River Water Quality in Tāmaki Makaurau / Auckland
2022 Annual Reporting and National Policy Statement for Freshwater Management Current State Assessment

R Ingley, J Groom, L Buckthought

July 2023

Technical Report 2023/16

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Cover image credits. RIMU Water Quality team field staff:

Native forest catchment surrounding Cascades Stream at Confluence (Waitākere Ranges),

Filamentous periphyton growth at Mahurangi at College.

Executive summary

Freshwater environments, including flowing rivers and streams, wetlands and lakes, are valued by the people of Tāmaki Makaurau / Auckland. RIMU monitors the state of rivers and streams in the region to provide evidence for the integrated environmental management outcomes that Auckland Council is responsible for, as required under section 35 of the Resource Management Act 1991 (as amended). River water quality is monitored monthly at 37 sites across the Auckland region to evaluate nutrient enrichment (toxicity and eutrophication), sedimentation and water clarity, metal contamination, and faecal pollution. These monitored factors are influenced by point and diffuse source discharges, land and instream erosion, as well as natural environmental and climatic variability.

The main forms of analysis of water quality that are presented in this report are:

- Commentary on notable water quality observations within the most recent hydrological year and summary annual statistics for this period (2021 to 2022 only).
- Presentation of range of values observed per site and water quality parameters over the past five years for all parameters and summary statistics for this period (July 201 7 to 30 June 2022).
- Grading against the National Policy Statement for Freshwater Management (NPS-FM) 2020 National Objectives Framework (NOF) bands for current state assessment. This assessment differs from previous current state reports as assessment has shifted to a five-year hydrological year period (from 1 July 2018 to 30 June 2022) rather than a calendar year (January to December) period. Assessment has also been revised to align with the amendments to the NPS-FM 2020 released by the Ministry for the Environment in December 2022.

Water quality has been summarised using the regional water quality index in relation to region-specific guidelines. This assessment was undertaken based on the three-year calendar period of 1 January to 2019 to 31 December 2021. The use of the regional water quality index is currently being phased out in preference of the NOF. The NPS-FM 2020 NOF defines a number of compulsory attributes to measure values of freshwater environments. This report specifically focuses on the water quality component of the ecosystem health value, and one measure of the human contact value.

Key messages derived from this national assessment are:

- Regionally there is a low risk of nitrate or ammonia toxicity effects to aquatic fauna even for the most sensitive species. There are localised issues where streams fail nitrate toxicity national bottom lines in the Pukekohe Specified Vegetable Growing Area (nitrate).
- Adverse effects from nutrient enrichment can occur at concentrations far lower than the toxicity thresholds. Pilot monitoring programmes have been initiated or expanded to monitor communities of periphyton (algae) and continuous measures of dissolved oxygen in streams

that will provide further information on ecosystem responses to nutrient enrichment in Auckland streams in the future.

- Only two monitored streams failed the national bottom line (band D) for visual clarity. This is a provisional assessment based on converted turbidity records. Direct measurement of visual clarity has been initiated from July 2022 to align assessment of this attribute. The visual clarity attribute is based on median conditions, i.e. how the stream is 50% of the time, and it does not address storm based sedimentation events that can contribute large loads of sediment to streams and coastal environments.
- Draft regional attributes have been proposed for metal (copper and zinc) toxicity. Metal contamination is predominantly an issue in urban waterways however the assessment of the risk of toxic effects on aquatic fauna will change when toxicity modifying factors that influence metal bio-availability, are further incorporated.
- Faecal contamination of rivers, as indicated by *Escherichia coli,* is a widespread issue across Auckland with all urban and rural streams falling in D or E bands. While this has implications for human contact with rivers and streams, this assessment is not in relation to identified primary contact sites or the summer bathing season.

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1 Introduction

Freshwater environments are valued by the people of Tāmaki Makaurau / Auckland. Water holds special significance to Māori. Mana whenua whakapapa to water bodies and have kaitiaki obligations to protect them. This is part of the customary practice of taonga tuku iho (protecting treasures or taonga passed down from previous generations).

Water quality is a core component of freshwater ecosystem health and influences the aesthetics and use of water bodies. The Auckland Council river water quality monitoring programme commenced in 1986. The information collected is used to understand the current state of water quality, and trends over time, and to inform environmental management and remedial action.

Water quality is currently monitored monthly at 37 river and stream sites, henceforth referred to as "rivers", across the region using a range of physical, chemical, and microbiological attributes. The monitored attributes focus on the key issues of nutrient enrichment (eutrophication), sedimentation and water clarity, metal contamination, and faecal pollution. The monitored attributes can be affected by land use activities, point and diffuse source discharges, and land and instream erosion.

Rivers form the interface between land and sea, conveying land-based contaminants to our estuaries, harbours, and coasts, where they can accumulate and disrupt natural processes and functions. Many of the region's rivers are small in length and width, most being less than a few metres wide, and drain directly to the coast. Many urban streams experience 'flashy' flows due to the increased proportion of impervious surface in the catchment and thus stormwater runoff under rainfall conditions (Allibone et al., 2001). The predominantly gentle topography and underlying sedimentary geology typically results in slow flowing, low gradient, soft-bottomed rivers. High gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitākere Ranges, Hunua Ranges and Aotea Great Barrier Island.

This report presents an annual update on the current state of river water quality within Tāmaki Makaurau / Auckland and is part of the feedback loop necessary for assessing whether Auckland Council's management strategies are effective in sustaining ecosystem functions.

1.1 Programme objectives

Auckland Council's river water quality monitoring programme supports the following wider objectives:

- Meet council's obligations under section 35 of the Resource Management Act 1991 (as amended) to monitor and report on the state of the environment, with specific regard to river water quality.
- Provide evidence of how the council is maintaining and enhancing the quality of Auckland's river environments (Local Government Act, 2002). Specifically, evidence for the Environment and Cultural Heritage component of the Auckland Plan 2050. A key direction for the region is to manage the effects of growth and development on our natural environment.
- Inform the efficacy and efficiency of council policy initiatives and strategies.
- Assist with the identification of large scale and/or cumulative impacts of contaminants associated with different land uses and disturbance regimes and correlative links to particular activities.
- Provide regionally specific baseline data to underpin sustainable management through resource consenting and associated compliance monitoring for river environments.
- Help identify the possible state of future river water quality in Auckland.
- Continuously increase the knowledge base for Aucklanders and promote awareness of regional river quality issues and their subsequent management.

1.2 NPS-FM National Objectives Framework

The National Policy Statement for Freshwater Management 2020 (NPS-FM) provides guidance to regional councils and unitary authorities toward achieving nationally consistent goals for managing freshwater resources under the Resource Management Act. The NPS-FM sets out high level objectives and policies for freshwater management and requires that freshwater systems are maintained or enhanced through time (MfE, 2020).

The National Objectives Framework (NOF) within the NPS-FM was developed to support councils to set effective freshwater objectives, limits and/or targets for rivers and lakes. Monitoring information is required in both the target setting process and to monitor progress towards targets through time.

The NOF includes four compulsory freshwater values which are ecosystem health, human contact, threatened species, and mahinga kai (Appendix 1A of NPS-FM 2020). Other values may also be identified (Appendix 1B of NPS-FM 2020). There are five key biophysical components that contribute to ecosystem health: water quality, water quantity, habitat, aquatic life and ecological processes. Several compulsory attributes are also defined to describe the state of our freshwater environments.

This report focuses on the compulsory attributes of the water quality component of river ecosystem health. Other compulsory attributes used to measure river ecosystem health are reported elsewhere (see Table 1-1).

Table 1-1: Summary of NPS-FM 2020 NOF compulsory river attributes reported here or elsewhere.

Freshwater type	Component	Attributes	Information
Rivers	Water quality	Ammonia (toxicity)	This report
	Water quality	Nitrate (toxicity)	This report
	Water quality	Dissolved oxygen	See TR 2022/18 (Casanovas et al., 2022). Additional monitoring initiated in 2021.
	Water quality	Suspended fine sediment (Visual clarity)	Provisional in this report. Monitoring initiated in 2022
	Water quality	Dissolved reactive phosphorus	This report
	Ecosystem processes	Ecosystem metabolism	See TR 2022/18 (Casanovas et al., 2022).
Wadeable Rivers	Aquatic life	Periphyton	Monitoring initiated in 2020
	Aquatic life	Fish Index of Biotic Integrity (IBI)	Monitoring initiated in 2022
	Aquatic life	Macroinvertebrate Community Index (MCI*/QMCI)	Land air and water Aotearoa (LAWA)
	Aquatic life	MCI Average Score Per Metric (ASPM)	Land air and water Aotearoa (LAWA)
	Habitat	Deposited fine sediment	Monitoring initiated in 2022
Rivers	**Human contact	*E. coli*	This report

* Refer to TR 2021/05 (Chaffe, 2021) for further information on MCI

**Note Human Contact is a compulsory freshwater value, but not one of the biophysical components driving ecosystem health.

1.3 Supporting reports

This is the 32nd annual report since the inception of the river water quality monitoring programme. Prior to 2000, the rivers streams and lakes and coastal water quality monitoring results were presented within combined reports.

For the most recent comprehensive trend analysis, please refer to *River water quality state and trends in Tāmaki Makaurau 2010-2019* (Ingley, 2021).

Previous annual data reports and supplementary data files relating to this report can be obtained from Auckland Council's Knowledge Auckland website www.knowledgeauckland.org.nz.

Water quality and ecology data, and attribute grades can also be viewed in an interactive platform at the national land air and water Aotearoa (LAWA) website: www.lawa.org.nz/explore-data/auckland-region/river-quality/

Further enquiries or data requests in relation to this or any other reports can be directed to environmentaldata@aucklandcouncil.govt.nz.

2 Methods

Auckland's river water quality monitoring programme currently includes 37 sites. Each of the 37 sites is sampled monthly as part of five sampling runs undertaken by Auckland Council's Research and Evaluation Unit (RIMU), except the Hoteo River, which is monitored exclusively by the National Institute for Water and Atmospheric Research (NIWA) as part of the National River Water Quality Network (NRWQN). Rangitopuni River was also previously monitored by NIWA however NIWA have discontinued monitoring of this location from July 2021. Auckland Council have monitored this site since 2016 and have retained this location.

2.1 Site locations

The monitoring programme is regionally representative in that it monitors a range of river and catchment sizes, stream orders (according to the River Environment Classification (REC), Snelder et al., 2010), catchment locations (upper, mid, lower) and catchment land uses. This enables Auckland Council to present a region-wide perspective on water quality and infer the likely water quality of other rivers in the region that are not monitored. Monitored site location details are outlined in Table 2-1 and sites are mapped in Figure 2-1.

A new monitoring site was established at a tributary of Whangapouri Stream at Paerata Rise development in 2019 to set a pre-development baseline. However, this site was discontinued from April 2022 due to a change in the channel shape and flow dynamics of the monitored reach that occurred from February 2022. No suitable alternative monitoring location was able to be identified further upstream or downstream.

Pakuranga Creek is no longer included in the regional summary of water quality state as this site is not considered to be adequately representative of the wider upstream catchment for assessing the state of the environment. However, monitoring of the site is continuing as an ongoing targeted investigation.

A review of the monitoring network was undertaken in early 2022 with additional monitoring sites implemented in July 2022. Further information on these additional sites and preliminary results for the first year of data will be available from the 2023 reporting year.

Table 2-1: Current river water quality monitoring sites.

Site name	NZTM X	NZTM Y	Year started	REC Class*	Stream order (REC)	Catchment area (ha)
Avondale Stream	1750593	5912264	2012	WW_Low_SS	3	339
Cascades Stream (Waitakere)	1735592	5916401	1986	WW_Low_VA	3	1388
Cascades Stream (Waiheke)	1785942	5923254	2013	WD_Low_HS	1	64
Hoteo River (NIWA)	1735254	5972546	1986	WW_Low_SS	5	26917
Kaukapakapa River	1735809	5945031	2009	WW_Low_SS	5	6157
Kumeu River	1739288	5928785	1993	WW_Low_SS	4	4566
Lucas Creek	1751468	5934510	1993	WD_Low_SS	3	616
Mahurangi River (Forestry)	1747742	5965032	1993	WW_Low_SS	2	490
Mahurangi River (Warkworth)	1748863	5970459	1993	WW_Low_SS	4	4844
Makarau River	1736092	5953231	2009	WW_Low_SS	4	4834
Matakana River	1753506	5976494	1986	WW_Low_SS	4	1385
Newmarket Stream	1759154	5918649	2020	WW_Low_SS	3	624
Ngakoroa Stream	1775142	5881630	1993	WW_Low_VA	3	466
Nukumea Stream	1749409	5951379	2012	WW_Low_SS	2	99
Oakley Creek	1751965	5917602	1994	WW_Low_SS	3	1129
Okura Creek	1751403	5938704	2003	WW_Low_SS	3	553
Omaru Creek	1766048	5916759	2009	WD_Low_SS	2	515
Onetangi Stream	1786242	5926203	2013	WD_Low_HS	2	68
Opanuku Stream	1742162	5915566	1986	WW_Low_SS	3	1566
Ōtara Creek (South)	1767364	5907661	1985	WD_Low_VA	3	880
Ōtara Creek (East)	1768317	5908381	1992	WD_Low_SS	3	1828
Oteha River	1751328	5933522	1986	WD_Low_SS	3	1221
Botany Creek	1770718	5913018	1992	WD_Low_SS	3	665
Pakuranga Creek	1769474	5910902	1992	WD_Low_VA	2	216
Papakura Stream (Upper)	1774236	5902622	2012	WW_Low_HS	4	2324
Papakura Stream (Lower)	1771226	5900293	1993	WW_Low_HS	4	4716
Puhinui Stream	1766420	5904316	1994	WD_Low_SS	3	1304
Rangitopuni River	1744440	5932293	1986	WW_Low_SS	5	8366
Riverhead Stream	1737101	5933325	2009	WW_Low_SS	2	410
Vaughan Stream	1755413	5938727	2001	WD_Low_SS	2	239
Wairoa Tributary	1786762	5892804	2009	WW_Low_HS	2	227
Wairoa River	1782663	5901676	1986	WW_Low_HS	5	14885
Waitangi Stream	1754283	5878534	2009	WW_Low_VA	3	1897
Waiwera Stream	1748615	5953656	1986	WW_Low_SS	4	3023
West Hoe Stream	1748302	5950580	2002	WW_Low_SS	2	53
Whangamaire Stream	1763596	5884597	2009	WW_Low_VA	2	814
Whangapouri Stream	1768327	5887871	2019	WW_Low_VA	1	88

* The REC organises information about physical characteristics of New Zealand's rivers such as climate, topography, geology, into hierarchical classes (Fraser & Snelder, 2021). All REC group classes and categories are defined in Snelder et al., 2010, with the categories in this table summarised in Appendix A.

Figure 2-1: Location of the 37 river water quality monitoring sites. Area shaded in red shows the extent of urban area in 2019 (Hoffman, 2019).

2.2 Catchment land cover

The percentage of catchment area in urban or pastoral land use is consistently, positively correlated with contaminant concentrations in freshwater rivers/streams and negatively correlated with ecological health indicators (Snelder et al., 2017; Whitehead et al., 2018; Larned et al., 2019; Gadd et al., 2020). Land cover in the upstream catchment has been shown to explain more variation in stream contaminant concentrations than land cover in the riparian zone (Larned et al., 2019). Further work by Fraser and Snelder (2021) showed an approximate linear relationship between increased water quality degradation and increasing pressure of the cumulative effects of pastoral and urban land uses.

Snelder and Biggs (2002) proposed broad land cover classes that have been adopted in numerous national and regional studies, including Auckland Council's river water quality monitoring programme (Larned et al., 2016, Gadd et al., 2020, Ingley, 2021). Fraser and Snelder (2021) found that there was no evidence of non-linear or threshold responses that would justify specific cut-off values to assign broad land cover classes. Rules assigning sites to a particular land cover category are necessarily based on professional judgement. They further reaffirmed that the rules established by Snelder and Biggs (2002) were appropriate for national application in the River Environment Classifications (REC). The Auckland river ecology monitoring programme uses a more conservative approach to land cover classification than Snelder NS Biggs (2002) and divides the broad rural land cover class into high and low pressure classes to give a better resolution of this pressure gradient where possible as the majority of Auckland remains within rural land cover (Chaffe, 2021). The differences between the two land cover classification approaches are outlined in Table 2-2 below.

In this report we have applied the same approach to land cover classification as Chafe, 2021 to enable a consistent and relevant approach across the river water quality and ecology programmes and a better reflection of the pressures within the catchments. This has resulted in three sites within the monitoring network being reassigned to different land use classifications than in previous reports. Onetangi and Opanuku Streams were previously categorised as 'native' based on the rules of Snelder and Biggs (2002). These have been reassigned to 'Urban' and 'Rural – low' respectively. The Papakura Stream (Lower) has also been reassigned from 'rural' to 'urban'.

A geospatial assessment of land cover was carried out for the specific catchment area upstream of each site using the New Zealand Land Cover Database V5.0 (Manaaki Whenua – Landcare Research) (LCDB 5). The upstream catchment areas were defined using natural drainage topography and the existing Auckland Council permanent streams network layer. Detailed land cover types defined by the LCDB 5 as of summer 2018/2019 were aggregated into broad level categories (Appendix A) and assigned based on the rules in Table 2-2. The proportion of land cover type within the upstream catchment of each monitoring site is outlined in Figure 2-2. Sites are ordered by increasing percentage of the dominant land cover class and presented in this order throughout.

Table 2-2: Land cover classes used to describe differences among river water quality monitoring sites.

Broad Land Cover Class	Previous definitions based on Snelder and Biggs 2002	Definitions based on Chaffe, 2021 applied in this report
Urban	More than 15% urban land cover in the upstream/surrounding catchment. If both urban and rural land cover exceed these thresholds, then 'urban' is considered the dominant land cover.	More than 7% urban land cover in the upstream/surrounding catchment.
Rural – High	More than 25% rural land cover is assigned to a single dominant land cover class of 'rural'. If both urban and rural land cover exceed these thresholds, then 'urban' is considered the dominant land cover.	Less than 50% exotic or native forestry cover remaining in the upstream/surrounding catchment.
Rural – Low		More than 50% of the upstream/surrounding upstream catchment that retains some forest or scrub.
Exotic	Where exotic forestry is the dominant land cover class and rural land use is <25% and urban land use is <15% of the upstream catchment	More than 80% of the upstream/surrounding catchment within exotic forestry.
Native	Where native forest or scrub is the dominant land cover class and rural land use is <25% and urban land use is <15% of the upstream catchment	More than 95% native forest or scrub remaining within the upstream/surrounding catchment. These are intended to represent reference quality conditions that have a very low level of land use pressure influence though they are not necessarily 'pristine'.

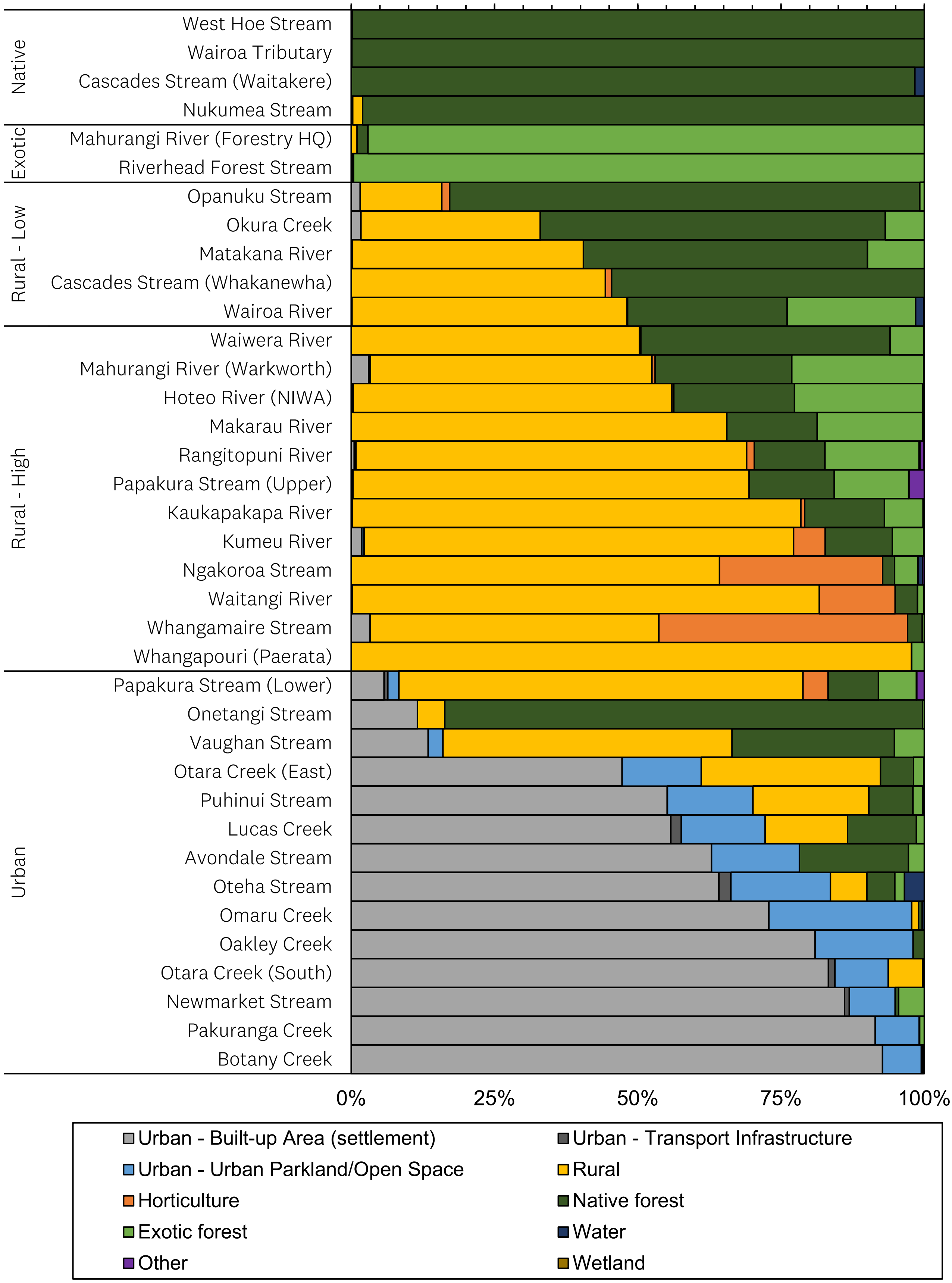


Figure 2-2: Summary of proportions of land cover in upstream catchments at 2018/2019 (LCDB5).

2.3 Data collection

The 37 sites are grouped into five sampling days which are undertaken within the same week of each month. Sites are visited in the same order on each sampling occasion to ensure sampling occurs at approximately the same time of day each month for each site. A full list of the parameters measured is shown in Appendix B.

At each sampling occasion, six measurements are obtained on-site using an EXO sonde portable water quality meter (Table B-1 Appendix B). Bottles of water are collected from each site, chilled, and sent to RJ Hills Laboratories Ltd (Hills), an IANZ accredited laboratory, for analysis of a range of physical, chemical and biological variables (Table B-1 Appendix B).

All field practices were conducted according to RIMU's quality assurance procedures, aligned with National Environmental Monitoring Standards (NEMS) where possible. NEMS details procedures for the collection, transport and storage of samples, and methods for data verification and quality assurance to ensure consistency and accuracy across monitoring programmes. These protocols were incrementally adopted over 2019 and 2020 with the NEMS QC framework subsequently adopted from January 2020. Data collected prior to 2020 were evaluated based on Auckland Council IANZ internal quality coding systems and are considered to be best practice at the time.

The NIWA monitored Hoteo River site is monitored for the same parameters except for salinity, suspended solids, and copper and zinc. Temperature and dissolved oxygen are determined in the field and the remainder are determined by laboratory analysis at NIWA's water quality laboratory in Hamilton. Quality assurance of these data are also undertaken by NIWA. Further information can be obtained from https://www.niwa.co.nz/freshwater/water-quality-monitoring-and-advice/national-river-water-quality-network-nrwqn.

Monitoring at Rangitopuni River was discontinued by NIWA in July 2021. This site has also been monitored by Auckland Council from July 2016. Results presented in this report are based on Auckland Council collected data only.

2.3.1 2020 Covid-19 impacts on monitoring

Water quality monitoring was suspended during Level 4 lockdown conditions (25 March-27 April 2020). Monitoring was resumed during Level 3 conditions.

Consequently, no samples were collected for streams within:

- the north-eastern area in March 2020 (West Hoe, Nukumea, Mahurangi Forestry, Mahurangi, Matakana, Okura, Vaughan, Lucas, and Oteha); and,
- the southern area in April 2020 (Papakura (upper and lower), Whangapouri, Whangamaire, Waitangi, Ngakoroa, Wairoa Tributary, Wairoa, Puhinui).

2.4 Data processing

All field and laboratory data were checked and assigned a quality assurance code in accordance with Auckland Council's internal Stream Water Quality Sampling Protocol. Updated NEMS were released in March 2019 and quality assurance standards have been aligned to NEMS for data collected from January 2020.

Water quality parameters are aligned with NEMS to achieve 'good' quality status the majority of the time. Poor quality data are excluded from all analyses unless otherwise noted. Several monitoring runs were impacted by excessive delays on delivery to the laboratory resulting in poor quality data for the Tamaki run (Otara (East and South), Pakuranga, Botany, Omaru, Newmarket, Avondale, and Oakley) in December 2021 and April 2022.

It is noted that turbidity (NTU) data can only achieve a maximum status of 'poor' quality in accordance with NEMS because it is not the NEMS recommended method. The NTU parameter has been retained due to the value of long-term data collection. Quality coding is managed through further 'child code' systems to identify any errors in the collected data (e.g. stream bed accidentally disturbed on sampling) which are otherwise excluded. Turbidity (FNU) field measurements (NEMS recommended method) were initiated in 2017 and ongoing procedural improvements have been implemented with 'good' field turbidity data obtained from late 2022.

The current membrane filtration method utilised by Auckland Council for the assessment of *Escherichia coli* is also inconsistent with NEMS and as a result, is considered to be of 'fair' quality.

It is noted that dissolved oxygen saturation data where saturation is greater than 100% can only achieve a status of 'fair' quality. For the period of January 2020 to October 2021, barometric pressure was not adequately accounted for due to an issue with the reference sensor. Over this time, all dissolved oxygen saturation data is considered to be 'poor' quality but was retained for assessment in this report. Dissolved oxygen saturation results presented over this period should therefore be treated with caution.

The water quality data is stored in Auckland Council's water quality archiving database (KiWQM). The data for the Hoteo River and Rangitopuni River (NIWA) were obtained from NIWA.

2.5 Data analysis

The main forms of analysis of water quality undertaken in this report are:

- Commentary on notable water quality observations within the most recent hydrological year and summary annual statistics for this period (2021 to 2022 only).
- Presentation of range of values observed per site and water quality parameters over the past five years for all parameters and summary statistics for this period (July 201 7 to 30 June 2022).
- Grading against the NPS-FM 2020 (amended December 2022) NOF bands based on the five-year hydrological year period from 01 July 2017 to 30 June 2022.

- Water quality has also been summarised using the regional water quality index in relation to region-specific guidelines. This assessment has been undertaken based on the three-year calendar period of 01 January to 2019 to 31 December 2021 and can be referred to in Appendix E.

2.5.1 Data summary

The distribution of all water quality parameters over the five-year period for the hydrological year from 01 July 2017 to 30 June 2022 are provided as box plots with summary statistics provided in supplementary files. Sites and parameters with a minimum of three years of data available are included in box plots. Whangapouri (Paerata) and Newmarket Stream are not included in the box plots as they had less than three years of data available.

Box plots were produced using the software package R, using Hazen percentile functions. The boxes represent the inter-quartile range (25th and 75th percentiles), the centre line is the median, and the whiskers show the 95 percentile. Values beyond that range are plotted as outliers. Some outliers were excluded from the graphics to improve visualisation of that data.

Refer to the summary statistics provided in supplementary data files for specific values.

2.5.1.1 Censored data and substituted values

For some water quality parameters, censored values are used when true values are too low (below the detection limit), or too high (above the reporting limit) to be measured with precision by the analytical method being used by the laboratory.

Censored values were replaced by imputed values generated using ROS[1] for the purposes of calculating the five-year state statistics for NOF grading.

Censored values were replaced by values half the detection limit for the purposes of calculating annual data and assessing the Water Quality Index.

2.5.1.2 Annual data

Descriptive statistics for the 2022 hydrological year, 01 July 2021 to 20 June 2022 are provided in supplementary files only. Annual data is provided for all 37 sites.

2.5.2 NPS-FM National Objectives Framework current state

The 2022 current state is based on data for the five-year period for the hydrological year from 01 July 2017 to 30 June 2022 for all attributes (consistent with the recommendations of McBride, 2016).

Summary statistics were calculated using the software package R, using Hazen percentile functions. Statistics were compared to the relevant NOF or proposed regional attribute bands (Appendix C).

[1] Regression on Order Statistics; Helsel, 2012

The overall band reflects the poorest of the different metrics for each attribute (e.g. median or 95th percentile state).

NOF grading is presented for 34 of the 37 sites as a minimum of five years of data is required for most attributes.

2.5.2.1 Minimum data

Using a five-year period rather than a single year reduces the likelihood and frequency of state switching[2]. Current state was determined based on the calculation of the relevant statistical measures.

Several NPS-FM 2020 attributes formerly specified minimum data requirements of five years requiring at least 60 samples (i.e., no missed samples), including suspended fine sediment (visual clarity), and *E. coli*. This requirement was changed in the December 2022 amendment to the NPS-FM to clarify that assessment is intended to be based on monthly monitoring over five years but enables a more pragmatic approach to minimum data requirements can be applied.

Auckland Council applies minimum data requirements in accordance with the approach utilised by LAWA through the regional sector where a minimum of 90 per cent of samples at each site, for each attribute are required for analysis, i.e., a minimum of 54 samples within the five-year assessment period. This minimum data threshold was reduced to 80% of samples for one native reference site (Nukumea) to maintain broad spatial coverage and regional representativeness.

2.5.2.2 Attributes

The NOF nitrate toxicity assessment is reported here using the proxy total oxidised nitrogen (nitrate + nitrite nitrogen). This assumes the nitrite fraction is almost always a negligible proportion of the total oxidised nitrogen (an assumption supported by previous analysis presented in Ingley and Groom, 2021). Nitrite and nitrate have been monitored separately since December 2018.

Total ammoniacal nitrogen refers to two chemical species that are in equilibrium in water – toxic ammonia (NH_3) and the relatively non-toxic ammonium ion (NH_4^+). The proportion of the two varies, particularly in response to pH and temperature. The NOF ammonia toxicity guidelines are standardised to a pH of 8.0. Total ammoniacal nitrogen results are adjusted for pH following a conversion table, as prescribed by the Ministry for the Environment (MfE, 2017) for comparison to NOF guidelines only. Calculation of this attribute was changed under the December 2022 amendment to the NPS-FM 2020 and is now based on the median and 95th percentile of observations rather than the median and maximum observation. Box plots are presented for unadjusted ammoniacal N and should not be compared to the NOF guidelines.

The NOF suspended fine sediment guidelines are based on visual clarity and differ between suspended sediment river classes. Sediment classes are based on the third tier of the REC classes. REC classes are shown in Table 2-1. Seven of the 37 rivers monitored fall into suspended sediment

[2] 'State switching' can occur where sample size is inadequate to reflect real changes within the state of a waterbody. For further detail, refer to Section 3.1 of McBride, 2016.

class one, with the remainder in class two. The NOF suspended fine sediment attribute allows for turbidity measurements to be converted to visual clarity for assessment. This was undertaken with reference to the technical memo prepared by NIWA for the Ministry for the Environment which identified a national regression relationship between site median visual clarity and site median turbidity (Franklin et al., 2020; Franklin et al., 2019) (Eq.1). Median turbidity values were natural log transformed and the national regression relationship equation was applied and then transformed via the exponential function as the inverse of the natural logarithm. This is considered to provide an indicative or provisional assessment of the NOF state only and further validation of this relationship is necessary. Direct monitoring of visual clarity was initiated in July 2022 to support this assessment.

National regression equation $\ln(\mathrm{CLAR}) = 1.21 - 0.72 \ln(\mathrm{TURB})$ Equation 1.

Note that visual clarity assessment for Hoteo River (NIWA) was based on NIWA direct visual clarity monitoring, not converted turbidity values.

The regionally important attributes **copper and zinc** are also included in this report. Copper and zinc are given a provisional grading using the proposed draft attribute bands developed by Auckland Council (Gadd et al., 2019; Appendix C). Guidelines were not adjusted for water hardness or dissolved organic carbon (DOC) as the guidelines and modifiers are currently under review. Auckland Council has been gathering data on DOC and hardness since 2017, and 2018 respectively.

See Appendix C for further information on the attribute bands and metrics applied.

3 Climate Summary

New Zealand's yearly and long-term climatic conditions are associated with decadal circulation and climate variations such as the Interdecadal Pacific Oscillation (IPO) and El Niño Southern Oscillation (ENSO) that influence prevailing winds and rainfall patterns. Variation in rainfall patterns influence river flows, runoff of contaminants from land, erosion processes, and interactions between the stormwater and wastewater networks, and partly control the use and abstraction of water. Thus, variation in water quality over time is in part attributable to periodic ENSO cycles (Snelder et al., 2022). Over the past five years, La Niña conditions have prevailed (Figure 3-1). Water quality responses to climate variability can be mitigated, or further amplified by a range of other catchment processes and anthropogenic pressures (Snelder et al., 2022).

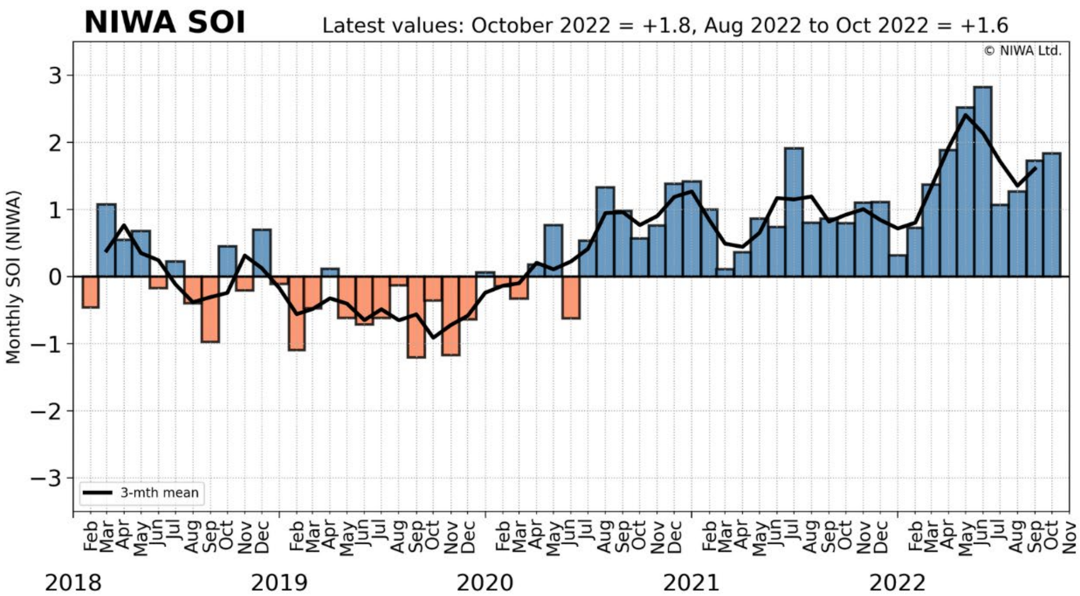


Figure 3-1: Auckland region drought index February 2018 - October 2022 (source: NIWA https://niwa.co.nz/climate/information-and-resources/elnino).

Over a period of three months or more, values below -1.0 correspond to El Niño conditions while values above 1.0 correspond to La Niña conditions. Values between -0.5 and -1.0 lean toward El Niño, while values between 0.5 and 1.0 lean toward La Niña. Values between -0.5 and 0.5 are considered neutral.

Rainfall in Auckland over 2021 was close to the annual average (NIWA, 2022). A severe meteorological drought occurred in January and February 2020 with drought conditions easing in April to May (Figure 3-2) (NIWA, 2019, NIWA, 2020). The 2020 mean annual low flows in rivers were the lowest on record for nearly 40 per cent of river flow monitoring stations spread across the region (Johnson, 2022). 2020 had the greatest number of low flow days in streams over the past forty years.

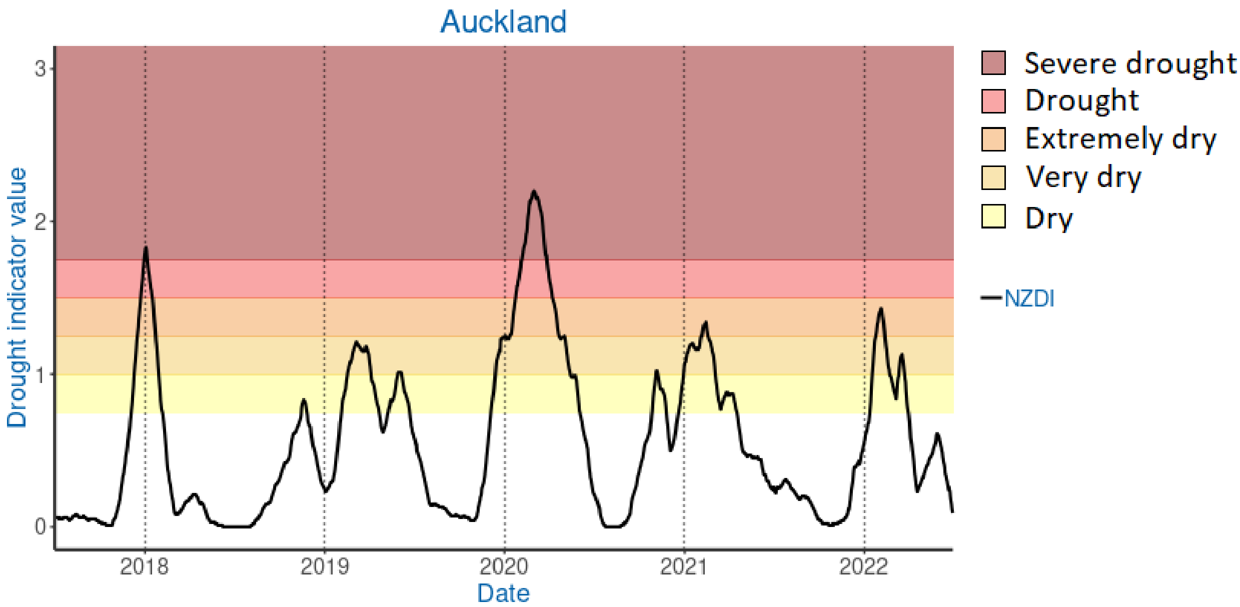


Figure 3-2: Auckland region drought index 01 July 2017 - 30 June 2022 (source: NIWA https://niwa.co.nz/climate/information-and-resources/drought-monitor).

It is important that water quality monitoring observations are unbiased with respect to flow to provide a robust estimate of current state (Snelder and Kerr 2022). Previous assessment of paired Auckland Council water quality and hydrology monitoring sites has demonstrated that the distribution of flows at the time of the monthly river water quality monitoring observations do not differ significantly from the full continuous distribution of flows that occur (over five-year assessment periods). The river water quality monitoring programme can therefore be considered unbiased with respect to flow (Snelder and Kerr, 2022).

Information from paired[3] water quality and hydrology monitoring sites is referred to in this report only to broadly characterise variation in river flows between sites, and to identify notable high flow events in the past annual period (June 2021 to July 2022) that may explain observations of high concentrations of contaminants in these rivers.

Figure 3-3 summarises the range of flows that occurred at each of the selected hydrology stations, on the river water quality monitoring days during 2021-2022, standardised by the per cent exceedance of flows compared to long term flow records (i.e. the range of flows that can be expected to occur at that river hydrology station[4]). High percentile exceedance indicates **low flow** conditions i.e. 90 per cent of flows within that stream over time are higher than the flow recorded on that day. Low percentile exceedance indicates **high flow** conditions i.e. where only 10 per cent of flows are higher than the flow recorded on that day.

Median flow levels tended to be slightly weighted to below the 50% percentile, with some clear exceptions (Otara Creek, Avondale, Waitangi. Vaughan and West Hoe) (Figure 3-3). This

[3] Thirteen hydrology monitoring stations are paired with water quality monitoring sites, with a further five located on the same stream but within approx. 1-2 km upstream or downstream.
[4] Based on the maximum data range available for the selected sites with a minimum of 10 years of records

demonstrates flow during sampling were generally above average, which is reflective of the relatively high rainfall observed in late 2021/early 2022. Furthermore, a number of streams (Waitangi, Papakura, Otara Creek) were also sampled during conditions equivalent to the lowest flows on record (at or near 100% exceedance).

The monitoring programme is not designed to capture particular river flow events. However, sampling at some sites was able to capture a range of both high and low flow conditions, including capturing both the upper and lower 10% of flows (indicated by the box and/or whiskers extending from above the blue line to below the yellow line, e.g. Vaughan, West Hoe, Rangitopuni, Papakura and Wairoa)

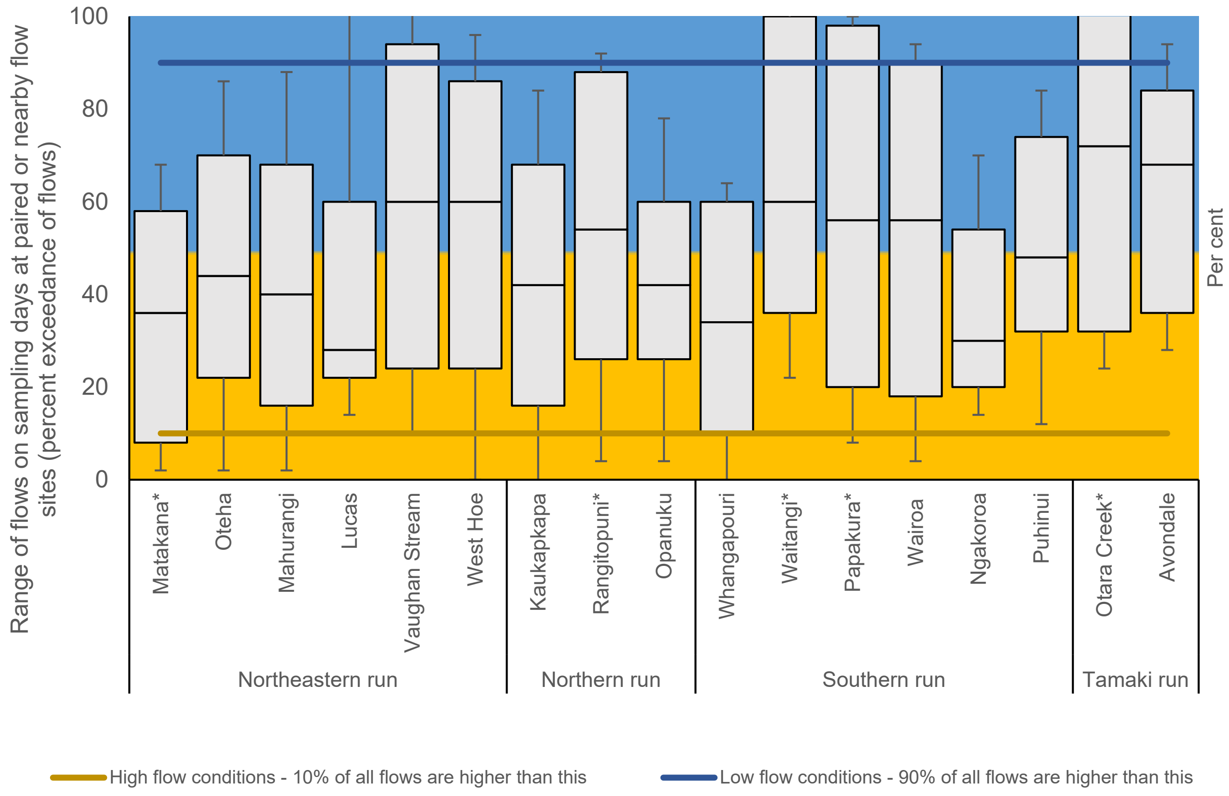


Figure 3-3: Range of river flows on water quality sampling days at paired or nearby flow sites.

Box plots show interquartile range and median, and whiskers show min-max flows. Sites noted with * are nearby water quality sites and not explicitly paired.

4 Results and Discussion

4.1 Data summary

Box plots are provided in section 4.1.3 below for each monitored water quality parameter, with sites grouped by land cover and ordered from the highest to lowest percentage of the dominant land cover class (as per Figure 2-2).

A high-level description of each of the parameters assessed is provided in Appendix B. Sites, and parameters that are new to the programme and this reporting series are outlined further in sections 4.1.1 and 4.1.2 respectively.

Some notable observations were recorded in 2021-2022 including:

- High concentrations of ammoniacal nitrogen >1 mg/L were recorded in September and November 2021 at Avondale Stream. This is an order of magnitude greater than typically recorded at this site (Figure 4-4). Nitrite concentrations also spiked at this time suggesting a nearby source of pollution. A review of Auckland Council records, and correspondence with Watercare did not identify any wastewater overflows reported in the upstream catchment over this time frame.
- Dissolved oxygen concentrations < 4 mg/L are likely to indicate significant stress on aquatic fauna[5]. Summer dissolved oxygen concentrations fell below this level in eleven streams in summer 2021/22, mostly in March. For three sites (Kaukapakapa Stream, Papakura Stream (upper) and Waitangi Stream) DO concentrations were < 4 mg/L for at least three consecutive months.
- Ammoniacal N concentrations at Oteha River in August 2021 were higher than the 98th percentile recorded at this site over the preceding 10 years. There was no rainfall event during or preceding this sampling.
- Dissolved copper concentrations at Onetangi Stream in December 2021 were three times higher than the 98th percentile recorded at this site over the preceding 10 years. There was heavy rain on the two days prior and the day of sampling.
- There was an order of magnitude outlier for total copper concentrations at Vaughan Stream in February 2022. There was no rainfall event during or preceding this sampling.
- Total phosphorus concentrations, total suspended sediment concentrations, turbidity and *E. coli* levels greater than the 98th percentile recorded over the past 10 years for the site were recorded at several locations associated with a large storm event on the 23rd of September 2021 (Kaukapakapa River, Kumeu River, Mahurangi River (Warkworth), Matakana Stream, Waiwera Stream Opanuku Stream, Oteha River, Rangitopuni River, and Cascades Stream (Waitakere) recorded high values for at least one of these parameters).

[5] Based on the national bottom line for 1-day minimum concentrations NPS-FM 2020.

- Total phosphorus concentrations at West Hoe Stream in March 2022 were five times higher than the 98th percentile recorded at this site over the preceding 10 years. There was no rainfall event during or in the days preceding this sampling. This sampling was not associated with high concentrations of TSS or DRP.

4.1.1 Site changes

No additional sites have been included in this report.

Whangapouri Stream was first reported in the 2020 annual water quality data report. However, this site was discontinued from May 2022 due to a change in the channel shape of flow dynamics of the monitored reach that occurred from February 2022. The stream was observed to flow primarily underground with limited, and largely stagnant, surface water remaining in the channel. River water quality monitoring sample collection should be undertaken in representative, well mixed parts of the channel collected from flowing runs. This site is therefore poorly comparable to other river water quality monitoring data.

The results of water quality monitoring obtained at this site over July 2021 to February 2022 are included in the annual summary statistics in supplementary files only. No further analysis or reporting against the national objectives framework or water quality index is undertaken.

Newmarket Stream is predominantly within an urban, residential landscape. The stream channel is artificially lined with concrete at the monitoring site. Monitoring at this site commenced in April 2020 and therefore there is insufficient data available to present box plots based on five years of data. Summary statistics of annual data only are provided in supplementary files.

Results for Pakuranga Stream are included in box plots and summary statistics only.

4.1.2 Parameter changes

No additional parameters have been added within this report.

Direct visual clarity monitoring (black disc) was implemented in June 2022 and further information on this parameter will be available in future reports.

Monthly monitoring of dissolved oxygen is likely to underestimate minimum concentrations in streams as the diurnal minimum typically occurs in the early hours of the morning. Continuous dissolved oxygen monitoring was initiated in November 2021 across a subset of water quality monitoring sites, to complement existing long term dissolved oxygen monitoring (see Casanovas et al., 2022 for further information). Future reports will provide further information on dissolved oxygen.

4.1.3 Summary Box Plots

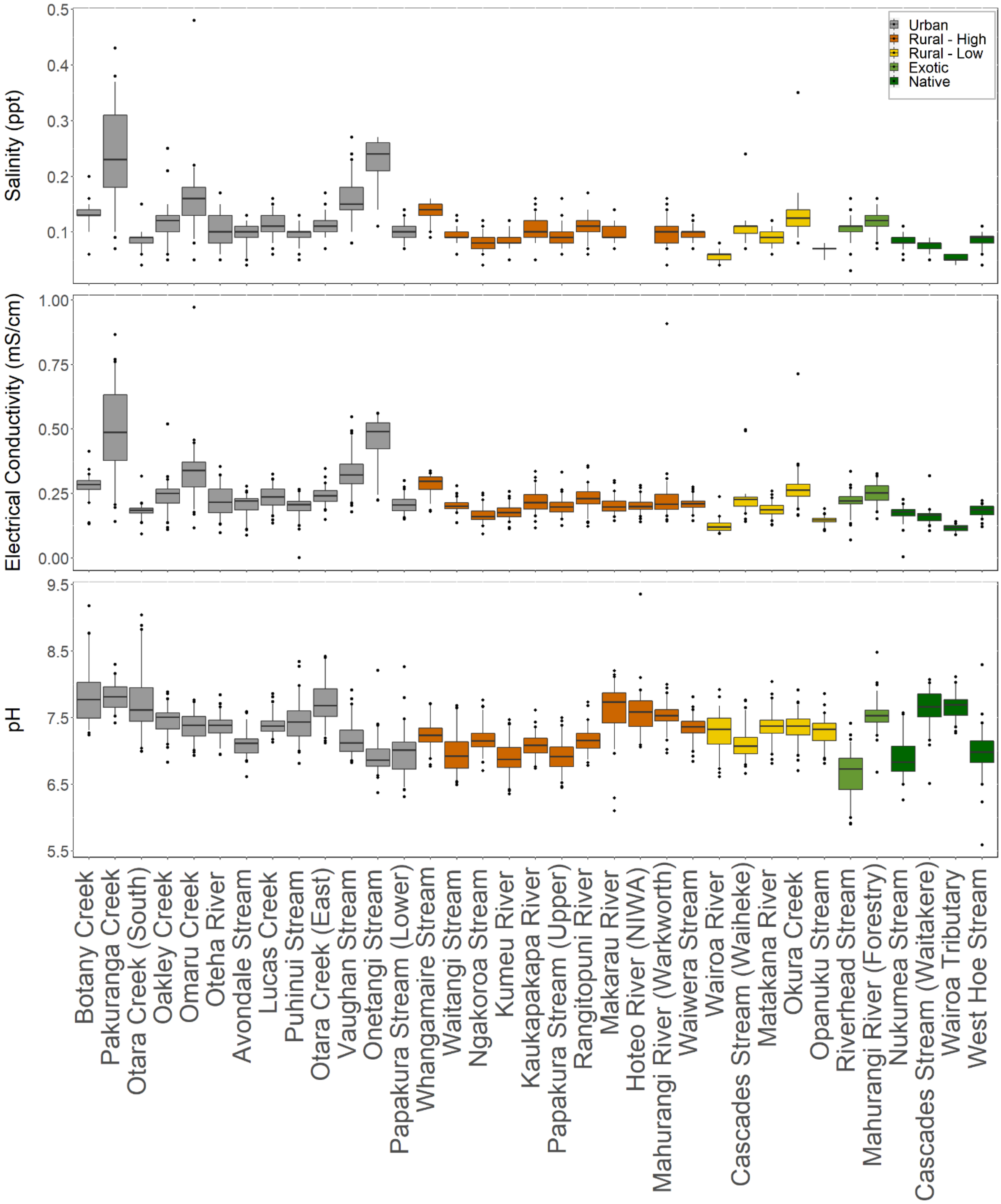


Figure 4-1: Box plots of salinity (ppt), electrical conductivity (mS/cm), and pH for river water quality data collected from July 2017 to June 2022.
pH based on field collected data for all sites except Hoteo River (NIWA) which is based on lab results. Salinity not monitored at Hoteo River (NIWA).

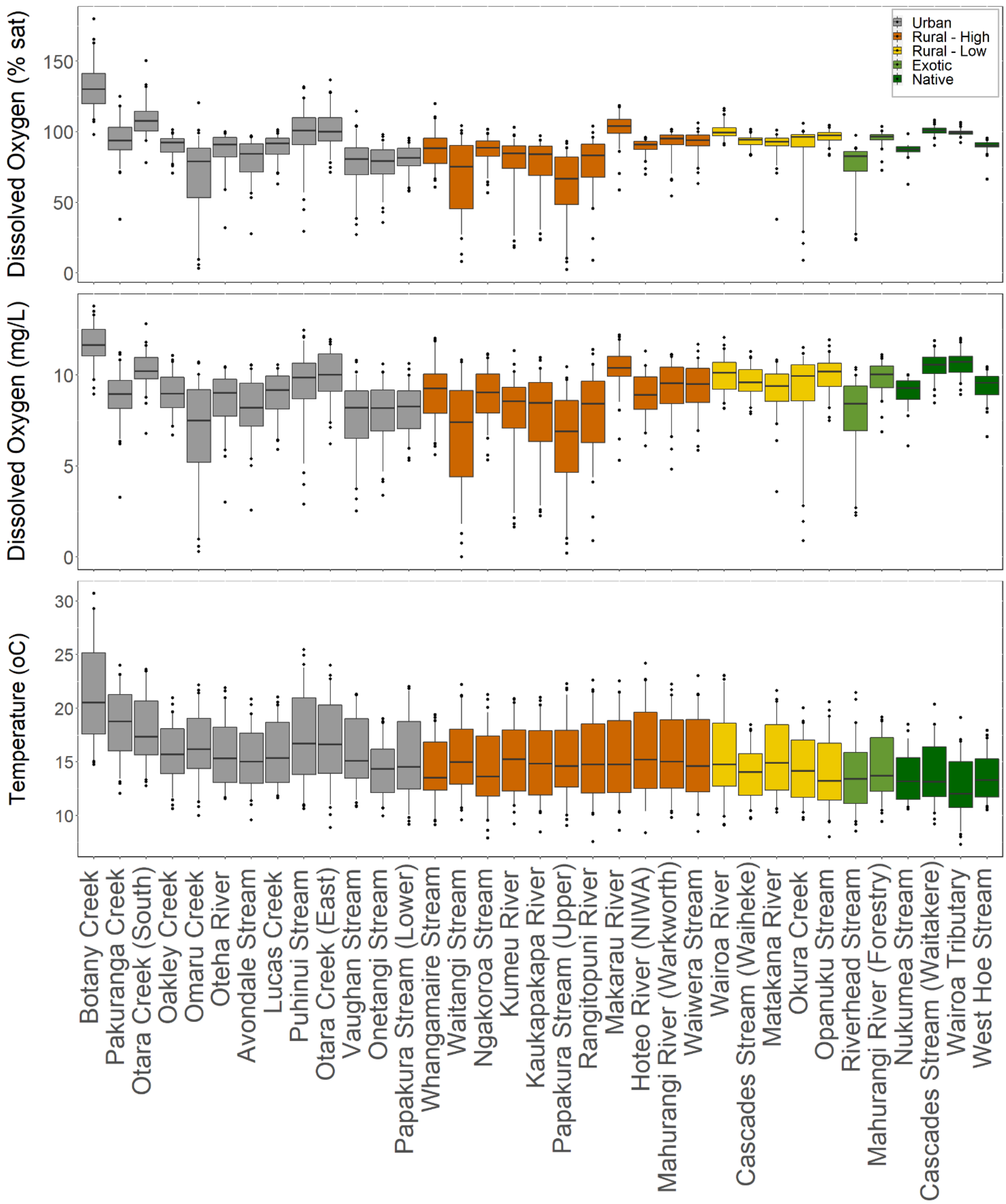


Figure 4-2: Box plots of dissolved oxygen as % saturation and concentration (mg/L) and temperature (°C) for river water quality data collected from July 2017 to June 2022.

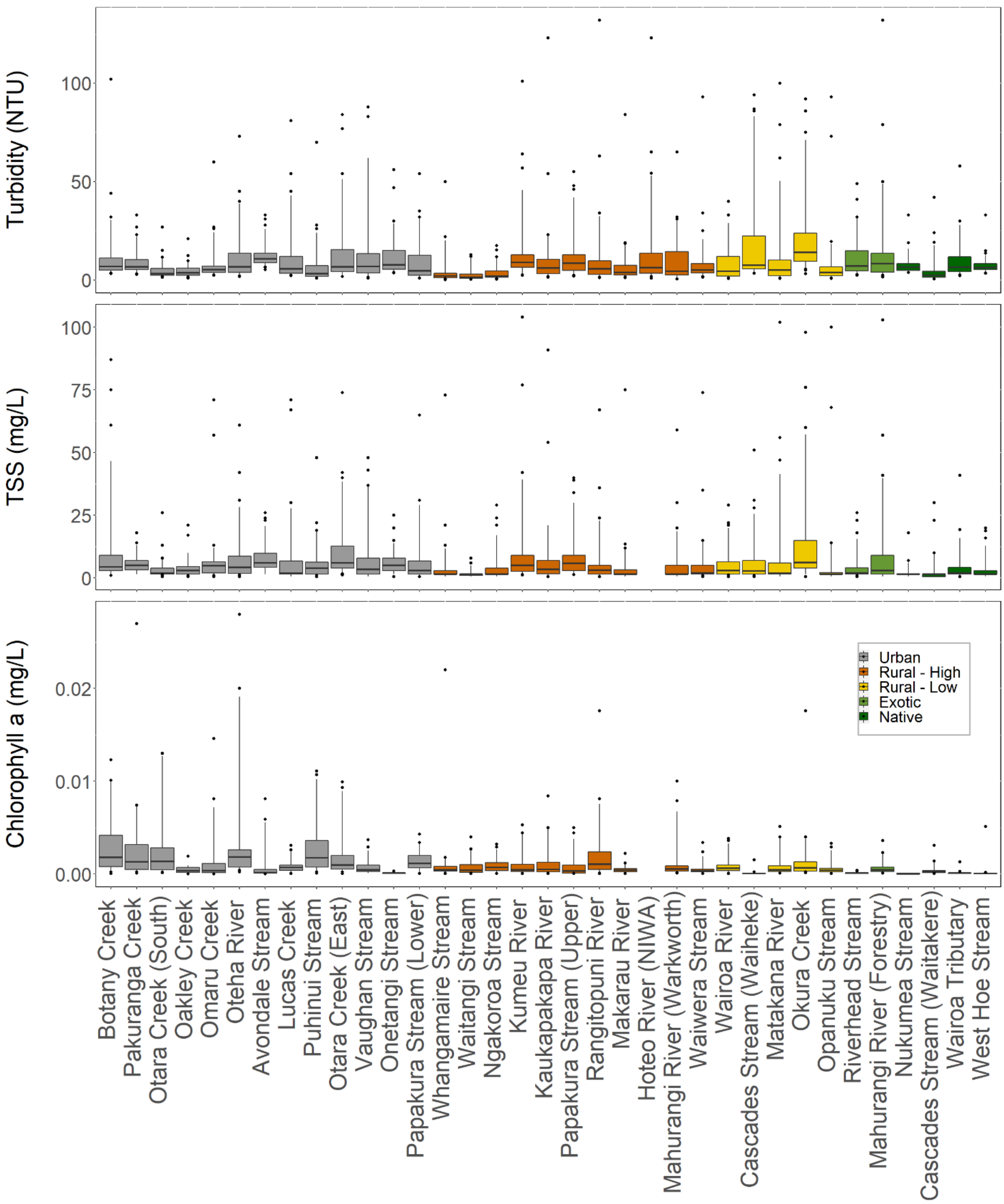


Figure 4-3: Box plots of turbidity (NTU), total suspended solids (mg/L) for river water quality data collected from July 2017 to June 2022, and chlorophyll *a* (mg/L) for river water quality data collected from July 2019 to June 2022.

Four outliers >200 NTU are not displayed including, Mahurangi River (Warkworth) (460 NTU, 240 NTU), Mahurangi River (Forestry) (240 NTU), Cascades (Waiheke) (210 NTU). Seven outliers for TSS are not displayed: Mahurangi River (Warkworth) (440, 175 mg/L), Mahurangi River (Forestry) (198 mg/L), Puhinui Stream (193 mg/L), Otara Creek (East) (184 mg/L), Omaru Creek (175 mg/L), Rangitopuni River (142 mg/L), and Vaughan Stream (160 mg/L). Four outliers for chlorophyll a are not displayed: Botany Creek (0.087, 0.042 mg/L), Pakuranga Creek (0.08 mg/L) and Oteha River (0.052 mg/L). TSS, and chlorophyll a are not assessed by NIWA at Hoteo River. Measurements of turbidity at Hoteo River changed from NTU to FNU from January 2019, these methods have been combined here assuming that results are comparable.

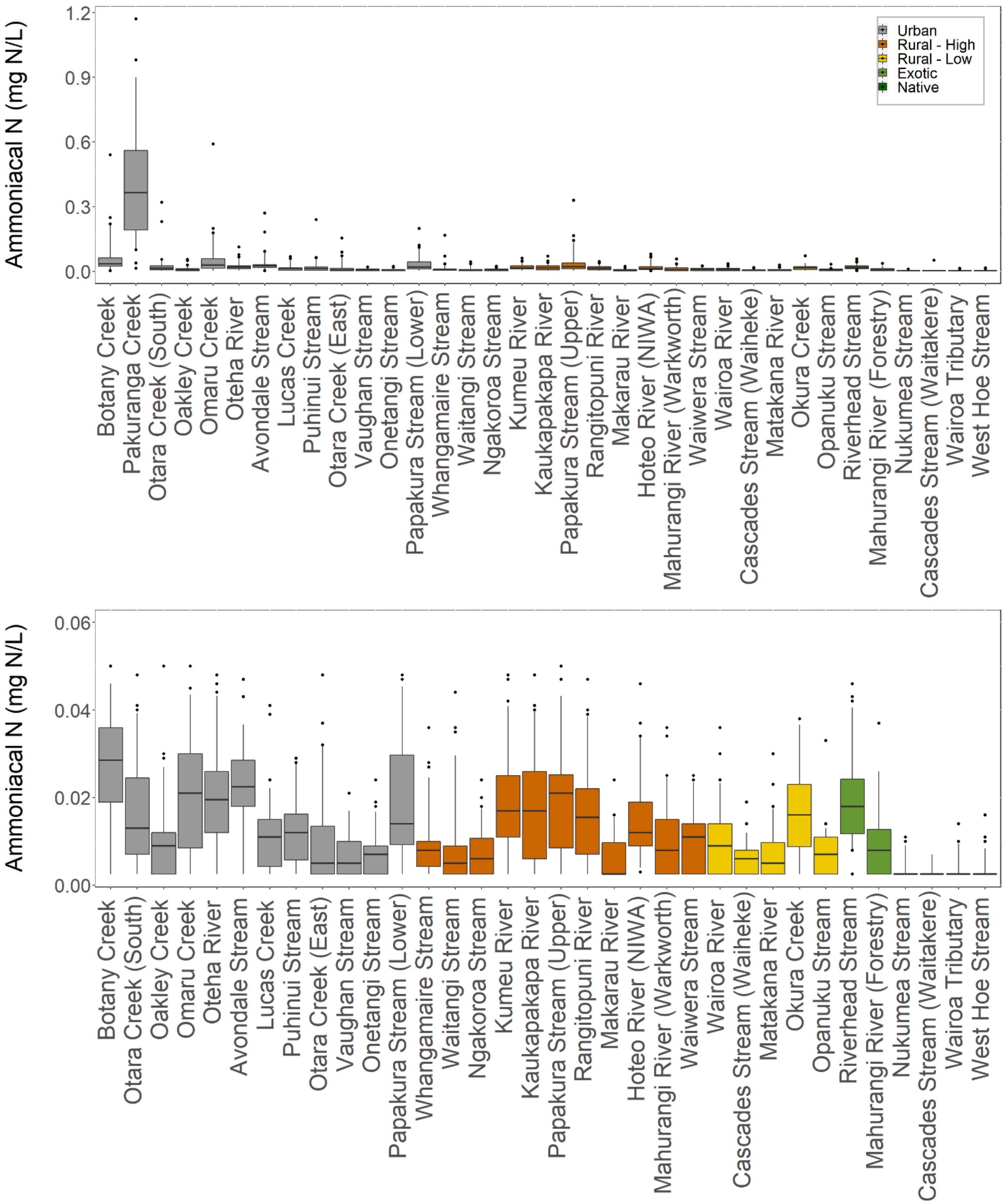


Figure 4-4: Box plots of ammoniacal N (mg/L) for river water quality data collected from July 2017 to June 2022. Top panel shows all sites. Bottom panel excludes Pakuranga Creek. Note difference in Y-axis scale between panels.

One outlier in panel is not displayed: Botany Creek (12.4 mg/L – sewage overflow event in Dec 2019). Four outliers in bottom panel are not displayed: Avondale Stream (1.73 and 1.16 mg/L), Otara Creek (South) (0.93 mg/L), Oteha River (0.88 mg/L). Ammoniacal N is not ammonia adjusted for pH.

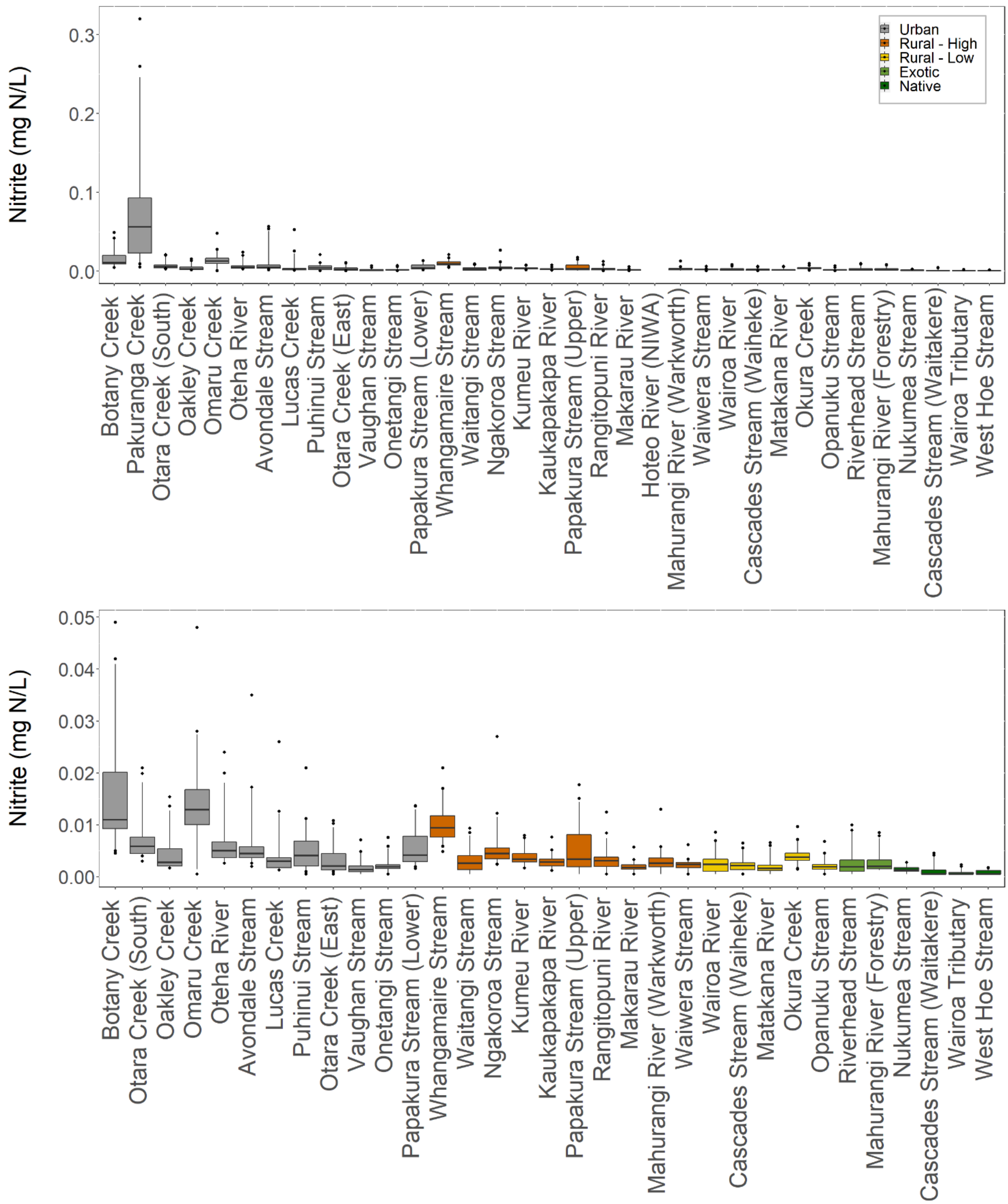


Figure 4-5: Box plots of nitrite N (mg/L)* for river water quality data collected from July 2019 to June 2022 Top panel shows all sites. Bottom panel excludes Pakuranga Creek. Note the difference in Y-axis scale between panels.

Two outliers in bottom graph are not displayed: Avondale Stream (0.086 mg/L) and Botany Creek (0.077 mg/L).

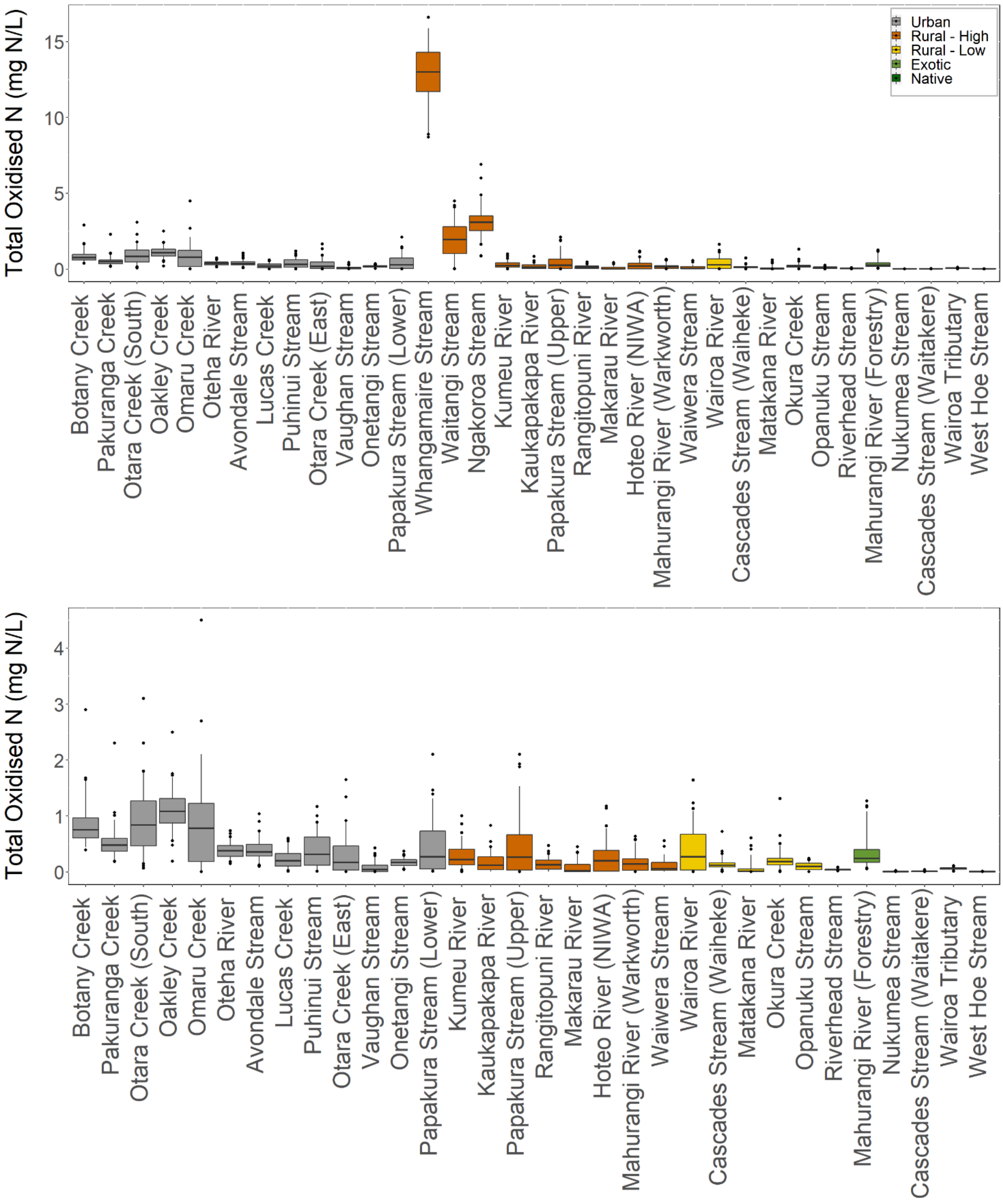


Figure 4-6: Box plots of total oxidised nitrogen (nitrate+nitrite) (mg/L), for river water quality data collected from July 2017 to June 2022: Top panel shows all sites. Bottom panel excludes streams in the Franklin area (Whangamaire, Waitangi, and Ngakoroa). Note the difference in Y-axis scale between panels.

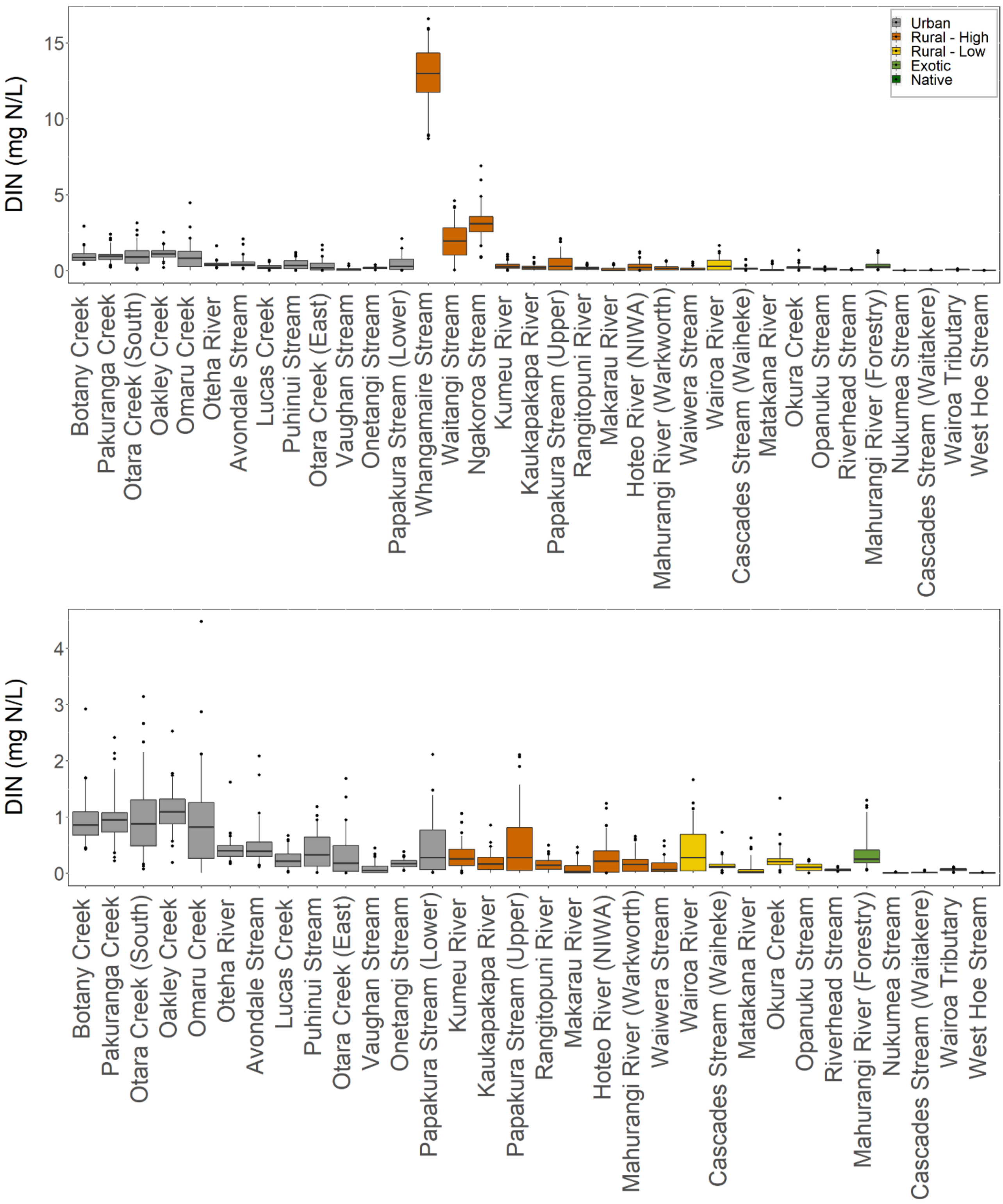


Figure 4-7: Box plots of dissolved inorganic nitrogen (mg/L), for river water quality data collected from July 2017 to June 2022: Top panel shows all sites. Bottom panel excludes streams in the Franklin area (Whangamaire, Waitangi, and Ngakoroa). Note the difference in Y-axis scale between panels.

One outlier for DIN is not displayed: Botany Creek (12.9 mg/L – sewage overflow event in Dec 2019).

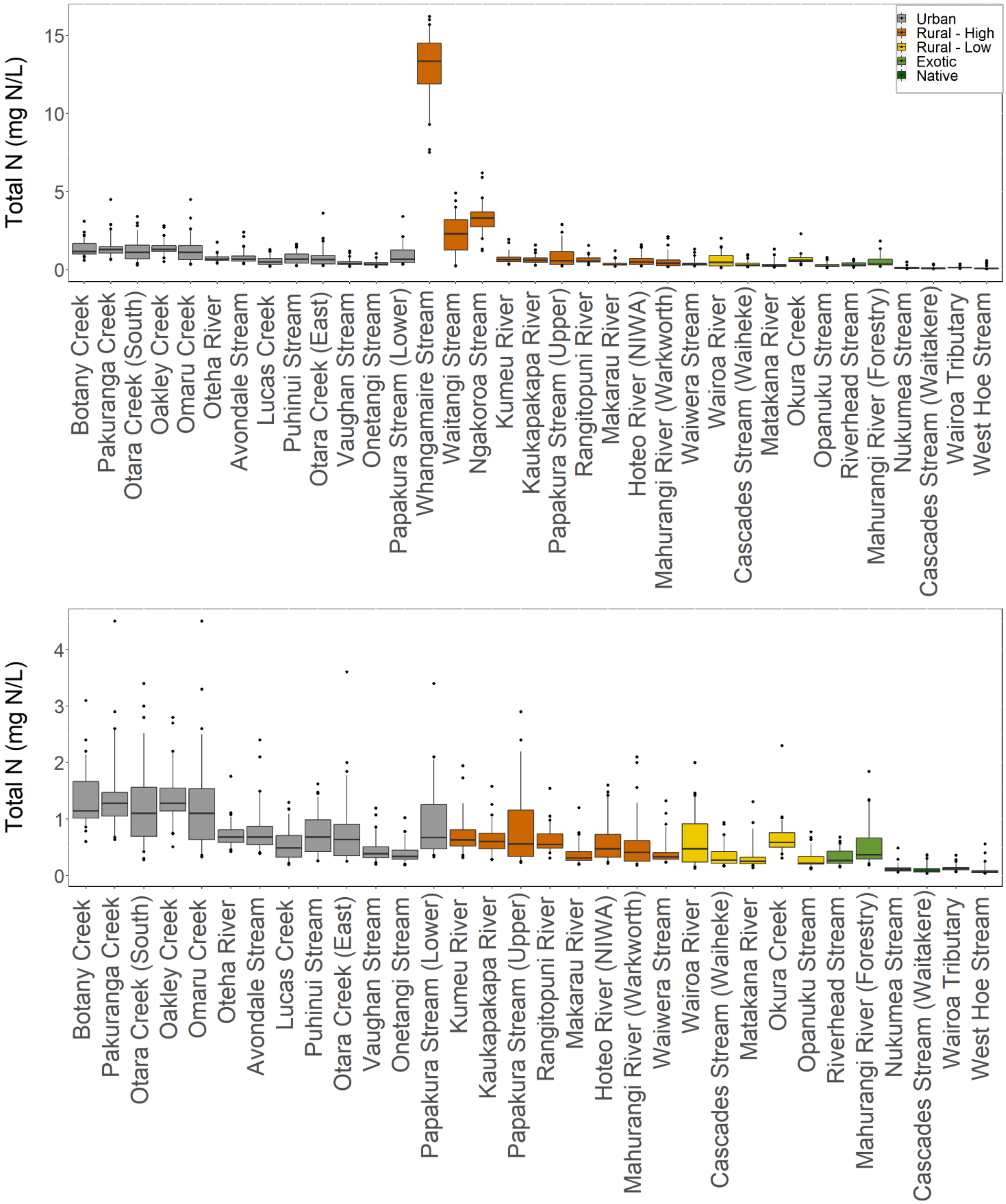


Figure 4-8: Box plots of Total nitrogen (mg/L), for river water quality data collected from July 2017 to June 2022. Top panel shows all sites. Bottom panel excludes streams in the Franklin area (Whangamaire, Waitangi, and Ngakoroa). Note the difference in Y-axis scale between panels.

Two outliers for Total N are not displayed: Botany Creek (18.1 mg/L – sewage overflow event in Dec 2019), Pakuranga Creek (12.6 mg/L – pollution event March 2022).

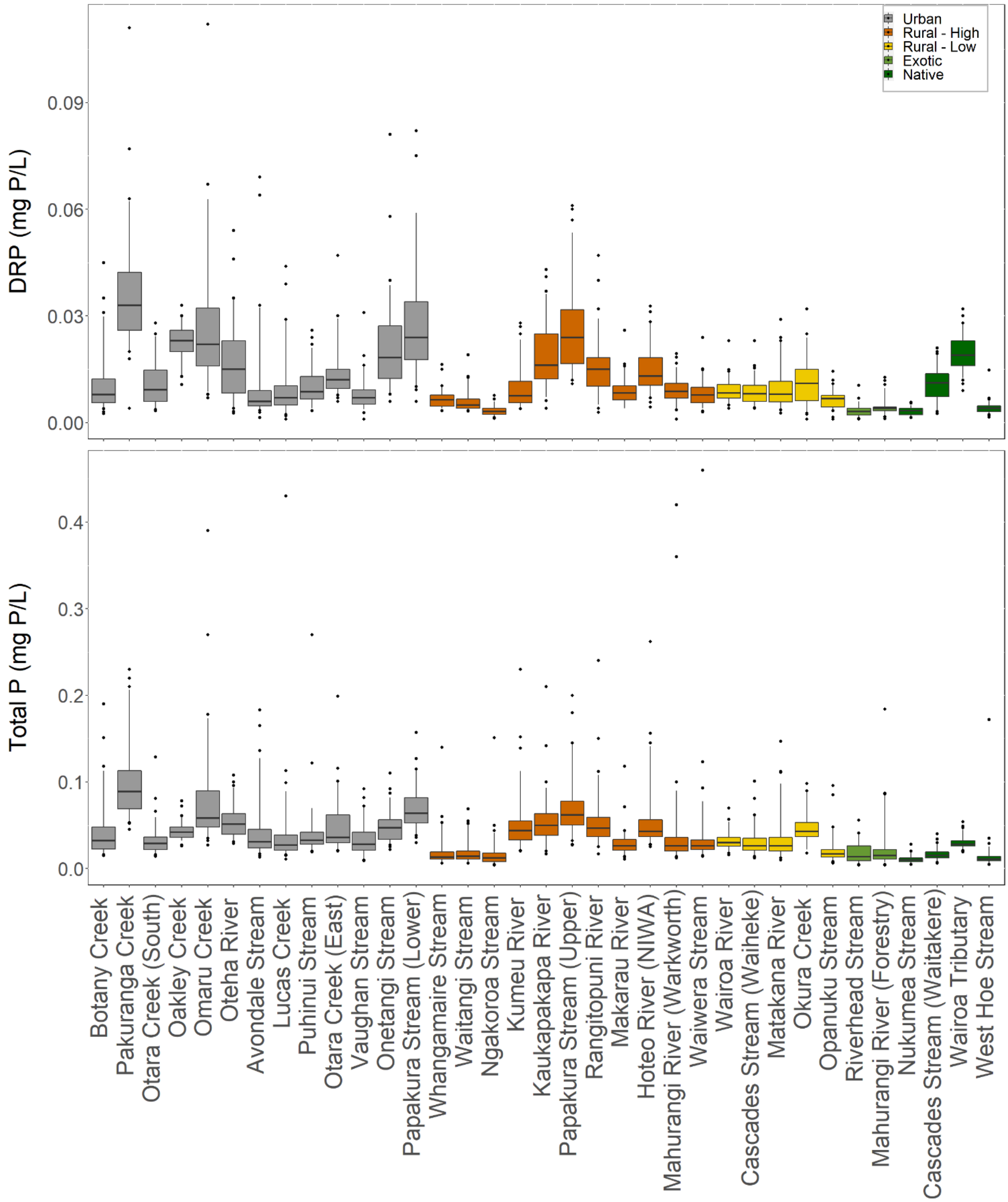


Figure 4-9: Box plots of dissolved reactive phosphorus (mg/L) and total phosphorus (mg/L) for river water quality data collected from July 2017 to June 2022.

Two outliers for DRP are not displayed: Botany Creek (0.93 mg/L – sewage overflow event in Dec 2019), Lucas Creek (0.29 mg/L – possible pollution event January 2020)

One outlier for Total P is not displayed: Botany Creek (1.85 mg/L – sewage overflow event in Dec 2019)

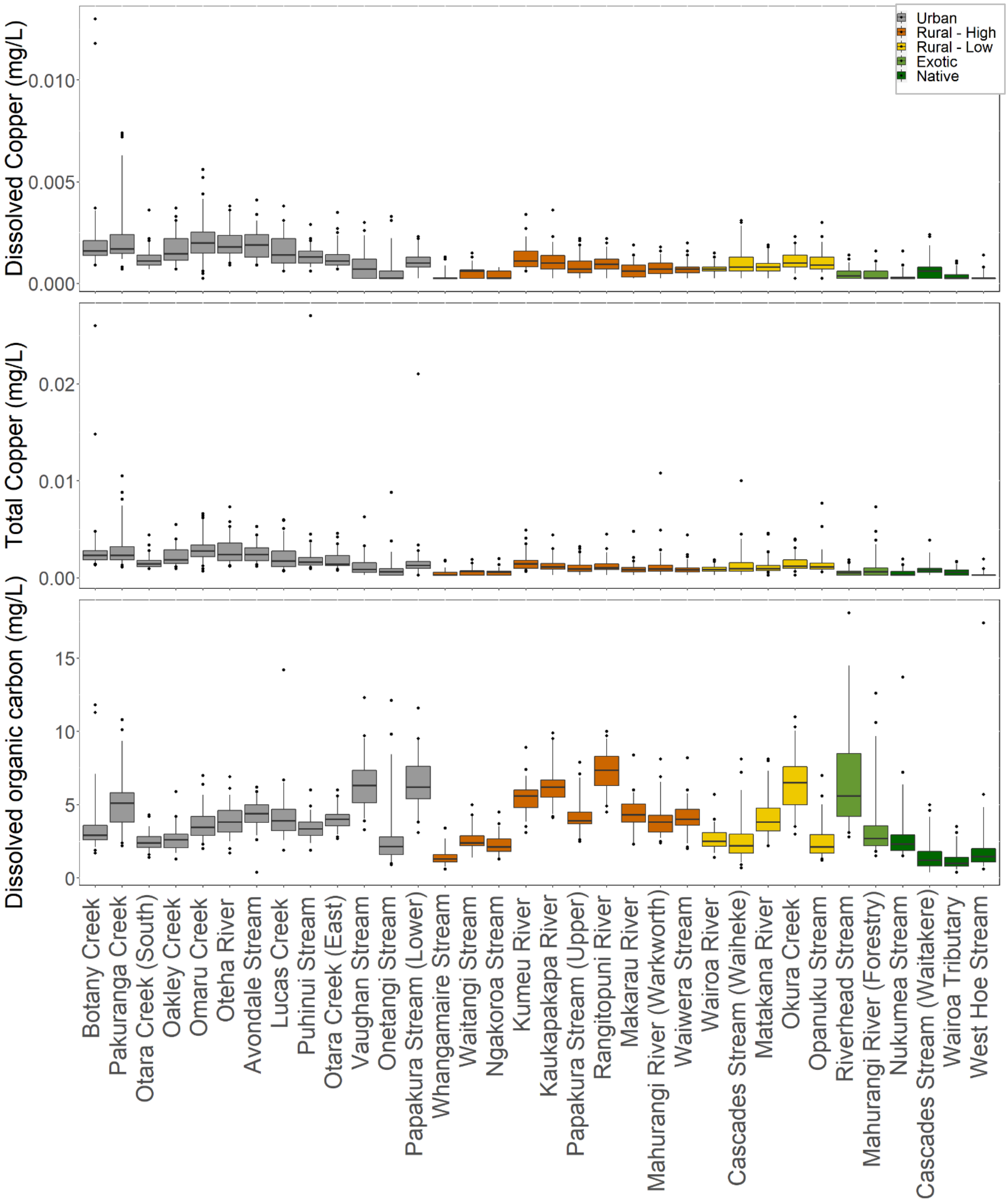
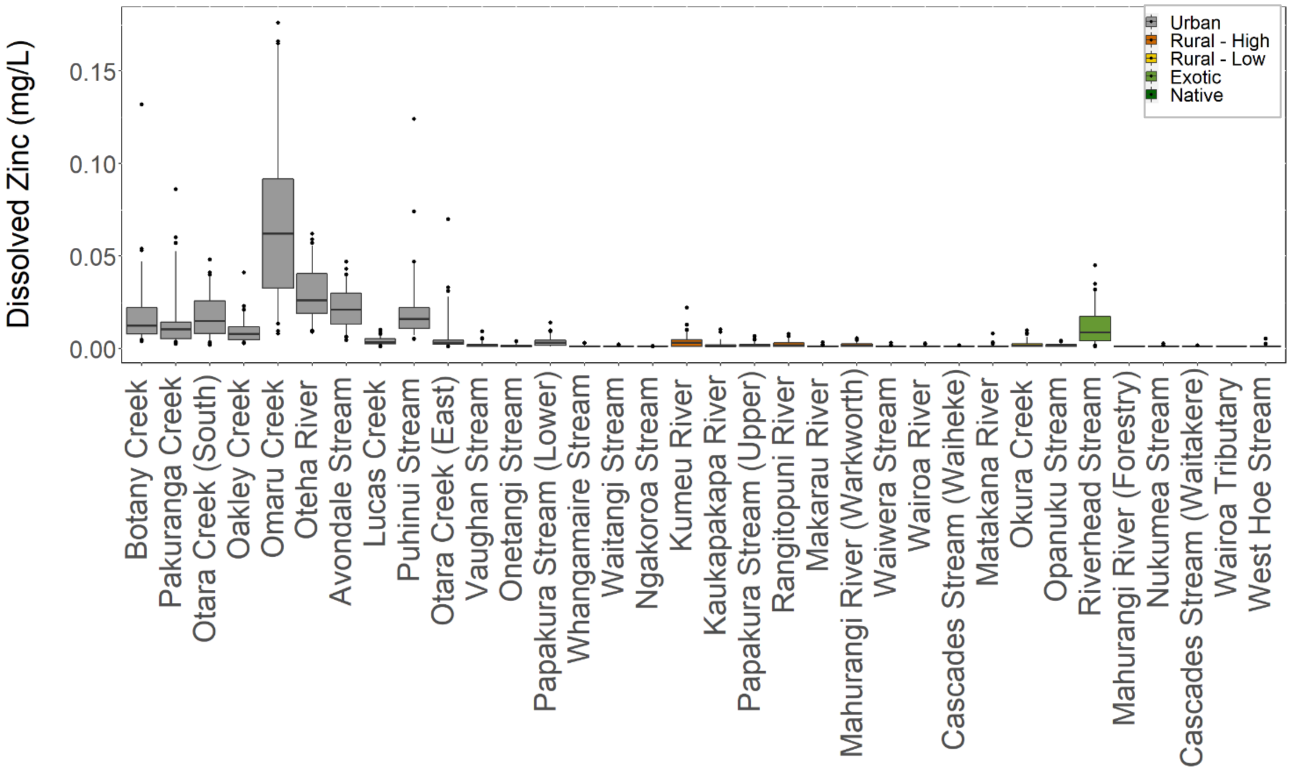


Figure 4-10: Box plots of dissolved copper (mg/L) and total copper (mg/L) for river water quality data collected from July 2017 to June 2022* and dissolved organic carbon (mg/L) for river water quality data collected from July 2018 to June 2022.

* For 11 sites, results are for observations from July 2018 to June 2022: Onetangi, Whangamaire, Waitangi, Ngakoroa, Kaukapakapa, Rangitopuni, Cascades (Waiheke), Opanuku, Cascades (Waitakere), Wairoa (Tributary), and West Hoe,
One outlier for total copper is not displayed: Vaughan Stream (0.071 mg/L).
Three outliers for DOC are not displayed: Omaru Creek (23 mg/L, 33 mg/L, 41 mg/L)
Metals and DOC are not assessed by NIWA for Hoteo River.



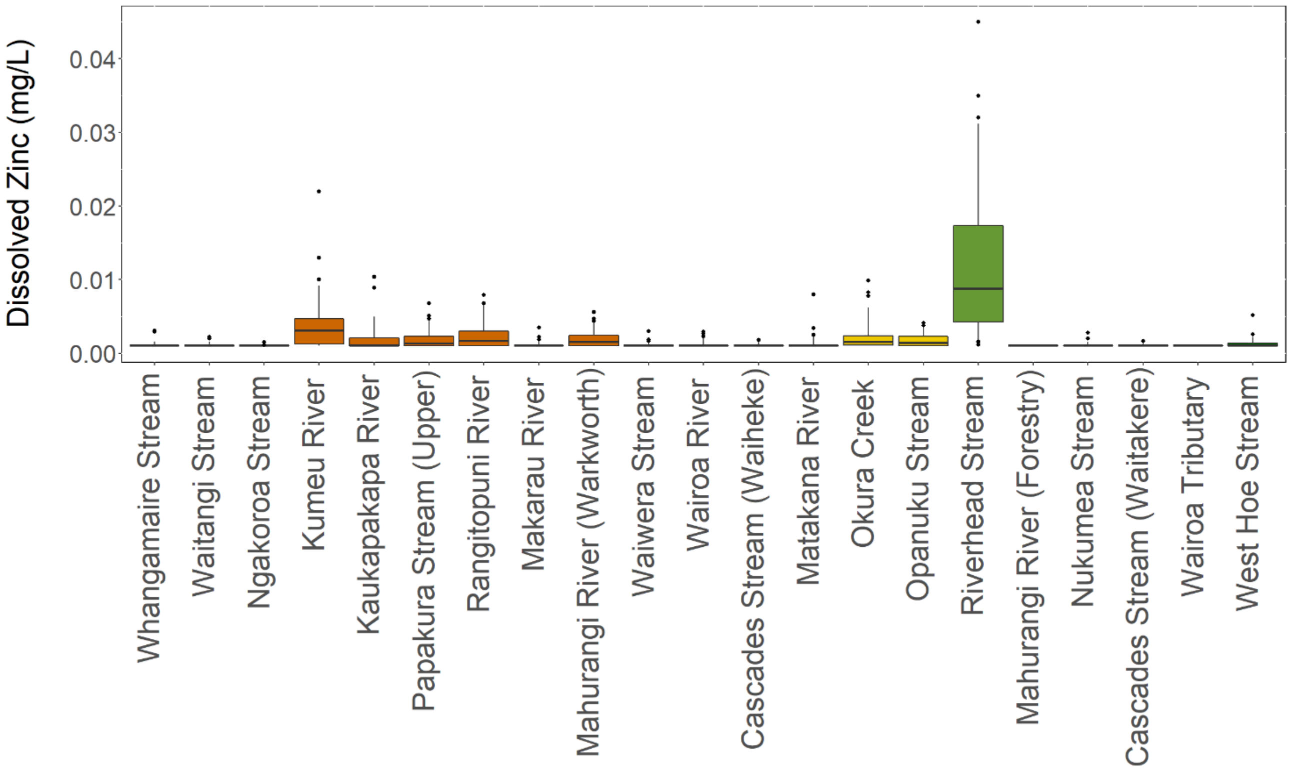


Figure 4-11: Box plots of dissolved zinc (mg/L) for river water quality data collected from July 2017 to June 2022*. Top – all sites. Bottom – rural and forest sites only, note difference in Y axis scale.

* For 11 sites, results are for observations from July 2018 to June 2022: Onetangi, Whangamaire, Waitangi, Ngakoroa, Kaukapakapa, Rangitopuni, Cascades (Waiheke), Opanuku, Cascades (Waitakere), Wairoa (Tributary), and West Hoe,

One outlier for dissolved zinc is not displayed: Pakuranga Creek (0.56 mg/L)

Metals not assessed by NIWA for Hoteo River.

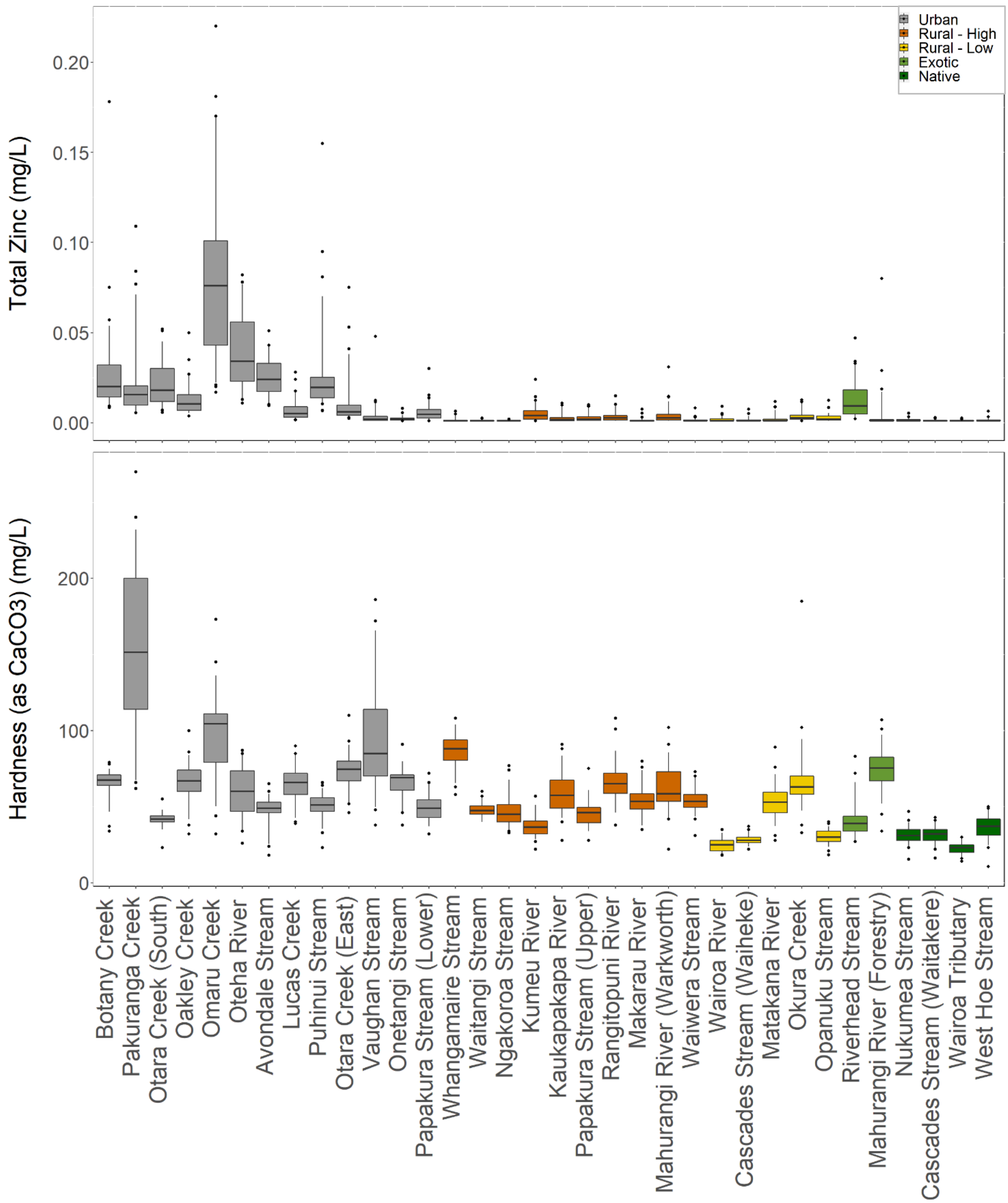


Figure 4-12: Box plots of total zinc (mg/L) for river water quality data collected from July 2017 to June 2022* and Total hardness (mg/L) for river water quality data collected from July 2018 to June 2022.

* Note for 11 sites, results are for observations from July 2018 to June 2022: Onetangi, Whangamaire, Waitangi, Ngakoroa, Kaukapakapa, Rangitopuni, Cascades (Waiheke), Opanuku, Cascades (Waitakere), Wairoa (Tributary), and West Hoe,
Two outliers for total zinc are not displayed: Pakuranga Creek (0.6 mg/L), Puhinui Stream (0.41 mg/L).
Metals and hardness are not assessed by NIWA for Hoteo River.

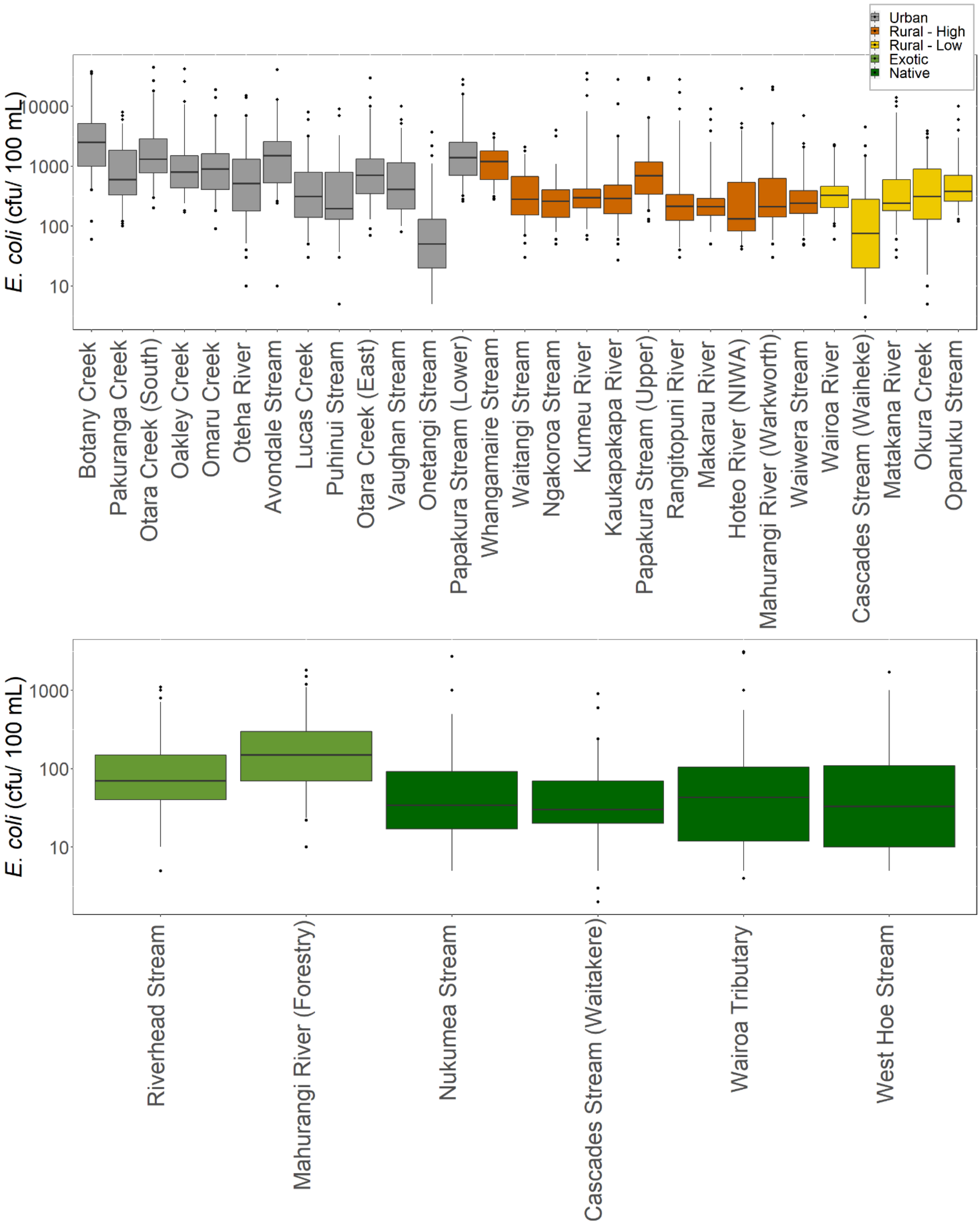


Figure 4-13: Box plots of *E. coli* (cfu/100mL) for river water quality data collected from January to December 2020. Top – urban and rural sites only. Bottom – Exotic and native forest sites only, note difference in Y-axis.

Four outliers for *E. coli* are not displayed: Botany Creek (2600000 CFU/ 100 mL – sewage overflow event in Dec 2019, 550000 CFU/ 100 mL, 100000 CFU/ 100 mL), Pakuranga Creek (900000 CFU/ 100 mL).
Note: *E. coli* analysed by NIWA at Hoteo River = is reported in MPN/100 mL but are considered to give comparable results and is included here.

4.2 NPS-FM 2020 National Objectives Framework current state assessment

Water quality data for the five-year period 2016-2020 was assessed against the attribute metrics in the NOF in the NPS-FM (2020) (see Appendix C) and reported as the relevant band for each monitored stream site for 2020. Bands range from A to D for most attributes, and A to E for *E. coli*.

The 'National Bottom Line' refers to the minimum state for some attributes. Where aspects of water quality are below a national bottom line, there is a risk of adverse effects on the health of aquatic fauna, including fish and macroinvertebrate communities[6].

This report does not include assessment of all compulsory attributes relating to water quality. As more information is gathered (outlines in section 1.2) our understanding, and thus reporting, of ecosystem health will develop.

There are several sources of uncertainty associated with assessments of water quality state including, for example, sampling error and hydrological and other sources of environmental variability. Using a period of five years to generate an assessment of state removes some of the uncertainty associated with environmental variability. However, flow regime can vary significantly among different five-year periods and thus we can expect some oscillations in attribute state over time (Snelder and Kerr, 2022).

One way of expressing the range of uncertainty in the numeric estimate of state is to refer to confidence intervals around the summary statistic. Further guidance is expected to be released in 2023 outlining the most appropriate approach to use for the purposes of grading attributes under the NPS-FM 2020. At this stage, it is important to recognise that the range of confidence in an assessment of state can span one or more attribute bands and the results presented here are based on the 'face value' of the assessment metrics. This face value assessment is considered to be the best information available at the time.

The overall bands for each attribute (water quality parameter) and provisional grades for metals (Gadd et al., 2019) are summarised across the region (Figure 4-10) and per dominant land cover class (Figure 4-11). The overall bands per stream site are mapped in Figure 4-12. Bands for the individual metrics (median, 95th percentile etc.) per stream site and attribute are reported in table form in Appendix D. The numeric values for the assessment metrics are provided in supplementary data files.

The distribution of grades for the 2017-2022 assessment period was similar to the previously reported 2016-2020 period. Key differences between these assessment periods include the shift from reporting to calendar year (January-December) to hydrological year (July to June), and the change from assessment of the maximum observation for ammonia toxicity to the 95th percentile.

Regionally there is a low risk of nitrate or ammonia toxicity effects. No sites were found to fall below the national bottom line for ammonia toxicity (See section 4.2.1.2 for further information). However,

[6] Unless existing natural conditions are identified to explain the band grading.

there are infrequent episodic events causing high concentrations of ammoniacal N in some urban streams (e.g. Pakuranga Creek) (Figure 4-15). Nitrate toxicity risks are localised to the three streams in the Pukekohe/Franklin area which are in the C/D bands.

Adverse effects of nutrient enrichment can occur at concentrations far lower than nutrient levels that cause toxicity. Nearly 50% of monitoring sites regionally have elevated DRP levels (bands C and D). Further assessment of periphyton community responses to instream nutrient concentrations (DRP and DIN) will improve our understanding of the trophic state of rivers.

Suspended fine sediment (visual clarity) grading is considered to be provisional as visual clarity was calculated based on measured turbidity and further regional calibration of turbidity against measured visual clarity is recommended. Additional monitoring was implemented in 2022 to enable this in the future. Only two monitored sites were below the national bottom line for suspended fine sediment (visual clarity). There was a smaller proportion of sites in band C (9%) in this assessment compared to the previous rolling assessment (23%).

All grading of the proposed copper and zinc attributes is considered to be provisional. Revision of the ANZ guidelines including consideration of toxicity modifying factors (including dissolved organic carbon and water hardness) is underway and this will change the assessment of these proposed attributes. Interim grades have also been reported here for an additional 11 monitoring sites for copper and zinc toxicity. The inclusion of these additional sites, which are predominantly within rural and native forest catchments, improves the regional representativeness for these parameters and is now comparable with other ecosystem health attributes presented. There is a higher proportion of sites graded in band 'A' for both copper and zinc compared to previous regional reporting for this attribute primarily due to changes in sites included.

Collectively, over 80 per cent of monitored sites had elevated *E. coli* levels demonstrating widespread potential human health risk across all rural and urban streams (Figure 4-14).

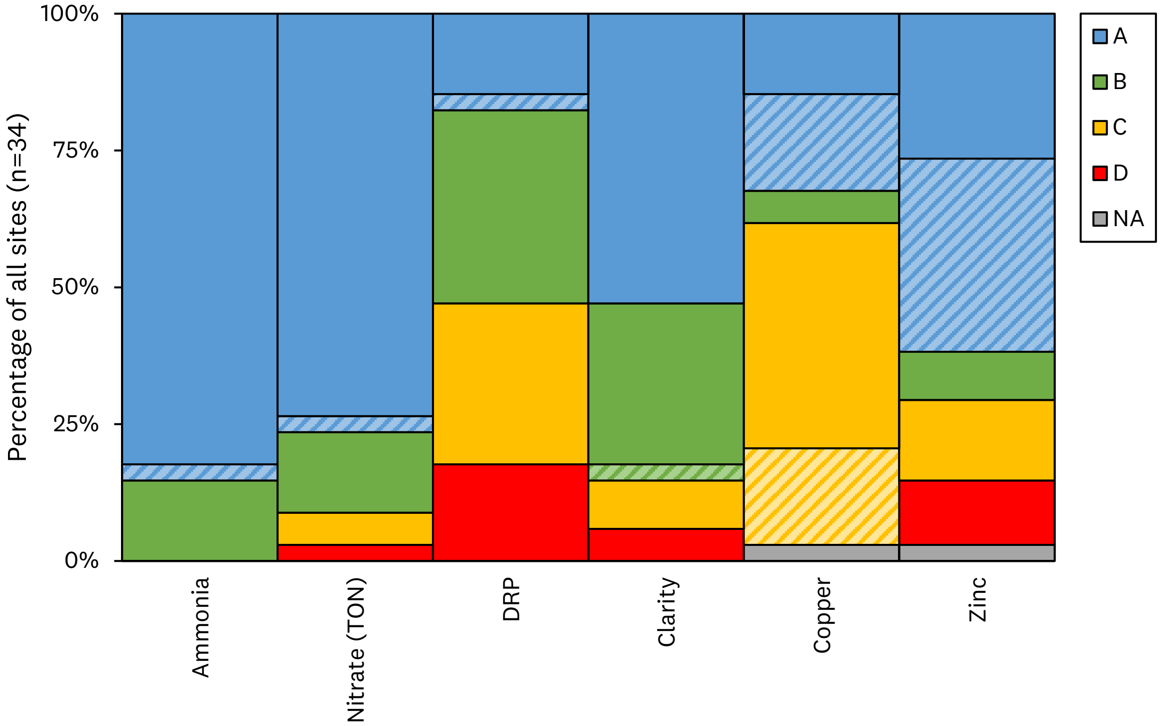


Figure 4-14: Proportion of sites within each overall band for NPS-FM 2020 NOF ecosystem health water quality attributes, and proposed Auckland specific regional attributes (copper and zinc) (2017-2022). Note striped boxes reflect interim grades based on 2018-2022 only for copper and zinc, or for other attributes, where a site only had 80% of data available.

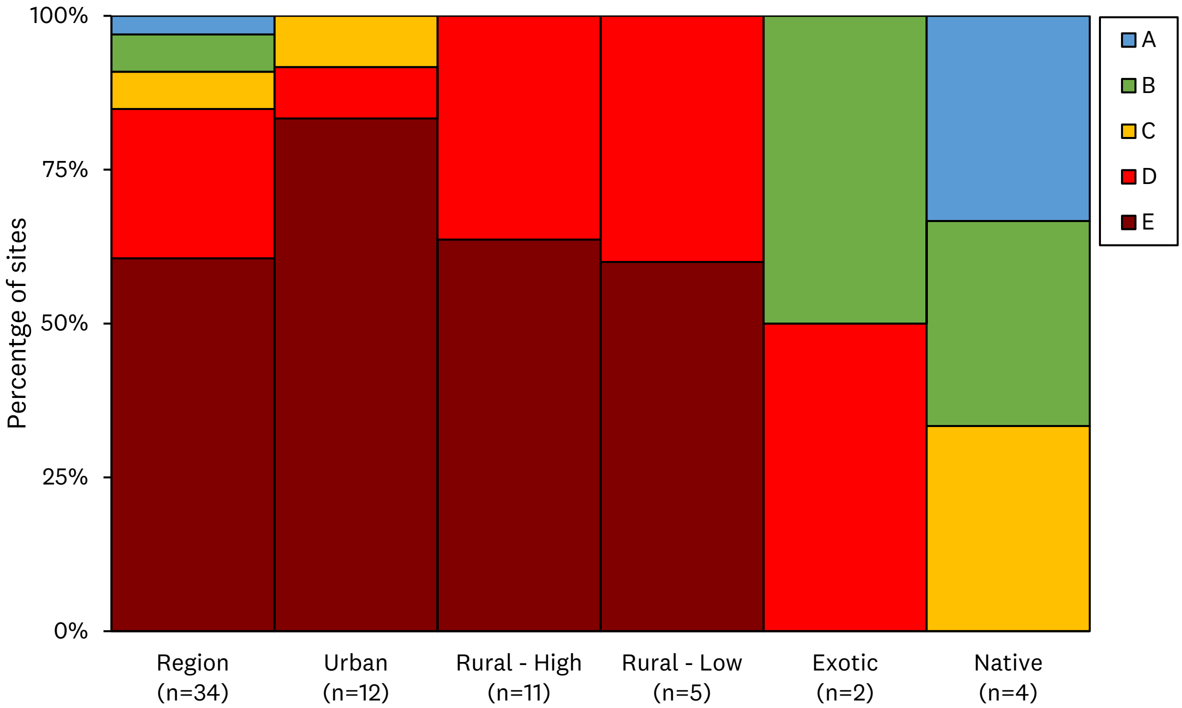


Figure 4-15: Proportion of sites within each overall band for NPS-FM 2020 NOF human contact river attribute (*E. coli*), regionally, and per dominant land cover class (2017-2022)

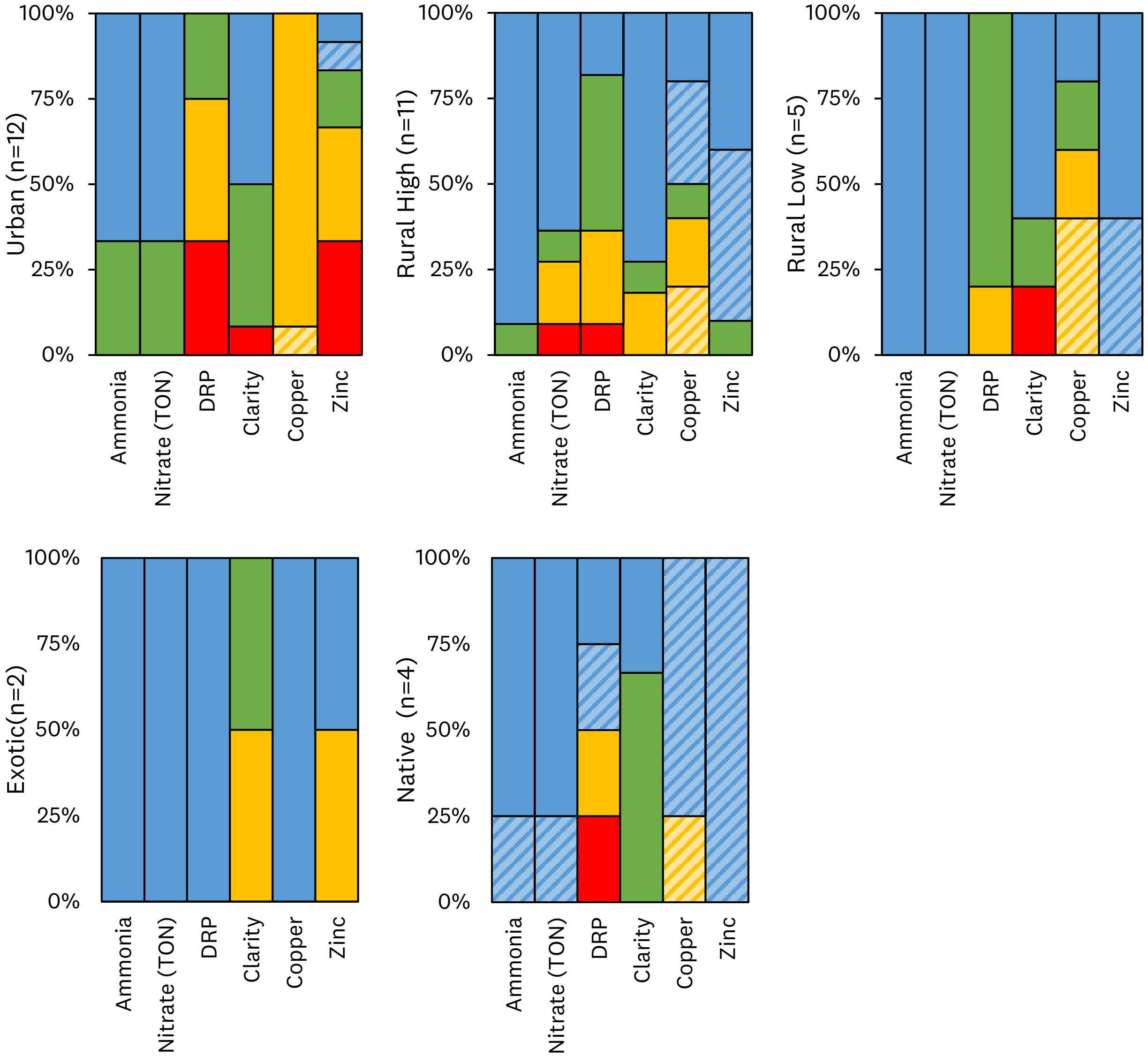


Figure 4-16: Proportion of sites within each overall NPS-FM 2020 band per dominant land cover class (2017-2022). Note striped boxes reflect interim grades based on 2018-2022 only for copper and zinc, or for other attributes, where a site only had 80% of data available.

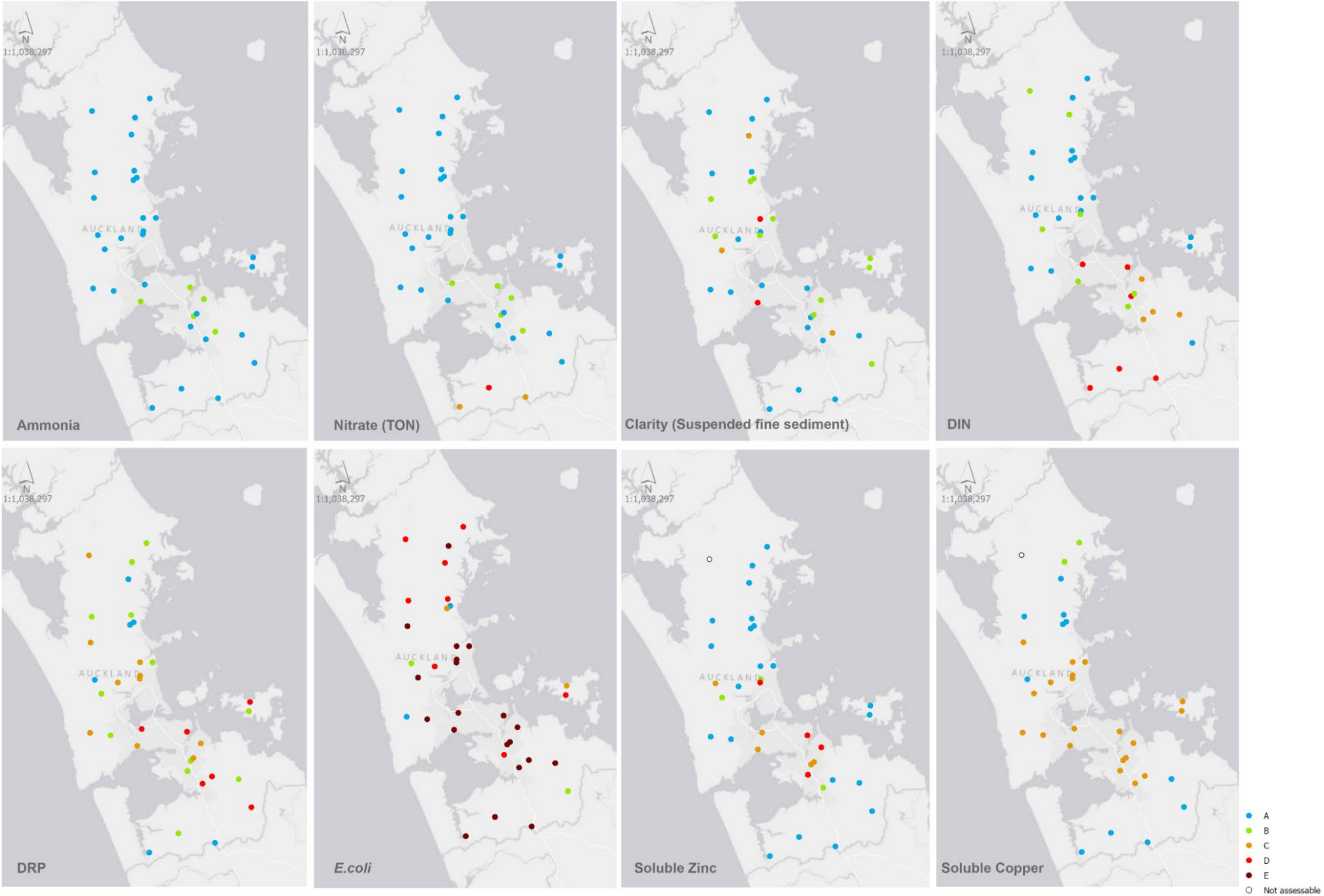


Figure 4-17: Tāmaki Makaurau / Auckland region summary maps of current state (July 2018-Jume 2022) for NPS-FM 2020 overall NOF attribute grade per site (including provisional grades for proposed regional copper and zinc guidelines).

4.2.1 Nutrients – Toxicity to aquatic life

Nitrate and ammonia can have direct impacts on macroinvertebrates and fish as these nutrients can be toxic at high concentrations.

4.2.1.1 Nitrate toxicity

Over 90 per cent of monitored river water quality sites do not exceed the national bottom line for nitrate toxicity[7](Figure 4-14). Thus, for most of the region little or no toxicity risk is expected even for the most sensitive instream species.

Three rural sites in the Franklin area (Ngakoroa Stream, Whangamaire Stream, and Waitangi Stream) fail the national bottom line for nitrate toxicity (Figure 4-15). There is a known issue of high nitrate concentrations in the underlying shallow volcanic aquifers which support stream baseflow (White et al., 2019). The high groundwater nitrate concentrations are a result of nitrate leaching from intensive horticultural activity over many decades in the Franklin area (Meijer et al., 2016). Further investigative research is underway to better characterise the groundwater and surface water interactions in this area. These three sites have the highest proportion of horticultural land cover of all monitored sites (see Figure 2-2). Two of the monitored Franklin sites were graded C indicating that potential adverse effects on growth for 20 per cent of sensitive species (i.e. fish) may be expected. There was an increase in the median metric for Waitangi Stream from band C in the previous rolling period to band B in this assessment. Whangamaire Stream was graded D, which signals that impacts on the growth of multiple instream species can be expected.

Central Government have acknowledged the national significance of food production from the Pukekohe (Franklin) area through a specific Pukekohe Specified Vegetable Growing Area exemption within the NPS-FM 2020. This exemption still retains the requirement to better manage instream nitrate concentrations and demonstrate improvements in water quality but allows for target attribute states to be set below national bottom lines for a ten-year period from the commencement date of the NPS-FM 2020.

Four urban streams (Oakley Creek, Omaru Creek, Ōtara Creek (South), and Botany Creek), and one rural stream (Papakura Stream (Upper)) are in the B band for nitrate toxicity. Only one of these streams, Oakley Creek is within this range for the median metric as well as the 95th percentile (Appendix D). This suggests that nitrate concentrations are more consistently elevated at this site compared to occasional events.

All other sites within the regional monitoring programme are in the A band for nitrate toxicity.

[7] Auckland Council NOF grading for nitrate toxicity has been assessed based on total oxidised nitrogen (nitrate + nitrite nitrogen) assuming that the nitrite fraction is almost always a negligible proportion of the total organic nitrogen (see Figure 4-5, Figure 4-6, Figure 4-8 and Ingley, 2020 for further evidence on the relative proportions of nitrate and nitrite).

4.2.1.2 Ammonia toxicity

The assessment of the ammonia toxicity attribute changed from considering the maximum value observed over the past five years, to considering the 95th percentile of observations over the past five years in accordance with the NPS-FM 2020 as amended in December 2022. This change has resulted in 30 per cent of sites being graded in a different band compared to the previous assessment. Previously, four urban streams failed the national bottom line for ammonia toxicity based on the maximum values. No sites failed the national bottom line under this revised assessment with 85 per cent of sites in band A. Three of the four urban sites that were previously below the national bottom line (C) were assessed as band B and one as band A. One rural site was also assessed as band B (Papakura Stream (upper)). Only one site, Avondale Stream, was found to have a poorer grade in the current assessment period (B) than previously (see section 4.1 above for further).

Overall, despite the change in ammonia toxicity assessment, the data suggest that the risk of ammonia toxicity is elevated in urban streams. It is noted that this attribute focuses on the risk of chronic toxicity risk, or long-term exposure. Acute or high short-term exposure may also occur in some urban waterways, and it is important to also consider where very high concentrations occur that are only occasionally intercepted by monthly routine monitoring.

Pakuranga Creek is no longer included in the regional summary of water quality state as this site is not considered to be adequately representative of the wider upstream catchment. Previous results have demonstrated that the site is subject to a nearby point source discharge with very high ammoniacal-N concentrations (the only site that would fail the national bottom line, based on median concentrations as well as the 95th percentile). Targeted investigations of discharges from the upstream catchment have been undertaken over the past year including a focus on improving industrial environmental management practices through proactive compliance initiatives. Investigative monitoring of this site is ongoing to evidence improvement moving forward.

4.2.2 Nutrients – Eutrophication

Eutrophication is characterised by excessive plant and algal growth associated with excessive instream nutrients, as well as other factors such as light, shading, and river substrate. Dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN) are forms of nutrients that are most readily taken up by plants and algae and thus stimulate the growth of plants and algae.

Both DIN and DRP need to be considered to understand the trophic state of rivers, including their influence on aquatic fauna and instream periphyton. The relationships between periphyton and nutrients are complex and spatially variable. A targeted periphyton monitoring programme has been underway since 2020 to support the development of instream nutrient targets to protect streams from the risks of eutrophication. Assessment of this data will be undertaken in mid-2023 after three years of monthly data collection has been carried out.

4.2.2.1 DIN

The proposed attribute table for DIN concentrations did not reach scientific consensus and was not included in the NPS-FM 2020, therefore grading for this attribute has not been undertaken in this report. For reference, the proposed bottom line (D band) for DIN was >1 mg/L for median concentration and >2.05 mg/L for the 95th percentile. Over the past five years, six sites would fail that proposed bottom line; the three streams in the Pukekohe Specified Vegetable Growing Area that have also been identified as failing the national bottom line for nitrate toxicity, and three urban streams, Oakley Creek, Otara Creek South, and Omaru Creek.

4.2.2.2 Dissolved reactive phosphorus (DRP)

There is no national bottom line for DRP. Overall, 18 per cent of monitored streams were in band D including urban, rural, and native forest streams. A further 29 per cent were in band C. Further work is necessary to contextualise the DRP band assessment with regard to what may be considered normal/background DRP concentrations for the region.

4.2.3 Suspended fine sediment/visual clarity (turbidity)

Sediment is a major driver of freshwater and marine biodiversity loss. Suspended fine sediment reduces the visual clarity of water or the light passing through the water. Suspended sediment can also clog gills of fish or filter feeding structures of macroinvertebrates.

Auckland Council did not routinely monitor visual clarity directly in rivers. We do have long term monitoring records for turbidity. Visual clarity is a direct measure of visibility in the water column (how far you can see) while turbidity is an index of water cloudiness or how suspended solids in the water column scatter light There are strong correlations between both measures. We have converted measurements of turbidity to visual clarity based on a relationship derived between these variables from a national dataset (Franklin et al., 2020). This is an approach that is provided for within the attribute table in the NPS-FM. However, regional verification of the national relationship is recommended. Therefore, grading of suspended fine sediment (visual clarity) is considered provisional at this time. Direct monitoring of visual clarity was established in July 2022 to support validation of this assessment and further review of this grading will be undertaken for future reporting.

The assessment of suspended fine sediment focuses on the median metric alone reflective of processes happening at typical baseflow or lower flow conditions (i.e. the state of water clarity 50 per cent of the time) and loads. Storm events also have a major influence on sediment processes[8], contributing large loads of sediment to rivers and coastal receiving environments, that are subsequently remobilised and transported over longer time periods. Ecological impacts from increased sedimentation have been observed in harbours and estuaries monitored across Auckland (Ingley, R., 2021).

Two sites, Okura Creek and Avondale Stream, failed the national bottom line (band D) for visual clarity (when converted from turbidity). Okura Creek has been consistently assessed as band D over

[8] In the Auckland region, storm event-based suspended sediment monitoring is undertaken primarily in large rural rivers (Hicks et al., 2021).
[9] It is noted that while Pakuranga Creek was excluded from the regional assessment this site would fall within band D for copper toxicity (based on the 95th percentile metric).

the past several rolling periods and further investigation of impacts on water clarity in this catchment is recommended. Avondale Stream was the only site in this rolling period that was in a lower band than previous rolling assessments. Eight other sites changed grade compared to the previous 2020 assessment, likely reflecting the greater uncertainty in assessment and climactic influence on this parameter.

4.2.4 Proposed Auckland specific attributes (metals)

Copper and zinc can have direct impacts on macroinvertebrates and fish communities as these metals can be toxic at high concentrations. These metals have been recognised as key contaminants, particularly in urban rivers, however they have not been included as national attributes in the NPS-FM Appendices. Work is ongoing to develop additional attributes for copper and zinc for Auckland (e.g. Gadd et al., 2019). Therefore, all grading of these proposed metal attributes is considered to be provisional at this time.

4.2.4.1 Copper

The assessment of copper toxicity will likely change in future reporting with regard to upcoming revision of the ANZ guidelines, and consideration of toxicity modification by dissolved organic carbon (DOC) (Warne et al., 2018; Gadd, et al., 2019).

No sites were below the proposed regional bottom line (band D) for dissolved copper[9]. All twelve urban sites were in band C (Figure 4-16). Seven of these were in band C for both the median and 95th percentile metrics. Three urban sites (Ōtara Creek (South and East) and Puhinui Stream) were in band B for the median attribute, and one urban stream (Vaughan Stream) remained in band A for the median state (see Table 2-1).

Thirty-six per cent of rural – high, and 60 per cent of rural – low monitoring sites were also assessed as band C (Figure 4-16). This grading was driven by the 95th percentile metric. Kumeu River, Kaukapakapa River, and Okura Creek were also in band B for the median state. Both monitored streams dominated by exotic forestry were in band A.

Three of the four streams within native forest were in band A however Cascades Stream (Waitakere) was assessed as band C based on the 95th percentile.

4.2.6.2 Zinc

The assessment of zinc toxicity will likely change in future reporting with regard to upcoming revision of the ANZ guidelines, and consideration of toxicity modification for instream water hardness (Warne et al., 2018; Gadd et al., 2019).

A third of monitored urban sites were below the proposed regional bottom line for dissolved zinc (D band, Figure 4-16). At these sites, toxicity could approach acute levels (i.e. risk of death for sensitive instream species). Concentrations at these sites exceeded the 95th percentile metric, with the exception of Omaru Creek which was graded D based on the median state. A further third of monitored urban sites were in band C.

All rural (high and low) sites were graded in band A except for Kumeu River (band B). Riverhead Stream (exotic forest) was within band C based on both the median and the 95th percentile attribute. The other predominantly exotic forestry site, and all four native forest sites were in band A.

Collectively this demonstrates that the risk of zinc toxicity to aquatic life is spatially localised to urban catchments.

4.2.5 Human Contact – *E. coli*

The human contact compulsory value refers to the way people connect with the water through a range of recreational activities, such as swimming, boating and fishing. This report does not identify grading for primary contact sites, or for rivers that are fourth order or larger in relation to the Ministry for the Environment's national target for primary contact. The NPS-FM 2020 includes a human contact attribute for all rivers and lakes based on *E. coli* levels. There are four *E. coli* metrics to derive the overall risk of infection: median, % exceedances > 260 CFU/100 mL, % exceedances > 540 CFU/100 mL and 95th percentile. There is no national bottom line for this attribute.

Band A indicates there is an overall average risk of infection of one per cent for someone swimming in that waterway. Band D indicates more than three per cent risk of infection and band E indicates more than seven per cent risk of infection. Not all infections will result in illness and the source of faecal contamination influences the infection risk. Contamination from human sources is considered much more infectious than contamination from ruminants or birds[10].

More than 80 per cent of monitored urban streams were in the lowest band, E (Figure 4-16). These streams were in the lowest band across all four metrics (Appendix D). One urban site was in band D (Puhinui Stream) and one urban site was in band C (Onetangi Stream). Puhinui Stream was in band D across all four metrics (Appendix D). Onetangi Stream was in band C based on the 95th percentile and would otherwise by graded B based on the percentage of events that exceeded 540 CFU/100/mL (Appendix D).

Approximately 60% of rural streams were also in the lowest band, E with the remainder in band D (Figure 4-16). The limiting metric was most commonly based on the median state with four streams in the lowest band across all four metrics (Appendix D).

The exotic and native forested sites were graded in bands A and B except for Mahurangi River (exotic forestry) which was in band D (based on the median state), and West Hoe which was in band C (based on the 95th percentile).

[10] Devane, M., Leonard, M., Eaton, C. (2021) *Refinement of the framework for assessment of recreational water quality.* Prepared by ESR for National Sciences Challenge: Our Land and Water. FW21020.

5 Summary

This report provides an annual summary of water quality across the regional Auckland river water quality monitoring network and a current state assessment of several ecosystem health and human contact water quality attributes under the NPS-FM 2020 (MfE, 2020 amended December 2022) using data from the five-year hydrological year period July 2017 to June 2022. It is important to note that this assessment does not include all NPS-FM 2020 compulsory attributes relating to water quality. Our understanding and reporting of ecosystem health will develop as more information is gathered particularly in relation to the effects of nutrient enrichment on periphyton, and dissolved oxygen concentrations.

Nitrate and ammonia can be toxic to aquatic fauna at high concentrations. For most of the region, little or no toxicity risk is expected, even for the most sensitive instream species. However, there are localised issues. Three rural stream sites in the Pukekohe/Franklin area failed the national bottom line for nitrate toxicity. This is a recognised issue associated with intensive horticultural production in the catchment and high concentrations of nitrate in the underlying shallow aquifers. Due to a change in assessment methodology under the latest amendment of the NPS-FM 2020, no monitored sites were found to fail the national bottom line for ammonia toxicity. Adverse effects of nutrient enrichment can occur at concentrations far lower than nutrient levels that cause toxicity. Further research is necessary to contextualise the assessment of nutrient enrichment and trophic responses within Auckland's waterways.

Visual clarity was assessed based on turbidity data via a national regression equation approach. This is a provisional grading that should be further calibrated against measured clarity for the region. Two streams were found to have failed the national bottom line (band D).

Two key metal contaminants were assessed in relation to chronic (long-term exposure) toxicity risk for river fauna. Interim grading was included for 10 additional sites this year providing better representation of the wider Auckland region. Metal contamination is primarily a risk for urban streams; a third of monitored urban sites were below the proposed regional bottom line for zinc toxicity, and all were in band C for copper toxicity. The risk of metal toxicity impacts will be reviewed following the revision of guidance on toxicity modifying factors for both copper and zinc.

Collectively, 26 per cent of monitored streams failed at least one national or proposed regional bottom line for water quality ecosystem health attributes (nitrate, ammonia, or metal toxicity, or visual clarity). This included 42 per cent of urban sites, and 25 per cent of rural sites. No sites were found to fail more than one bottom line. No sites with predominantly native or exotic forest in the upstream catchments failed any attribute bottom lines.

Faecal contamination of rivers as indicated by *E. coli* is the most widespread issue facing Tāmaki Makarau / Auckland across urban and rural streams. While this has implications for human contact with rivers and streams, this assessment is not in relation to identified primary contact sites or the summer bathing season.

6 References

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Appendix A. Contributing catchment information and REC information

Table A-1: Summary of LCDB Land Cover Classes and Broad Aggregations.

LCDB Land Cover Classes within catchments upstream of river water quality monitoring sites	Aggregated Land Cover Classes	Broad Level Dominant Land Cover
Broadleaved Indigenous Hardwoods	Native forest	Native
Indigenous Forest	Native forest	Native
Manuka and/or Kanuka	Native forest	Native
Deciduous Hardwoods	Exotic forest	Exotic
Exotic Forest	Exotic forest	Exotic
Forest – Harvested	Exotic forest	Exotic
Orchard, Vineyard or Other Perennial Crop	Horticulture	Rural
Short-rotation Cropland	Horticulture	Rural
Gorse and/or Broom	Rural	Rural
High Producing Exotic Grassland	Rural	Rural
Low Producing Grassland	Rural	Rural
Built-up Area (settlement)	Urban	Urban
Transport Infrastructure	Urban – Transport Infrastructure	Urban
Urban Parkland/Open Space	Urban Parkland	Urban
Sand or Gravel	Other	NA
Surface Mine or Dump	Other	NA
Lake or Pond	Water	NA
Mangrove	Water	NA
Flaxland	Wetland	NA
Herbaceous Freshwater Vegetation	Wetland	NA

Table A-2: Summary of River Environment Classification (REC) categories and notations used in Table 2-1.

REC Category	Notation
Climate Categories	
Warm-Extremely-Wet	WX
Warm-Wet	WW
Warm-Dry	WD
Cool-Extremely-Wet	CX
Cool-Wet	CW
Cool-Dry	CD
Source-of-Flow Categories	
Glacial-Mountain	GM
Mountain	M
Hill	H
Low-Elevation	L
Lake	Lk
Spring	Sp
Wetland	W
Regulated	R
Geology Categories	
Alluvium	Al
Hard-Sedimentary	HS
Miscellaneous	M
Plutonic	Pl
Soft-Sedimentary	SS
Volcanic-Acidic	VA
Volcanic-Basic	VB

*Categories and notations taken from Snelder et al., (2010)

Appendix B. Physio-chemical parameters

Table B-1: Summary of river water quality parameters, detection limits, analytical methods and two sources of data collection (from October 2020).

Parameter	Unit	Detection limit	Method	Source
Dissolved oxygen	ppm	0.1	EXO2 Sonde (Xylem Analytics)	Field
Dissolved oxygen saturation	% sat	0.01	EXO2 Sonde (Xylem Analytics)	Field
Temperature	°C	0.01	EXO2 Sonde (Xylem Analytics)	Field
Conductivity	mS cm	0.01	EXO2 Sonde (Xylem Analytics)	Field
Salinity	ppt	0.2	EXO2 Sonde (Xylem Analytics)	Field
pH	pH units	0.01	EXO2 Sonde (Xylem Analytics)	Field
Total suspended solids	mg/L	3 1*	APHA (2017) 2540 D	Lab
Turbidity	NTU	0.05	APHA (2017) 2130 B (modified)	Lab
Chlorophyll a	mg/L	0.0002	APHA (2017) 10200 H (modified)	Lab
Nitrate nitrogen (NO3N)	mg/L	0.001	Calculation ((NO3N+NO2N) – NO2)	Lab
Nitrite nitrogen (NO2 N)	mg/L	0.001	APHA (2017) 4500-NO2 I (modified)	Lab
Total oxidised nitrogen (NO2N + NO3N)	mg/L	0.001	APHA (2012) 4500-NO3 I (modified)	
Ammoniacal nitrogen (NH4-N)	mg/L	0.005	APHA (2012) 4500-NH3 H (modified)	Lab
Total Kjedahl nitrogen (TKN)	mg N/L	0.01	Calculation: TN – (NO3N + NO2N)	Lab
Total nitrogen (TN)*	mg N/L	0.01	APHA (2017) 4500-N C & 4500 NO3 I (modified)	Lab
Dissolved reactive phosphorus	mg/L	0.001	APHA (2017) 4500-P G	Lab
Total phosphorus*	mg/L	0.004	APHA (2017) 4500-P B & E (modified)	Lab

Parameter	Unit	Detection limit	Method	Source
Dissolved copper	mg/L	0.0005	ICP-MS trace level. APHA (2017) 3125 B	Lab
Total copper	mg/L	0.00053	ICP-MS trace level. APHA (2017) 3125 B / US EPA 200.8	Lab
Dissolved zinc	mg/L	0.001	ICP-MS trace level. APHA (2017) 3125 B	Lab
Total zinc	mg/L	0.0011	ICP-MS trace level. APHA (2017) 3125 B / US EPA 200.8	Lab
Total Hardness	mg/L	1 mg/L as $CaCO_3$	Calculated from calcium and magnesium.	Lab
Dissolved calcium	mg/L	0.05	ICP-MS trace level. APHA (2017) 3125 B	Lab
Dissolved magnesium	mg/L	0.02	ICP-MS trace level. APHA (2017) 3125 B	Lab
Dissolved non-purgeable organic carbon	mg/L	0.3	APHA (2017) 5310 C	Lab

Table B-2: Summary of parameters assessed.

Parameter	Description
Salinity and Conductivity	Salinity levels increase as the influence of saline water increases i.e. in the lower parts of some streams where water becomes brackish. Salinity levels affect the toxicity of some contaminants. Electrical conductivity reflects the total ionic content of the water which is affected by the presence of dissolved salts such as chloride, nitrate, nitrite, phosphate, sodium, magnesium, calcium etc.
Temperature	Surface water temperature is primarily driven by seasonal and diurnal changes in solar radiation. The size of the water body and level of overhead shading affect the degree of influence of solar radiation i.e. small shallow unshaded waterways are warmed faster than deep well shaded waterways. The extent of catchment imperviousness also influences stream temperature where stormwater runoff passes over heated impervious surfaces (roads, roofs, etc). Temperature affects biological processes and moderates the toxicity of contaminants.
pH	pH is a measure of acidity/alkalinity. The geology and source of water often determines the pH of a stream. Alkalinity reflects the buffering capacity or how resilient the pH is to change. Diurnal cycles of photosynthesis and respiration can influence pH in streams with a high plant or

Parameter	Description
	algal biomass with maximum pH values typically occurring in the late afternoon, and minimum values in the early morning. pH affects biological processes and moderates the toxicity of contaminants.
Dissolved Oxygen (DO)	Oxygen is released by plants during photosynthesis and taken up by plants, animals and bacteria for respiration. Oxygen can also be transferred from the air to water particularly in areas of turbulence such as waterfalls or over riffles. Oxygen-scavenging compounds associated with organic matter also affect DO levels. High DO values can reflect high primary production while low DO values can reflect high rates of decomposition of organic matter. Reduced dissolved oxygen levels can affect the growth and reproduction of aquatic organisms. In extreme cases low DO levels due to respiration and/or chemical uptake can stress or kill aquatic organisms i.e. reduce the life-supporting capacity of the water. DO levels are diurnally and seasonally variable. DO is typically higher during the day and decreases at night. The concentration of dissolved oxygen at 100 % saturation in water is influenced by temperature, salinity, and atmospheric pressure. Colder waters hold more oxygen than warmer water.
Chlorophyll a	Chlorophyll a is a green photosynthetic pigment in plants and algae and is used as a measure of algal (phytoplankton) biomass in the water column. Excess nutrients in a stream can cause nuisance levels of algae to grow which can reduce habitat availability and quality for fish and instream invertebrates; and increase the oxygen demand in streams over diurnal and seasonal cycles. Phytoplankton communities can also be influenced by river flows, shading, and grazing by zooplankton or other fauna.
Turbidity Suspended solids	Turbidity is a measure of the degree to which light is scattered in water by particles, such as sediment and algae. Total suspended solids are a measure of the amount of suspended material in the water column such as plankton, non-living organic material, silica, clay and silt. These variables are usually closely correlated but can vary where tannins or other coloured compounds can increase turbidity but are not associated with solid particles. The main potential sources of river transported sediment are sheetwash and hill erosion (hillslope erosion), mass wasting (e.g. landslides, earth flows etc.), gully erosion and stream bank erosion. The relative contribution of these sources depends on catchment geology, slope, rainfall, land cover, and the history of land use. Large quantities of sediment are mobilised during periods of land cover transitions (deforestation, urban development). Sediment is a primary stressor in many river environments. Excess deposited, or suspended fine sediment can reduce habitat quality, food resources, and reduce reproductive success of aquatic fauna. Terrestrial sediments transported to the coast may also cause estuary infilling, contribute to mangrove expansion, smother biota and habitats, clog gills and impede the feeding of aquatic organisms.
Nitrite (NO_2), Nitrate (NO_3) Total Oxidised Nitrogen (TON, NO_2 +NO_3-N)	Nitrite is the intermediate step in the conversion of ammonia to nitrate. It is usually short lived in the aquatic environment in the presence of oxygen and is typically an indication of a source of nitrogenous waste in the immediate vicinity of the sampling site. Ammonium-N and nitrate-nitrite-N are dissolved forms of nitrogen that are immediately available for plant and algae uptake and growth. Ammoniacal N is a combination of un-ionised ammonia (NH3) and the ammonium ion (NH4). Un-ionised ammonia is the more toxic form to aquatic life and is highly dependent on water temperature, salinity and pH.

Parameter	Description
Ammoniacal Nitrogen (NH_3 + NH_4-N) Dissolved inorganic nitrogen (DIN) Total Kjedahl Nitrogen (TKN) Total Nitrogen (TN)	Dissolved inorganic nitrogen is the sum of ammoniacal nitrogen, nitrate and nitrite nitrogen. In surface waters, most of the dissolved inorganic nitrogen is in the form of nitrate, and ammonia and nitrite are rapidly oxidised to nitrate. Therefore, higher levels of nitrite or ammonia often indicate localised inputs of wastewater or fertiliser. Total Kjedahl Nitrogen is the sum of ammoniacal nitrogen and organic nitrogen (amino acids and proteins). Total Nitrogen includes all forms of dissolved and particulate nitrogen (TKN + TON). Particulate nitrogen consists of plants and animals, and their remains, as well as ammonia adsorbed onto mineral particles. Particulate nitrogen can be found in suspension or in the sediment. Total Nitrogen is usually higher in upper estuarine sites where particulate matter is higher. Low dissolved forms of nitrogen compared to total nitrogen suggest that most of the nitrogen present is particulate matter such as plants, animals, and adsorbed to sediment particles. High nutrient levels can cause algal blooms, nuisance plant growth and eutrophication. High concentrations of some nutrients are also toxic to aquatic organisms.
Dissolved Reactive Phosphorus (DRP) Total Phosphorus (TP)	Phosphorus is found in water as dissolved and particulate forms. Dissolved Reactive Phosphorus is immediately available for uptake and growth by phytoplankton and macroalgae. Particulate phosphorus consists of plants and animals and their remains, as well as phosphorus in minerals and adsorbed onto mineral surfaces. Total Phosphorus is a measure of both dissolved and particulate forms in a water sample. The adsorption and desorption of phosphate from mineral surfaces forms a buffering mechanism that regulates dissolved phosphate concentrations in rivers and estuaries. Sources of phosphorus include sewage and animal effluent, cleaning products, fertilisers, and industrial discharges. Earthworks and forestry can also release phosphorus through soil erosion. Wetland drainage can expose buried phosphorus.
Dissolved copper Total copper Dissolved organic carbon	Copper can be toxic to aquatic fauna in high concentrations. The concentration of metals that is dissolved in the water rather than bound up in sediments or other complexes more closely represents the bioavailable portion in rivers, but several other water chemistry factors may influence this. The relationship between in-stream concentrations of metals and rainfall/stream flow can be very complex with different phases of flushing and dilution. The toxicity of copper to freshwater organisms is most strongly influenced by interactions with dissolved organic matter with lower toxicity in the presence of dissolved organic carbon content. Dissolved organic carbon is a form of organic matter in streams that is a source of energy in stream food webs and consequently has an influence on stream ecosystem metabolism. The main sources of DOC are from the decay of leaf litter and macrophytes and algae and from leaching through organic rich soils (such as wetlands), or from the discharge of wastewater. Dissolved organic carbon includes humic substances that can be yellow or black in colour which can attenuate light and reduce water clarity.
Dissolved zinc Total zinc Total hardness	Zinc can be toxic to aquatic fauna in high concentrations. The concentration of metals that is dissolved in the water rather than bound up in sediments or other complexes more closely represents the bioavailable portion in rivers, but several other water chemistry factors may influence

Parameter	Description
	this. The relationship between in-stream concentrations of metals and rainfall/stream flow can be very complex with different phases of flushing and dilution. The toxicity of zinc to freshwater organisms is most influenced by pH, temperature, and water hardness. Total water hardness is the sum of calcium and magnesium concentrations as calcium carbonate in the water. These compounds generally originate from the weathering of rocks and soil. Water containing calcium carbonate at less than 60 mg/L is generally considered 'soft', 60-120 mg/L 'moderately hard', and 120-180 mg/L 'hard' (WHO, 2011). Most New Zealand waters are considered to be soft (MoH, 2018).
E. coli	*E. coli* bacteria are found in the gut of warm-blooded animals (including humans, cows, ducks etc.). When found in rivers, *E. coli* are indicative of faecal pollution and other harmful bacteria or viruses may also be in the water, causing increased risk to human health.

Appendix C. Attribute bands

Table C-1: NPS-FM National Objectives Framework 2020 (amended December 2022) Appendix 2A attribute bands.

NOF River Attribute	Ammonia (Ecosystem Health – toxicity)		Nitrate (Ecosystem Health – toxicity)		Suspended fine sediment (Ecosystem Health)	
Metric	Annual Median	Annual 95th %il	Annual Median	Annual 95th %ile	Median Class 1	Median Class 2
Unit	mg NH4-N/L pH adjusted		mg NO3-N/L		Visual clarity (m)	
A	≤ 0.03	≤ 0.05	≤ 1.0	≤ 1.5	≥ 1.78	≥ 0.93
B	> 0.03 and ≤0.24	> 0.05 and ≤ 0.40	> 1.0 and ≤ 2.4	> 1.5 and ≤ 3.5	< 1.78 and ≥1.55	< 0.93 and ≥0.76
C	> 0.24 and ≤1.30	> 0.40 and ≤2.20	> 2.4 and ≤ 6.9	> 3.5 and ≤ 9.8	< 1.55 and >1.34	< 0.76 and >0.61
D	> 1.30	> 2.20	> 6.9	> 9.8	< 1.34	< 0.61

NOF River Attribute	*Escherichia coli* (Human Contact)			
Metric	% > 540	% > 260	Median	95th %ile
Unit	cfu/100mL			
A	< 5%	< 20%	≤ 130	≤ 540
B	5-10%	20-30%	≤ 130	≤ 1000
C	10-20%	20-34%	≤ 130	≤ 1200
D	20-30%	> 34%	> 130	> 1200
E	> 30%	> 50%	> 260	> 1200

Table C-2: NPS-FM (2020) (amended December 2022) Appendix 2B attribute bands.

NOF River Attribute	DRP	
Metric	Median	95th %ile
Unit	mg/L	
A	≤ 0.006	≤ 0.021
B	> 0.006 and ≤ 0.01	> 0.021 and ≤0.030
C	>0.01 and ≤0.018	> 0.030 and ≤0.054
D	> 0.018	> 0.054

Table C-3: Proposed Regional Attribute Bands for dissolved metal contaminants.

NOF River Attribute	Dissolved Copper		Dissolved Zinc	
Metric	Annual Median	Annual 95th %ile*	Annual Median	Annual 95th %ile*
Unit	mg/L		mg/L	
A	≤ 0.001	≤ 0.0014	≤ 0.0024	≤ 0.008
B	>0.001 and ≤ 0.0014	>0.0014 and ≤ 0.0018	>0.0024 and ≤ 0.008	>0.008 and ≤ 0.015
C	>0.0014 and ≤ 0.0025	>0.0018 and ≤ 0.0043	>0.008 and ≤ 0.031	>0.015 and ≤ 0.042
D	> 0.0025	> 0.0043	> 0.031	> 0.042

Appendix D. NPS-FM 2020 and regional attributes current state band by metric

Table D-1: Auckland region current state bands (2017-2022) per metric by attribute.

Note the lowest band represents the overall band for each attribute. Bands in red denote bottom line failure.

* = Interim grade (2018-2022 only), I.D = Insufficient data to calculate grade. N.A = not assessed.

Land cover	Site name	Copper		Zinc		*E. coli*				Nitrate (TON)		NH_4-N		DRP		Clarity (Turbidity)
		Med	95th	Med	95th	Med	95th	>260	>540	Med	95th	Med	95th	Med	95th	Med
Urban	Botany Creek	C	C	C	D	E	DE	E	E	A	B	A	B	B	C	B
Urban	Pakuranga Creek[11]	C	D	C	D	E	DE	E	E	A	A	C	C	D	D	B
Urban	Ōtara Creek (South)	B	C	C	C	E	DE	E	E	A	B	A	B	B	B	A
Urban	Oakley Creek	C	C	B	C	E	DE	E	E	B	B	A	A	D	B	A
Urban	Omaru Creek	C	C	D	D	E	DE	E	E	A	B	A	B	D	D	A
Urban	Oteha River	C	C	C	D	E	DE	E	E	A	A	A	A	C	C	B
Urban	Avondale Stream	C	C	C	C	E	DE	E	E	A	A	A	B	A	C	D
Urban	Lucas Creek	C	C	B	A	E	DE	E	E	A	A	A	A	B	C	A
Urban	Puhinui Stream	B	C	C	D	D	DE	D	D	A	A	A	A	B	A	A
Urban	Ōtara Creek (East)	B	C	B	C	E	DE	E	E	A	A	A	A	C	B	B
Urban	Vaughan Stream	A	C	A	A	E	DE	E	E	A	A	A	A	B	A	B
Urban	Onetangi Stream	A*	C*	A*	A*	ABC	C	A	B	A	A	A	A	D	C	B
Urban	Papakura Stream (Lower)	B	C	B	B	E	DE	E	E	A	A	A	A	D	D	A
Rural - High	Whangamaire Stream	A*	A*	A*	A*	E	DE	E	E	D	D	A	A	B	A	A
Rural - High	Waitangi Stream	A*	A*	A*	A*	E	DE	E	D	B	C	A	A	A	A	A
Rural - High	Ngakoroa Stream	A*	A*	A*	A*	E	C	D	C	C	C	A	A	A	A	A
Rural - High	Kumeu River	B	C	B	B	E	DE	E	D	A	A	A	A	B	B	C

[11] Pakuranga Creek is included here for completeness but has not been included in results presented in section 4.2.

Land cover	Site name	Copper		Zinc		*E. coli*				Nitrate (TON)		NH_4-N		DRP		Clarity (Turbidity)
		Med	95th	Med	95th	Med	95th	>260	>540	Med	95th	Med	95th	Med	95th	Med
	Kaukapakapa River	B*	C*	A*	A*.	E	DE	E	D	A	A	A	A	C	C	B
	Papakura Stream (Upper)	A	C	A	A	E	DE	E	E	A	B	A	B	D	C	C
	Rangitopuni River (Auckland	A*	C*	A*	A*	D	DE	D	C	A	A	A	A	C	B	A
	Makarau River	A	A	A	A	D	DE	BC	C	A	A	A	A	B	A	A
	Hoteo River (NIWA)	N.A.	N.A.	N.A.	N.A.	D	DE	D	D	A	A	A	A	C	B	A
	Mahurangi River (Warkworth)	A	B	A	A	D	DE	D	E	A	A	A	A	B	A	A
	Waiwera Stream	A	A	A	A	D	DE	D	C	A	A	A	A	B	A	A
Rural - Low	Wairoa River	A	A	A	A	E	DE	E	C	A	A	A	A	B	A	A
Rural - Low	Cascades Stream (Waiheke)	A*	C*	A*	A*	ABC	DE	BC	C	A	A	A	A	B	B	B
Rural - Low	Matakana River	A	B	A	A	D	DE	D	D	A	A	A	A	B	B	A
Rural - Low	Okura Creek	B	C	A	A	E	DE	E	E	A	A	A	A	C	B	D
Rural - Low	Opanuku Stream	A*	C*	A*	A*	E	DE	E	E	A	A	A	A	B	A	A
Exotic	Riverhead Stream	A	A	C	C	ABC	B	A	B	A	A	A	A	A	A	B
Exotic	Mahurangi River (Forestry)	A	A	A	A	D	C	BC	C	A	A	A	A	A	A	C
Native	Nukumea Stream[12]	A	A	A	A	ABC	A	A	A	A	A	A	A	A	A	B
Native	Cascades Stream (Waitakere)	A*	B*	A*	A*	ABC	A	A	A	A	A	A	A	C	A	A
Native	Wairoa Tributary	A*	A*	A*	A*	ABC	DE	A	B	A	A	A	A	D	B	B
Native	West Hoe Stream	A*	A*	A*	A*	ABC	B	A	B	A	A	A	A	A	A	B

[12] Nukumea Stream did not meet minimum data requirements of 90% of observations. Results presented here are based on min of 80% of observations.

Appendix E. Water Quality Index

The water quality index (WQI) is used to simplify how we communicate the state or changes of complex water quality data by incorporating multiple factors (parameters) into a single number or score.

The water quality index represents the deviation from reference, or non-human influenced, conditions as evidenced by monitored reference sites in the Auckland region, rather than indicating whether the water quality is suitable for a particular purpose or activity. This has been presented as an overview of water quality across Tāmaki Makaurau and differences between dominant land cover types (section 2.2). This enables us to compare overall river water quality across multiple parameters, in a relative sense, between sites.

The water quality index used in this report is largely based on that developed by the Canadian Council of Ministers for the Environment (CCME) (2001) with some modifications to ensure the method aligns with the Auckland Council Marine water quality index (Foley, 2018). This approach uses the water quality results of seven specific water quality parameters to produce four water quality indices, from which a water quality class is then assigned ranging from Excellent, to Poor.

Water quality index methods

Each water quality index class and its associated narrative outcome is outlined in Table E-1. The water quality index represents an assessment of water quality as it relates to ecosystem health but does not represent any human health values assessment.

The water quality index used in this report is based on that developed by the Canadian Council of Ministers for the Environment (CCME, 2001) based on how many of the seven variables exceeded guidelines (scope), how often (frequency) and by how much (magnitude):

$WQI = 100 - [\{\sqrt{(Scope^2 + Frequency^2 + Magnitude^2)}\} \div 1.732]$

Table E-1: Water quality index class and scoring ranges used by Auckland Council.

Score range	WQI Class	Expected narrative outcome
95-100	Excellent	Water quality is protected with a virtual absence of threat or impairment, conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within guidelines **all** the time.
80-94	Good	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels or water quality guidelines.
65-79	Fair	Water quality is usually protected, but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels or water quality guidelines.
45-64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels or water quality guidelines.
0-44	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels or water quality guidelines.

Water quality index guidelines were derived from data observed at four reference sites that represent the best achievable water quality in the Auckland region. Specifically, the water quality index guidelines were derived from the 98th percentile (and 2nd percentile where appropriate) of 10 years of region-specific water quality data (2007-2016) for a subset of six parameters, and the 90th percentile for a seventh parameter (turbidity) (Table 7-2). The reference sites were Cascades Stream (Waitākere), Nukumea Stream, Wairoa Tributary and West Hoe Stream.

Rolling three-year monthly median values were used to calculate the 2020 water quality index scores i.e. 2018 to 2020 (Foley, 2018; Buckthought et al., 2020).

Table E-2: River water quality index guideline values for the Auckland region (Buckthought et al., 2019).

Parameter	Upper	Lower
Dissolved oxygen (% saturation)	111.4	79.5
pH	8.03	5.96
Temperature	17.65	
Nitrate + nitrite nitrogen (mg/L)	0.079	
Ammoniacal nitrogen (mg/L)	0.043	
Turbidity (NTU)	14.0	
Dissolved reactive phosphorus (mg/L)	0.042	

Water quality index results

Regional

In the current assessment period of 2019-2021, 60 per cent of monitored sites had water quality that was 'marginal' to 'poor' and 14 per cent of monitored sites had 'good' to 'excellent' water quality (Figure E-1). The distribution of these scores per site is shown in Figure E-2. Refer to Table E-3 for a summary of scores for each site over the past rolling time periods.

Rivers in urban catchments had the poorest scores, rivers in rural catchments typically ranged from poor to fair and, as expected, rivers dominated by native forested catchments had good to excellent river water quality based on the overall water quality index scores (Figure E-2).

The most common water quality issues affecting monitored sites across the region were elevated total oxidised nitrogen, water temperature, and either lower or higher dissolved oxygen saturation (Figure E-3). Over the first four rolling time periods there were more guideline exceedances for temperature, total oxidised nitrogen, and turbidity, however these parameters had fewer exceedances in the last two rolling periods. There was a higher proportion of exceedances of dissolved oxygen guidelines in the most recent rolling time period.

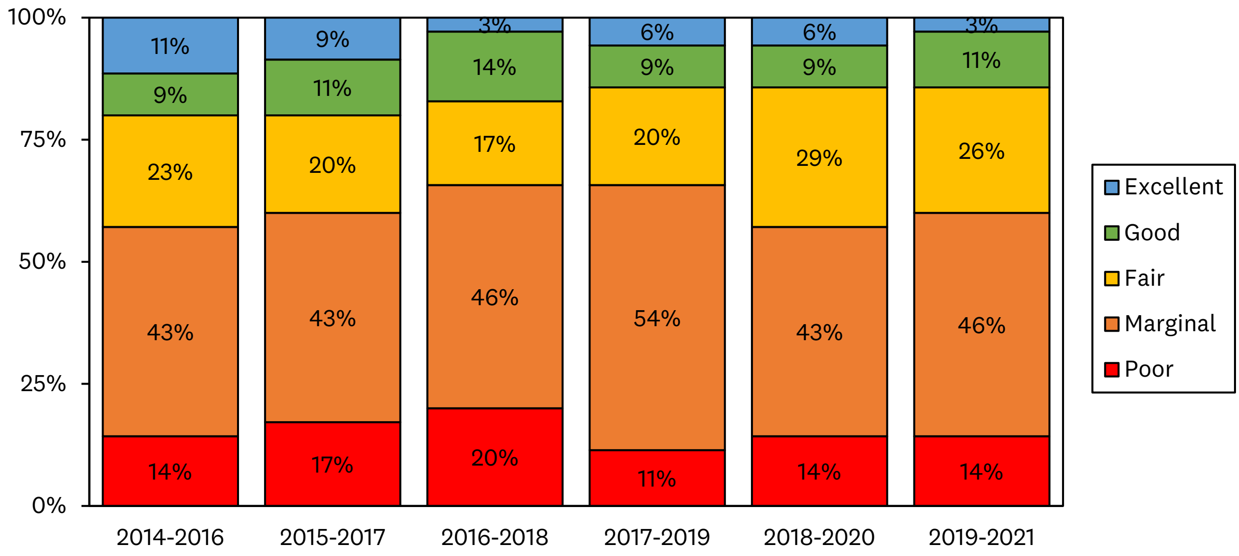

Figure E-1: Percentage of monitored sites (n=35) in each water quality index class for each three-year rolling period.

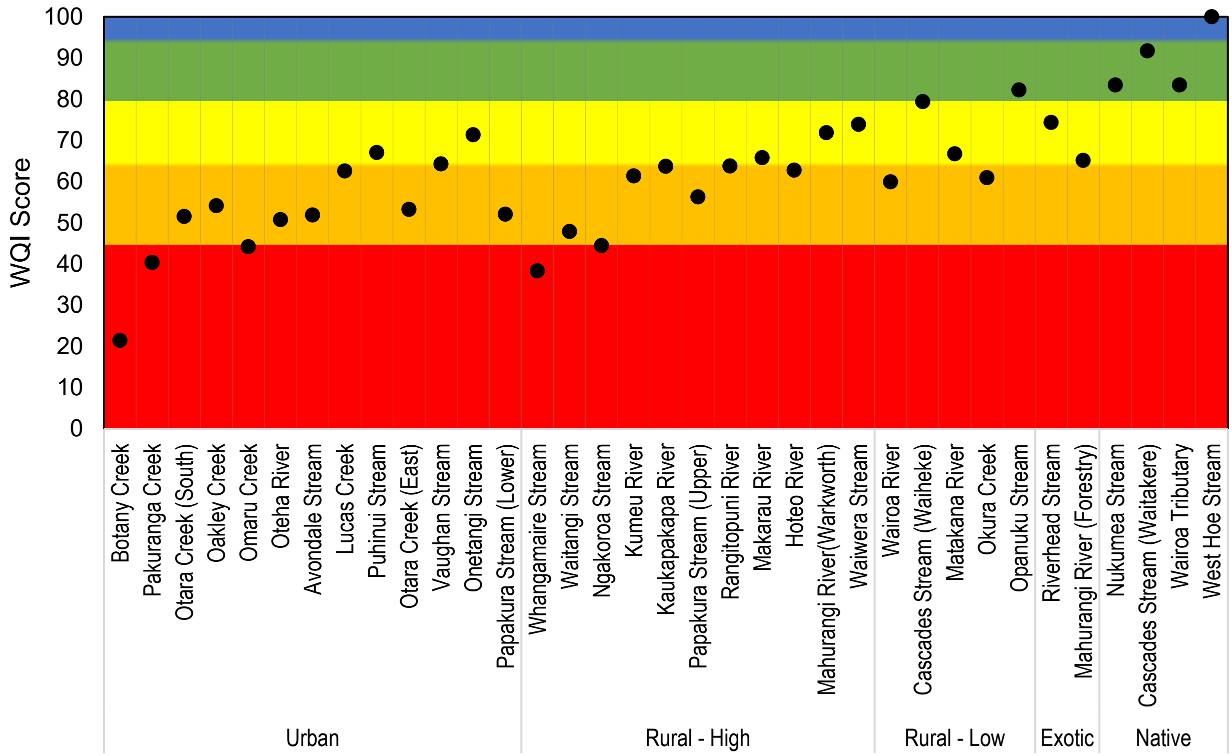

Figure E-2: Water quality index score for 2019-2021 (median values). Sites (n=35) are ordered by highest percentage of urban or rural dominant land cover. Coloured bands indicate excellent (blue) through to poor (red) water quality index classes.

Rivers in urban catchments tend to be affected by elevated nutrients, and elevated temperature and dissolved oxygen levels (Figure E-4). Pakuranga Creek was the only urban stream that had consistently elevated ammoniacal N concentrations. Exceedances across multiple parameters drive scores lower. Elevated total oxidised nitrogen, temperature, and turbidity, and low dissolved oxygen were the most common issues affecting rural streams Rivers with lower rural land use in the upstream catchment, and exotic forestry areas. As expected, water quality was typically within guideline values at the reference site streams (Figure E-4).

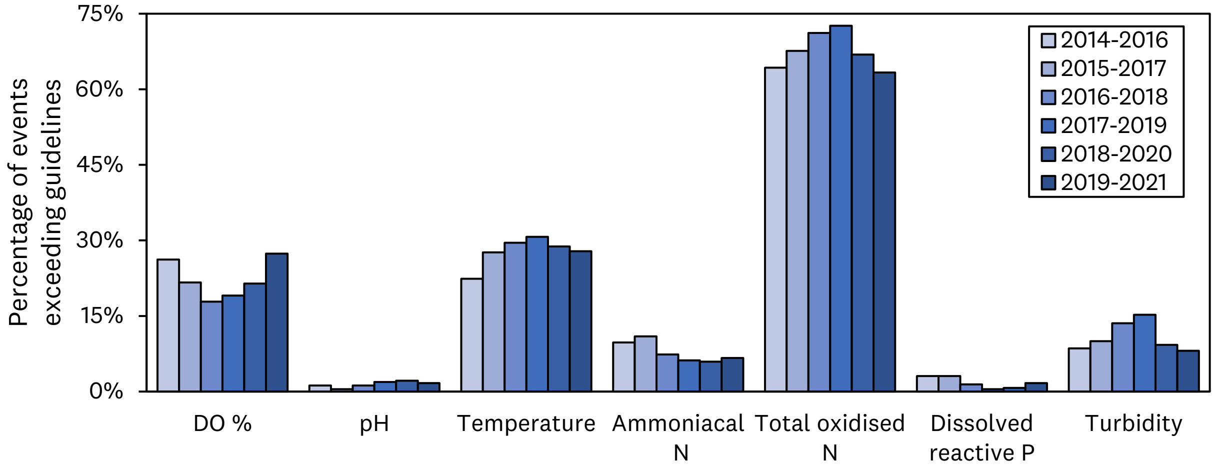

Figure E-3: Percentage of monthly median sampling events that exceeded the relevant water quality guideline for each three-year rolling period (n=35 sites).

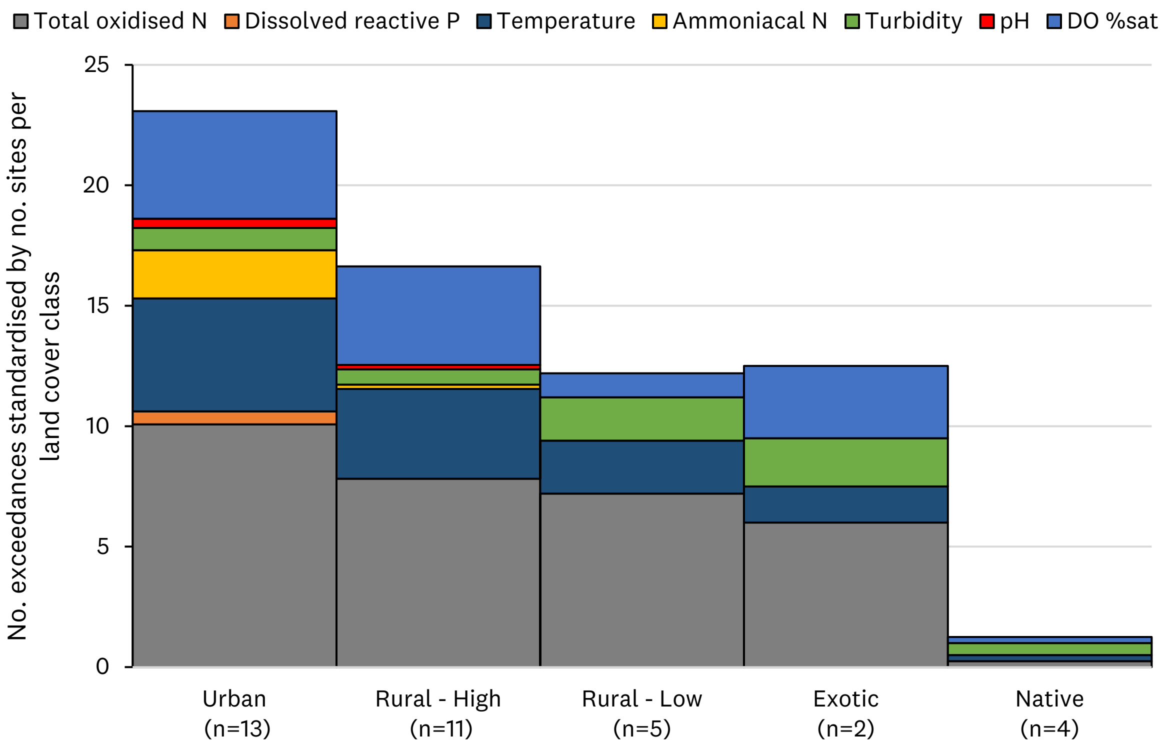

Figure E-4: Number of exceedances of the relevant guideline value standardised by number of sites per land cover class (2018-2021 median values).

Table E-3: River water quality index scores and classes based on rolling three-year median value across 2014 to 2020. Blue = Excellent, Green = Good, Yellow = Fair, Orange = Marginal, Red = Poor.

Land cover	Site name	WQI Score (2014-2016)	WQI Score (2015-2017)	WQI Score (2016-2018)	WQI Score (2017-2019)	WQI Score (2018-2020)	WQI Score (2019-2021)
Urban	Botany Creek	35.9	34.6	40.9	34.8	42	21.5
	Pakuranga Creek	32.4	39.2	33.3	33.1	33.8	40.3
	Ōtara Creek (South)	50.4	50.4	42.4	48.8	50	51.6
	Oakley Creek	55.8	56.2	53	57.1	53.8	54.2
	Omaru Creek	40.5	43.4	46.1	45.3	51	44.2
	Oteha River	52	52.4	53	58.5	51.7	50.8
	Avondale Stream	50.8	58.4	52.1	51.8	51.9	51.9
	Lucas Creek	62.1	61.8	61.4	61.4	63	62.6
	Puhinui Stream	65	57.5	49.6	64.2	52.8	67.0
	Ōtara Creek (East)	62.2	62.7	55.2	54.4	53.3	53.3
	Vaughan Stream	56.2	55.6	64.3	64.5	65.4	64.3
	Onetangi Stream	71.8	72.4	63.4	63	62.6	71.4
	Papakura Stream (Lower)	51.3	42.9	42.8	44.1	44.5	52.1
	Whangapouri Creek					41.5	42.0
	Whangamaire Stream	34.6	38.4	34.5	38.4	38.1	38.3
	Waitangi Stream	48.1	46.1	44.8	45.1	45.8	47.9
	Ngakoroa Stream	43.9	46.8	47	47.4	44.4	44.5
	Kumeu River	59.7	51.5	58.7	59.4	61.4	61.4
	Kaukapakapa River	47.5	46.8	62.7	63	71.7	63.7
	Papakura Stream (Upper)	49.5	40.9	41.1	49	52.2	56.3
	Rangitopuni River	66.4	63.3	64.3	63.2	64.6	63.8
	Makarau River	73.9	81.6	81.6	65.4	73.7	65.8
	Hoteo River (NIWA)	70.5	70.3	60.9	60.5	54.1	62.8
	Mahurangi River (Warkworth)	73.5	73.4	72.7	72.7	72.1	71.9
	Waiwera Stream	65.4	73	73.5	73.6	73.9	73.9
	Wairoa River	67.2	64.6	63.6	64.2	67	59.9
	Cascades Stream (Waiheke)	81.2	79.4	70.4	77.2	77.7	79.4
	Matakana River	83.1	83.1	75	74.9	66.7	66.7
	Okura Creek	45.9	61.6	62.3	61.2	61.2	60.9
	Opanuku Stream	74.3	82.1	80.9	81.1	82.1	82.3
Exotic	Riverhead Stream	65.8	66	66.1	74.2	74.2	74.4
	Mahurangi River (Forestry)	80.8	72.5	70.9	69	66.3	65.1
Native	Nukumea Stream	100	100	91.7	100	100.0	83.4
	Cascades Stream (Waitakere)	100	100	100	91.7	91.7	91.7
	Wairoa Tributary	100	91.7	91.7	82.6	91.3	83.4
	West Hoe Stream	100	100	91.7	100	100	100

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