 1.02 m^3/s at Waipoua_4-5_2A (Figure 12).

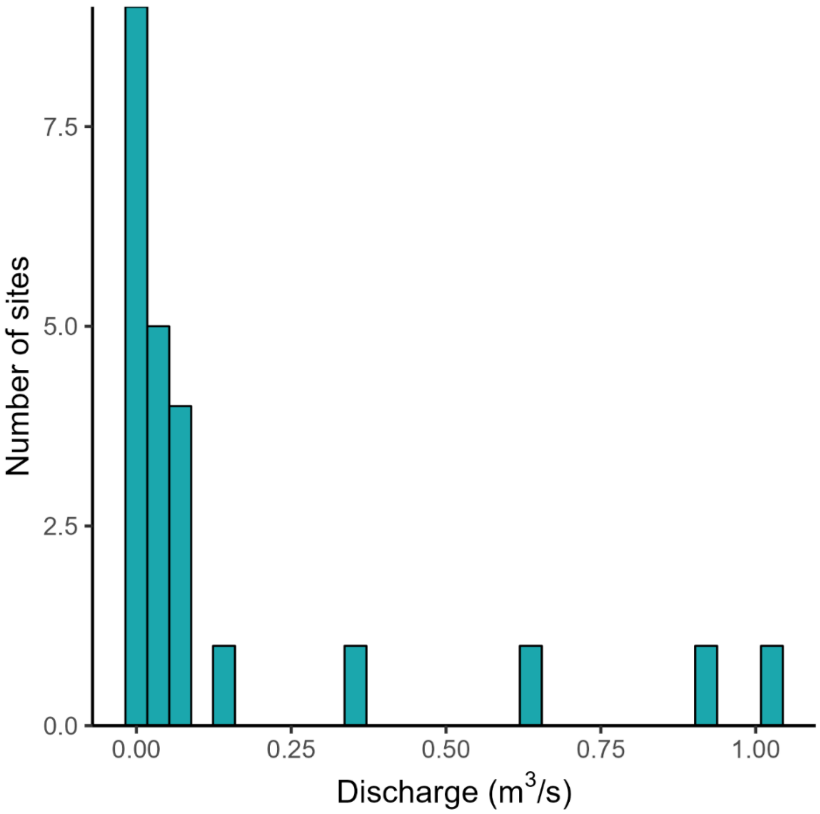


Figure 12. The range of discharge rates in cubic metres per second among sites sampled.

4.3. Substrate stability

The Pfankuch index of substrate stability (Pfankuch 1975) is a measure of the ability of a reach to resist the mobilisation of streambed and streambank materials under variable flow conditions. In Aotearoa New Zealand and overseas, the stability of a reach has been correlated with periphyton biomass (Death 1991) and the taxonomic richness and density of macroinvertebrates (Rounick and Winterbourn 1982; Collier et al. 1993). In Aotearoa New Zealand, it is also associated with habitat quality for *Hymenolaimus malacorhynchos* (blue duck / whio) (Collier et al. 1993). The index comprises a range of factors relating to the upper banks, lower banks and streambed of the site. Collier et al. (1993) provides an excellent introduction to scoring the index in an Aotearoa New Zealand context, with explanatory notes for each scoring category.

The Pfankuch index has been applied by various regional councils in Aotearoa New Zealand. This has resulted in the Pfankuch score being categorised into broad stream stability bands, representing very high stability (scores < 38), high stability (39–76), moderate stability (77–114) and low stability (> 115) (NRC 2011). It has been suggested that the association between benthic macroinvertebrate communities and the Pfankuch index scores is stronger when considering only the streambed component of the index (Death and Winterbourn 1994).

The Pfankuch index for the sites demonstrated a range of substrate stabilities, from low to high substrate stability. Most sites (66.7%) were highly stable, with the remainder moderately stable.

4.4. Deposited sediment and substrate heterogeneity

4.4.1. Fine sediment cover

There was high variation in fine sediment cover (minimum = 0 %, mean = 9.42 %, maximum = 73.5 %). The site with the highest fine sediment cover (Waipoua_3_2B) was classified as a hard-bottomed site for macroinvertebrate analysis due to the presence of a cobbled base underneath a layer of fine sediment, while the other site with sediment cover > 30% was considered soft-bottomed (Waipoua_1_10A, 72.5% fine sediment cover). No fine sediment cover assessment was carried out at the other site classified as soft-bottomed (Waipoua2_2A).

Fine sediment cover was correlated with both land cover and the Pfankuch index. Sites located in pastoral land had higher fine sediment cover than sites in indigenous forest (Figure 13), although no conclusions could be drawn regarding the influence of exotic forestry as fine sediment cover was assessed at only one site in exotic forestry. In relation to the Pfankuch index, highly stable sites had minimal fine sediment cover, while moderate stability sites had a variable amount of fine sediment. The Pfankuch index includes scoring components associated with deposited sediment within the stream, but this result indicates that the other aspects of the scoring method (upper and lower bank stability) are also associated with the deposited sediment cover (Figure 14).

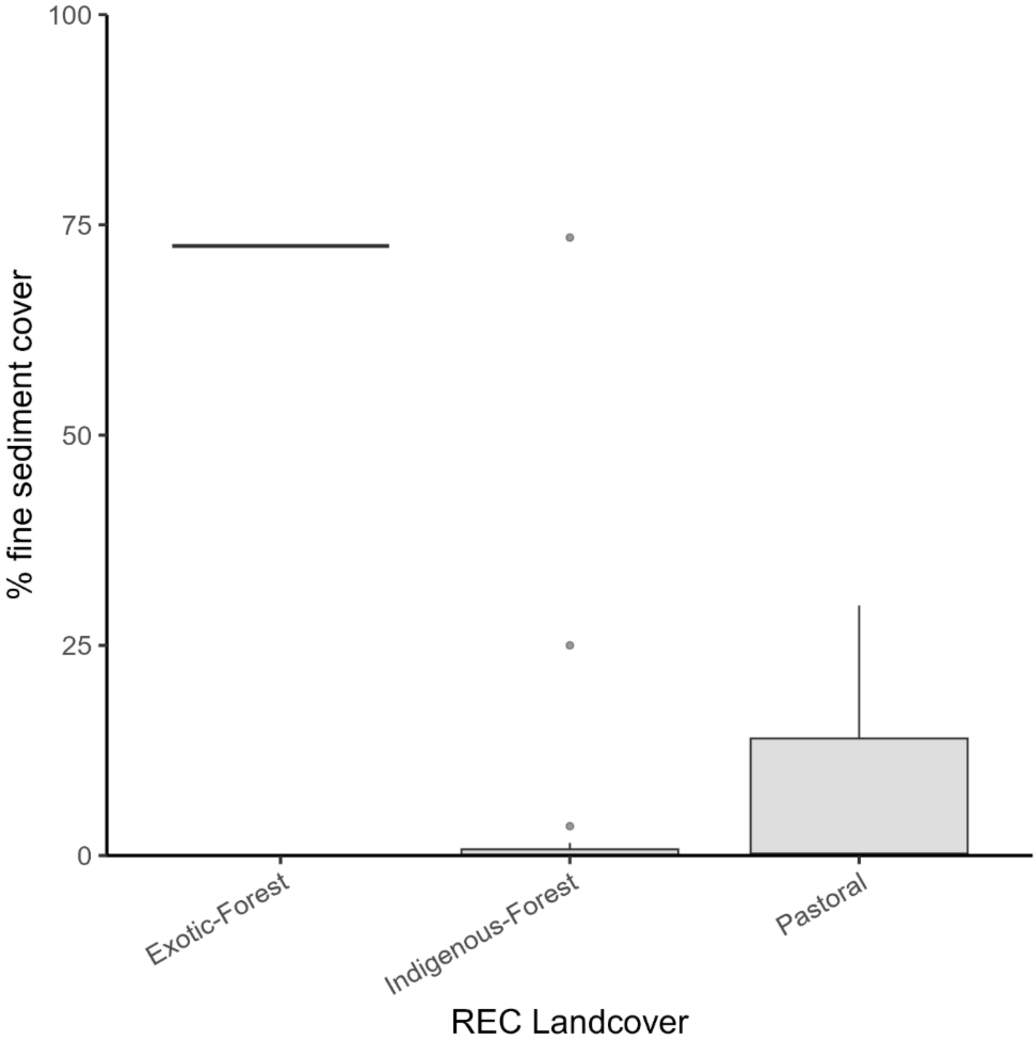


Figure 13. Fine sediment cover for each New Zealand River Environment Classification (REC) land cover category (one site in exotic forest, 22 in indigenous forest and nine in pastoral land).

High levels of fine sediment cover can impact the habitat quality of cobble-bedded rivers for macroinvertebrates and fish. The sediment fills interstitial spaces (the gaps between rocks), reducing habitat availability and refugia for both macroinvertebrates and fish (Clapcott et al. 2011).

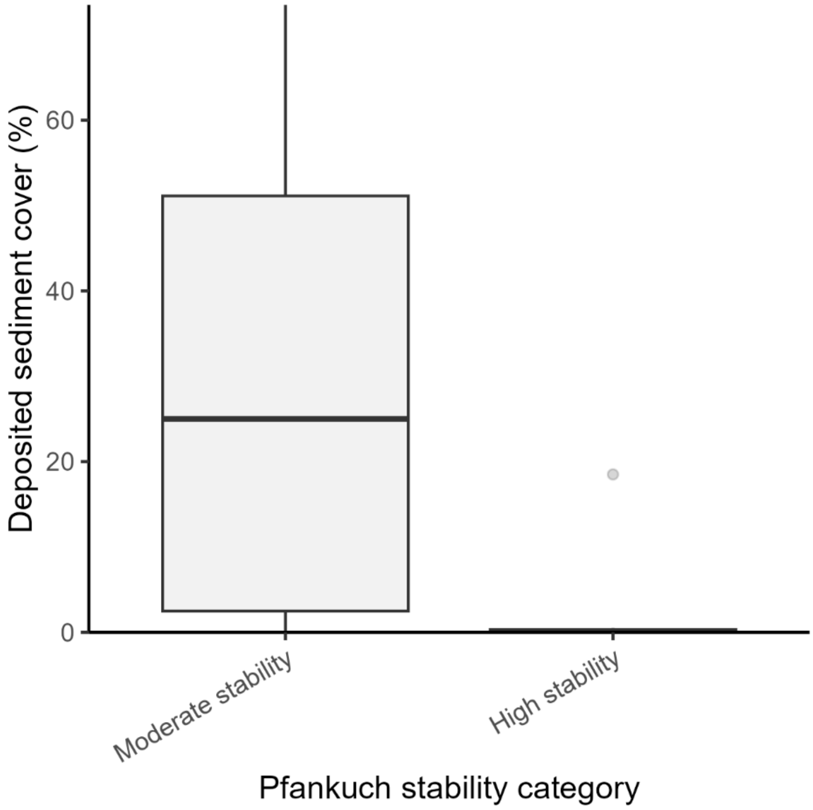


Figure 14. Mean deposited sediment cover across the periphyton transects by the Pfankuch stability category of the sites.

4.4.2. Substrate heterogeneity

The Wolman pebble count (method SAM-3) is a component of the sediment assessment protocols (Clapcott et al. 2011). The purpose of the metric is to quantify the contribution of different size classes of substrate to the overall substrate composition at a site. Like the other sediment assessment metrics, this protocol is intended for use at hard-bottomed sites. In particular, the Wolman pebble count is intended to quantify the percentage of fine sediment relative to guideline values for the preservation of instream values of biodiversity and salmonid spawning habitat. The guideline values for preservation of biodiversity are less than 20% of the substrate as fine sediment or within 10% of a reference condition. For salmonid spawning habitat, the guideline value is less than 20% of substrate composition as fine sediment. There were three sites where fine sediment exceeded 20% of the substrate composition (Figure 15).

Although metrics such as the dominant size class and some indices of substrate diversity can be calculated from the Wolman pebble count data, these are largely habitat descriptors for the sites. There are no anticipated ecological relationships between macroinvertebrate communities based on those metrics, beyond the known relationships between fine sediment and macroinvertebrate and fish communities.

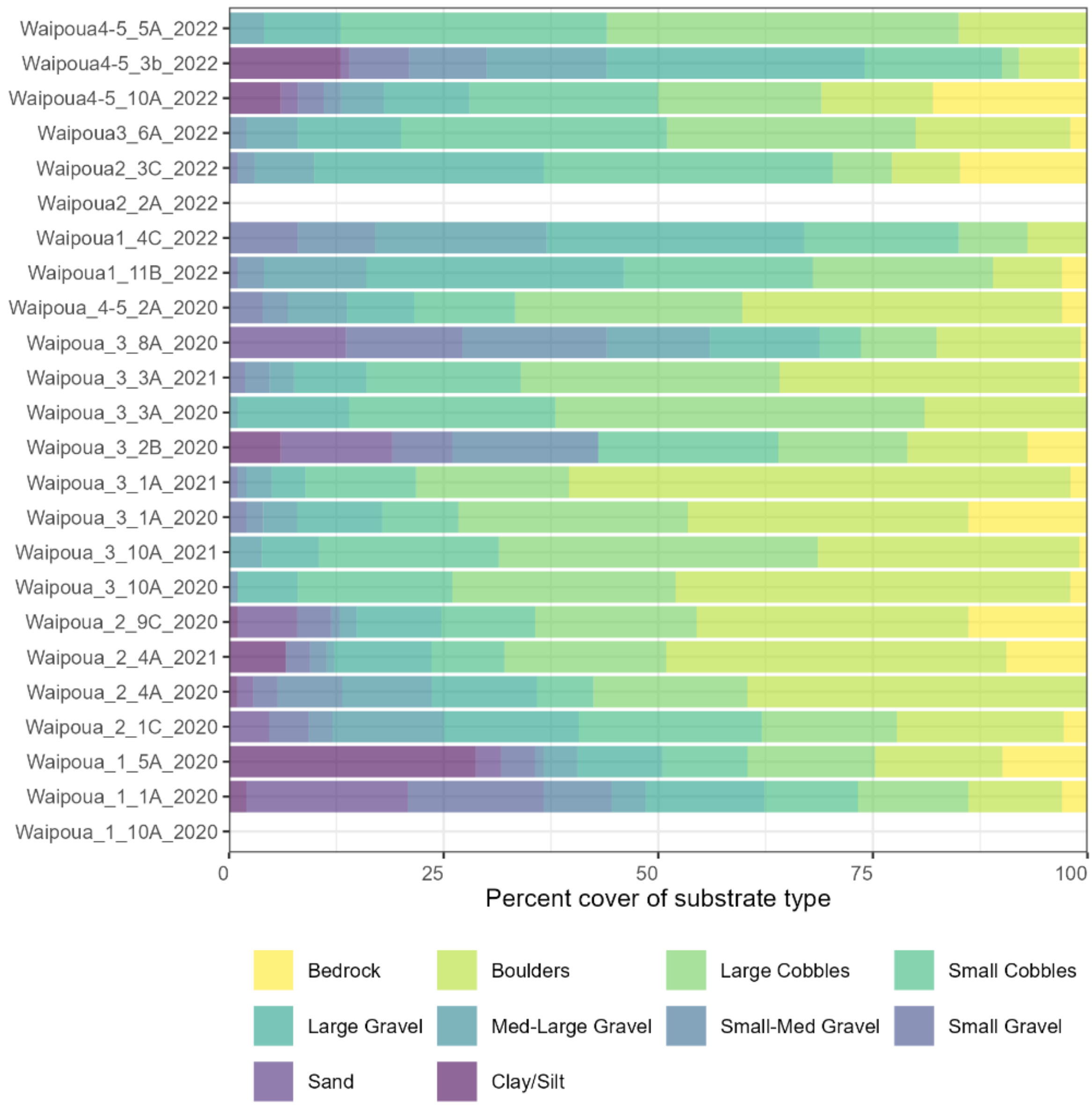


Figure 15. Substrate composition from the Wolman pebble count (SAM-3) assessment. Sand and clay / silt are considered fine sediment using this method. Note that no Wolman pebble count was conducted at the two soft-bottomed sites.

4.4.3. Pesticides

Where sediment samples could be collected at sites, sediment was tested for a range of pesticide residues from Hills Laboratories (including acid herbicides, multiresidue pesticides and organochlorine pesticides). Two organochlorine compounds were detected at Waipoua_2_9C: aldrin, found at 0.0017 mg/kg dry weight; and heptachlor, found at 0.0019 mg/kg dry weight. Aldrin is an organochlorine that was used in sheep dips in the 1950s and 1960s (MfE 2006), while heptachlor is an insecticide. Both are classed as persistent organic pollutants and were banned in Aotearoa New Zealand in 2004 under the Imports and Exports (Restrictions) Prohibition Order (No 2) 2004.

While above the detection limit, the concentration of aldrin found was below soil guideline values. The most stringent soil contaminant guideline value for aldrin is the minimal risk guideline value of 0.002 mg/kg set for the protection of aquatic life by MfE for the management of risks associated with former sheep-dip sites (MfE 2006). This is significantly stricter than the strictest standard for aldrin in the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health, which is 1.1 mg/kg in rural residential land (MfE 2012). The default guideline value for aldrin in water is 0.001 µg/L (ANZG 2018).

There is no soil contaminant guideline value for heptachlor in Aotearoa New Zealand, but the concentration found at Waipoua_2_9C was above the Canadian Environmental Quality Guidelines value of 0.0006 mg/kg for the protection of aquatic life (Canadian Council of Ministers of the Environment 2002). The default guideline value for heptachlor in water is 0.001 µg/L (ANZG 2018).

5. WATER QUALITY

5.1. Visual clarity

Visual clarity was assessed using black disc measurements. Nine samples met the requirements for A band for visual clarity based on their suspended sediment class in the NPS-FM, two fell into the band, two into C band and five into D band. No visual clarity assessment could be carried out on two sampling occasions due to the quantity of algae present and insufficient water depth (Waipoua2_2A in 2022/23 and Waipoua_3_10A in 2021/22), while a maximum observable clarity distance was measured for four sites as the habitat available for black disc measurements was not long enough to get a reading (Waipoua1_4C, Waipoua_1_5A, Waipoua_1_10A and Waipoua1_11B). For the site with the highest maximum observable clarity distance (7 m at Waipoua_1_10A), it was noted that the reading was likely an overestimate of the true visual clarity due to the shallow water depth interfering with recording the measurement. The variability in clarity among sites indicates that the amount of suspended sediment in the water column varies across the catchment (Figure 16).

Turbidity (laboratory measurements) was low across most sites, with a mean of 2.94 FNU and a median of 2.11 FNU. The maximum turbidity value was 21 FNU at Waipoua_1_10A, which was a soft-bottomed site. Values at all other sites were below 5 FNU. Laboratory measurements were assessed as the *in situ* data included some negative values, indicating likely issues with instrument calibration as negative values are not valid readings for turbidity. The same issue was noted in data collected for the NFMP (Kelly et al. 2023), so care should be taken in maintaining and calibrating the instruments used for data collection.

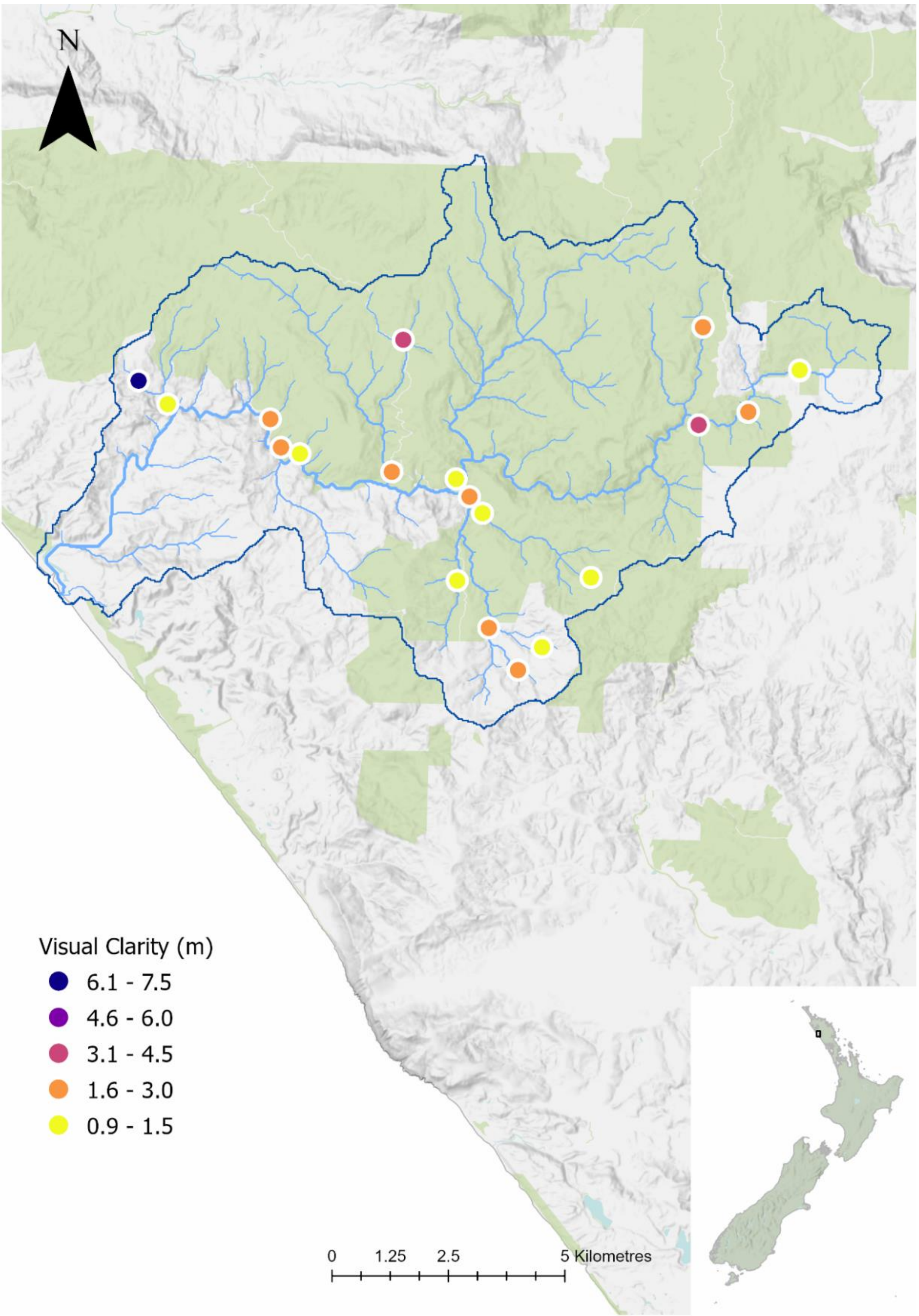


Figure 16. Visual clarity readings across the Waipoua catchment presenting black disc readings or maximum observable clarity for sites where the habitat available prevented a black disc reading from being taken. For repeated sites, the most recent data are shown, except for Waipoua_3_10A as no value could be recorded here in the 2021/22 monitoring season. Basemaps generated by Eagle Technologies (2023), sourced from LINZ Data Service (2023) and licensed for reuse under CC BY 4.0.

5.2. Nutrient concentrations

5.2.1. Dissolved reactive phosphorus

Concentrations of dissolved reactive phosphorus (DRP) ranged from 0.004 g/m^3 to 0.015 g/m^3, with concentrations for 17 samples below the laboratory detection limit (Figure 17, Table 6). When compared to the NPS-FM attribute band for DRP (which assesses median concentrations over 5 years of monthly samples), 17 sites met the threshold for A band, indicating pristine conditions. Another two sites corresponded to B band and the remaining one corresponded to C band, suggesting minor and moderate DRP elevation, respectively. Of the four sites repeated in the 2021 monitoring, only Waipoua3_10A displayed a change in DRP, going from below detection limit to 0.007 g/m^3.

5.2.2. Nitrogen

Concentrations of nitrate-N ranged from 0.002 g/m^3 to 0.32 g/m^3, with five samples below detection limits (Figure 18, Table 6). The observed concentrations of nitrate-N were well below the 1 g/m^3 threshold for the nitrate (toxicity) A band in the NPS-FM, although bands are assessed using annual medians from monthly samples. Concentrations of total ammoniacal nitrogen and nitrite-N were below detection limits for all samples, so dissolved inorganic nitrogen consisted entirely of nitrate-N at all sites.

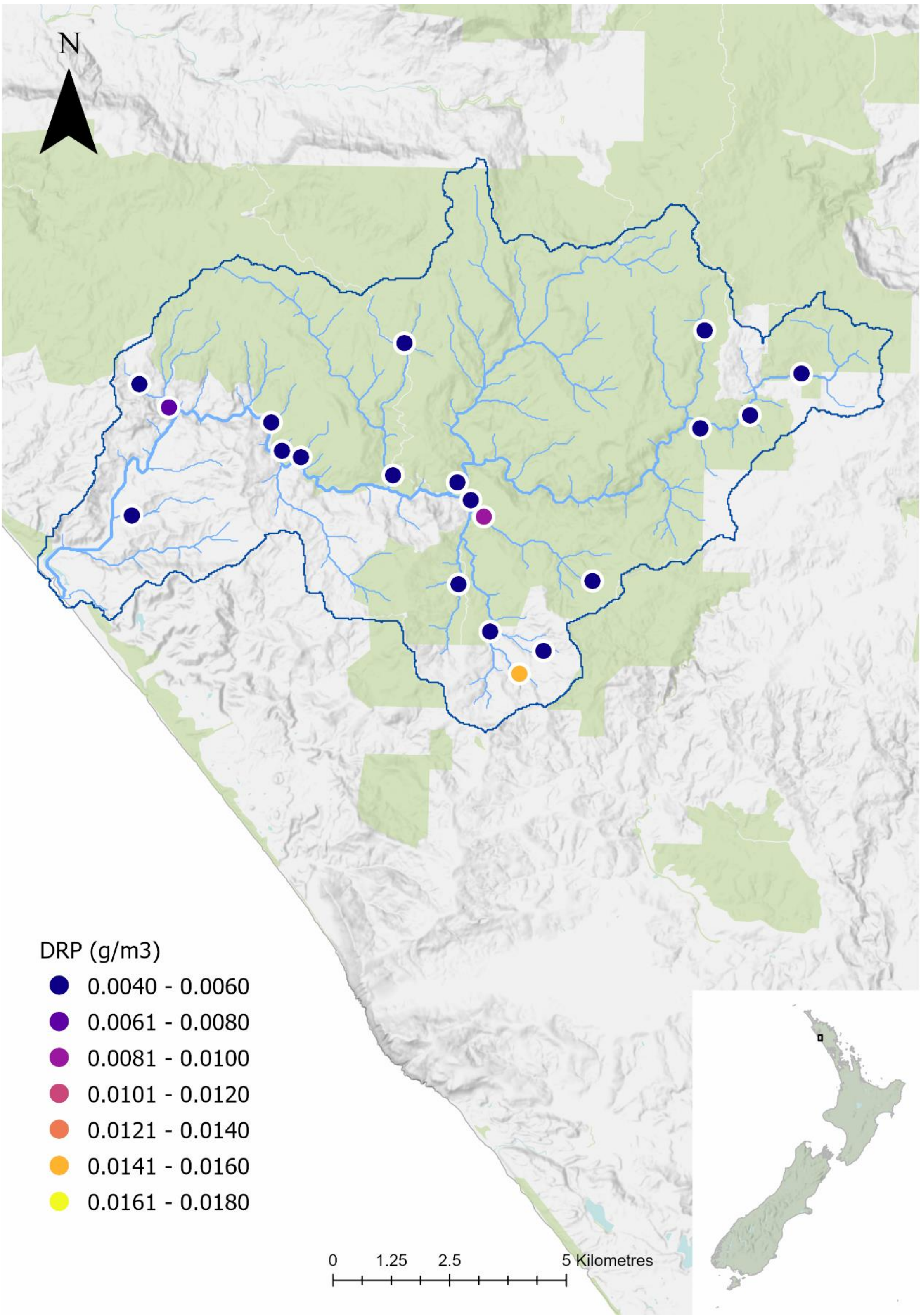


Figure 17. Dissolved reactive phosphorus (DRP) concentrations across the Waipoua catchment. For repeated sites, the most recent data are shown. Basemaps generated by Eagle Technologies (2023), sourced from LINZ Data Service (2023) and licensed for reuse under CC BY 4.0.

Table 6. Nutrient concentrations recorded for all sites. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in, with repeated sites shaded in grey.

UID	Total nitrogen (g/m^3)	Total ammoniacal-N (g/m^3)	Nitrite-N (g/m^3)	Nitrate-N (g/m^3)	Nitrate-nitrite (g/m^3)	Total Kjeldahl nitrogen (g/m^3)	Dissolved reactive phosphorus (g/m^3)	Total phosphorus (g/m^3)
Waipoua_1_10A_2020	0.22	< 0.01	< 0.002	0.002	0.002	0.22	< 0.004	0.024
Waipoua_1_1A_2020	0.40	< 0.01	< 0.002	0.320	0.320	0.10	< 0.004	0.002
Waipoua_1_5A_2020	0.11	< 0.01	< 0.002	0.006	0.007	0.10	0.004	0.004
Waipoua_2_1C_2020	0.11	< 0.01	< 0.002	0.015	0.015	0.10	< 0.004	0.002
Waipoua_2_4A_2020	0.11	< 0.01	< 0.002	0.003	0.004	0.10	0.005	0.002
Waipoua_2_4A_2021	0.11	< 0.01	< 0.002	0.003	0.003	0.10	< 0.004	0.004
Waipoua_2_9C_2020	0.11	< 0.01	< 0.002	0.019	0.020	0.10	0.015	0.019
Waipoua_3_10A_2020	0.11	< 0.01	< 0.002	0.018	0.020	0.10	< 0.004	0.006
Waipoua_3_10A_2021	0.11	< 0.01	< 0.002	0.066	0.067	0.10	0.007	0.008
Waipoua_3_1A_2020	0.11	< 0.01	< 0.002	0.030	0.031	0.10	< 0.004	0.006
Waipoua_3_1A_2021	0.18	< 0.01	< 0.002	0.051	0.052	0.13	< 0.004	0.008
Waipoua_3_2B_2020	0.11	< 0.01	< 0.002	0.034	0.035	0.10	< 0.004	0.005
Waipoua_3_3A_2020	0.15	< 0.01	< 0.002	0.047	0.048	0.10	< 0.004	0.007
Waipoua_3_3A_2021	0.17	< 0.01	< 0.002	0.052	0.053	0.12	< 0.004	0.009
Waipoua_3_8A_2020	0.20	< 0.01	< 0.002	0.120	0.122	0.10	0.006	0.015
Waipoua_4-5_2A_2020	0.15	< 0.01	< 0.002	0.061	0.063	0.10	< 0.004	0.008
Waipoua1_11B_2022	0.11	< 0.01	< 0.002	0.005	0.006	0.10	< 0.004	0.005
Waipoua1_4C_2022	0.11	< 0.01	< 0.002	0.010	0.010	0.10	0.005	0.012
Waipoua2_2A_2022	0.11	< 0.01	< 0.002	< 0.002	< 0.002	0.10	< 0.004	0.002
Waipoua2_3C_2022	0.11	< 0.01	< 0.002	0.003	0.003	0.10	0.010	0.014

UID	Total nitrogen (g/m^3)	Total ammoniacal-N (g/m^3)	Nitrite-N (g/m^3)	Nitrate-N (g/m^3)	Nitrate-nitrite (g/m^3)	Total Kjeldahl nitrogen (g/m^3)	Dissolved reactive phosphorus (g/m^3)	Total phosphorus (g/m^3)
Waipoua3_6A_2022	0.11	< 0.01	< 0.002	< 0.002	< 0.002	0.10	< 0.004	0.003
Waipoua4-5_10A_2022	0.11	< 0.01	< 0.002	< 0.002	< 0.002	0.10	< 0.004	0.009
Waipoua4-5_3b_2022	0.11	< 0.01	< 0.002	< 0.002	< 0.002	0.10	< 0.004	0.006
Waipoua4-5_5A_2022	0.11	< 0.01	< 0.002	< 0.002	< 0.002	0.10	< 0.004	0.007

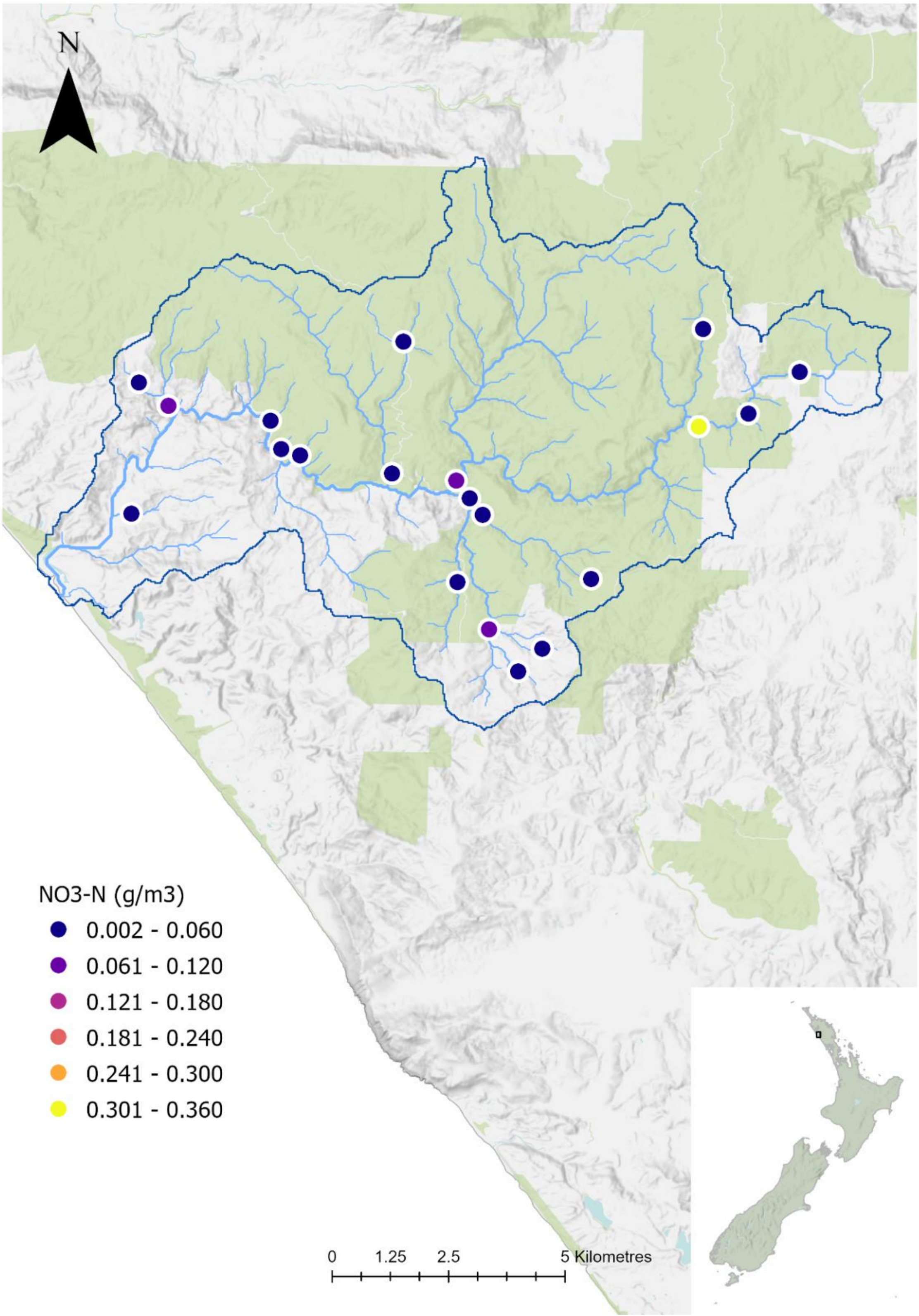


Figure 18. Nitrate concentrations across the Waipoua catchment. For repeated sites, the most recent data are shown. Basemaps generated by Eagle Technologies (2023), sourced from LINZ Data Service (2023) and licensed for reuse under CC BY 4.0.

5.3. Water chemistry

The pH is a measure of the acidity or alkalinity of the water and is largely influenced by the underlying geology and land cover. While many sites were circumneutral, field measurements varied significantly, with two sites recorded as below pH 6.0 and four recorded as above pH 9.0 (minimum = 4.19, mean = 7.42, maximum = 10.36). However, laboratory-measured pH values displayed much less variation (minimum = 4.3, mean = 6.96, maximum = 7.40), with all but one site being circumneutral. While field pH measurements are generally preferred because of the potential for biological activity and carbon dioxide equilibrating within the sample to alter the pH between sample collection and processing (US EPA 2023), the discrepancy between laboratory and field measurements suggests that there has been a measurement or calibration issue when recording pH in the field.

This apparent issue with field pH measurement is supported by the fish and macroinvertebrate data collected. The low pH value recorded at one site with both laboratory and field measurements corresponds with records elsewhere of streams draining peatland or bogs, as well as the known tolerances of the relatively depauperate macroinvertebrate and fish communities found (Davies-Colley et al. 2013). However, the field results indicating that four sites were highly basic seem implausible given the pH tolerances of the fish species found at these sites (Davies-Colley et al. 2013). Further to this, the four sites with abnormally high pH were sampled on consecutive days by the same field team, suggesting an instrument or calibration issue. Therefore, any reporting or further analysis of the pH data collected from the Waipoua catchment should report the laboratory values, and care should be taken when calibrating instruments and taking field water quality measurements.

Dissolved oxygen was high (> 8 mg/L) at all but one site (minimum = 7.90 mg/L, mean = 9.90 mg/L, maximum = 10.74 mg/L). As these values are from single daytime spot measurements, they cannot be compared with the 7-day mean minimum or 1-day minimum values presented in the NPS-FM as minimum DO typically occurs at nighttime / dawn. However, the values observed significantly exceed the ANZECC minimum limit of 6 mg/L for the protection of the early life stages of aquatic organisms (ANZECC 1992).

A broad range of other water physico-chemical data were collected, including the conductivity and summaries of dissolved ions such as bicarbonate, dissolved metal ions, sodium, chloride, sulphate and carbon (Appendix 6). The values associated with these results do not have specific guideline values; rather, the data are helpful on a site-by-site level to contextualise other results. Much of the water chemistry is influenced by the underlying geology and can impact primary and secondary production in streams.

6. NATIONAL CONTEXT

To investigate how monitoring results in the Waipoua catchment compared to other streams and rivers on PCL, 25%, 50% and 75% quantiles were calculated from a combined dataset of recent monitoring conducted on or near PCL. This included data from the NFMP (Kelly et al. 2023), as well as other data collected as part of the Ngā Awa river restoration programme from the Waipoua (reported here), Te Hoiere / Pelorus River (Eveleens and Kelly 2023a) and Waikanae (Eveleens and Kelly 2023b) catchments, spanning 109 sites located across the North and South Islands. For sites in the Waipoua catchment with repeat monitoring, only the most recent results were included.

Quantiles were calculated for periphyton biomass, MCI, QMCI, ASPM, F-IBI, deposited fine sediment cover, visual clarity, nitrate, ammoniacal nitrogen, total nitrogen, DRP and total phosphorus. For all metrics, quantiles are arranged so that quantile 1 represents the best condition for each water quality or ecosystem health metric. Given that many sites included in the combined dataset displayed good water quality and ecosystem health, the quantiles presented here represent only those instances where metric values fall in relation to other sites in the NFMP and Ngā Awa programmes – i.e. metric values in quantile 4 are likely still indicative of a relatively undegraded state. This is because most of the sites that comprise the dataset are from within the conservation estate. For specific detail on the state of metrics for each site, refer to Sections 3, 4 and 5 of this report.

Compared to the combined dataset, sites in the Waipoua catchment displayed variable values for all metrics, with many results falling between 50% and 75% of the recorded values (Figure 19). Most sites had at least one metric in the lowest 25% of the combined dataset. Specifically, eight sites were in the best 25% of the combined dataset for nitrate, although four were in the worst 25% of the combined dataset. Twelve sites were in the lowest 25% of the combined dataset for QMCI, and eight sites were in the lowest 25% of the combined dataset for visual clarity.

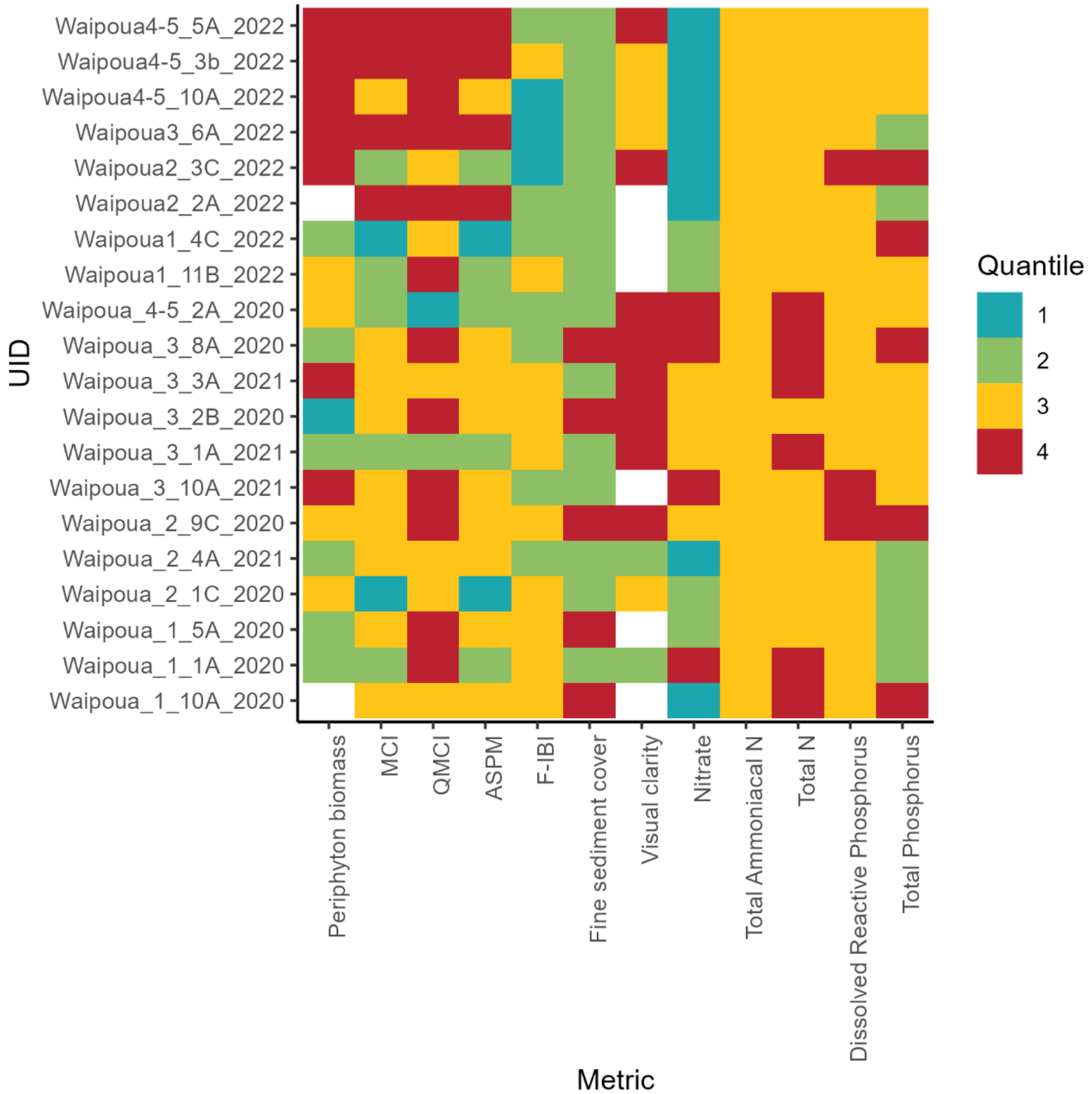


Figure 19. Quantiles for selected ecological health and water quality metrics in the Waipoua catchment calculated from a combined national dataset of 109 sites. Quantile 1 represents sites in the best 25% of recorded values for each metric, quantile 2 represents sites between the best 25% and 50% of recorded values, quantile 3 represents sites between 50% and 75% of recorded values, and quantile 4 represents sites in the lowest 25% of recorded values. Blank squares represent metrics where a complete measurement could not be collected at a site.

7. DISCUSSION

7.1. Overview of findings

Across the attributes measured at the 20 sites surveyed between 2020 and 2023, results were mixed. Where relevant, interpretation of results relative to NPS-FM attribute bands has been included for the purpose of providing context. However, the sampling regime needed to meet the data thresholds for the NPS-FM, which means that the data for many of the metrics cannot be specifically designated to these bands.

Aquatic life scores were indicative of healthy biodiversity at many sites, although other sites displayed moderate scores, including for F-IBI. The survey site reaches harboured a significant number of At Risk and Threatened native freshwater fish taxa; specifically, six species of Threatened or At Risk fish were identified. Brown bullhead catfish, an invasive introduced species, was also detected using eDNA. This may be the first detection of brown bullhead within the Waipoua catchment; however, it is highly recommended that this preliminary detection is followed by confirmatory surveys.

Macroinvertebrate communities were indicative of good or reference conditions at many sites, although MCI or QMCI indicate moderate or severe degradation for multiple sites. Some of the observed degradation may be due to exotic forestry or pastoral land use, but sites within indigenous forest also displayed low scores. While most macroinvertebrates (approximately 58%) could not be assigned to a threat class due to taxonomic resolution issues or lack of information, two At Risk: Declining, five At Risk: Naturally Uncommon and one Data Deficient species were found.

Megainvertebrate presence was observed at 12 sites, with both kōura and shrimps caught during electric fishing. Freshwater mussel surveys detected *Echyridella menziesii* at one site on the lower Waipoua River.

Primary production was low at all survey sites, with low periphyton biomass results. Periphyton cover almost entirely comprised bare substrate or thin mats / films, with low cover of thick mats or long algal filaments at a small number of sites. Bryophytes were present at seven sites. Sixteen bryophyte taxa were identified, of which two were endemic and two were At Risk: Naturally Uncommon species.

A diverse array of habitats were recorded across the survey sites. Most sites had more than three meso-habitats available for a range of organisms. Discharge was biased towards relatively low-flow sites, but this reflects both the survey intent to sample all stream orders and the size of the waterways present within the Waipoua catchment. Substrate stability spanned from moderate to high, with most sites being highly stable.

Deposited fine sediment cover was variable, with many sites having low deposited sediment cover. A diverse range of substrate size classes were present, offering good-quality habitat for macroinvertebrates and fish. However, three sites had high amounts of deposited sediment cover. Pesticide residue from two chemicals was detected at one of the sites tested, with the concentration of heptachlor being above an international guideline value.

Water quality data showed that nutrient concentrations were low at all sites. Visual clarity results were suggestive of some impact of suspended fine sediment throughout the catchment at levels that may be impacting biotic communities.

When compared with other recent monitoring of streams and rivers in or near PCL, sites displayed variable results, with many metrics in the worst half of values from the combined dataset of recent monitoring. It should be noted that in many cases, even when the sites scored in the worst half of sites from the Ngā Awa river restoration programme and NFMP datasets, the values do not necessarily indicate poor water quality or ecosystem health.

7.2. Potential future investigations

The data presented here give insight into the current state of the Waipoua catchment and provide a foundation for guiding restoration efforts and the future assessment of change over time. In terms of potential future investigations, we have grouped our recommendations into risks requiring follow-up, the design of repeated sampling, knowledge gaps, hypotheses-driven questions and the use of other datasets, with further detail provided below.

Risks requiring follow-up

As there are no previous records of brown bullhead (*Ameiurus nebulosus*) within the Waipoua catchment in the NZFFD, we recommend further investigation is carried out to confirm whether the species is present in the catchment. This should include pursuing whether local monitoring organisations possess any unpublished records of brown bullhead presence, accompanied by further sampling to confirm the presence of the fish with a physical detection. Given the discrepancy between eDNA and electric fishing for many sites in the analyses presented here, care should be taken in selecting the sampling methods used and ensuring that sampling personnel are adequately experienced. While it is expected that electric fishing and eDNA results will differ because eDNA detects species present upstream of the reach being sampled, the field notes and site photos accompanying the data suggest that sampling conditions within the Waipoua catchment are challenging. As a result, the selection of suitable sampling methods and personnel for each site will influence the ability to detect species if they are present.

Design of repeated sampling

Given that the Waipoua catchment is actively being restored, the wide-ranging dataset collected and presented here offers a baseline to inform future analyses of temporal change and restoration effectiveness at the catchment scale. For future monitoring, we recommend care is taken to ensure that data collection is informed by the monitoring objectives being assessed. The current mix of repeating some sites while continuing to add new sites may create challenges for separating spatial and temporal variation. If assessment of restoration effectiveness is desired, targeted monitoring where restoration actions have been implemented will be beneficial. In addition, one site was noted to be an artificial channel created to drain a wetland (Waipoua2_2A), which appears to be outside of the scope of the draft Waipoua awa monitoring plan (West et al. 2022).

Sampling at some sites was also restricted to a small number of sub-reaches due to deep pools and kauri dieback protocols limiting movement (especially at Waipoua_3_2B). Consideration should be given to the minimum number of sub-reaches required to collect representative data from a site. At partially measured sites, the decision of whether the sub-reaches that can be sampled are representative of the entire site is currently reliant on the judgement of the field team. From an analytical perspective, this creates an unknown risk of the data collected at partially measured sites being unrepresentative of the site, as after collection there is no means of evaluating whether the data collected are representative of the site as a whole. In addition, the value of including sites in exotic forestry should be considered, as the low number of sites in this land cover category limits the value of those sites for statistical analyses.

Knowledge gaps

No specific knowledge gaps were identified from the analyses presented here.

Hypotheses-driven questions

The active restoration of the Waipoua catchment provides an opportunity for the specific evaluation of restoration actions such as fish passage improvements and riparian fencing, and the subsequent ecological response over time.

Use of other datasets

The availability of other datasets for the Waipoua catchment is unclear, although state of the environment water quality data collected by Northland Regional Council could be used to support the analyses of changes in the catchment over time.

8. APPENDICES

Appendix 1. Site information for all sites measured, with repeated sites shaded in grey. The GPS coordinates are for the midpoint of the site. Note that the waterway names have been reproduced here from the field data sheets and are not necessarily the official names for these features.

Site identifier	Waterway name	Region	Monitoring season	Easting (NZTM)	Northing (NZTM)	NZ reach number
Waipoua_1_10A	Huaki Stream Tributary	Northland Region	2020/21	1645050	6056809	1017466
Waipoua_1_1A	Waipoua Stream Tributary	Northland Region	2020/21	1657071	6055863	1017807
Waipoua_1_5A	Kopai Stream Tributary	Northland Region	2020/21	1654763	6052582	1018605
Waipoua_2_1C	Waipoua Stream Tributary	Northland Region	2020/21	1657171	6057956	1017275
Waipoua_2_4A	Waikohatu Stream	Northland Region	2020/21	1650731	6057682	1017165
Waipoua_2_4A	Waikohatu Stream	Northland Region	2021/22	1650735	6057691	1017165
Waipoua_2_9C	Okawawa Stream Tributary	Northland Region	2020/21	1653196	6050590	1018923
Waipoua_3_10A	Huaki Stream	Northland Region	2020/21	1645675	6056307	1017647
Waipoua_3_10A	Huaki Stream	Northland Region	2021/22	1645684	6056306	1017647
Waipoua_3_1A	Waipoua Stream	Northland Region	2020/21	1659238	6057024	1017512
Waipoua_3_1A	Waipoua Stream	Northland Region	2021/22	1659238	6057035	1017512
Waipoua_3_2B	Mirowharara Stream	Northland Region	2020/21	1651896	6052513	1018604
Waipoua_3_3A	Waipoua Stream	Northland Region	2020/21	1658137	6056135	1017736
Waipoua_3_3A	Waipoua Stream	Northland Region	2021/22	1658140	6056142	1017736
Waipoua_3_8A	Okawawa Stream	Northland Region	2020/21	1652571	6051498	1018805

Site identifier	Waterway name	Region	Monitoring season	Easting (NZTM)	Northing (NZTM)	NZ reach number
Waipoua_4-5_2A	Waipoua River	Northland Region	2020/21	1651864	6054704	1017987
Waipoua1_11B	Okawawa Stream Tributary	Northland Region	2022/23	1653711	6051088	1018942
Waipoua1_4C	Waipoua River Tributary	Northland Region	2022/23	1648514	6055240	1017785
Waipoua2_2A	Takapu Tohoro Stream	Northland Region	2022/23	1644889	6053991	1018261
Waipoua2_3C	Kopai Stream	Northland Region	2022/23	1652437	6053964	1018264
Waipoua3_6A	Waikohatu Stream	Northland Region	2022/23	1650488	6054856	1017848
Waipoua4-5_10A	Okawawa Stream	Northland Region	2022/23	1652153	6054319	1018149
Waipoua4-5_3b	Waipoua River	Northland Region	2022/23	1647876	6055985	1017773
Waipoua4-5_5A	Waipoua River	Northland Region	2022/23	1648110	6055381	1017925

Appendix 2. R packages and versions used for data curation, analysis and plotting.

Package	Version	Reference
base	4.3.0	R. Core Team (2023)
colorblindcheck	1.0.2	Nowosad (2019)
ggnewscale	0.4.9	Campitelli (2023)
ggpubr	0.6.0	Kassambara (2023)
ggVennDiagram	1.2.2	Gao (2022)
grafify	3.2.0	Shenoy (2021)
gridExtra	2.3	Auguie (2017)
gt	0.9.0	Iannone et al. (2023)
knitr	1.43	Xie (2014, 2015, 2023)
maptools	1.1.7	Bivand and Lewin-Koh (2023)
moonBook	0.3.1	Moon (2015)
nzffdr	2.1.0	Lee and Young (2021)
plotrix	3.8.2	Lemon (2006)
quantreg	5.95	Koenker (2023)
rgeos	0.5.9	Bivand and Rundel (2021)
rmarkdown	2.22	Xie et al. (2018, 2020), Allaire et al. (2023)
rprojroot	2.0.3	Müller (2022)
sf	1.0.13	Pebesma (2018), Pebesma and Bivand (2023)
tidyverse	2.0.0	Wickham et al. (2019)
viridisLite	0.4.2	Garnier et al. (2023)
webr	0.1.5	Moon (2020)

Appendix 3. Fish observations at all sites, including all methods used. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in.

UID	Scientific name	Common name	NZTCS category	NZTCS status	Bio status	Detection method
Waipoua_1_10A_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
Waipoua_1_1A_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
Waipoua_1_5A_2020	*Anguilla dieffenbachii*	Longfin eel	At Risk	Declining	Endemic	eDNA
Waipoua_2_1C_2020	*Anguilla dieffenbachii*	Longfin eel	At Risk	Declining	Endemic	eDNA
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	eDNA
Waipoua_2_4A_2020	*Anguilla dieffenbachii*	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	eDNA
Waipoua_2_4A_2021	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
Waipoua_2_9C_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
Waipoua_3_10A_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Cheimarrichthys fosteri	Torrentfish	At Risk	Declining	Endemic	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
	Gobiomorphus huttoni	Redfin bully	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
	Gobiomorphus spp.	Unidentified bully	NA	NA	NA	Electric fishing

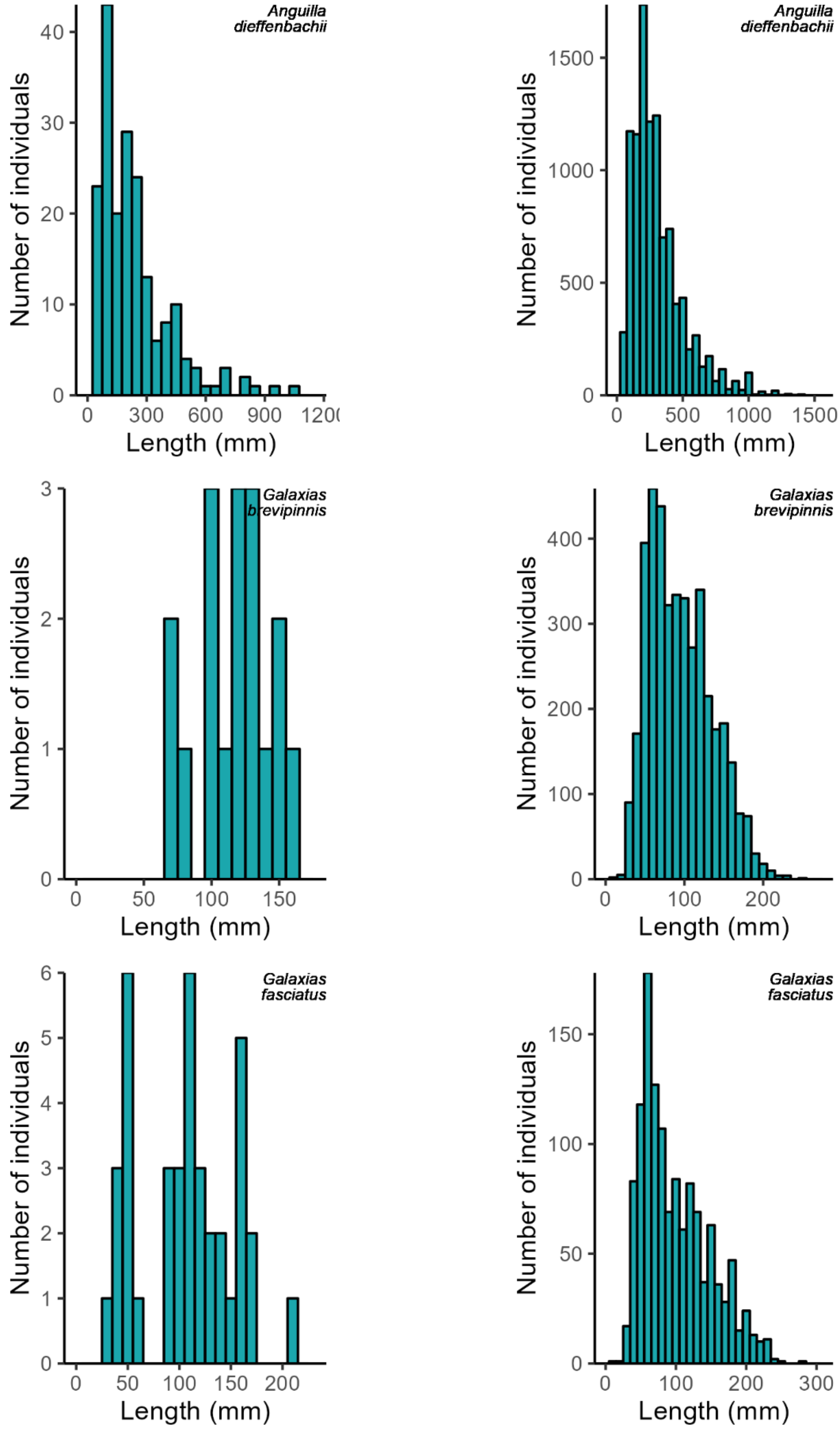
UID	Scientific name	Common name	NZTCS category	NZTCS status	Bio status	Detection method
Waipoua_3_10A_2021	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
Waipoua_3_10A_2021	*Anguilla* spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
	Gobiomorphus huttoni	Redfin bully	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
Waipoua_3_1A_2020	*Anguilla dieffenbachii*	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing
Waipoua_3_1A_2021	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
Waipoua_3_2B_2020	*Anguilla dieffenbachii*	Longfin eel	At Risk	Declining	Endemic	eDNA
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	eDNA
Waipoua_3_3A_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing & eDNA
Waipoua_3_3A_2021	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	eDNA
Waipoua_3_8A_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
Waipoua_4-5_2A_2020	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	Electric fishing & eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla spp.	Unidentified eel	NA	NA	NA	Electric fishing

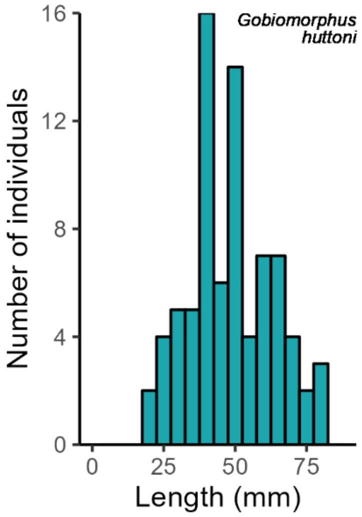
UID	Scientific name	Common name	NZTCS category	NZTCS status	Bio status	Detection method
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	eDNA
Waipoua1_11B_2022	*Anguilla dieffenbachii*	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla sp.	NA	NA	NA	NA	Electric fishing
Waipoua1_4C_2022	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla sp.	NA	NA	NA	NA	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
Waipoua2_2A_2022	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	eDNA
	Anguilla sp.	NA	NA	NA	NA	Spotlighting
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Spotlighting & eDNA
	Galaxias maculatus	Īnanga	At Risk	Declining	Non-endemic	Spotlighting & eDNA
	Galaxias sp.	NA	NA	NA	NA	Spotlighting
	Gobiomorphus cotidianus	Common bully	Not Threatened	Not Threatened	Endemic	eDNA
	Gobiomorphus huttoni	Redfin bully	Not Threatened	Not Threatened	Endemic	Spotlighting & eDNA
Waipoua2_3C_2022	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
	Galaxias maculatus	Īnanga	At Risk	Declining	Non-endemic	eDNA
	Galaxias sp.	NA	NA	NA	NA	Electric fishing
Waipoua3_6A_2022	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
	Galaxias sp.	NA	NA	NA	NA	Electric fishing
	Gobiomorphus huttoni	Redfin bully	Not Threatened	Not Threatened	Endemic	eDNA

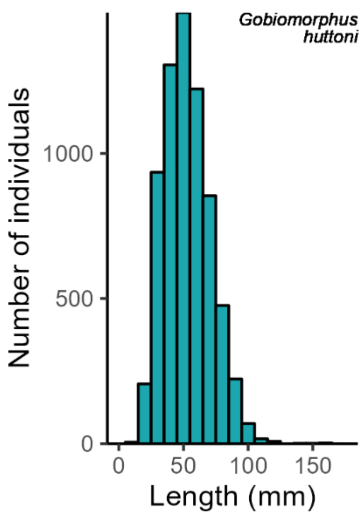
UID	Scientific name	Common name	NZTCS category	NZTCS status	Bio status	Detection method
Waipoua4-5_10A_2022	*Ameiurus nebulosus*	Brown bullhead	Introduced and Naturalised	Introduced and Naturalised	Exotic	eDNA
	Anguilla australis	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	Electric fishing & eDNA
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
Waipoua4-5_10A_2022	*Galaxias maculatus*	Īnanga	At Risk	Declining	Non-endemic	eDNA
	Galaxias postvectis	Shortjaw kōkopu	Threatened	Nationally Vulnerable	Endemic	eDNA
	Galaxias sp.	NA	NA	NA	NA	Electric fishing
	Gobiomorphus cotidianus	Common bully	Not Threatened	Not Threatened	Endemic	eDNA
Waipoua4-5_3b_2022	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	eDNA
	Cheimarrichthys fosteri	Torrentfish	At Risk	Declining	Endemic	eDNA
	Galaxias brevipinnis	Kōaro	At Risk	Declining	Endemic	eDNA
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	eDNA
	Galaxias maculatus	Īnanga	At Risk	Declining	Non-endemic	Trapping & eDNA
	Gobiomorphus huttoni	Redfin bully	Not Threatened	Not Threatened	Endemic	eDNA
	Retropinna retropinna	NA	Not Threatened	Not Threatened	Endemic	eDNA
Waipoua4-5_5A_2022	*Anguilla australis*	Shortfin eel	Not Threatened	Not Threatened	Non-endemic	Electric fishing & eDNA
	Anguilla dieffenbachii	Longfin eel	At Risk	Declining	Endemic	Electric fishing & eDNA
	Anguilla sp.	NA	NA	NA	NA	Electric fishing
	Galaxias fasciatus	Banded kōkopu	Not Threatened	Not Threatened	Endemic	Electric fishing & eDNA
	Geotria australis	Lamprey	Threatened	Nationally Vulnerable	Non-endemic	eDNA

Appendix 4. Length distributions of fish taxa where more than 15 individuals were caught across all sites sampled in the Waipoua catchment, compared to length records stored in the NZFFD.

Waipoua sampling **NZFFD records**




Gobiomorphus
huttoni
Number of individuals
0
4
8
12
16
0
25
50
75
Length (mm)


Gobiomorphus
huttoni
Number of individuals
0
500
1000
0
50
100
150
Length (mm)

Appendix 5. Taxon-Independent Community Index (TICI) results for all replicates collected at all monitoring sites. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in. The reliability of each result is presented as received from Wilderlab.

UID	Monitoring season	TICI value	TICI rating	Number of sequences included	Reliability
Waipoua_1_1A_2020	2020/21	107.68	Good	84	Low
	2020/21	112.22	Excellent	110	Low
	2020/21	113.83	Excellent	91	Low
Waipoua_1_5A_2020	2020/21	121.78	Pristine	150	Average
	2020/21	121.68	Pristine	145	Low
	2020/21	122.31	Pristine	125	Low
Waipoua_2_1C_2020	2020/21	123.75	Pristine	113	Low
	2020/21	127.17	Pristine	94	Low
	2020/21	124.83	Pristine	127	Low
Waipoua_2_4A_2020	2020/21	113.70	Excellent	62	Low
	2020/21	117.36	Excellent	78	Low
	2020/21	115.96	Excellent	93	Low
Waipoua_2_9C_2020	2020/21	114.73	Excellent	169	Average
	2020/21	116.74	Excellent	174	Average
	2020/21	117.63	Excellent	154	Average
Waipoua_3_10A_2020	2020/21	113.22	Excellent	164	Average
	2020/21	116.64	Excellent	182	Average
	2020/21	118.95	Excellent	161	Average
Waipoua_3_1A_2020	2020/21	101.88	Good	136	Low
	2020/21	102.65	Good	128	Low
	2020/21	101.23	Good	96	Low
Waipoua_3_2B_2020	2020/21	113.36	Excellent	130	Low
	2020/21	110.29	Excellent	128	Low
	2020/21	109.29	Good	145	Low
Waipoua_3_3A_2020	2020/21	110.06	Excellent	184	Average
	2020/21	114.52	Excellent	201	Average
	2020/21	108.35	Good	149	Low

UID	Monitoring season	TICI value	TICI rating	Number of sequences included	Reliability
Waipoua_3_8A_2020	2020/21	111.89	Excellent	185	Average
	2020/21	111.20	Excellent	163	Average
	2020/21	112.71	Excellent	173	Average
Waipoua_4-5_2A_2020	2020/21	112.56	Excellent	158	Average
	2020/21	110.10	Excellent	185	Average
	2020/21	110.00	Excellent	112	Low
Waipoua_2_4A_2021	2021/22	115.17	Excellent	203	Average
	2021/22	116.48	Excellent	238	Average
	2021/22	118.03	Excellent	306	High
	2021/22	115.05	Excellent	219	Average
	2021/22	118.68	Excellent	220	Average
	2021/22	118.19	Excellent	229	Average
Waipoua_3_10A_2021	2021/22	108.52	Good	258	High
	2021/22	110.68	Excellent	280	High
	2021/22	113.83	Excellent	309	High
	2021/22	111.46	Excellent	294	High
	2021/22	111.17	Excellent	285	High
	2021/22	114.19	Excellent	284	High
Waipoua_3_1A_2021	2021/22	106.07	Good	229	Average
	2021/22	105.27	Good	266	High
	2021/22	103.90	Good	250	High
	2021/22	103.77	Good	230	Average
	2021/22	106.82	Good	239	Average
	2021/22	105.68	Good	219	Average
Waipoua_3_3A_2021	2021/22	114.68	Excellent	255	High
	2021/22	114.54	Excellent	256	High
	2021/22	114.44	Excellent	281	High
	2021/22	117.50	Excellent	229	Average
	2021/22	114.42	Excellent	282	High
	2021/22	113.49	Excellent	288	High

UID	Monitoring season	TICI value	TICI rating	Number of sequences included	Reliability
Waipoua1_11B_2022	2022/23	121.02	Pristine	169	Average
	2022/23	119.88	Excellent	146	Low
	2022/23	118.30	Excellent	161	Average
	2022/23	121.70	Pristine	131	Low
	2022/23	120.98	Pristine	170	Average
	2022/23	119.37	Excellent	177	Average
Waipoua1_4C_2022	2022/23	121.07	Pristine	200	Average
	2022/23	119.14	Excellent	237	Average
	2022/23	118.20	Excellent	184	Average
	2022/23	121.10	Pristine	169	Average
	2022/23	118.78	Excellent	177	Average
	2022/23	117.77	Excellent	161	Average
Waipoua2_2A_2022	2022/23	93.18	Average	121	Low
	2022/23	97.16	Average	118	Low
	2022/23	96.99	Average	138	Low
	2022/23	96.49	Average	129	Low
	2022/23	94.56	Average	120	Low
	2022/23	96.99	Average	112	Low
Waipoua2_3C_2022	2022/23	119.38	Excellent	190	Average
	2022/23	118.25	Excellent	160	Average
	2022/23	119.26	Excellent	156	Average
	2022/23	118.39	Excellent	206	Average
	2022/23	119.35	Excellent	200	Average
	2022/23	120.16	Pristine	221	Average
Waipoua3_6A_2022	2022/23	108.61	Good	228	Average
	2022/23	109.36	Good	182	Average
	2022/23	107.28	Good	200	Average
	2022/23	108.60	Good	203	Average
	2022/23	110.91	Excellent	180	Average
	2022/23	111.01	Excellent	248	Average

UID	Monitoring season	TICI value	TICI rating	Number of sequences included	Reliability
Waipoua4-5_10A_2022	2022	106.31	Good	333	High
	2022	110.22	Excellent	275	High
	2022	109.35	Good	290	High
	2022	109.47	Good	338	High
	2022	109.51	Good	355	Very high
	2022	108.07	Good	388	Very high
Waipoua4-5_3b_2022	2022	105.10	Good	258	High
	2022	107.19	Good	285	High
	2022	105.05	Good	297	High
	2022	105.96	Good	249	Average
	2022	105.43	Good	278	High
	2022	106.59	Good	267	High
Waipoua4-5_5A_2022	2022	106.91	Good	289	High
	2022	107.04	Good	282	High
	2022	106.40	Good	332	High
	2022	106.83	Good	299	High
	2022	106.48	Good	238	Average
	2022	106.06	Good	280	High

Appendix 6. Supplementary water chemistry results for each site. The sampling unique identifier (UID) indicates the site name and the monitoring season data was collected in, with repeated sites shaded in grey. TSS = total suspended solids, DOC = dissolved organic carbon, TOC = total organic carbon.

UID	Anions (mEq/L)	Cations (mEq/L)	Turbidity (FNU)	Conductivity (mS/m)	TSS (g/m^3)	Calcium (g/m^3)	Magnesium (g/m^3)	Potassium (g/m^3)	Sodium (g/m^3)	Chloride (g/m^3)	Sulphate (g/m^3)	DOC (g/m^3)	TOC (g/m^3)
Waipoua_1_10A_2020	1.64	1.63	21.00	21.8	34	3.20	4.70	0.21	24.0	39.0	26.0	4.6	5.8
Waipoua_1_1A_2020	0.57	0.60	1.19	6.9	3	1.54	1.39	0.30	9.2	14.7	2.3	4.1	3.4
Waipoua_1_5A_2020	1.00	1.10	4.50	11.7	4	3.40	3.00	0.93	15.1	21.0	2.9	1.1	1.4
Waipoua_2_1C_2020	0.50	0.53	0.82	5.9	3	1.19	1.18	0.36	8.3	12.6	2.0	3.0	2.8
Waipoua_2_4A_2020	0.73	0.75	0.99	8.4	3	1.68	1.88	0.28	11.7	18.0	2.3	1.4	1.4
Waipoua_2_4A_2021	0.82	0.81	0.79	9.4	3	2.60	2.20	0.36	11.3	18.8	2.3	0.9	1.4
Waipoua_2_9C_2020	1.13	1.27	3.20	12.9	3	4.90	3.40	0.93	16.6	19.8	3.3	0.8	1.4
Waipoua_3_10A_2020	1.22	1.32	1.54	14.6	3	4.40	3.40	0.62	18.4	28.0	4.3	4.9	4.6
Waipoua_3_10A_2021	1.84	1.86	1.01	20.0	3	8.80	5.40	0.85	22.0	35.0	4.7	1.4	2.2
Waipoua_3_1A_2020	0.52	0.56	3.00	6.3	3	1.90	1.26	0.30	8.1	12.8	3.1	3.4	3.0
Waipoua_3_1A_2021	0.50	0.53	3.70	5.7	3	1.66	1.19	0.30	7.8	12.0	2.4	2.7	4.1
Waipoua_3_2B_2020	1.14	1.19	2.30	13.2	3	3.80	3.20	0.57	16.6	25.0	3.2	2.4	3.2
Waipoua_3_3A_2020	0.55	0.59	2.60	6.5	4	2.20	1.41	0.39	8.3	12.4	2.8	3.3	3.7
Waipoua_3_3A_2021	0.58	0.58	2.80	6.4	5	2.20	1.44	0.36	7.8	11.9	2.3	2.2	2.7
Waipoua_3_8A_2020	1.15	1.18	3.70	13.2	3	4.30	3.30	0.77	15.6	23.0	3.4	1.0	2.8
Waipoua_4-5_2A_2020	0.68	0.71	3.10	7.9	3	2.80	1.86	0.45	9.3	13.6	2.1	2.4	2.9
Waipoua1_11B_2022	1.03	1.11	1.92	12.1	3	3.50	2.90	0.72	15.7	22.0	3.1	1.2	2.3

UID	Anions (mEq/L)	Cations (mEq/L)	Turbidity (FNU)	Conductivity (mS/m)	TSS (g/m^3)	Calcium (g/m^3)	Magnesium (g/m^3)	Potassium (g/m^3)	Sodium (g/m^3)	Chloride (g/m^3)	Sulphate (g/m^3)	DOC (g/m^3)	TOC (g/m^3)
Waipoua1_4C_2022	1.31	1.36	2.30	15.4	5	4.00	3.60	0.82	19.4	29.0	3.3	4.7	10.3
Waipoua2_2A_2022	2.70	2.80	4.00	32.4	3	5.80	8.60	1.23	41.0	71.0	25.0	6.4	7.0
Waipoua2_3C_2022	1.21	1.20	1.34	13.1	3	5.10	3.60	0.77	14.5	23.0	2.3	0.5	2.8
Waipoua3_6A_2022	1.00	1.12	0.84	11.5	3	4.20	3.50	0.55	14.0	21.0	2.2	8.2	8.5
Waipoua4-5_10A_2022	1.18	1.23	1.27	12.9	3	4.40	3.40	0.74	16.2	24.0	3.1	27.0	21.0
Waipoua4-5_3b_2022	3.80	1.08	0.89	11.4	3	4.40	3.20	0.64	13.3	19.7	2.1	6.8	8.6
Waipoua4-5_5A_2022	0.95	0.95	1.90	10.4	3	3.90	2.60	0.63	12.1	18.8	2.7	2.0	4.3

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