RIMU Water Quality Scientists

Baseline State Evaluation: Ecosystem Health and Human Contact Values

NPS-FM 2020 Plan Change Implementation

October 2023, Version 1.2

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Auckland Council

Research and Evaluation Unit, RIMU

Version Control

Version	Authors	Date	Changes	Sign-off
V 1.0	Laura Buckthought, Ange Chaffe, Jane Groom, Rhian Ingley, Janine Kamke	June 2022	Initial draft	Coral Grant
V 1.1	Janine Kamke, Rhian Ingley	Dec 2022	Addition of Ecosystem Metabolism (Table 21) and Dissolved Oxygen (Table 17) attribute assessment for rivers but only from long term EM sites. Update of Ammonia (toxicity) for rivers and lakes based on change of attribute state metric from annual maximum to annual 95^{th}%ile In Dec amendment to NPS-FM 2020. Updated references to AC published FWMT reports. All ancillary data files also updated.	Coral Grant
V 1.2	Laura Buckthought, Rose Gregersen, Chris Drake, Janine Kamke, Jane Groom	October 2023	Update to new definition of baseline state for compulsory attributes and provision of additional data to inform expert panels incl. new lake sites, continuous DO, periphyton, ecosystem metabolism, and continuous temperature. Update figures. Included interim baseline states for attributes that do not fulfill minimum data requirements stated in the policy, in appendices. Update of copper and zinc based on latest guideline recommendations from Jenni Gadd (NIWA). General formatting and review.	Coral Grant

Recommended citation

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Note
This report supports Auckland Council's consultation on implementing the National Policy Statement for Freshwater Management in Auckland. The report is a working document and will be updated as other compulsory or regional values and attributes are incorporated into the work programme, and as any new information becomes available.

Approved for publication by:
Dr Jonathan Benge, Head of Research, Evaluation and Monitoring

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Contents

Glossary

Term	Definition
Attribute	A measurable characteristic or parameter (those presented here are numeric) which is used to determine the state of freshwater systems in relation to values.
Attribute band	A grading system used to describe the condition or performance of each attribute which supports the described narrative outcome (A – best, B, C, D/E – worst).
Baseline state	The state of compulsory attributes as of the **7 September 2017,** defined as an attribute band.
Compulsory attribute	Identified attributes which have standards aimed at maintaining current state (at minimum) or achieving improvement over time. Outlined in Appendix 2A and 2B of NPS-FM (2020) as amended December 2022.
Compulsory value	Values of ecosystem health and human contact for recreation.
Current state	The state of compulsory attributes at the time of reporting, generally based on data for the five-year period preceding assessment and defined as an attribute band.
Interim state	Used where the data available to assess state does not satisfy the outlined data requirements specified by each attribute table, or where data were not available for the 2017 baseline period.
National bottom line	A minimum standard set for some attributes. Councils must direct improvement above these thresholds.
Measured	Data collected as part of Auckland Council's State of the Environment monitoring.
Modelled	Data from national, regional, or local models.
River order	Measure of river size based on the number of input tributaries.
Value	Freshwater component which is important to the health of freshwater systems.

Acronyms	Definition
ASPM	Average Score Per Metric (for macroinvertebrates)
AUP	Auckland Unitary Plan (Operative in part)
DIN	Dissolved Inorganic Nitrogen
DRP	Dissolved Reactive Phosphorus
Fish IBI	Fish Index of Biotic Integrity
FMU	Freshwater Management Unit
LCDB5	Land Cover Database v5.0
MCI	Macroinvertebrate Community Index
MfE	Ministry for the Environment
NOF	National Objectives Framework
NPS-FM	National Policy Statement for Freshwater Management 2020
Pukekohe SVGA	Pukekohe Specified Vegetable Growing Area – as specified in Appendix 5 of the NPS-FM
QMCI	Quantitative Macroinvertebrate Community Index
SOE	State of the Environment

Introduction

The National Policy Statement for Freshwater Management 2020 (as amended February 2023, NPS-FM) forms part of the Government's *Essential Freshwater* reform package which outlines the statutory direction for freshwater management across New Zealand. The main aims of this reform package are to prevent further degradation of New Zealand's freshwater ecosystems, improve water quality within five years, and address past damage to return freshwaters to a healthy state within a generation (20-30 years). The NPS-FM is underpinned by the fundamental concept of Te Mana o te Wai. Te Mana o te Wai prioritises the health and well-being of freshwater systems over provisions for human health needs and other forms of utilisation. Te Mana o te Wai, and other components of the NPS-FM, are managed through a National Objectives Framework (NOF) which requires Auckland Council to **identify values** associated with waterbodies in the region and set ambitious but achievable **desired environmental outcomes and objectives**.

Under the NOF, the NPS-FM identifies four compulsory national values (Appendix 1A of the NPS-FM) and 22 accompanying compulsory national attributes (Appendix 2A and 2B of the NPS-FM) which must be managed to safeguard and promote the health of the region's lakes, and rivers and streams (collectively referred to as rivers henceforth). The four compulsory national values are:

- **Ecosystem health** – refers to the maintenance of ecological processes, such that the waterways support diverse communities of native plants and animals. This value includes five biological and physical components that are supported by 19 compulsory attributes (Table 1).
- **Human contact** – refers to the way people connect with the water through a range of recreational activities, such as swimming, boating, and fishing. This value is supported by three compulsory attributes (Table 1).
- **Threatened species** – refers to the maintenance of critical habitats and conditions required to sustain populations and enable the recovery of threatened native plants and animals.
- **Mahinga kai** – refers to native freshwater species that are traditionally used for food, tools, and other customary practices, as well as the places they are found and how they are gathered.

Elevated stream temperature and concentrations of several metals have been identified as key stressors in urban streams in Auckland. Regional attributes for temperature and bioavailable copper and zinc are also included in this iteration of understanding baseline state for our region. Auckland Council has identified these additional attributes which will sit under the value of ecosystem health for rivers.

The NPS-FM provides a long-term framework for achieving desired environmental outcomes through direct involvement with mana whenua, including the use of mātauranga Māori, and consultation with community and other regional stakeholders. To inform management decisions and enable constructive consultation it is important to **determine a starting point** or **baseline state** for each attribute. Establishing a baseline state provides context to understand the current condition of Auckland's freshwater environments and to identify where degradation or improvement has occurred. Baseline state information will also help to inform remediation and management targets that are relevant to the systems in question, enable progress towards such targets to be monitored, and inform choices about maintaining or improving the outcomes for our waterbodies. Furthermore, establishing baseline state is a prerequisite step required by the NPS-FM (clause 3.10) to set target attribute states that at least maintain, and in some cases improve, on baseline state.

The purpose of this report is to detail the baseline state of the compulsory attributes for **ecosystem health** and **human contact** values as detailed in Appendix 2A and 2B of the NPS-FM based on state of the environment monitoring data. Additional regional attributes pertaining to these values and the requirements outlined in clause 3.13 of the NPS-FM regarding nutrient management are also included.

No additional non-compulsory attributes have been assessed in this report for the compulsory values of threatened species and mahinga kai and the water quantity component of the compulsory ecosystem health value, while policy direction is sought on how these will best be applied in the Auckland region[1]. Baseline state for *Escherichia coli* (*E. coli*), an indicator of faecal pollution in relation to primary contact sites, and dissolved oxygen specifically below point sources, are not included in this report, and are being progressed by other parts of council's NPS-FM programme.

This report will support the consultation process and help Auckland Council to meet its obligations under clause 3.10 of the NPS-FM and inform implementation of the NOF process (clause 3.7 of the NPS-FM). The report is a working document and will be updated as other compulsory or regional values and attributes are incorporated into the work programme, and as any new information becomes available prior to plan notification. For a summary of the results reported here, please see the "Summary of out identified baseline state" section on page 47.

Reported values and attributes.

This report covers the compulsory values and 22 compulsory attributes as described in Appendix 2A and 2B of the NPS-FM, and the additional regional attributes of copper, zinc, and temperature (Table 1).

To achieve target attribute states in rivers for the periphyton attribute (Table 2 Appendix 2A of the NPS-FM) and all other attributes affected by nutrients, Auckland Council is required under NPS-FM clause 3.13 to set nutrient outcomes as instream concentrations, or loads, of nitrogen and phosphorus. To assist with considering how to implement clause 3.13 this report includes assessments of baseline state for both dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN). While DRP itself is listed as an action planning attribute under the NPS-FM Appendix 2B, DIN is not included via a compulsory attribute table. This report includes an assessment of DIN baseline state under the ecosystem health value based on an attribute table proposed by the Freshwater Science and Technical Advisory Group in 2019[2].

[1] It is expected that regional attributes developed to represent threatened species and mahinga kai values, and the water quantity ecosystem health component, will be included in later iterations of this report.
[2] Freshwater Science and Technical Advisory Group (2019). Report to the Minister for the Environment – June 2019.

Table 1: Compulsory national and proposed regional values and attributes for the Auckland region. * Indicates regional attributes

Ecosystem type		Biophysical component	Attributes	Limit/ Action plans
Rivers	Ecosystem health	Aquatic life	Macroinvertebrates (MCI/QMCI)	Action
			Macroinvertebrates (ASPM)	Action
			Fish (IBI)	Action
			Periphyton (eutrophication) – Interim	Action
		Water quality	Ammonia: toxicity to aquatic life	Limit
			Nitrate: toxicity to aquatic life	Limit
			Dissolved reactive phosphorus (DRP): eutrophication	Action/other criterion
			Dissolved inorganic nitrogen (DIN): eutrophication	Other criterion
			Dissolved oxygen	Action
			*Dissolved copper: toxicity to aquatic life	To be decided
			*Dissolved zinc: toxicity to aquatic life	To be decided
			*Temperature	Action
			Suspended fine sediment	Limit
		Physical habitat	Deposited sediment – data requirements not yet met	Action
		Ecosystem processes	Ecosystem metabolism (EM)	Action
		Water quantity	Not included to date[1]	
	Human contact		*Escherichia coli* (*E. coli*)	Limit
			E. coli (primary contact sites) – not reported here; input from **Healthy Waters** required.	Action
	Threatened species		Not included to date[1]	To be decided
	Mahinga kai		Not included to date[1]	To be decided
Lakes	Ecosystem health	Aquatic life	Phytoplankton (trophic state)	Limit
			Submerged plants (natives)	Action
			Submerged plants (invasive species)	Action
		Water quality	Total Nitrogen (trophic state)	Limit
			Total Phosphorus (trophic state)	Limit
			Ammonia (toxicity)	Limit
			Lake-bottom dissolved oxygen	Action
			Mid-hypolimnetic dissolved oxygen	Action
	Human contact		*Escherichia coli* (*E. coli*)	Limit
			E. coli (primary contact sites) – not reported here, needs input from **Healthy Waters**	Action
			Cyanobacteria (planktonic)	Limit
	Threatened species		Not included to date[1]	To be decided
	Mahinga kai		Not included to date[1]	To be decided

Determining baseline state

One aspect of the NPS-FM attribute assessment process is to use long term monitored sites to evaluate freshwater management outcomes through time, by reporting on changes to state at individual monitoring sites. The baseline states reported here provide a condition from which change in each attribute can be assessed. Furthermore, baseline states will allow Auckland Council to identify where **attributes fall below agreed national bottom lines** and **set thresholds from which to prevent further degradation**. Understanding the condition of each attribute will enable **target attribute states to be identified**.

Auckland Council will describe baseline states as of 7 September 2017 in accordance with the NPS-FM definition of baseline state. Recent clarifications on how to interpret the clauses defining baseline state in the NPS-FM has prompted a revision of the definition of baseline state for Auckland Council[3], with the following interpretations:

1. For all nationally compulsory attributes (those in Appendix 2A and 2B of the NPS-FM), baseline attribute state means using the best information available to estimate the state of the attribute on 7 September 2017; and
2. For any ‘other’ non-compulsory attributes identified for the region (e.g., zinc, copper, and temperature), baseline attribute state means the best state out of that estimated for 7 September 2017 and any more recent state estimated at the time Auckland Council decides to identify the ‘other’ attribute (under clause 3.10(1)(b) or (c)).

For nationally compulsory attributes at monitoring sites with no or insufficient data during the 2017 baseline period, baseline state can be inferred from partial monitoring data, modelled data, and/or by expert panel, or a combination of these options. The main body of this report contains NOF grades based on data considered statistically robust[4] for state assessment for the baseline period describing state at 7th of September 2017 (see Appendix B). For attributes/sites with insufficient or no monitoring data for the baseline period, any available state results for later assessment periods that may aid in future expert panel discussions are provided in Appendix C of this report. It is envisioned that once baselines state has been determined for these latter (Appendix C) sites an updated and final version of NOF baselines states will be released.

The **2017 baseline state** will be calculated using data from the hydrological years of 1 July 2012 to 30 June 2017, and in accordance with the guidelines provided in Appendix 2A and 2B of the NPS-FM which are typically based on the five-year median, five-year 95th percentile, or other metrics, unless otherwise stated (refer to Appendix B – Methods for more information). The baseline state for each attribute will be described using the attribute band grading system (Table 2) and national bottom lines outlined in the NPS-FM (and Ministry for the Environment (MfE) supporting guidance), where applicable. For a given lake or river, the **overall band outcome** will be the lowest scoring of the contributing metrics. Further detail on the numeric attribute values is provided in supplementary data files. As this report aims to provide a summary of regional baseline state and not act as a technical report, baseline state is reported here without measures of uncertainty.

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[3] Grant and Norton (2023). Memo: Identifying baseline state as part of implementing the NPS-FM National Objectives Framework. Auckland Council Internal Memo.
[4] McBride, G. (2016). *National Objectives Framework: Statistical considerations for design and assessment*. Prepared for the Ministry for the Environment. Report number: CR 250

Table 2: NPS-FM attribute bands used to describe baseline state.

	NPS-FM attribute band				
Ecosystem health	A	B	C	D	
	Conditions similar to natural reference state	Conditions slightly impacted, causing minor stress to native animal communities	Moderate impact on conditions and native animal communities	Conditions are highly impacted, causing severe losses to native animal communities	
Human contact	A	B	C	D	E
	Very low risk of infection	Low risk of infection	Moderate risk of infection	High risk of infection	Very high risk of infection

Data sources

Auckland Council has adhered to the NPS-FM data hierarchy when determining the best available information for baseline state, using measured data in the first instance, and drawing on alternate methods where knowledge gaps exist in accordance with NPS-FM clause 1.6. for setting baseline state.

The measured data used to calculate baseline state is from Auckland Council's State of the Environment (SOE) monitoring. Auckland Council undertakes SOE monitoring to meet core Resource Management Act 1991 reporting requirements[5] in managing the region's natural resources. The SOE monitoring covers a suite of NOF attributes and data collection follows nationally standardised protocols, which are repeatable and quality assured. Though not all waterways within the region are monitored, the SOE monitoring networks are considered representative of the region's waterways, covering a variety of river and lake types, catchment sizes, river orders, and land cover categories. Measured SOE data can be used to infer the state of waterbodies with similar characteristics (i.e., dominant land cover, river order) across the region which are not monitored. Freshwater fish have not been monitored by Auckland Council prior to 7 September 2017. Thus, to determine baseline state for the fish IBI attribute, the national fish index of biotic integrity (fish IBI) dataset[6] was used. Where measured data was not available for a particular attribute for the 2017 baseline state, an interim state has been described using data from more recently established SOE monitoring programmes implemented in response to the NPS-FM (interim states are presented in Appendix C). Interim grades will be assessed in future via freshwater expert conferencing and amended as needed.

There are critical assumptions and limitations of various data sources that should be considered when interpreting outputs, details of which are outlined in Appendix B – Methods.

[5] Under section 35 (2) of the Resource Management Act 1991 (RMA).

[6] MfE (2019). *Fish Index of Biotic Integrity in New Zealand Rivers 1999–2018*. Wellington: Ministry for the Environment. Data retrieved from https://data.mfe.govt.nz/table/104589-fish-index-of-biotic-integrity-1998-2018/webservices/.

Presentation of baseline state

Freshwater Management Units (FMUs) and land cover

The NPS-FM requires councils to split respective regions into **Freshwater Management Units (FMUs)** at the largest scale that recognises integrated freshwater management for whole catchments (ki uta ki tai) and is suitable for surface water accounting purposes. FMUs must be designated so that all waterbodies (including rivers, lakes, wetlands, and aquifers) and their catchments are encompassed by at least one FMU.

Auckland Council has identified three geographical FMUs: **Kaipara, Hauraki, and Manukau** (Figure 1). These FMUs encompass the river systems contributing to the region's three major coastal receiving environments; Kaipara Harbour, Manukau Harbour, and Hauraki Gulf; and have common management issues pertaining to each. The **Pukekohe Specified Vegetable Growing Area (SVGA)** within the Manukau and Hauraki FMUs has been identified as a part-FMU given the distinct management issues associated with this area[7]. **Lakes across the region, along with their contributing catchments, are presented separately from the three river FMUs** because they are not directly connected to the coast and are currently identified in two spatial management overlays (natural lakes and urban lakes) in the Auckland Unitary Plan (AUP).

While the available measured data is considered representative of some conditions within the corresponding FMUs, it is acknowledged that representation across land cover classes within FMUs may be a limiting factor. The river water quality and dissolved oxygen monitoring programmes have recently been reviewed and expanded to achieve better representation of land cover classes in all FMUs. New sites from these programmes will be included in future reporting as the minimum data reporting requirements for the new sites are not met yet.

Land use intensity is a primary driver of water quality and ecosystem health in rivers and lakes. The river and lake monitoring sites are categorised into five dominant land cover classes (Table 3) based on land use in the catchment area upstream of monitored river sites and surrounding lake sites. Sites within the Pukekohe SVGA part-FMU are categorised as a separate land cover category due to the unique catchment-derived nutrient pressures on these streams. **The baseline state of river attributes is presented for different land cover classes (as a proxy for land use intensity) within each proposed FMU. The baseline state for lake attributes is described per lake.** Further information on land cover classes and land cover delineation is outlined in Appendix B – Methods.

[7] The boundaries of the area are defined in Appendix 5 of the NPS-FM, and the identified area overlaps the jurisdictional boundary with Waikato Regional Council.

Table 3: Land cover classes used to describe differences in the state of ecosystem and human contact attributes for rivers and lakes.

Land Cover Class	Definition
Urban	More than 7% urban land cover in the upstream/surrounding catchment. This reflects the disproportionate influence of urban land use on water quality and ecological health. Some ‘urban’ waterways also have a high proportion of rural land use within the catchment.
Rural – High	The majority of Auckland is in rural land cover. Two different classes are included to indicate there is a gradient in pressure on the environment from different intensities of rural use. Rural – high has less than 50% exotic or native forestry cover remaining, while rural – low has more than 50% of the upstream/surrounding catchment that retains some forest or scrub.
Rural – Low	
Exotic	More than 80% of the upstream/surrounding catchment within exotic forestry.
Native	These sites have 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 on the environment though they are not necessarily ‘pristine’.

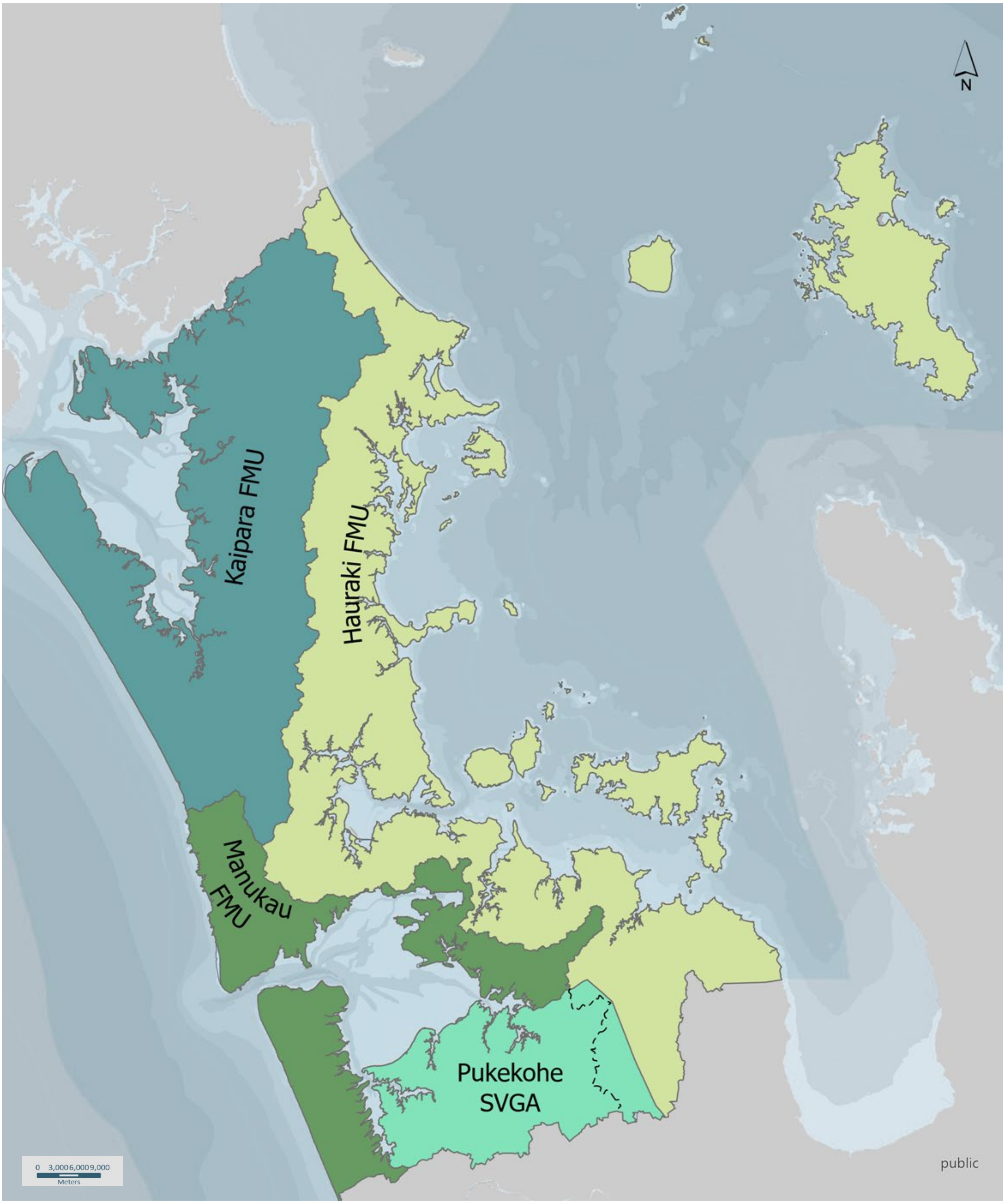

Figure 1: Freshwater Management Units for rivers in the Auckland region. The dotted line in the Pukekohe SVGA (Specified Vegetable Growing Area) part-FMU denotes the border between the Hauraki and Manukau FMUs.

Hauraki FMU

The Hauraki FMU encompasses a land area of approximately 2182 km^2 and extends from Te Arai in the north, down the east coast to the region's southern boundary in the Hunua Ranges (Figure 1). The Hauraki FMU includes central areas surrounding the Waitematā Harbour, as well as regional islands within the Hauraki Gulf (e.g., Waiheke Island, Aotea/Great Barrier Island, and smaller islands).

Like much of the region, rivers in the Hauraki FMU are typically low gradient (i.e., very little drop in elevation) in character, with high gradient rivers generally restricted to areas in the Hunua Ranges and Aotea/Great Barrier Island. The Hauraki FMU includes rivers of varying size and substrate types, including first-order rivers and the region's second largest river, the Wairoa River (fifth order at its mouth, catchment area of 260 km^2). All rivers drain to the Hauraki Gulf, either directly via the coast or from contributing harbours, such as the Waitematā and Mahurangi.

The Hauraki FMU is comprised of 37% rural land cover, predominantly consisting of grazed pasture, 35% native forest or scrub, 8% exotic forest, and 20% urban (Figure 2). The Hauraki FMU has the highest proportion of urban land cover of the three proposed FMUs. The urban areas are concentrated in highly populated areas in central parts of the region, from Albany and through the suburbs of west and east Auckland.

Kaipara FMU

The Kaipara FMU is in the north-west of the Auckland region, extending from the region's northern boundary down to the Muriwai and Waitakere townships in the south-west (Figure 1) and covers a land area of approximately 1611 km^2. Most rivers in the Kaipara FMU drain to the Kaipara Harbour; however, a small proportion also drain directly to the Tasman Sea from the coast between Muriwai and Kaipara Harbour's South Head.

The Kaipara FMU is generally comprised of low gradient rivers, though high gradient rivers are present in areas of higher elevation, such as Dome Valley and Atuanui Scenic Reserve (Mt Auckland). The rivers range from small, first-order rivers with catchments of less than 1 km^2 to larger, higher order rivers, including Auckland's largest, the Hoteo River, which is seventh order at its mouth and has a catchment area of approximately 405 km^2.

Land cover within the Kaipara FMU is comprised of 62% rural, which primarily includes grazing pasture and some cropland, 16% native forest or scrub, 20% exotic forest, and 2% urban (Figure 2). The urban land cover is concentrated around urban centres, such as Kumeu and Helensville.

Manukau FMU

The Manukau FMU encompasses approximately 1106 km^2, is in the south-west of the region, spans from Onehunga in the north down to the region's south-western boundary and includes the Waitākere Ranges south of Muriwai (Figure 1).

Rivers in the Manukau FMU are predominantly low gradient, with high gradient rivers mostly confined to the Waitākere Ranges. Most of the rivers within the Manukau FMU are relatively small (first to third order).

The Manukau FMU is comprised of 59% rural land cover, 24% native forest or scrub, 2% exotic forest, and 15% urban (Figure 2). Though the rural areas are predominantly grazed pasture, the Manukau FMU has the highest proportion of horticultural cropland (7%) of the proposed FMUs. Much of the native forest in the Manukau FMU is located within the Waitākere Ranges Regional Park and the urban areas are concentrated in south Auckland (12% of the FMU) and in Pukekohe (3% of the FMU).

The Pukekohe SVGA covers 41% of the Manukau FMU[8]. This part-FMU is almost entirely rural and includes most of the horticultural land within the FMU, which amounts to 13% of the SVGA area (Figure 2).

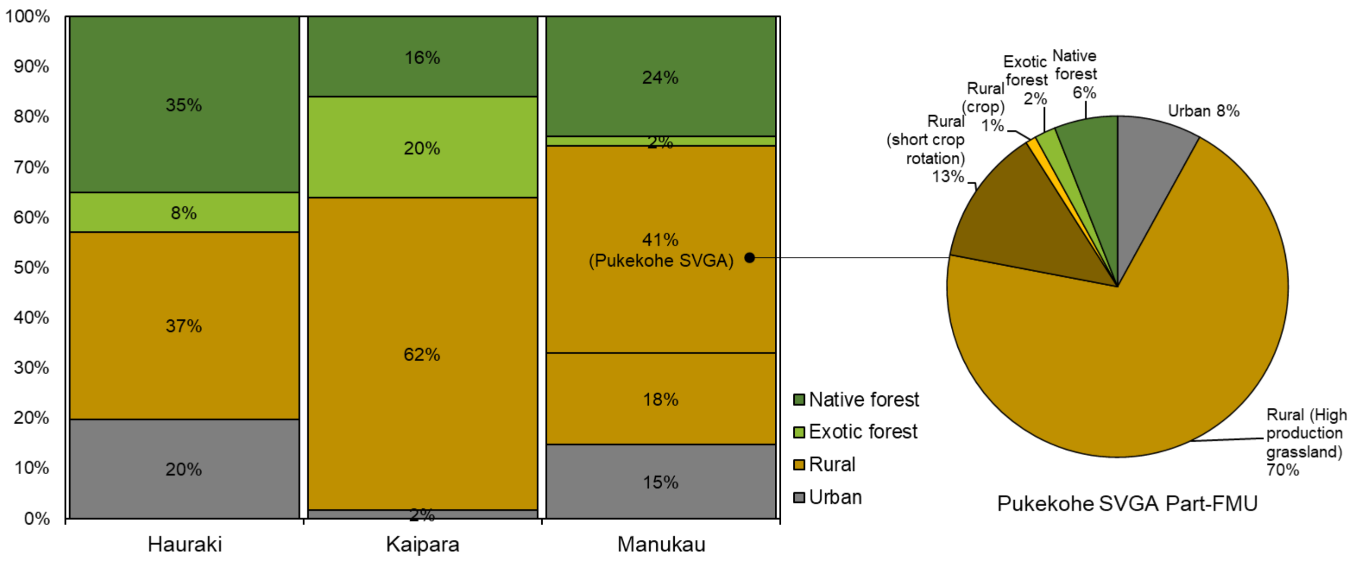

Figure 2: Dominant land cover within the Hauraki, Kaipara, Manukau, and Pukekohe SVGA Part Freshwater Management Units, based on 2018 LCDB5 data.

Lakes

Lakes across the region, along with their contributing catchments, are presented as a part-FMU, separately from the three river FMUs, as they are not directly connected to the coast. There are 17 lakes identified in the current AUP, split into overlays of management focused on 'urban' and 'natural' lakes. Thirteen of the 17 lakes in the AUP have been monitored monthly since 2020[9].

Results are presented for five lakes that have measured data available for the 2017 baseline state. The five lakes presented include volcanic and dune lakes[10], and cover each broad land cover class (Table 3; Figure 3); urban (Lake Pupuke), rural high (Lake Kuwakatai), rural low (Lake Rototoa), exotic forest (Lake Tomorata), and native forest (Lake Wainamu). The two lakes that are classed as predominantly rural (low

[8] The boundaries of the Pukekohe Specified Vegetable Growing Area (SVGA) as described in Appendix 5 of the NPS-FM do not follow the river catchment or FMU boundaries and this extends across to the Hauraki FMU (13% of the designated area), however for the purposes of this assessment the Pukekohe SVGA is discussed in relation to the area within the Manukau FMU only.
[9] From 2020, fifteen of these seventeen lakes are monitored monthly, except for Lake Paekawau and Western Springs not currently included in the monitoring programme. Lakes Pehiakura Big and Pehiakura Small have been monitored inconsistently since 2020 therefore are not reported on here.
[10] Note that the Auckland region does not have any lakes that are intermittently open to the sea, therefore there is no requirement for separating data for analysis of closed periods and open periods for the attributes: phytoplankton (Table 1), Total Nitrogen (Table 3) and Total Phosphorus (Table 4) in Appendix 2A of the NPS-FM.

vs high) land cover in the catchment, also have between 40-65% of the catchment comprised of both exotic and native forest.

Lake Pupuke is one of two lakes in the AUP 'Urban Lakes' management area overlay. It is a volcanic lake that is fed by precipitation and groundwater and has no input from rivers. Lake Pupuke is surrounded by a well-established urban catchment and is valued for its open-space, recreational and amenity values.

The four other lakes are in the AUP 'Natural Lakes' overlay which refers to dune lakes predominantly located in rural areas of the region. These lakes are in three main areas: South Kaipara Peninsula, north-east coast inland of Pākiri Beach, and Āwhitu Peninsula. These lakes are typically fed by small streams, groundwater, and overland flows from the surrounding catchment. The lakes have varying water quality, quantity, ecological values, recreational values, and land cover within their catchments.

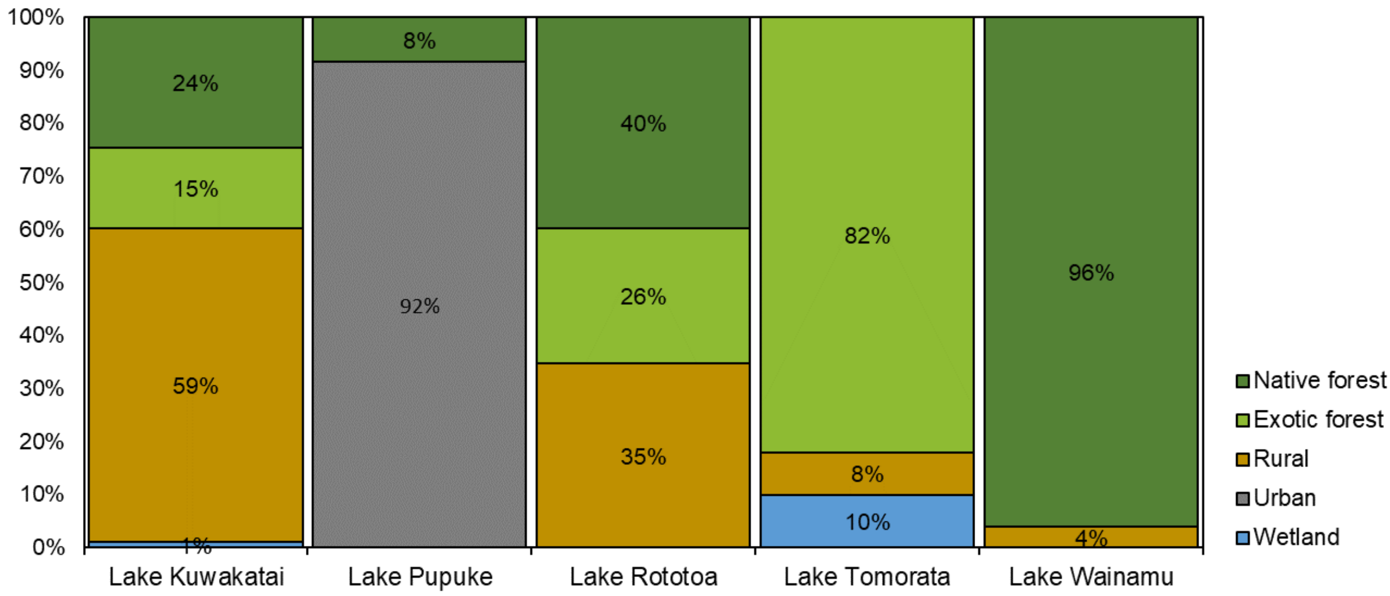

Figure 3: Breakdown of catchment land cover for each lake, based on 2018 LCDB5 medium level class data.

River Baseline State

Each compulsory attribute is described within the context of its effect on ecological communities and differences between bands. Results are presented as the proportion of monitoring sites in each attribute band for each land cover category within each FMU for the 2017 baseline state. Results are based on monitored information unless otherwise stated.

Compulsory value: Ecosystem health

The ecosystem health compulsory value includes five components, four of which have compulsory attributes: aquatic life, water quality, habitat, and ecological processes. The compulsory attributes for these components support our understanding of ecosystem health and refer to the maintenance of ecological processes to support diverse communities of freshwater native plants and animals.

The aquatic life component refers to the types and amounts of freshwater plants and animals present in Auckland's rivers. The aquatic life component designates periphyton, and fish and macroinvertebrate communities as outcome attributes for management. These aquatic life attributes are influenced by water quality, water quantity, physical habitat, and ecological processes. The compulsory attributes for water quality, habitat, and ecological processes focus on key impacts to ecological integrity. Further, regional attributes consider the toxic effects of metal contaminants and elevated stream summer temperature.

Aquatic life – Macroinvertebrates

Macroinvertebrates are small animals, such as insects, larvae, and snails, which are typically visible with the naked eye and commonly found living on or under rocks, logs, aquatic vegetation, and organic debris. Macroinvertebrates respond differently to changes in water quality and quantity **and are a common tool for assessing the ecological health of wadeable rivers**[11]. The NPS-FM has three macroinvertebrate community scoring metrics split into two attributes (Table 14 and 15 of the NPS-FM):

- Macroinvertebrate Community Index[12] (MCI) and Quantitative Macroinvertebrate Community Index[12] (QMCI) – these metrics are calculated by assessing the types (and numbers for QMCI) of macroinvertebrate taxa present.
- Average Score Per Metric[13] (ASPM) – this metric assesses the types and number of specific macroinvertebrate taxa groups which are known to be sensitive to poor water quality and incorporates MCI to produce a single score.

Under the NPS-FM, MCI and QMCI (Attribute Table 14, Appendix 2B of the NPS-FM) are used to assess the effects of organic pollution (such as pesticides and industrial chemicals) and/or nutrient enrichment on the composition of macroinvertebrate communities. The overall band outcome for the MCI/QMCI is set at the lowest scoring of the two attributes. The ASPM (Attribute Table 15, Appendix 2B of the NPS-FM) is used to assess the ability of Auckland's wadeable rivers to support and maintain diverse macroinvertebrate communities (referred to as ecological integrity). **For the two macroinvertebrate attributes (MCI/QMCI and ASPM) the national bottom line is set below the lower band C threshold.**

Results

Measured regional data for the 2017 baseline period indicates that **instream macroinvertebrate communities and ecological integrity in heavily modified urban and rural high intensity catchments are severely altered by land use practices**. For rivers in urban and rural high land cover classes:

- 96% (n = 22) of sites failed national bottom line for the MCI/QMCI and ASPM attributes across the FMUs (Figure 4).
- The single site that did not fail the national bottom line is an urban site located in the Hauraki FMU (Figure 4).

The ecological integrity of rivers in urban and high intensity rural catchments across all FMUs, including biological communities, are severely impaired, indicating that land use activities and associated river habitat and flow modification[14] are adversely impacting instream habitat and riparian vegetation quality, and water quality.

[11] Wadeable rivers are typically described as locations where ≥90% of the sample reach is ≤0.6m deep, with a mean wetted width of ≤12m. These are typically first to third-order rivers which account for ~91% of the region's rivers.
[12] Stark, J. (1985). *A macroinvertebrate community index of water quality for stony streams*. Water and Soil Miscellaneous Publication No. 87. Wellington: National Water and Soil Conservation Authority.
[13] Collier, K.J. (2008). Average score per metric: an alternative metric aggregation method for assessing wadeable stream health. *New Zealand Journal of Marine and Freshwater Research*, 42 (4), pp. 367-378.
[14] Storey R, Brierley G, Clapcott J, Collier K, Kilroy C, Franklin P, Moorhouse C and Wells R (2013). *Ecological responses to urban stormwater hydrology*. Prepared by National Institute of Water and Atmospheric Research for Auckland Council. Auckland Council technical report, TR2013/033

Rivers within forested catchments generally have healthier macroinvertebrate communities and ecological integrity across the FMUs. For rivers in native forested catchments:

- 70% (n = 7) and 100% (n = 10) of sites scored above the national bottom line for MCI/QMCI and ASPM respectively (Figure 4).
- The sites that failed the national bottom line for MCI/QMCI (n = 3) are distributed across all FMUs (Figure 4).
- Two sites in the Manukau FMU graded in attribute band A for the ASPM attribute.

For rivers in exotic (production) forested catchments (Hauraki and Kaipara FMUs only):

- 67% (n = 2) of sites scored above the national bottom line for MCI/QMCI and ASPM (Figure 4).
- The site that failed the national bottom line for MCI/QMCI is in the Hauraki FMU (Figure 4).
- The site that failed the national bottom line for ASPM is in the Kaipara FMU (Figure 4).
- One site in the Hauraki FMU graded in attribute band A for both MCI/QMCI and ASPM.

Rivers in native forested catchments typically support diverse biological communities and are characterised by diverse instream habitat, intact riparian margin vegetation and little to no human-induced disturbance. While rivers in exotic forested catchments graded relatively highly for macroinvertebrate attributes compared to those in urban and rural catchments, the data presented here do not account for the impacts of production forestry harvesting on stream macroinvertebrate communities[15] that have or will occur outside of the baseline state period.

There is insufficient data (measured or otherwise) to describe the baseline state of macroinvertebrate attribute metrics in the rural low intensity land cover class within the Kaipara and Manukau FMUs.

See Appendix C Figure 18 for baseline state assessment including interim grades for sites that were added to Auckland Council's SOE network after 2017 or that had insufficient data over the baseline period. Data used in interim baseline state assessments for macroinvertebrates include data from up to 2021, inclusive.

[15] Baillie, B. R., Collier, K. J., and Nagels, J. (2005). Effects of forest harvesting and woody debris removal on two Northland streams, *New Zealand. New Zealand Journal of Marine and Freshwater Research*, 39 (1), 1-15.
Death, R. G., Baillie, B., and Fransen, P. (2003). Effect of *Pinus radiata* logging on stream invertebrate communities in Hawke's Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 37 (3), 507-520.

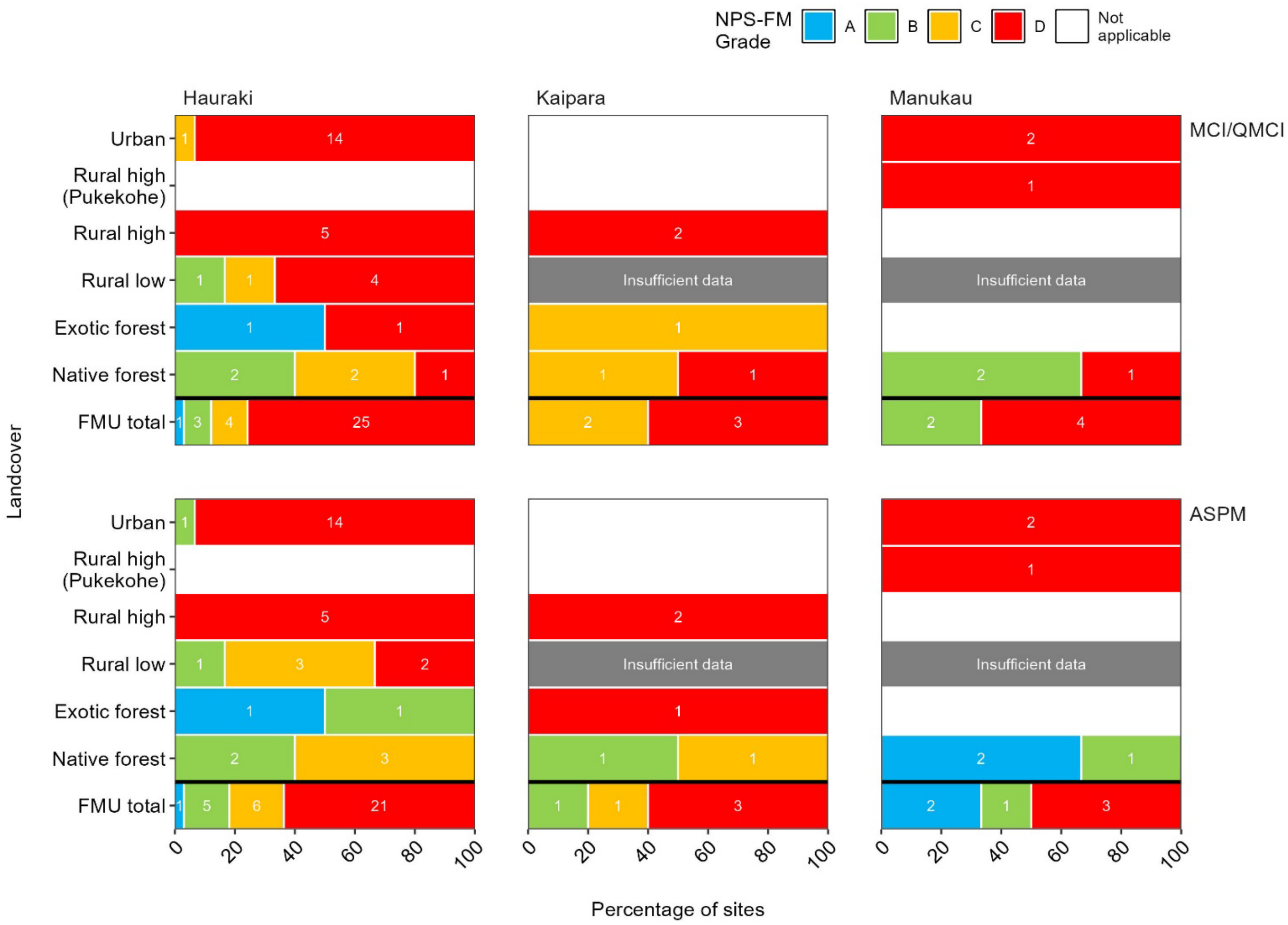

Figure 4: Grading for the MCI/QMCI and ASPM macroinvertebrate attributes for aquatic life in wadeable rivers, across all dominant land cover classes and FMUs over the baseline period (2013-2017). Overall grade displayed. The national bottom line for these attributes is the lower threshold of band C (band D). The number in bars is the number of sites.

Aquatic life – Fish

The Auckland region supports sixteen native freshwater fish species, many of which are at risk or threatened[16]. Freshwater fish communities are influenced by catchment land cover type, instream habitat, water quality, fishing pressures, and migratory access. Diverse fish communities generally indicate a healthy river system.

The NPS-FM uses the fish IBI[17] (Attribute Table 13, Appendix 2B of the NPS-FM) to assess the condition of fish communities in wadeable rivers, and as a measure of habitat quality and migratory access. The freshwater fish-IBI contrasts with a macroinvertebrate index assessment of river health which is primarily influenced by site-specific proximal habitat factors and upstream catchment influences, to also include downstream factors. There is currently no national bottom line for the fish-IBI attribute.

Results

Measured fish-IBI score data (national and regional) indicates that there is a decline in freshwater fish community health with increased land cover modification (Figure 5).

- Sites in catchments dominated by native forest had the highest percentage of sites graded in attribute band A for the fish IBI at 73% (n = 62) (Hauraki and Manukau FMUs only), followed by 61% (n = 19) in exotic forestry (Hauraki and Kaipara FMUs only), 52% (n = 60) in rural (all FMUs, and including the Pukekohe part-FMU), and 39% (n = 38) in urban (Hauraki and Manukau FMUs only) (Figure 5).

Urban and rural[18] catchments had higher percentages of sites graded in C and D bands than sites in native and exotic forestry.

- Urban catchments (in the Hauraki and Manukau FMUs only) had 46% (n = 45) of sites graded in attribute bands C and D followed by 26% (n = 30) in rural catchments, 9% (n = 8) in native forestry, and 3% (n = 1) in exotic forestry (present in the Hauraki and Kaipara FMUs only) (Figure 5).
- The Manukau FMU had the highest proportion of sites graded in attribute bands C and D, at 29% (n = 21) across all landcover types. The Hauraki and Kaipara FMUs had 24% (n = 57) and 25% (n = 6) of sites graded in attribute bands C and D across all landcover types, respectively (Figure 5).

The lower health (or integrity) of native fish communities in urban and rural areas is likely a result of several interrelated and cumulative pressures. In addition to migration barriers (natural and engineered), pressures include the presence of non-native and pest fish species, lack of forest cover and shading, sediment loading, and nutrient enrichment which all act to degrade habitat and place stress on native fish species.

[16] Stoffels, R. (2022). New Zealand Freshwater Fish Database (extended). The National Institute of Water and Atmospheric Research (NIWA). Sampling event dataset https://doi.org/10.15468/jbpw92. Dunn, N.R., Allibone, R.M., Closs, G.P., Crow, S.K., David, B.O., Goodman, J.M., Griffiths, M., Jack, D.C., Ling, N., Waters, J.M., Rolfe, J.R. (2018). *Conservation status of New Zealand freshwater fishes, 2017*. New Zealand Threat Classification Series 24. Wellington: Department of Conservation.
[17] Joy, M.K., and Death, R.G. (2004). Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. *Environmental Management*, 34 (3), 415-428.
[18] Due to the resolution of national-level data, rurally classified data could not be refined into the pre-described high and low impact land cover classes. As a result, rural fish IBI scores are presented in single class.

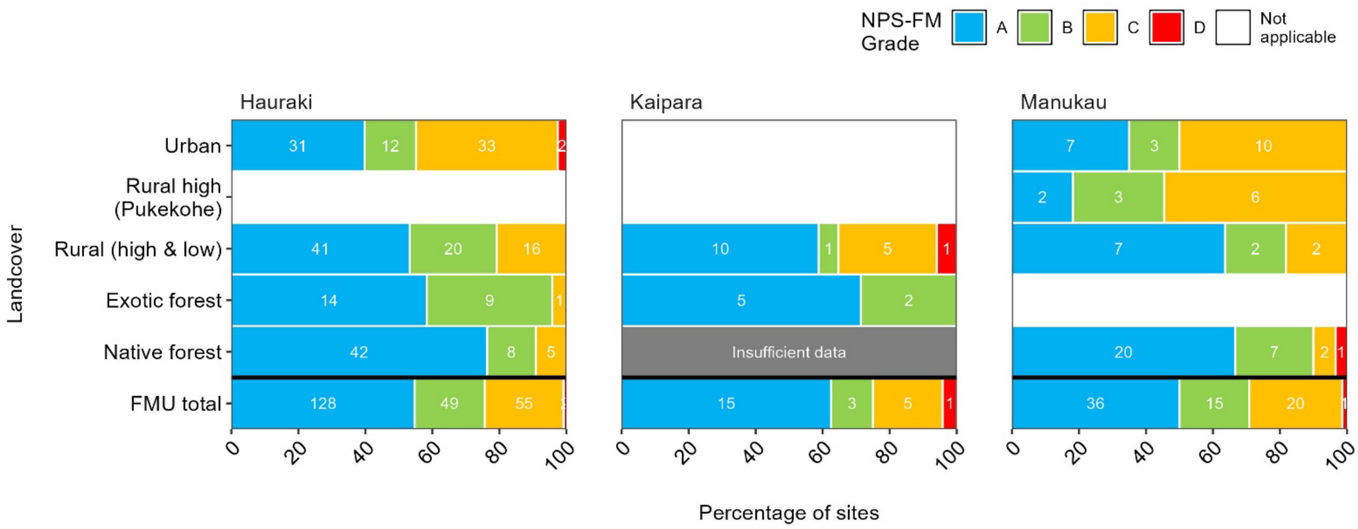

Figure 5: Grading for the fish-IBI attribute for aquatic life in wadeable rivers, across four dominant land cover classes and FMUs. There is no national bottom line for the fish-IBI attribute. Numbers in bars are the number of sites.

Aquatic life – Periphyton: eutrophication

Periphyton is a combination of microalgae and bacteria which grow on riverbed surfaces, providing habitat and food sources for macroinvertebrates and fish. Although periphyton naturally occurs in rivers and streams, excessive growth can negatively impact river habitat and function, particularly during periods of consistent low flow.

The periphyton attribute (Table 2 – Appendix 2A of the NPS-FM) is assessed by measuring levels of chlorophyll-*a* in hard-bottom rivers. **The national bottom line is set below band C.** There is currently no regional data (either measured or modelled) to describe the state of the periphyton attribute for the 2017 baseline period. Direct monitoring of periphyton was established in 2020 and **interim grades, based on data from years 2020 to 2023, are available for some land cover classes across the region in Appendix C**. Further review and expert conferencing are required prior to these grades being confirmed as baseline state.

Water quality – Nutrients: toxicity to aquatic life

At high concentrations, plant nutrients nitrate and ammonia can have direct impacts on instream macroinvertebrate and fish communities through toxic effects.

The NPS-FM nitrate and ammonia toxicity attributes (Table 5 and Table 6 in Appendix 2A of the NPS-FM) are based on managing the **risk of long-term exposure (chronic) toxicity to river fauna. The national bottom line is set below band B** indicating that both bands C and D may have unacceptable effects on the growth and survival of '*sensitive*' species such as some freshwater fish.

Results

Nitrate toxicity effects may be occurring in waterways in the Pukekohe SVGA part-FMU.

- Two out of three river sites monitored in this area failed the national bottom line (Figure 6).
- The third site graded very close to the threshold between bands B and C and thus is also likely at risk (see Supplementary data).

As this assessment is driven by the median metric it demonstrates that nitrate levels are likely elevated in the rivers in the Pukekohe SVGA at least half of the time.

No other sites show evidence of nitrate toxicity effects.

- All other monitored sites across the three FMUs graded in bands A and B for nitrate toxicity (Figure 6).

Ammonia toxicity effects may be occurring in some urban waterways.

- One monitored urban site (in the Hauraki FMU) failed the national bottom line for chronic ammonia toxicity (band C, Figure 6).

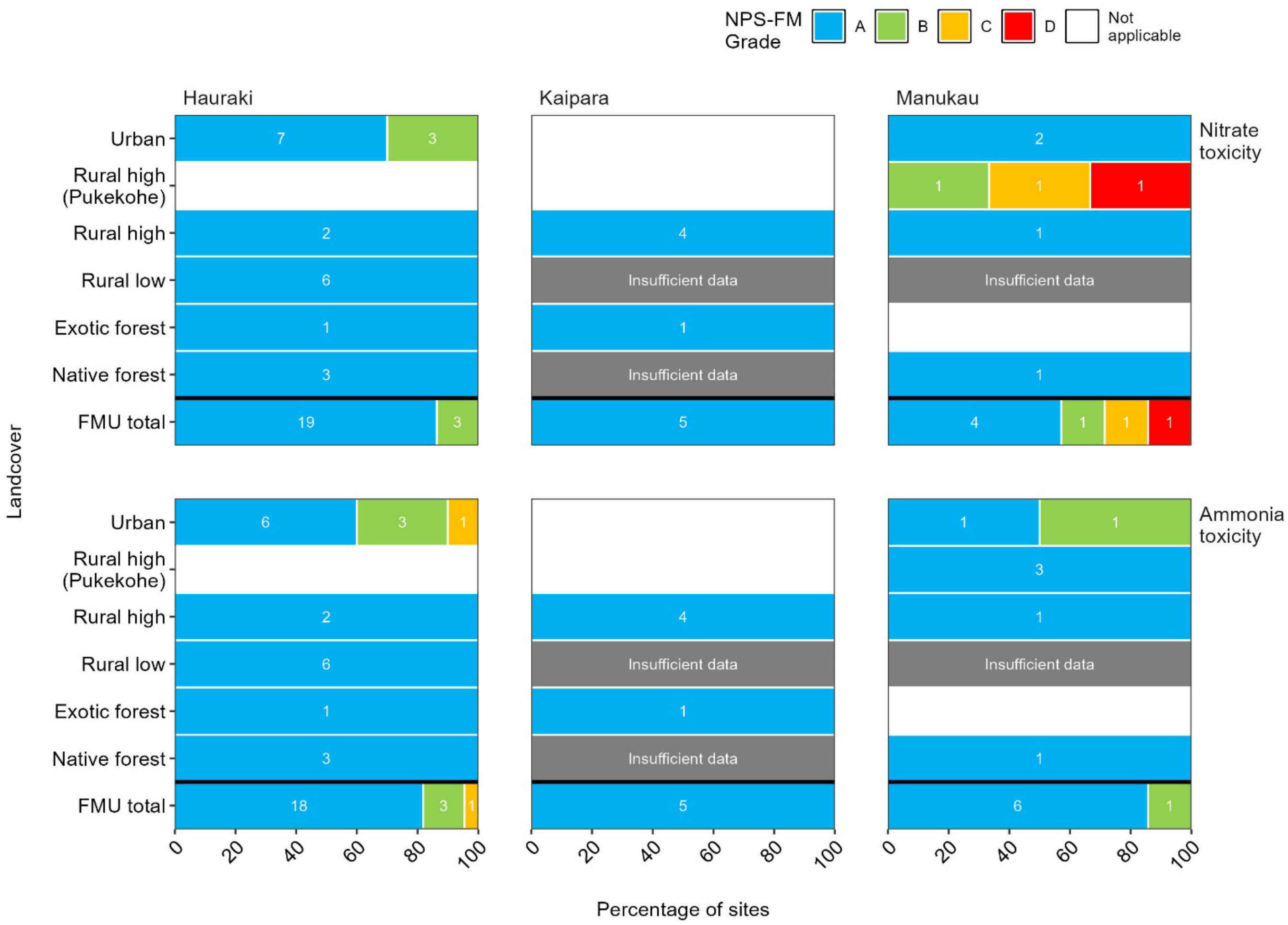

Figure 6: Grading for the Nitrate and Ammonia toxicity attributes for water quality in all rivers, across five dominant land cover classes and FMUs. Overall grade displayed. Bands C and D are below the national bottom line. Numbers in bars are the number of sites.

Water quality – Nutrient instream criteria: eutrophication

Eutrophication is characterised by excessive plant and algal growth from elevated concentrations of instream nutrients. **Dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN)** are readily plant available forms of nutrients and thus stimulate the growth of plants and algae. The NPS-FM makes it clear that toxicity bottom-lines for nutrients in rivers are insufficient on their own to provide for ecosystem health.

There is currently **no national bottom line for DRP** to manage excessive periphyton growth or other nutrient affected attributes[19]. MfE considered that one bottom line that applies nationally risked being ineffective and inequitable because DRP shows significant natural variation in different river types. Further, several river types under natural reference conditions were modelled to have states below the A band[20]. Based on the River Environment Classifications included in the model, rivers in the Auckland Region can naturally grade between A and C band.

Furthermore, the proposed attribute table for DIN concentrations was not included in the 2020 NPS-FM and strengthening the nitrate and ammonia NBLs to protect 95 per cent of species was introduced as way to improve the protection of soft bottom rivers[19]. However, DIN has been included here for context as it may be important to manage and define nutrient targets and exceedance criteria for both forms of nutrients to achieve target attribute states for other attributes affected by nutrients, as set out in clause 3.13 of the NPS-FM. Attribute bands for DIN were assigned based on an attribute table proposed by the Freshwater Science and Technical Advisory Group in 2019[21]. The 2019 proposed national bottom line for DIN is the lower band C.

Results

Elevated DRP concentrations occur across the region's rivers.

- No monitored sites were within band A for DRP (Figure 7).
- 93% (n = 26) of sites across urban and rural landcover catchments scored in bands C and D across all FMUs (Figure 7).
- Native and exotic forested rivers generally had lower concentrations of DRP than in rural and urban waterways with 50% (n = 2) and 100% (n = 2) of sites scoring in band B respectively. However, high concentrations (band D) were observed in two sites with 100% native forest catchments in the Hauraki (Hunua Ranges) and Manukau (Waitākere Ranges) FMUs (Figure 7).
  It is likely that naturally high background levels of P in the underlying geology of these native forest areas is responsible for the high concentrations of DRP, however further investigation is required.
- Lower concentrations of DRP were observed in the soft volcanic waterways[22] in the Pukekohe SVGA (67% (n = 2) of sites in band B),

[19] Ministry for the Environment. (2021) *A guide to setting instream nutrient concentrations under clause 3.13 of the National Policy Statement for Freshwater Management 2020*. Wellington: Ministry for the Environment.
[20] Ministry for the Environment (2020). *Regulatory Impact Analysis, Action for Healthy Waterways, Part 2; Detailed analysis. 6 May 2020*. Wellington: Ministry for the Environment.
[21] Freshwater Science and Technical Advisory Group (2019). Report to the Minister for the Environment – June 2019.
[22] This is contrary to expectations as rivers in landscapes with soft sediment, and volcanic geologies are considered more likely to be naturally enriched with nutrients, particularly phosphorus (MfE, 2021).

Elevated DIN concentrations were primarily localised to rural sites in the Manukau FMU (including the Pukekohe SVGA), and some urban sites (Figure 7).

- 100% (n = 6) of rural sites in the Manukau FMU (including those in the Pukekohe SVGA part FMU) (n = 1) graded band C or D for DIN. Sites that graded band D were all within the Pukekohe SVGA part FMU (Figure 7).
- 40% of urban sites in the Hauraki FMU (n = 4) graded bands C and D, and 100% of urban sites in the Manukau FMU (n = 2) graded in band C for DIN (Figure 7).
- All other sites graded in bands A and B for DIN (Figure 7).

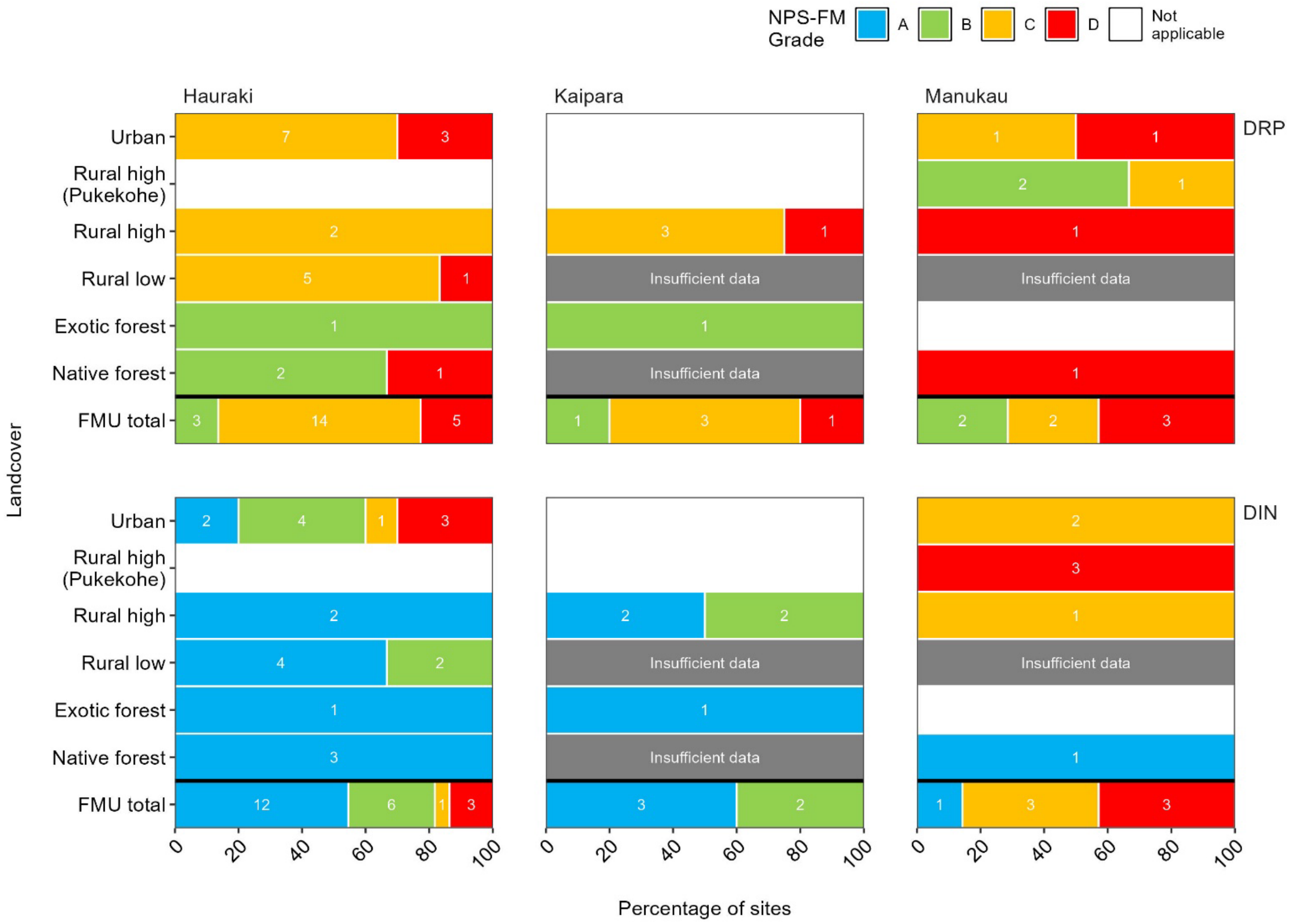

Figure 7: Grading for the Dissolved Reactive Phosphorus (DRP) and draft proposed grading for Dissolved Inorganic Nitrogen (DIN) attributes for water quality in all rivers, across five dominant land cover classes and FMUs. Overall grade displayed. There is no national bottom line for DRP. The proposed bottom line for DIN is below band C. Numbers in bars are the number of sites.

Water quality – Dissolved oxygen

Dissolved oxygen (DO) is essential for most forms of life. Low levels can impact the growth and reproductive success of fish and macroinvertebrates, and very low levels can be lethal. Minimum instream DO concentrations typically occur in summer and are associated with high plant and algae growth, decaying organic matter, low flows, and increased water temperature. The lowest DO levels usually occur near dawn resulting from plant respiration overnight. Thus, continuous monitoring is essential to capture the seasonal and daily cycles of instream dissolved oxygen.

A national bottom line of the lower band C applies to DO (Attribute Table 17 – Appendix 2B of the NPS-FM). Auckland Council has historically undertaken DO monitoring at a subset of sites primarily in larger rural rivers. Monitoring data for the baseline period was analysed for 12 sites[23], with 11 having sufficient data for baseline state reporting. See Appendix C for interim state assessments.

Results

There is evidence that rivers in urban, rural-high, and Pukekohe catchments experience more DO stress on aquatic organisms than those with less intensive land use (native forest and rural-low).

- 75% (n = 6) of sites in urban and rural high catchments failed the national bottom line for DO (Figure 8). Sites failing the bottom line were present in all FMUs.
- The three sites in native forest and rural-low catchments (all in the Hauraki FMU) were at or above the national bottom line (Figure 8).

No sites were in the A band for DO (Figure 8).

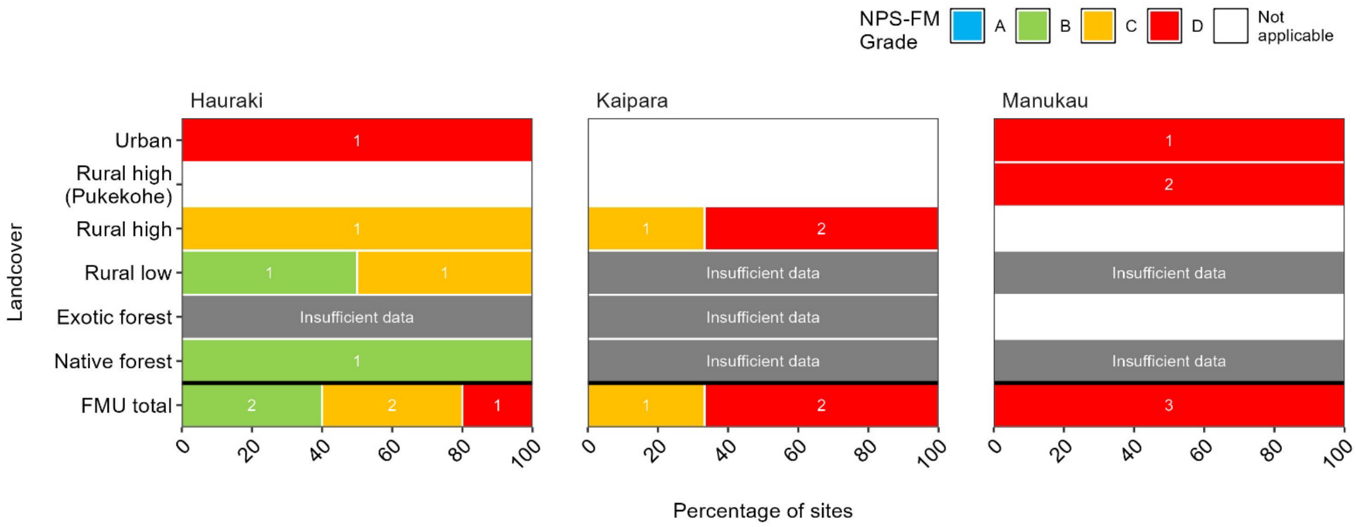

Figure 8: Grading for the Dissolved oxygen (DO) attribute across five dominant land cover classes and FMUs over the baseline period. Overall grade displayed. Sites in D band are below the national bottom line. Numbers in bars are the number of sites.

[23] Casanovas, P. et al., (2022). *Dissolved oxygen and ecosystem metabolism in Auckland rivers 2004-2020. State of the environment reporting*. Auckland Council technical report, TR2022/18. Prepared by the Cawthron Institute for Auckland Council.

Water quality – Trace metal toxicity to aquatic life (regional attribute)

Copper and zinc can have toxic effects on instream communities at high concentrations and are key contaminants in urban and rural rivers. Copper and zinc are not included as national attributes in the NPS-FM and have been included as additional attributes for Auckland due to the intensity of some activities that produce copper and zinc (e.g., vehicle use and building materials) in some urban catchments across the region.

The toxicity of a contaminant is influenced by its bioavailability, or how readily it is absorbed by organisms. New advice, to establish ANZG guidelines and update NOF bands for copper and zinc based on data modified to account for bioavailability, is currently being finalised[24]. Baseline state grading in this report is in accordance with the proposed NOF tables, which include a **proposed bottom line at the lower B band**. Confirmation of the final ANZG guidelines and subsequent revision of the proposed regional copper and zinc NOF attributes for Auckland Council is still an outstanding task for the future. Therefore, grading is considered provisional at this time.

Baseline assessments for copper and zinc were made for the 2023 hydrological year using approximately four years of data, depending on availability. Earlier assessments using bioavailable copper and zinc are not possible as monitoring of modifying parameters did not start earlier than June 2018. The later baseline period for this regional attribute is in accordance with NPS-FM clause 1.4 (a).

Results

Zinc toxicity effects are occurring in some urban waterways (Figure 9).

- 56% (n = 5) of monitored urban rivers in the Hauraki FMU and 50% (n = 10) in the Manukau FMU **failed the proposed regional bottom line (below band B)** (Figure 9).
- The one monitored exotic forest site in the Kaipara failed the proposed regional bottom line for the 95th percentile (Riverhead Stream, C Band) (Figure 9).
- Scores for sites that failed the bottom line were almost equally associated with episodic events (indicated by the 95th percentile metric) and under typical baseflow or lower flow conditions (median metric).
- All other sites across the three FMUs, except one urban site in the Hauraki FMU, graded in band A for zinc toxicity (Figure 9).

All monitored sites were above the proposed bottom line for copper toxicity (Figure 9) and elevated copper concentrations occurred in some urban and rural sites.

- 55% (n = 5) of monitored urban rivers and 33% (n = 2) of rural rivers in the Hauraki graded in band B (Figure 9).
- In the Hauraki FMU, half of B band scores were driven by the median metric indicating elevated concentrations during typical flow conditions rather than event driven scores.

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[24] Gadd et al., (in preparation) *Implementing bioavailability-based guidelines for copper and zinc toxicity in Aotearoa New Zealand. Technical guidance for scientists and practitioners, focusing on freshwater applications*. Prepared for MBIE Envirolink and Horizons Regional Council.

- One native forest stream in the Manukau FMU was in B band for both metrics (Cascades Stream, Waitakere) (Figure 9).

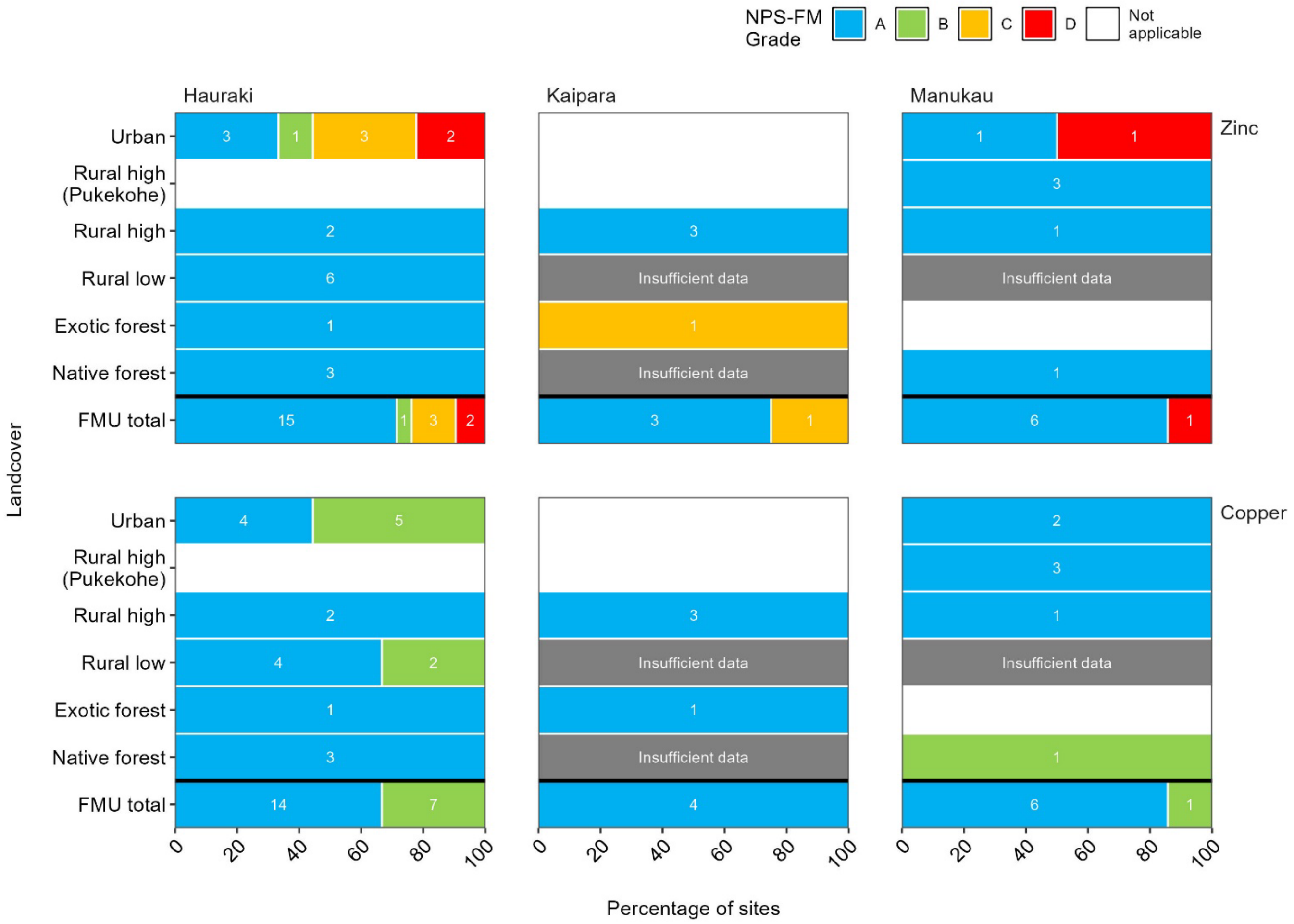

Figure 9: Grading for the Zinc and Copper (toxicity) regional attributes for water quality in all rivers, across five dominant land cover classes and FMUs over the specific baseline period for these attributes (2019-2022). Overall grade displayed. Sites in band C and D fall below the proposed regional bottom line. Numbers in bars are the number of sites.

Water quality – Temperature (regional attribute)

Water temperature in streams is fundamental in regulating the solubility of oxygen and other chemical constituents and is a significant environmental issue in Auckland rural and urban areas. Unshaded rural streams and urban stormwater are particularly prone to high temperatures and can have considerable negative impacts on aquatic ecology. Temperature has been included as an additional attribute for Auckland due to the high proportion of urban and rural streams in the region and the ongoing and future urban development planned. Temperature baseline state grading in this report is in accordance with proposed criteria for a water temperature attribute for the Auckland region developed by Clapcott et. al. (2015)[25]. This was adapted from Davies-Colley et al. (2013)[26] which proposed temperature attribute states based on the Cox-Rutherford Index (CRI – average of daily mean and maximum temperatures) and maximum temperatures, with a proposed regional bottom line below the C band.

Baseline assessments for temperature were made for the baseline state period (2013-2017) from between three to five years of continuous data, according to availability. The data used to make this baseline assessment for temperature are from long term hydrological monitoring stations and thus the distribution of sites across landcover categories is biased towards urban and rural systems.

Results

There is significant thermal stress on aquatic organisms in urban and rural waterways (Figure 10).

- 58% (n = 11) of monitored urban rivers in the Hauraki FMU and 100% (n = 2) in the Manukau FMU failed the proposed regional bottom line for temperature (below band C) (Figure 10).
- In rural rivers (high and low), 60% (n = 3) in the Hauraki FMU and 30% (n = 1) in the Kaipara FMU failed the proposed regional bottom line (below band C) (Figure 10).
- All other urban and rural sites across all FMUs graded in band C.

The one native forested site monitored, located in the Hauraki FMU, graded in band B for the temperature attribute (Figure 10), and thus shows evidence of minor thermal stress to aquatic organisms.

No sites were graded in band A for temperature.

[25] Clapcott JE, Afoa E, Young D (2015). *Towards a temperature attribute for Auckland streams*. Prepared for Auckland Council. Cawthron Report No. 2751. 27 p. plus appendices.
[26] Davies-Colley R, Franklin P, Wilcock B, Clearwater S, Hickey C (2013). *National Objectives Framework – Temperature, Dissolved Oxygen and pH, Proposed thresholds for discussion*. Prepared for Ministry for the Environment. NIWA Client Report No: HAM2013-056.

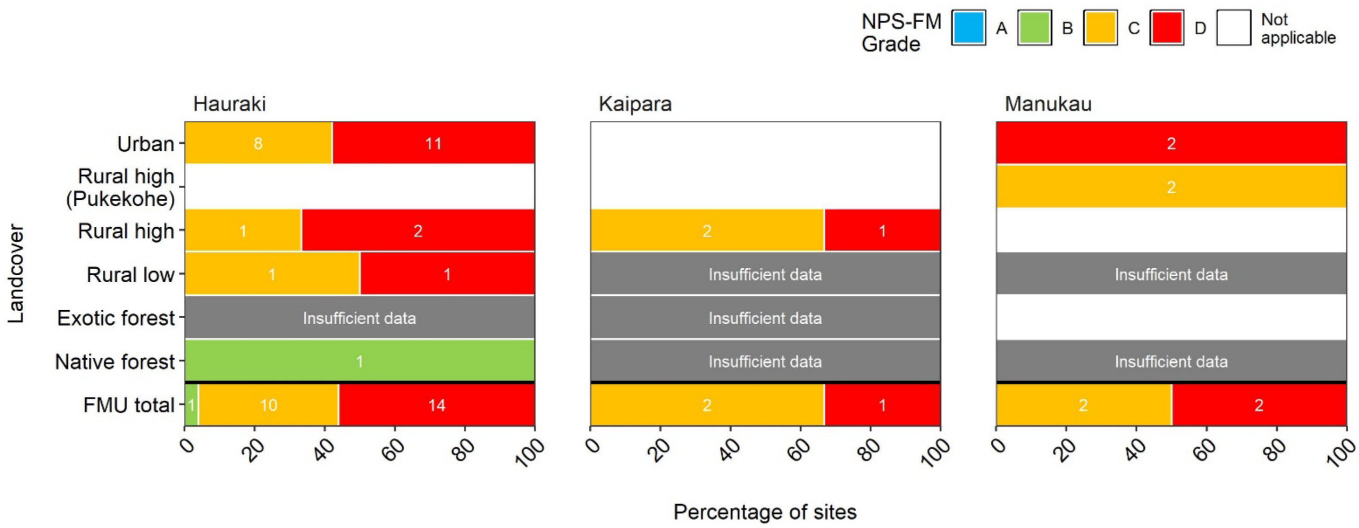

Figure 10: Grading for the temperature regional attributes for water quality in all rivers, across five dominant land cover classes and FMUs over the baseline period (2013-2017). Overall grade displayed. Sites in band D fall below the proposed regional bottom line. Numbers in bars are the number of sites.

Water quality – Suspended sediment

Excess delivery of fine sediment (mud, clay, silt) is a major driver of aquatic biodiversity loss. Excess sediment impacts aquatic environments via two main pathways: as suspended fine sediment and deposited fine sediment (covered in next section). Suspended fine sediment negatively affects freshwater aquatic flora and fauna by, for example, reducing light availability and by clogging the gills of fish and filter feeding structures of macroinvertebrates.

Auckland Council did not historically monitor visual clarity in rivers for the baseline time period yet does have long term monitoring records for turbidity. Visual clarity and turbidity measurements are strongly correlated, and thus to estimate visual clarity baseline state, measurements of turbidity were converted to visual clarity based on a relationship derived from a national dataset[27]. This approach is provided for within the attribute table in the NPS-FM, however it is intended that regional verification of the national relationship will be confirmed in future work. Therefore, **grading of suspended fine sediment (visual clarity) is considered interim** at this time (Appendix C). Direct monitoring of visual clarity was established in July 2022 to support validation of this assessment and further review and expert conferencing is to be undertaken prior to confirming interim grades as baseline.

[27] Franklin, P., Booker, D., Stoffels, R. (2020) Contract 23184: Task 2 – Turbidity and visual clarity threshold conversion. NIWA Memo to the Ministry for the Environment

Physical habitat – Deposited sediment

Excess deposited fine sediment clogs the spaces between gravels and rocks in hard bottomed rivers, and smothers wood and other habitat features, thus reducing both the space available for living organisms, and the quality of that habitat.

Auckland Council initiated a pilot monitoring programme for **deposited fine sediment in wadeable hard-bottomed rivers** in December 2021. A minimum of five years (60 samples) of data are required to grade the state of deposited fine sediment in waterways, which will be met by Auckland councils monitoring programme in 2026. Currently available models[28] for predicting deposited fine sediment in New Zealand rivers and streams are not suitable for estimating baseline state due to low levels of explained variance in measured data and high prediction errors. Thus, Auckland council intends to calculate a recommended **interim grade** following at least two years of monthly data collection (min 24 samples) which **may be available by 2024**[29].

[28] Hicks, DM., Clapcott, J., Davies-Colley, R., Dymond, J., Greenwood, M., Hughes, A., Shankar, U., Walter, K. (2016) Sediment Attributes Stage 1. NIWA Client Report No: CHC2016058:189 prepared for Ministry for the Environment
Clapcott JE, Goodwin EO (2017) Technical report on developing a deposited sediment classification for New Zealand streams. Prepared for Ministry for the Environment. Cawthron Report No. 2994. 36 p. plus appendices
Hicks, M., Haddadchi, A., Whitehead, A., Shankar, U. (2019) Sediment load reductions to meet suspended and deposited sediment thresholds. NIWA Client Report No. 2019100CH, prepared for Ministry for the Environment, June 2019.
[29] High flow conditions experienced at a site may not permit monitoring to be undertaken safely in all months and a longer time period may be necessary.

Ecosystem processes – Ecosystem metabolism

Ecosystem metabolism is a measure of ecosystem function that uses dissolved oxygen as an estimate of organic carbon production and utilisation in the river food chain. Higher rates of ecosystem metabolism indicate more organic matter input and production and subsequent decomposition, and overall, lower life-supporting capacity. Under the NPS-FM, ecosystem metabolism is reported as an integrated measure of gross primary production (GPP) and ecosystem respiration (ER) and is used to assess the ecological health of rivers.

The ecosystem metabolism attribute does not currently have prescribed attribute bands in the NPS-FM (Attribute Table 21 – Appendix 2B of the NPS-FM). However, a recommendation for scoring metrics has been made for GPP and ER rates based on the data from 213 reference sites from international literature[30] and refined for conditions specific to New Zealand[31]. Based on this research, monitoring sites can be classified as good/healthy, satisfactory, or poor. The most recent advice to MfE by the freshwater Science and Technical Advisory Group (STAG, 2019)[32] is that ecosystem metabolism attribute states (A to D bands) for wadable and non-wadable rivers should be implemented **without a national bottom line.**

Results

Analysis of Auckland Council's long term ecosystem metabolism data was completed in September 2022 and reports attribute state based on the banding recommended to the STAG[33].

Currently the Hauraki FMU has the best representation over the different land cover categories with a total of six sites. There are fewer monitoring sites in the Kaipara and Manukau FMUs (three in each).

Across all sites grades declined with likely higher land-use intensity; native and rural-low catchments were in the best bands (A and B), while rural-high, Pukekohe and urban sites were in C and D bands (Figure 11).

Before a more representative understanding of the state of EM over land cover classes in all FMUs can be gained, more monitoring sites are necessary.

[30] Young et al. 2008 Organic matter breakdown and ecosystem metabolism: functional indicators for assessing river ecosystem health. *J. North American Benthological Society*. 2008, 27 (3):605-625.
[31] Clapcott JE 2015. Development of management bands for ecosystem metabolism in non-wadeable rivers. Prepared for Waikato Regional Council. Cawthron Report No. 2770.
[32] Freshwater Science & Technical Advisory group 2019. Report to the Minister for the Environment. Publication reference number: CR 372. 58 p. https://environment.govt.nz/publications/freshwater-science-and-technical-advisory-group-report-to-the-minister-for-the-environment/
[33] Casanovas, P. et al., (2022). *Dissolved oxygen and ecosystem metabolism in Auckland rivers 2004-2020. State of the environment reporting.* Auckland Council technical report, TR2022/18. Prepared by the Cawthron Institute for Auckland Council.

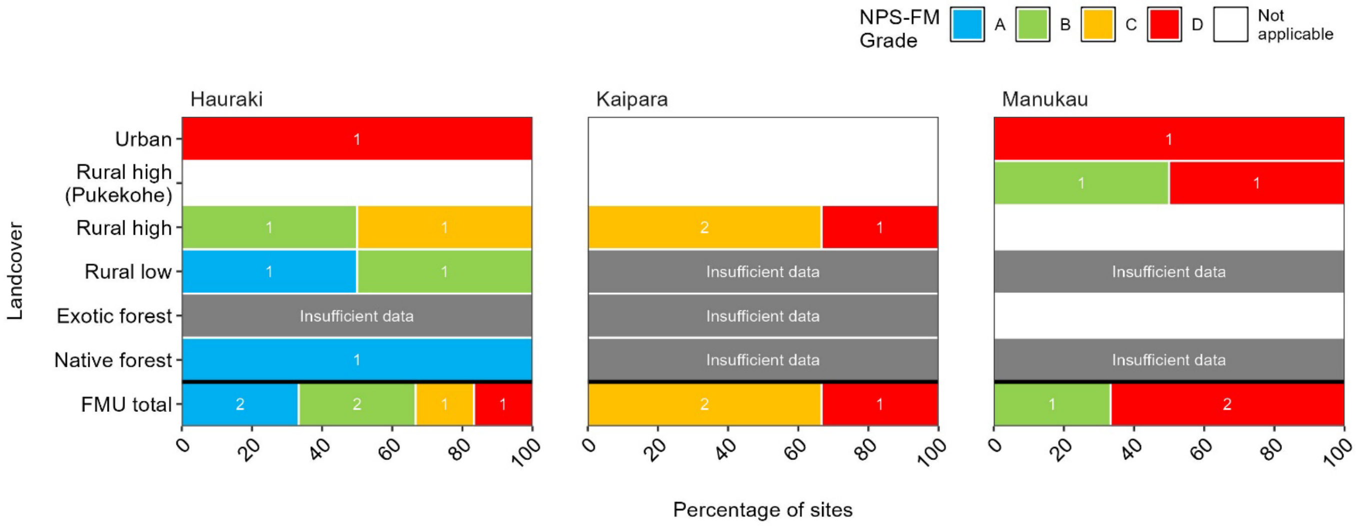

Figure 11: Provisional grading for the Ecosystem Metabolism attribute for river water quality, across five dominant land cover classes and FMUs over the baseline period (2012-2017). Proportion of monitored sites in each band as proposed to the STAG in 2019, per land cover class. There is no national bottom line for Ecosystem Metabolism. Numbers in bars are the number of sites.

Compulsory value: Human contact

The human contact compulsory value refers to people's connection with the water through recreational activities such as swimming, boating, and fishing. The NPS-FM includes a human contact attribute for all rivers and lakes that is based on *E. coli* levels (Attribute Table 9 – Appendix 2A of the NPS-FM). The NPS-FM also includes a cyanobacteria human contact attribute for lakes and lake fed rivers (Attribute Table 10 – Appendix 2A of the NPS-FM). However, there are no significant lake fed rivers in the Auckland region. For more information on cyanobacteria and human health refer to the interim human contact value for Lake Baseline State (Appendix C). This report does not identify grading for primary contact sites (Attribute Table 22 – Appendix 2B of the NPS-FM), or for rivers that are fourth-order or larger in relation to MfE's national target for primary contact (Appendix 3 of the NPS-FM).

In freshwater environments, the presence of *E. coli* is indicative of faecal pollution and associated harmful bacteria or viruses. The NPS-FM *E. coli* attribute is based on the risk to humans of bacterial *Campylobacter* infection from swimming in water and the attribute bands reflect relative risk of infection. There are four underlying metrics used to determine the overall attribute state: the median concentration (*E. coli*/100mL), 95^{th} percentile of *E. coli* concentration, the percentage of samples exceeding 260 *E. coli* per 100mL, and percentage of samples exceeding 540 *E. coli* per 100mL.

There is no national bottom line for the *E. coli* attribute as not all infections will result in illness and the source of faecal contamination influences the infection risk[34].

Results

***E. coli* levels are high and potential human health risks are widespread across the region for all FMUs**. In rivers with urban and rural catchments:

- 92% (n = 11) of urban rivers graded in band E for the *E. coli* attribute. The one urban site that did not grade in band E was in the Hauraki FMU and has a low proportion of urban land cover compared to other urban sites (Figure 12).
- 50% (n = 8) of rural rivers graded in band E and 50% (n = 8) in band D for the *E. coli* attribute (Figure 12).
- The underlying metrics indicate that *E. coli* is elevated most of the time in these urban and rural rivers (median concentrations in bands D and E), which suggests that contamination is not just associated with specific wastewater overflow or storm events.

E. coli levels in exotic and native forestry sites were generally lower than for urban and rural rivers:

- Native forest sites (n = 4, in Hauraki and Manukau FMUs only) graded in band A and B for the *E. coli* attribute (Figure 12).
- The two exotic forestry sites graded in bands D and B in the Hauraki and Kaipara FMUs respectively (Figure 12).

[34] 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.

- In exotic and native forestry rivers, the metric driving grading was the percentage of sampling events >540 CFU/100 ml suggesting contamination is more likely to be associated with specific events.

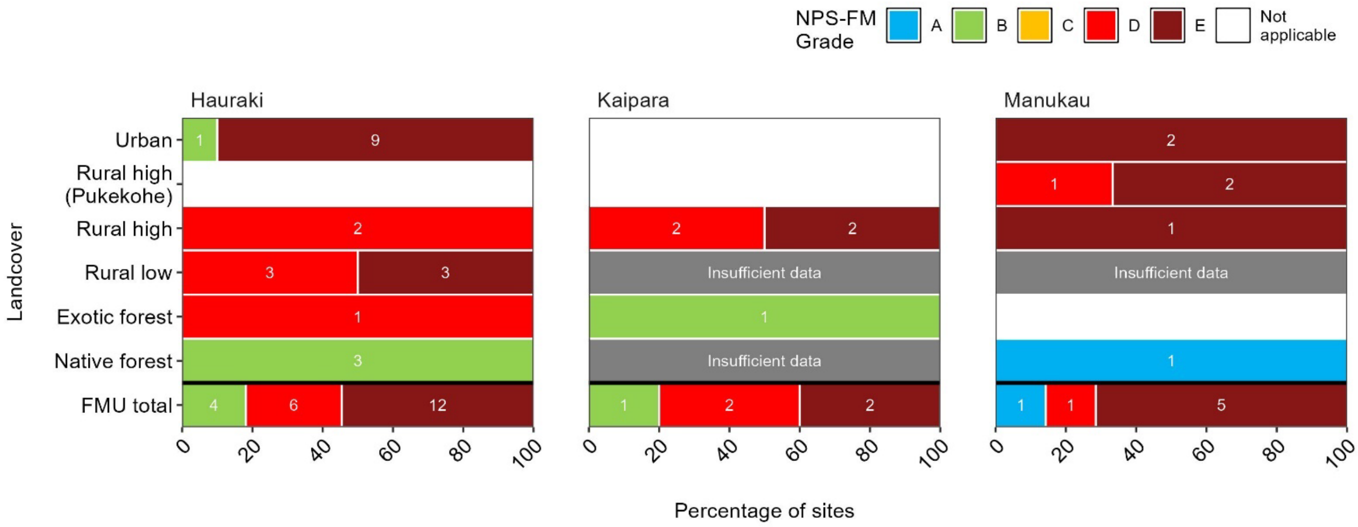

Figure 12: Grading for the *E. coli* attribute (long term improvement) for water quality in all rivers, across five dominant land cover classes and FMUs over the baseline period (2012-2017). Overall grade displayed. Proportion of monitored sites in each overall NOF band per land cover class. There is no national bottom line for *E. coli*. Numbers in bars are the number of sites.

Lake Baseline State

Each compulsory lake attribute is described within the context of effect on ecological communities and differences between bands. Baseline attribute grades are presented for each lake.

Robust monitoring data that spans back to pre-2017 is not available for all the region's currently monitored lakes and consequently baseline state is only presented where robust data is available. For the region's remaining monitored lakes, interim grades are provided in Appendix C. In this iteration of the report, interim lake grades are based on three years of data from 2020 to 2023. Interim lake grades will be assessed via expert conferencing and amended as needed in future.

Compulsory value: Ecosystem health

The attributes within the ecosystem health compulsory value for lakes refer to the maintenance of ecological processes to support diverse communities of native plants and animals. Two components of the ecosystem health value have compulsory attributes in the NPS-FM applicable to lakes: aquatic life and water quality.

Aquatic life

The aquatic life component of ecosystem health in lakes refers to the types and amounts of algae and freshwater plants present in Auckland's lakes. These are fundamental parts of the aquatic food web; producing oxygen, absorbing nutrients in the water, and providing organic biomass that other organisms depend on. Excessive algae and plant growth are a sign of nutrient enrichment and lead to further eutrophication effects in lakes.

Aquatic life – Phytoplankton

Phytoplankton are photosynthetic organisms (e.g., algae and plants) that live suspended in the water column of lakes and rivers. While phytoplankton naturally occur in lakes and are an important part of the lake food web and in nutrient cycling, excessive growth can negatively impact lake communities and lake function. For example, increased phytoplankton growth in a lake can reduce water clarity and affect the availability of light for native macrophytes (submerged plants). Excessive phytoplankton growth is usually the result of enrichment of waterbodies with the nutrients nitrogen and phosphorus; or 'eutrophication'.

The compulsory phytoplankton attribute is assessed by measuring concentrations of chlorophyll-*a*. Chlorophyll-*a* is a photosynthetic pigment in plants and algae. The concentration of chlorophyll-*a* in lake water can be used as an indication of the total biomass of phytoplankton in a lake. Consistently elevated concentrations of chlorophyll-*a* suggest ecological communities are impacted by excessive algal and plant growth likely due to nutrient enrichment. The **national bottom line for phytoplankton is set below band C** (Attribute Table 1 – Appendix 2A of the NPS-FM).

Results

There is evidence of excess phytoplankton growth in all monitored lakes.

- Two lakes, Tomorata and Kuwakatai, failed the bottom line for the phytoplankton attribute, and graded in band D (Figure 13).

- The three other lakes; Wainamu, Rototoa, and Pupuke, graded B to C and above the bottom line for the phytoplankton attribute (Figure 13).

Aquatic life – Submerged plants

Submerged plants play key roles in lake ecological structure and function. Submerged plants provide habitat for fish, macroinvertebrates, and epiphytic organisms, and are an important food source for a suite of organisms. They also help to maintain clear water conditions in lakes by preventing fine bottom sediments and nutrients from being re-suspended into the water column. Submerged plant beds in lakes can be negatively impacted by grazing by invasive pest fish species, over-production of phytoplankton (or eutrophication), and competition of invasive submerged plants.

There are two submerged plant attributes in the NPS-FM: native and invasive species (Attribute Tables 11 and 12 in Appendix 2B of the NPS-FM respectively). The submerged plant attributes are measured using the Lake Submerged Plant Index (LakeSPI). The LakeSPI characterises the ecological health of lakes based on the amount of native and invasive plants growing below the lake surface. For example, a high percentage of submerged *native* plants (bands A and B) suggest good ecological conditions within the lake, with native plant communities largely intact, while a high percentage of submerged *invasive* plants indicates invasive plants are having negative impacts on the native vegetation, and thus ecological condition.

If a lake is classed as non-vegetated, a grade for the submerged plants (invasive species) is not included, because lakes without submerged vegetation cannot be considered invaded or uninvaded[35]. It is important to note that due to the methodology of the LakeSPI survey, a classification of 'non-vegetated' does not necessarily mean a lake is completely un-vegetated. **The national bottom line for both submerged plant attributes is set below band C.**

Clause 3.13 of the NPS-FM requires councils **to set appropriate instream concentrations and exceedance criteria, or instream loads,** for nitrogen and phosphorus to achieve outcomes for periphyton (with this attribute only applying to river management goals) and for any other attribute target that is affected by nutrients (i.e., submerged plants (invasive), lake-bottom dissolved oxygen and mid-hypolimnetic dissolved oxygen). However, **this clause is not applicable to lakes in the Auckland region, as none of the lakes meet the definition of a downstream receiving environment from a contributing river** as outlined in *A guide to setting instream nutrient concentrations* published by MfE, as they are mostly dune lakes, or are predominantly rainwater or groundwater fed.

Results

There is likely widespread impact to native plant populations across the region and some well-established invasive plant populations. Of the five lakes with baseline state for the phytoplankton and submerged plants attributes (Figure 13):

- Lake Rototoa was the only lake that did not fail the national bottom line for native plants, scoring band B, suggesting that native plant communities are largely intact within the lake (Figure 13).
- All other lakes were below the national bottom line for native plants, scoring band D (Figure 13).

[35] de Winton, M. D., S. R. Elcock, A. T. Taumoepeau (2022). *LakeSPI assessment of 15 Auckland lakes: 2021/2022*. Prepared by the National Institute of Water and Atmospheric Research, NIWA for Auckland Council. Auckland Council technical report, TR2022/21

- Lake Kuwakatai failed the national bottom line for invasive plants, scoring band D (Figure 13).
- All other lakes scored band C for invasive plants, suggesting these lakes are impacted from invasive plants with dense weed beds forming (Figure 13).
- Lake Tomorata did not receive a score for invasive plants as the lake is considered "non-vegetated". This, combined with the poor scores for submerged native plants and phytoplankton in the lake, suggest the macrophyte beds in Tomorata have collapsed and the lake has tipped into a phytoplankton dominated state.

For the lakes that have baseline state for submerged plants, but not phytoplankton (Figure 14):

- Lakes Whatihua and Pokorua did not fail the national bottom line for native plants, scoring band B, suggesting that native plant communities are largely intact within these lakes (Figure 14). Lake Okaihau scored band C for native plants, suggesting the native plant communities are impacted.
- All other lakes were below the national bottom line for native plants, scoring band D (Figure 14).
- All other lakes scored band C or D for invasive plants, suggesting these lakes are impacted from invasive plants with dense weed beds forming (Figure 14).
- Lakes Slipper and Spectacle did not receive a score for invasive plants as these lakes are considered non-vegetated, suggesting these lakes are in a phytoplankton dominated state.

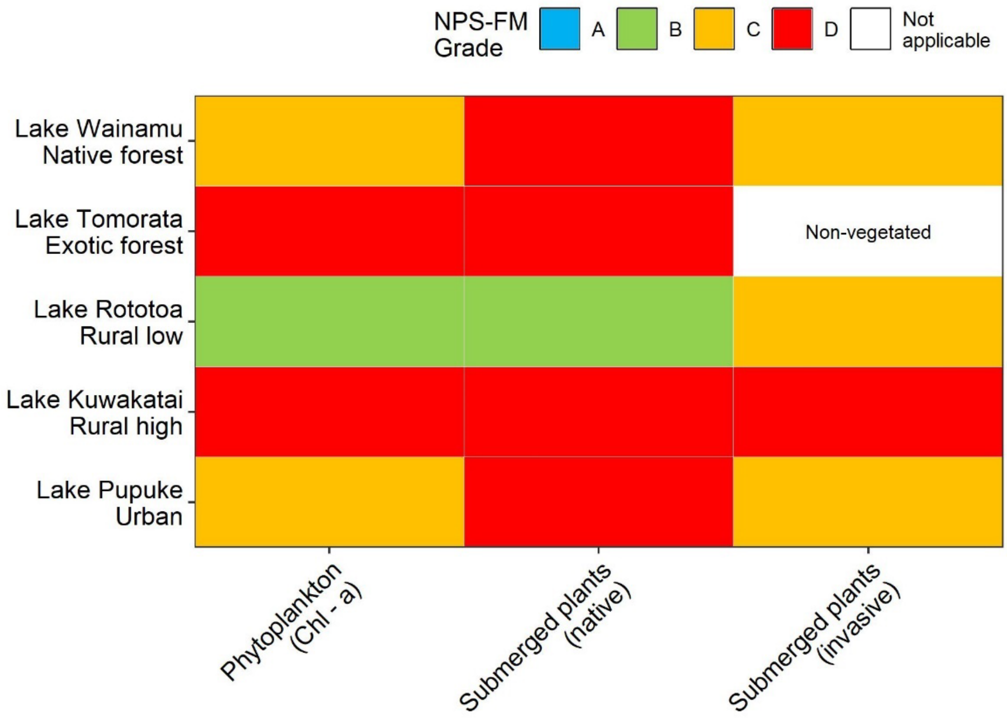

Figure 13: Grading for the Phytoplankton and Submerged Plants (native and invasive) attributes for aquatic life in five monitored lakes in the Auckland region. Overall grade displayed for the phytoplankton attribute. Note: Lake Wainamu was last monitored for submerged plants in 2007 and is included here as phytoplankton and submerged plants are ecologically interrelated and it is best to interpret them together.

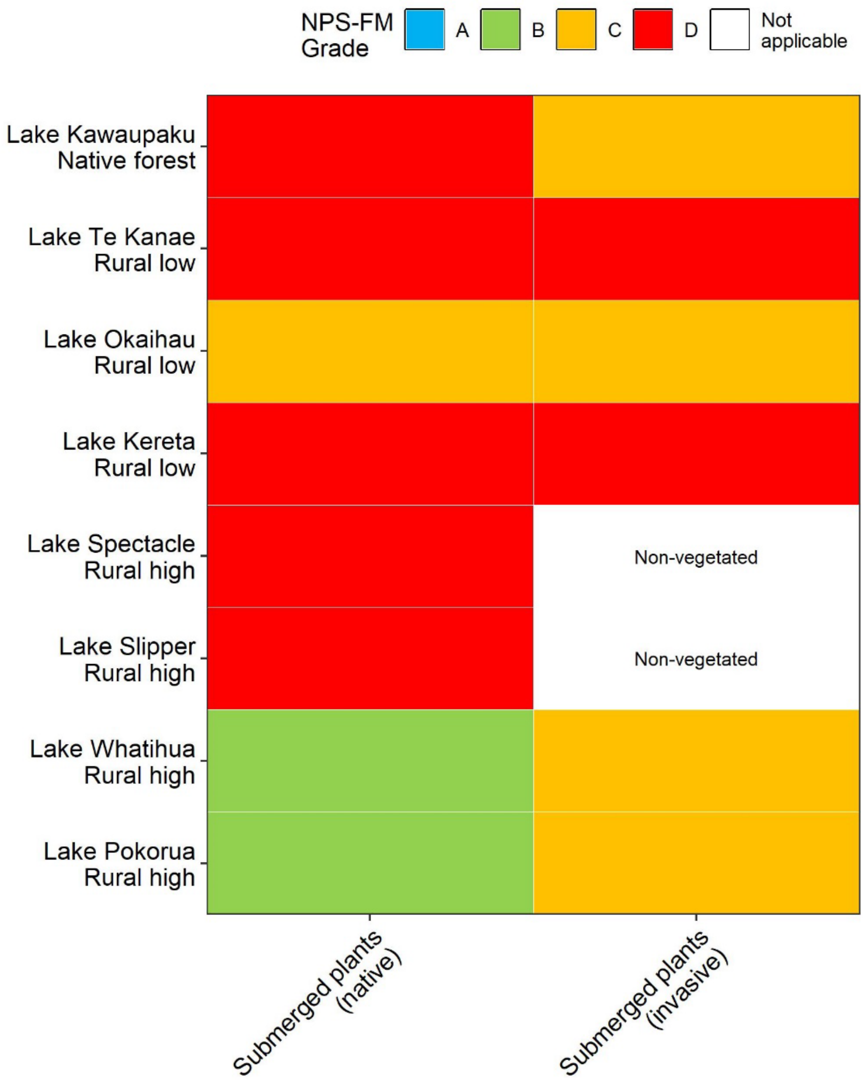

Figure 14: Grading for the Submerged Plants (native and invasive) attributes for aquatic life in monitored lakes that do not yet have confirmed baseline state for the Phytoplankton attribute.

Interim baseline states for the phytoplankton attribute for the remaining monitored lakes are presented in Appendix C – Aquatic Life.

Water quality – Nutrients: trophic state/eutrophication

Nitrogen and phosphorus are key nutrients that can stimulate the excessive growth of algae and plants in lakes and promote eutrophication. Excessive plant and algal growth can have an impact on water clarity, light availability, and dissolved oxygen concentrations.

A primary concern for lakes is the decrease in dissolved oxygen in lake bottom waters that can result from the microbial breakdown of excessive plant growth stimulated by nutrients. Dissolved oxygen in the water is vital for fish and other aquatic life to breathe. When dissolved oxygen reaches critically low thresholds, sensitive species inhabiting lake bottom waters are either killed or displaced to shallower waters. Furthermore, there is a positive feedback loop between decreasing dissolved oxygen and increasing nutrient concentrations in lakes; as lake-bottom oxygen levels decline, there is an increased likelihood of biogeochemical conditions that promote the release of nutrients from lake sediments, thus furthering eutrophication.

The NPS-FM has two nutrient attributes for lakes: total nitrogen (TN) and total phosphorus (TP) (Attribute Tables 3 and 4, Appendix 2A of the NPS-FM respectively), and two dissolved oxygen attributes: lake bottom- and mid-hypolimnetic dissolved oxygen (Attribute Tables 18 and 19, Appendix 2A of the NPS-FM respectively). **The national bottom lines for TN, TP, lake bottom-, and mid-hypolimnetic dissolved oxygen are set below band C.**

The lake-bottom dissolved oxygen compulsory attribute is assessed by measuring oxygen levels within one metre of the sediment bed in the deepest part of the lake. The mid-hypolimnetic dissolved oxygen attribute is only assessed for seasonally stratifying lakes. Stratification is a naturally occurring process whereby the lake water splits into density layers, or "strata", during warm months. When surface water temperatures rise, cooler more dense water sinks to the bottom of the lake, this cool layer is called the "hypolimnion". Some shallow lakes do not stratify, and the water column remains mixed throughout the year (these are "polymictic" lakes). The mid-hypolimnetic dissolved oxygen attribute is calculated from the centre of the hypolimnion.

Results

There is some evidence of excess nutrient concentrations in the monitored lakes:

- No lakes failed the national bottom line for TN and TP (Figure 15).
- There is elevated TN and TP concentrations in Lake Kuwakatai (graded in C band for both attributes) and elevated TP in Lake Wainamu (graded in band C) (Figure 15).
- No lakes graded in band A for TN and two lakes (Rototoa and Pupuke) graded in band A for TP (Figure 15).

There is likely widespread DO stress on aquatic organisms in the monitored lakes:

- All lakes, except Tomorata, graded below the national bottom line for both dissolved oxygen attributes (Figure 15). Lake Tomorata is the only polymictic lake represented here, meaning the lake is shallow and the water is well mixed throughout the depth profile of the lake.

Water quality – Nutrients: toxicity to aquatic life

At certain concentrations, nutrients can have direct impacts on lake macroinvertebrate and fish communities through toxic effects.

The NPS-FM ammonia toxicity attribute (Table 5, Appendix 2A of the NPS-FM) includes both rivers and lakes and reports on the level of species protection expected from managing the long-term chronic toxicity effects. Bands A and B indicate 99% or 95% species protection respectively, with bands C and D having <80% species protection, with a reduced survival and risk of death for '*sensitive*' lake species. **The national bottom line is set below band B for the ammonia attribute.**

Results

There is little evidence of toxic effects of ammonia in the monitored lakes.

- All five monitored lakes scored above the national bottom line for the ammonia toxicity attribute (Figure 15) and thus are considered to have above 95% species protection under the ammonia (toxicity) attribute (all in A or B band).

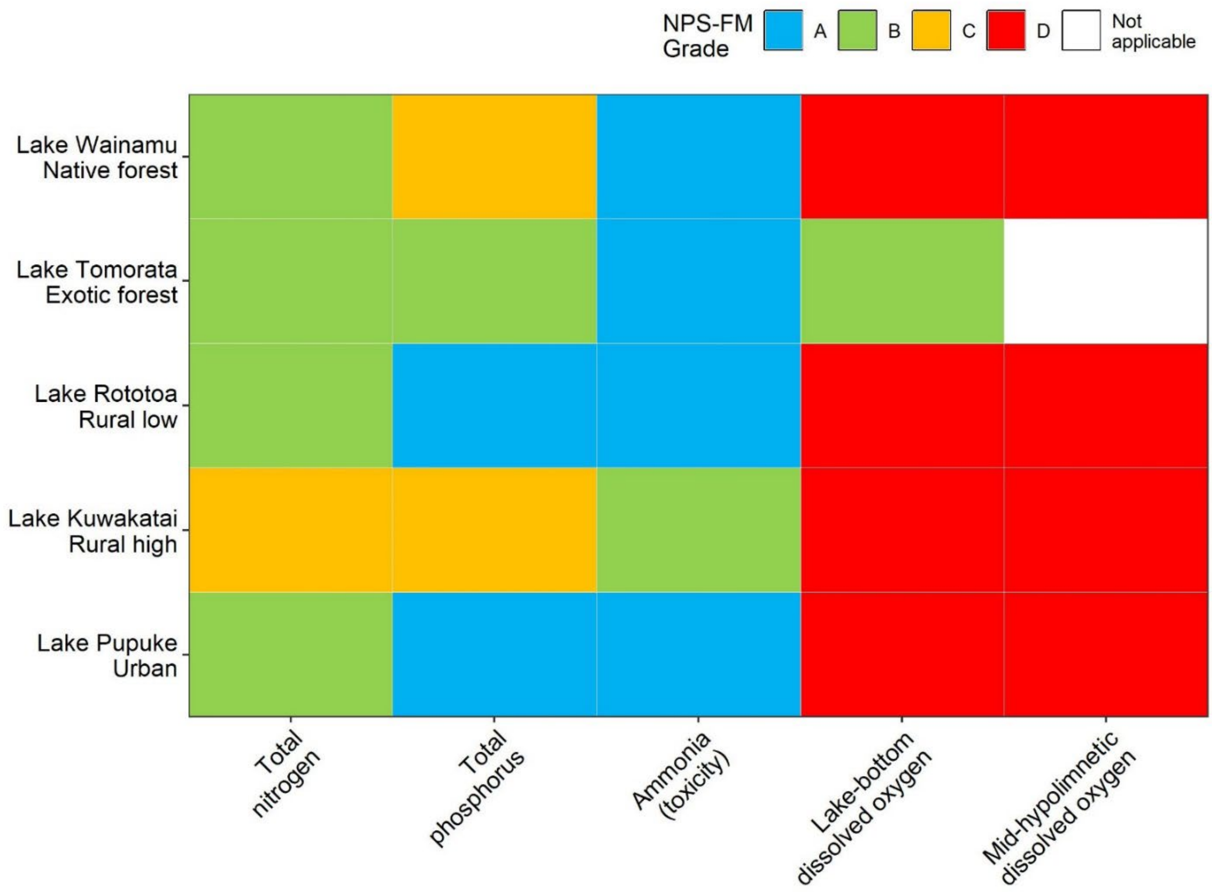

Figure 15: Grading for the Total Nitrogen, Total Phosphorus, Ammonia (toxicity), Lake-bottom Dissolved Oxygen and Mid-Hypolimnetic Dissolved Oxygen attributes for water quality in five monitored lakes in the Auckland region. Overall grade displayed for the ammonia (toxicity) attribute.

Interim baseline states for water quality attributes for the remaining monitored lakes are presented in Appendix C – Water Quality.

Compulsory value: Human contact

Human Contact – Faecal contamination and toxic freshwater algae

The human contact compulsory value refers to the way people connect with lake water through a range of recreational activities, such as swimming, boating, and fishing.

There are **three compulsory attributes supporting this value for lakes** (Attribute Table 9 and Table 10 – Appendix 2A of the NPS-FM), although one, surveillance monitoring for *E. coli* at primary contact sites in lakes during the bathing season (Attribute Table 22 – Appendix 2B of the NPS-FM), is not reported in this version of the report. For further explanation of the *E. coli* attribute and its effects on human health please refer the rivers section of this report on page 32.

Additional to the *E. coli* attribute, planktonic cyanobacteria are also a key indicator of human health risks for lakes. Planktonic cyanobacteria (blue-green algae) naturally occur in lakes, usually in low concentrations. Under favourable conditions (i.e., warm temperature, low inflow, and elevated nutrient levels), cyanobacteria blooms can form. **Whilst cyanobacteria blooms are a natural phenomenon, there is an increased risk to human health for people that encounter lake water due to some cyanobacteria producing toxins** that can be poisonous to the nervous system in humans and animals. The health risks associated with contact with cyanobacteria increase as the concentration of cyanobacteria increases.

There are currently no baseline state grades for the two human contact compulsory attributes in Auckland lakes due to a lack of robust measured or modelled data over the baseline period. Monthly monitoring of *E. coli* started in January 2020 at lakes across the region and cyanobacteria monitoring for six publicly accessible lakes in January 2020, with the other lakes in the region monitored from July 2021. Interim baseline states based on available data are presented in Appendix C – Human Contact.

Summary of our identified baseline state

While a healthy ecosystem includes all the NPS-FM NOF compulsory values components, due to data and modelling limitations, this report focuses on two of the four compulsory values: ecosystem health and human contact, for both lakes and rivers. Thus, currently our understanding of the baseline state is mostly informed by the state of aquatic life and water quality in our rivers and lakes.

Table 4 provides a summary, for each compulsory attribute, of whether this report presents a robust baseline state or interim grade for 2017. The table also shows the future availability of a baseline state (for those attributes that are currently interim or where data is not currently available), and a snapshot of National Bottom Lines are exceedance.

Regional rivers snapshot

There is a general pattern of water quality decline with increasing land use intensity and from headwater to lowland systems. Rivers in areas with native forest land cover generally had the highest water quality and ecological health values and had the most diverse macroinvertebrate and freshwater fish communities. Such systems are usually headwater streams at the top of catchments, and as they traverse urban and rural areas in their catchments, their water quality and ecological health typically decline.

- One of the biggest challenges for the Auckland region is maintaining the healthy functioning of macroinvertebrate communities. More than 70% of the monitoring sites failed the national bottom line for macroinvertebrate attributes (Figure 16), largely in rural and urban environments.
- There is widespread nutrient enrichment with over 80% of monitored sites in bands C or D for dissolved reactive phosphorus (Figure 16). This includes high nutrient levels observed in some native forest catchments.
- Many sites have reduced life supporting capacity with 55% being below the national bottom line for dissolved oxygen and 53% below the proposed regional bottom line for temperature. The DO assessment will be confirmed by introducing additional monitoring site assessments in further iterations of this report in future.
- While the NPS-FM has not included a grading system or national bottom line for Ecosystem metabolism, using the bands as recommended to the STAG showed a full range of states across the Auckland Region, with more impacted sites being in urban streams and varying impacts for streams in rural areas.

Our understanding of the links between nutrient enrichment and effects on aquatic life and ecosystem health will improve as more information on periphyton communities, and additional dissolved oxygen and ecosystem metabolism monitoring sites are included in future iterations of this report.

There are localised issues for nitrate, ammonia, copper, and zinc toxicity.

- There are high potential effects of nitrate toxicity to aquatic sites connected to the shallow volcanic aquifers within the Pukekohe Specified Vegetable Growing Area (SVGA). Sites in the Pukekohe SVGA were the only ones to fail the national bottom line for nitrate toxicity.
- Potential effects of ammonia and zinc toxicity were primarily associated with urban waterways. One urban monitoring site failed the national bottom line for chronic ammonia toxicity. Twenty two per cent of monitored waterways failed the regional bottom line for zinc. No sites failed the regional bottom line for copper and elevated levels were primarily associated with urban waterways.

Potential human health risks are widespread across the region with over 80% of monitored sites assessed as bands D or E (Figure 16). Only sites in exotic and native forestry had low risks of *Campylobacter* infection (using *E. coli* as a proxy – bands A to C). Urban streams had the highest potential risks to human health.

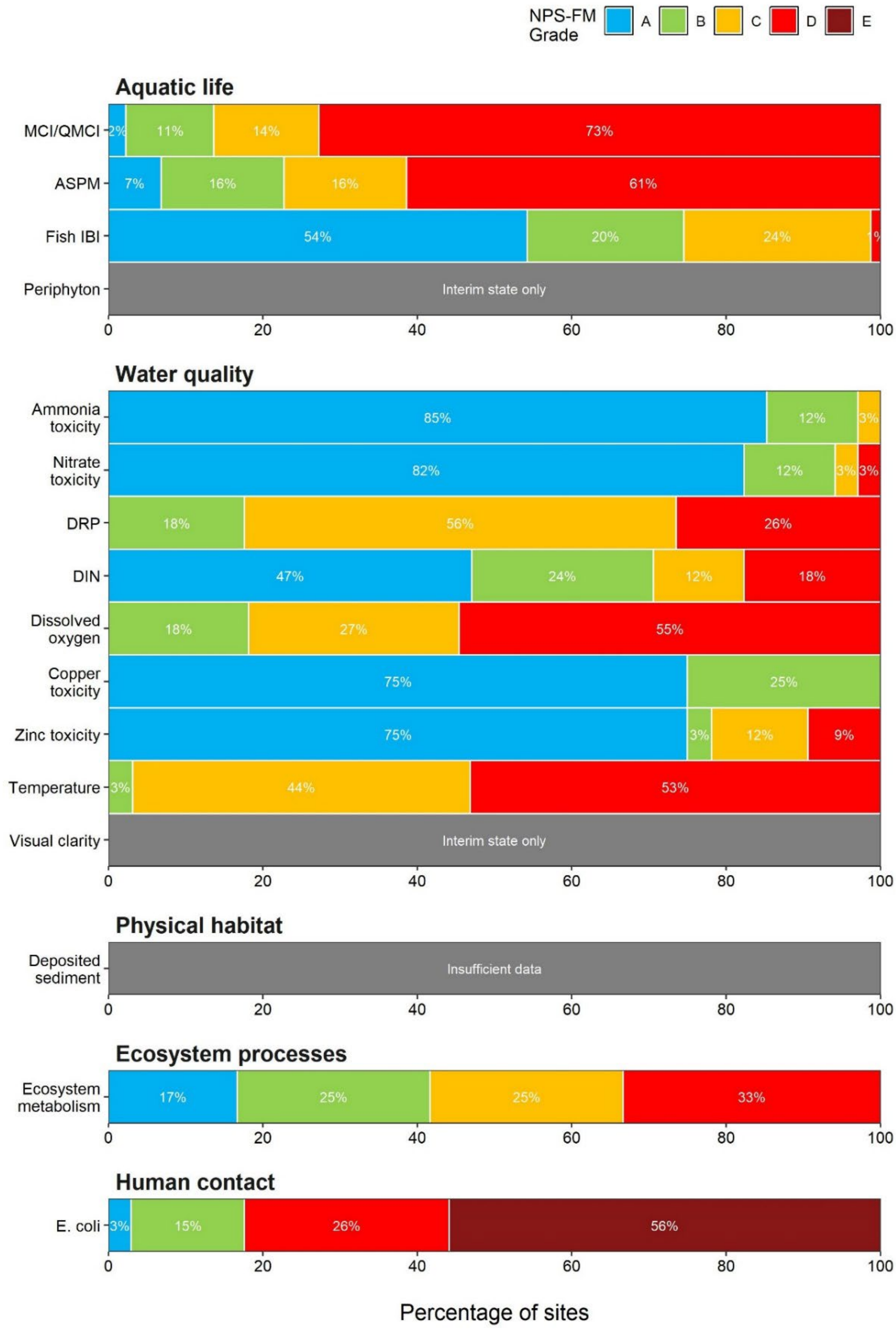

Figure 16: Summary of **regional** baseline state (2012-2017) for compulsory attributes for river ecosystem health, additional proposed **regional** attributes for ecosystem health (metals), and compulsory attributes for human contact values. In this regional summary, grades are based on measured data only. See Appendix C for interim estimates of state for the attributes indicated in grey.

Table 4: Baseline state summary for the Auckland region (as at August 2023).

Ecosystem type	Compulsory values	Biophysical component	Attributes	Robust baseline state for 2017	Interim grades	National bottom line exceedances
Rivers	Ecosystem health	Aquatic life	Macroinvertebrates (MCI/QMCI)	Y	Y – additional sites	Y
			Macroinvertebrates (ASPM)	Y	Y – additional sites	Y
			Fish (IBI)	Y	N	No NBL
			Periphyton (eutrophication) – Interim	N	Y – all sites	Not yet assessed
		Water quality	Ammonia: toxicity to aquatic life	Y	N	Y
			Nitrate: toxicity to aquatic life	Y	N	Y
			Dissolved reactive phosphorus (DRP): eutrophication	Y	N	No NBL
			Dissolved inorganic nitrogen (DIN): eutrophication	Y	N	No NBL
			Dissolved oxygen	Y	Y – additional site	Y
			*Dissolved copper: toxicity to aquatic life	Y	NA	N
			*Dissolved zinc: toxicity to aquatic life	Y	NA	Y
			*Temperature	Y	NA	Y
			Suspended fine sediment	N	Y – all sites	Not yet assessed
		Physical habitat	Deposited sediment – data requirements not yet met	N	N	Not yet assessed
		Ecosystem processes	Ecosystem metabolism (EM)	Y	Y – 2 additional sites, TBD	No NBL
		Water quantity	Not included to date[1]	Not assessed here		
	Human contact		*Escherichia coli* (*E. coli*)	Y	N	No NBL
			E. coli (primary contact sites) – not reported here.	Not assessed here		
	Threatened species		Not included to date[1]	Not assessed here		
	Mahinga kai		Not included to date[1]	Not assessed here		
Lakes	Ecosystem health	Aquatic life	Phytoplankton (trophic state)	Y	Y – additional lakes	Y
			Submerged plants (natives)	Y	Y – additional lakes	Y
			Submerged plants (invasive species)	Y	Y – additional lakes	Y
		Water quality	Total Nitrogen (trophic state)	Y	Y – additional lakes	N
			Total Phosphorus (trophic state)	Y	Y – additional lakes	N

Ecosystem type	Compulsory values	Biophysical component	Attributes	Robust baseline state for 2017	Interim grades	National bottom line exceedances
			Ammonia (toxicity)	Y	Y – additional lakes	N
			Lake-bottom dissolved oxygen	Y	Y – additional lakes	Y
			Mid-hypolimnetic dissolved oxygen	Y	Y – additional lakes	Y
	Human contact		*Escherichia coli* (*E. coli*)	N	Y – all lakes	Not yet assessed
			E. coli (primary contact sites) – not reported here.	Not assessed here		
			Cyanobacteria (planktonic)	N	Y – all lakes	Not yet assessed
	Threatened species		Not included to date[1]	Not assessed here		
	Mahinga kai		Not included to date[1]	Not assessed here		

Hauraki

For the rivers in the Hauraki FMU in rural and urban areas (see Figures 4 to 12):

- Almost all rural and urban sites failed the national bottom line for macroinvertebrate community attributes.
- Fish communities ranged from A to D, with a higher proportion of sites in band C and two sites in band D.
- Forty per cent of monitored urban streams failed the proposed regional bottom line for zinc toxicity.
- One urban river failed the national bottom line for ammonia toxicity.
- DRP levels were graded in bands C and D and DIN was highest in urban rivers suggesting that aquatic communities may be impacted by potential effects of eutrophication as well as chronic toxicity. It is possible that DRP levels are naturally elevated, particularly in the Wairoa catchment, associated with the underlying geology in the Hunua Ranges however further research is needed.
- Dissolved oxygen monitoring shows a range from B to D band. Sites graded in C and D were in urban and rural-high catchments.
- Over half of the sites were graded below the proposed national bottom line for temperature.
- All urban rivers except one (Onetangi stream) were graded in band E for human health and rural rivers ranged from band D to E.

For rivers in native and exotic forestry:

- Aquatic communities (macroinvertebrates and fish) were typically healthier than those in urban and rural catchments, though two sites were graded in band D for the macroinvertebrate MCI/QMCI attribute.
- Most water quality indicators were in band A except for DRP (band B to D), dissolved oxygen (band B) and temperature (band B).
- For human contact, native forested sites graded band B and exotic forest band D.

Kaipara

For the rivers in the Kaipara FMU, in rural areas (see Figures 4 to 12):

- All monitored rivers in highly modified rural (high) catchments failed the national bottom line for macroinvertebrate community scoring metrics.
- National level data indicates that fish community health was variable, with fish IBI grades ranging from bands A to D.
- River water quality indicators were generally good with some indication of potential eutrophication impacts (DRP ranged from C to D, and DIN ranged from A to B).
- Dissolved oxygen is only monitored at rural-high sites and was in D band (below the national bottom line) at two out of three sites. The same sites were rated B and C for ecosystem metabolism parameters.
- Temperature is only monitored at rural-high sites and was in band D (below the proposed national bottom line) in one of the three sites.
- Human health risk was elevated in rural rivers (band D to E).

In native and exotic forestry areas:

- Banding across aquatic life attributes was varied from bands A to D within native and exotic catchments. Though these areas typically support diverse macroinvertebrate communities, some sites were below the national bottom line for MCI/QMCI.
- Fish communities in these areas were generally in good to excellent health, with grading in exotic forest catchments between bands A and B.

Manukau

Within the Manukau FMU, rivers in the Pukekohe SVGA (see Figures 4 to 12):

- Have very high nitrate concentrations, particularly in the upper catchments. These waterways fail the national bottom line for nitrate toxicity indicating that there are potentially unacceptable effects on the growth and survival of sensitive freshwater animals.
- Macroinvertebrate community attributes failed the national bottom line for all metrics.
- While the health of fish communities was varied, most are graded within band C.
- Both sites monitored for dissolved oxygen were graded in D band, below the national bottom line.
- Both sites monitored for temperature graded in band C, above the proposed national bottom line of D.
- Ecosystem metabolism indicated better ecosystem functioning in the upper catchment (Ngakoroa) compared to the lower catchment (Waitangi) of this area, with a B and D-band grading, respectively.

Outside of the Pukekohe SVGA, in the urban and rural rivers in the Manukau FMU (see Figures 4 to 12):

- Ecosystem health is impacted in urban and rural rivers in the Manukau FMU.
- All urban rivers failed the national bottom line for macroinvertebrate community attributes.
- The health of fish communities was varied, ranging from bands A to C.
- Nutrients (DIN and DRP) were elevated (bands C to D).
- Only one urban site is monitored in the Manukau FMU for dissolved oxygen and ecosystem metabolism. This site fell into the D band for both attributes and is below the national bottom line for dissolved oxygen.
- Both sites monitored for temperature failed the proposed national bottom line (band D).
- All urban and rural rivers were in band E for human contact.

In native forested rivers in the Waitākere Ranges (see Figures 4 to 12):

- Macroinvertebrate community grades were varied across sites, ranging from bands B to D.
- Fish communities were in relatively good health, with most sites in bands A and B.
- Most indicators of water quality and human health were good (bands A or B) except for dissolved reactive phosphorus (band D).
- The one site monitored for human health graded in band A.

Lakes snapshot

Baseline state is reported for eight compulsory attributes under the ecosystem health compulsory value (incorporating the components water quality and aquatic life). Grades are provided for lakes that have measured data available for the 2017 baseline state period (see Figures 13 to 15). These lakes have different typologies (dune lakes and a volcanic lake) and have differing catchment land cover types. The two human contact compulsory attributes are included as interim states in Appendix C.

Despite no lakes being below the national bottom lines for nutrient attributes, there is evidence that all five lakes are impacted by elevated nutrient levels with grades ranging from A to C (Figure 17). Elevated concentrations of nutrients suggest ecological communities may be impacted by excessive algal and plant growth, which is supported by two lakes below the national bottom line for the phytoplankton attribute. Lake Pupuke and Lake Rototoa had the best grades for nutrients and algae out of the five lakes presented (see Figures 13 to 15).

All lakes are above the national bottom line for the ammonia (toxicity) attribute, suggesting species are protected from chronic toxicity effects (Figure 17). However, most lakes fail the national bottom line for both dissolved oxygen attributes (Figure 17) which means that aquatic organisms are vulnerable to stress and potentially even extinction due to low oxygen. Low oxygen levels not only could result in a loss of ecological integrity, but there is an increased likelihood of nutrient release from lake-bed sediments and subsequent contribution towards elevated nutrient enrichment and eutrophication.

Lake ecological health as indicated by the submerged plants attributes suggests poor ecological health across most lakes, with most lakes failing the national bottom line for native plants and some close to failing the national bottom line for invasive plants (Figure 17).

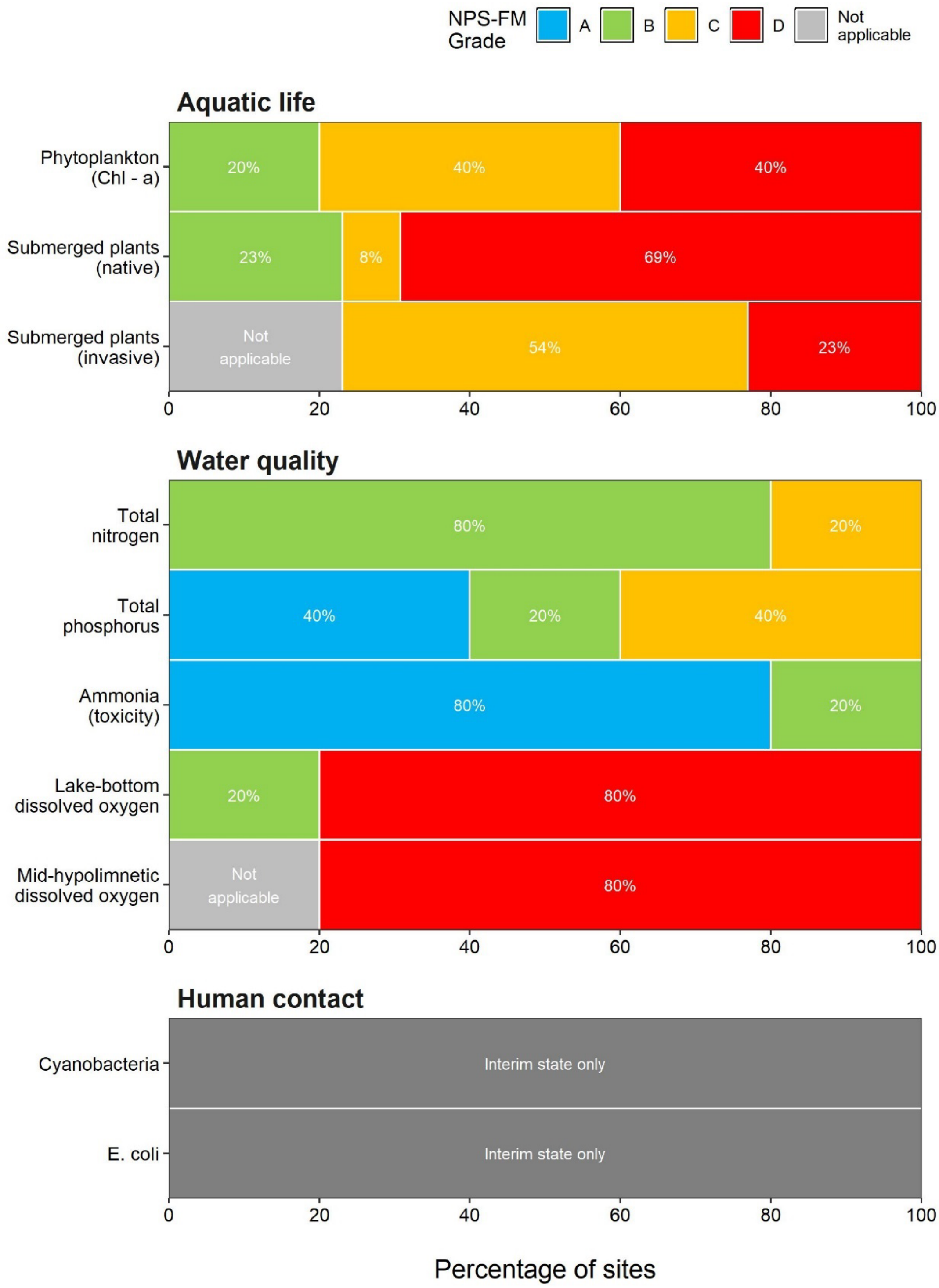

Figure 17: Proportion of lakes in each band for each compulsory attribute for the baseline state period. See Appendix C for interim estimates of state for the attributes indicated in grey.

Appendix A – State terminology

As this is a working document that will change as data is continually collected, or model improvements are completed, it is important to clarify differences in terminology used throughout the NPS-FM reporting suite.

Whilst these key terms are outlined in the glossary, further detail is provided in the table below.

Term	Definition
Baseline state	• The state of all NPS-FM compulsory attributes as of **7 September 2017**, defined as an attribute band. • This is required to understand the condition of a waterbody type, and for setting realistic outcomes for maintaining or improving condition, and monitoring progress towards this over time. • Period of assessment for this is July 2012 – June 2017 (i.e., five years of data). • Where measured or modelled data exists for an attribute over this period it will be reported as **baseline state** via an attribute band assessment. This is a **final** assessment (i.e., it will not change). • If there is not enough data to make a 'robust' assessment for baseline state, an '**interim state**' will be available for a future period.
Current state	• The state of compulsory attributes at the time of most recent reporting, generally based on data for the five-year period preceding assessment and defined as an attribute band. • The current state will be annually updated over time. • Comparison of any baseline state to its current state equivalent (by site) helps us understand if the waterbody condition is improving or declining through time. • Current state is not reported in this report.
Interim state	• Used where the data available to assess baseline state does not satisfy the full data requirements for that period. • Where an assessment of baseline state cannot be made over the identified period, because measured or modelled data is not available, an interim state can be determined as and when data becomes available (albeit being in a different time period from baseline state). • Where an assessment of current state does not satisfy the full data requirements for that period. • The minimum data requirements for an interim state have been defined by Auckland Council as 30 samples over three years. • Will become a complete assessment after five years of data collection or following confirmation be expert conferencing (or otherwise as specified in Appendix 2A and 2B of the NPS-FM). • Exception is for cyanobacteria in lakes, where interim state is calculated from a minimum of two years of data due to the complete assessment of the attribute only requiring three years of data.

Appendix B – Methods

Land cover

Dominant land cover within FMUs and land cover classes for river attribute grading is based on data from the New Zealand Landcover Database version 5.0[36] (LCDB5), using the latest summer 2018/2019 layer to best describe land cover composition during the 2017 baseline period.

The LCDB5 detailed landcover classes were aggregated to achieve the four broad land cover classes for baseline state reporting (Table 5). The median level classes are those described by LAWA (Land Air Water Aotearoa)[37]. Note that waterbodies occurring within each FMU accounted for less than 0.5% of total cover and were therefore excluded from assessments.

Table 5: Land cover classification hierarchy for describing land cover during the 2017 baseline period.

LCDB5 detailed classes	Median classes	Baseline broad classes
Surface Mine or Dump	Artificial bare surfaces	Urban
Transport Infrastructure		
Gravel or Rock	Natural bare/lightly vegetated surfaces	
Landslide		
Sand or Gravel		
Built-up Area (settlement)	Urban area	
Urban Parkland/Open Space		
Orchard, Vineyard or Other Perennial Crop	Cropping/horticulture	Rural
Short-rotation Cropland		
High Producing Exotic Grassland	Exotic grassland	
Low Producing Grassland		
Gorse and/or Broom	Exotic scrub/scrubland	
Mixed Exotic Shrubland		
Deciduous Hardwoods	Exotic forest	Exotic forest
Exotic Forest		
Forest – Harvested		
Broadleaved Indigenous Hardwoods	Indigenous forest	Native forest/ scrub
Indigenous Forest		
Fernland	Indigenous scrub/scrubland	
Mangrove		
Manuka and/or Kanuka		
Matagouri or Grey Scrub		
Flaxland	Other herbaceous vegetation	

[36] Manaaki Whenua – Landcare Research. (2020). LCDB v5.0 – Land Cover Database version 5.0, Mainland New Zealand GIS data. Palmerston North: In Manaaki Whenua – Landcare Research, (ed.). LRIS Portal.
[37] Refer to the LAWA's land cover factsheet: https://www.lawa.org.nz/learn/factsheets/land/land-cover-and-why-it-is-important/.

LCDB5 detailed classes	Median classes	Baseline broad classes
Herbaceous Freshwater Vegetation		
Herbaceous Saline Vegetation		
Estuarine Open Water	Waterbodies	Waterbodies
Lake or Pond		
River		

The dominant land cover categories for the upstream catchment area of each site were determined according to the following criteria:

- Native forest – comprised of greater than 95% native forest or scrub cover.
- Exotic forest – comprised of greater than 80% exotic forest cover.
- Urban – comprised of greater than 7% urban land cover.

Sites not meeting the above criteria were classed as having predominantly rural land cover and were further divided into the following categories to differentiate rural catchments based on the proportion of grassland or pastoral cover:

- Rural – low – rural catchment with 50% forest cover (native and exotic) or greater.
- Rural – high – rural catchment with less than 50% forest cover.

Data sources

Measured Data

The monitoring programmes designed for SOE monitoring provide coverage across the Auckland region, with sites selected to be representative of a range of environmental conditions (e.g., land cover, catchment location) and type (e.g., lake type, river size). It is important to note that these monitoring programmes evolve over time, with sites added or removed according to varying regional management priorities and the spatial scale of management required. For further details on methodological processes and considerations, please refer to technical reports (Table 6).

All measured data is collected according to Auckland Council's Research and Evaluation Unit's (RIMU) quality assurance procedures. Any data that were assigned a quality assurance code of questionable quality were removed from analysis. Furthermore, any value that is below laboratory detection limits has been replaced by imputed values using Regression Order Statistics (ROS), where estimated values are consistent with the distribution of uncensored values.

Table 6: Summary of recent individual programme reports

Monitoring programme	Frequency of monitoring	Report
River water quality	Monthly	2022 annual report State and trends 2010-2019
River ecology	Annually	State and trends 2010-2019
Lake water quality	Quarterly	State and trends 2010-2019
River Ecosystem Metabolism and Dissolved oxygen	Continuous Data	State of the environment report 2004-2020.

Fish IBI data

The data used to describe baseline state for the fish IBI attribute was obtained from a national database (MfE, 2019[6]) (*n* = 286) and a limited number of regional surveys (*n* = 44). The national data was collected by various organisations for different purposes and is generally comprised of one-off surveys, with repeated sampling rare. Though this data is considered the best available at this time, there are a number of limitations associated with its interpretation of baseline state:

- Data period extends outside the baseline period (2013-2017) to include inputs from 1999 to 2018, creating a trade-off between using recent data and having enough data.
- To avoid potential biases from different sampling methods, the data used to calculate national IBI scores was restricted to surveys undertaken via backpack electrofishing only.
- The national data only considered records in which fish have been identified which may lead to overall IBI scores in FMUs to be over exaggerated.
- Though surveys are undertaken for a variety of reasons, they are largely undertaken to support development or assess reference state. As a result, national data is concentrated around more highly populated areas and native forest in regional parks.
- As discussed in the 'land cover' section of Appendix B (page 51), land cover classification is based on a dated dataset. As a result, some site-specific classifications may not be current to the baseline period.

Due to these limitations, the fish IBI baseline state will be confirmed in future by expert conferencing.

Data requirements

A number of compulsory attributes have defined data requirements for the calculation of state in the NPS-FM (Table 7).

Table 7: NPS-FM monitoring requirements for compulsory attributes and Auckland Council's data standards for reporting. *Indicates regional attributes.

Ecosystem type	Biophysical component	Attributes	NPS-FM monitoring requirements			Auckland council's data standards
			Frequency	Minimum duration	Season	
Rivers	Aquatic life	Macroinvertebrates	Annual	Five years	Summer	Minimum 3 of 5 years
		Fish	Annual	Not specified	Summer	TBD
		Periphyton (eutrophication)	Monthly	Three years	-	
	Water quality	Nutrients: toxicity to aquatic life	Monthly	Five years	-	90% of samples over five years
		Nutrients: eutrophication	Not specified	Not specified	-	90% of samples over five years
		Dissolved oxygen	Continuous	Seven days	Summer	Five years of continuous summer measurements. Min. 90 of 180 summer days for inclusion.
		*Trace metal toxicity to aquatic life	NA	NA	NA	Monthly sampling, 90% of samples over five years

Ecosystem type	Biophysical component	Attributes	NPS-FM monitoring requirements			Auckland council's data standards
			Frequency	Minimum duration	Season	
		*Temperature	NA	NA	NA	Continuous monitoring over five years, minimum 3 years
		Suspended fine sediment	Monthly	Five years	-	90% of samples over five years
	Physical habitat	Deposited sediment	Monthly	Five years	-	TBD
	Ecosystem processes	Ecosystem metabolism	Continuous	Five years	At least 7 days of summer	5 years. Use whole year data[38].
	Human contact	*Escherichia coli*	Monthly	Five years		90% of samples over five years
Lakes	Aquatic life	Submerged plants	Not specified	Not specified	-	Assessed every three-five years
		Phytoplankton (trophic state)	Not specified	Not specified	-	Monthly sampling, with minimum of 80% of samples over five years
	Water quality	Nutrients: eutrophication	Not specified	Not specified	-	
		Ammonia (toxicity)	Not specified	Not specified	-	
		Dissolved oxygen	Monthly or continuous	Not specified	-	
	Human contact	*Escherichia coli*	Monthly	Five years	-	
		Cyanobacteria (planktonic)	Minimum 12 samples	Three years	-	Minimum of 80% of samples over three years

For river water quality, the minimum data standard was reduced to 80 per cent of samples for two monitoring sites, Onetangi Stream (Urban) and Cascades Stream (Rural – Low) on Waiheke Island[39] to maintain broader spatial coverage by inclusion of these sites for the baseline period. The minimum data standard was also reduced to 80% for the NIWA monitored sites of Rangitopuni River and Hoteo River for the nitrate attribute only.

During the baseline state period, lake water quality was measured quarterly, therefore associated grades based on measured data are calculated using between 17 and 20 samples over the five years. Discontinuities in the dataset exist, with a period between August 2013 and August 2014 where no samples were collected. Due to the limited quarterly lake water quality monitoring, state calculations can be skewed by a single value, and seasonal patterns may not be adequately captured. The initiation of monthly lake monitoring in January 2020 will enable more robust calculation of state in future.

[38] Casanovas, P. et al., (2022). Dissolved oxygen and ecosystem metabolism in Auckland rivers 2004-2020. State of the environment reporting. Auckland Council technical report, TR2022/18. Prepared by the Cawthron Institute for Auckland Council.
[39] As these sites were established part way though the baseline period, in February 2013.

For LakeSPI baseline state, the most recent survey conducted before 2017 is used to determine the baseline state.

Adjustments and modifiers

Some water quality attributes require measured values to be modified or adjusted before state calculations are made. Further details on the methodology for each are provided in the most recent river water quality state report, but in summary:

- Measured ammoniacal nitrogen data is adjusted for pH values to calculate ammonia (toxicity) state in both rivers and lakes.
- Nitrate (toxicity) attribute uses the proxy measurement of total oxidised nitrogen (nitrate + nitrite nitrogen). Nitrite is typically a negligible proportion of total oxidised nitrogen.
- Copper (toxicity) is adjusted for dissolved organic carbon.
- Zinc (toxicity) is adjusted for pH, total hardness, and dissolved organic carbon.

Appendix C – Interim baseline state

Rivers

Aquatic life – Macroinvertebrates

In the baseline state period, 22 of Auckland's 66 macroinvertebrate monitoring sites had insufficient data for reporting (less than three of the five years). Thus, to supplement the baseline data and provide a more spatially representative picture of macroinvertebrate community health in Auckland, data from outside of the 2013-2017 baseline period up to 2021 was used to calculate interim baseline states for these 22 sites (Figure 18). These will be assessed for inclusion as baseline states via expert conferencing in future.

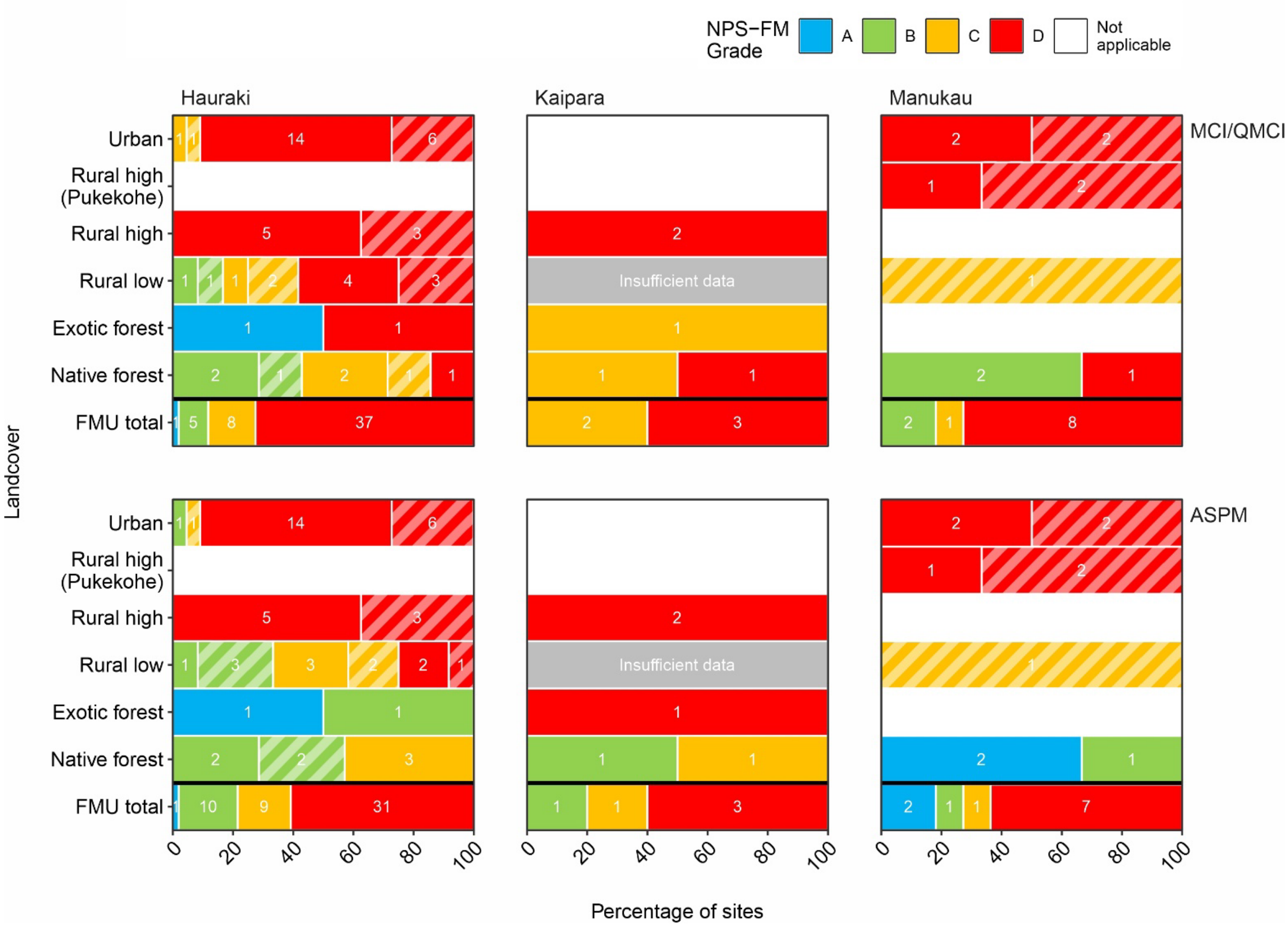

Figure 18: Grading for the MCI/QMCI and ASPM macroinvertebrate attributes for aquatic life in wadeable rivers, across all dominant land cover classes and FMUs. Striped bars indicate interim grade based on more recent data outside the baseline state period. Overall grade displayed. The national bottom line for these attributes is the lower threshold of band C (band D). The number in bars is the number of sites.

Aquatic life – Periphyton: eutrophication

Auckland Council's periphyton monitoring programme was initiated in July 2020 and as such there is no periphyton data available for the baseline state period.

The minimum data period for reporting periphyton is three years (NPS-FM 2020). With the current data set beginning in July 2020 and the latest available data up to March 2023, this does not meet the minimum requirements. Furthermore, some samples were missed during Covid lockdown periods and heavy rainfall events making sampling unsafe or impossible, therefore, the minimum data thresholds for calculating periphyton grades cannot be met until later in 2023.

The Auckland region has few naturally hard-bottomed streams. The streams in the Periphyton programme are those that were identified as being hard-bottomed, being co-located with a flow site, being safely accessible and having enough accessibility down a reach to enable the correct number of transects and views to be measured. There were no sites meeting these criteria identified in the Kaipara FMU and only two in the Manukau FMU. The remainder and majority of sites are in the Hauraki FMU and are dominated by urban land cover in the upstream catchment.

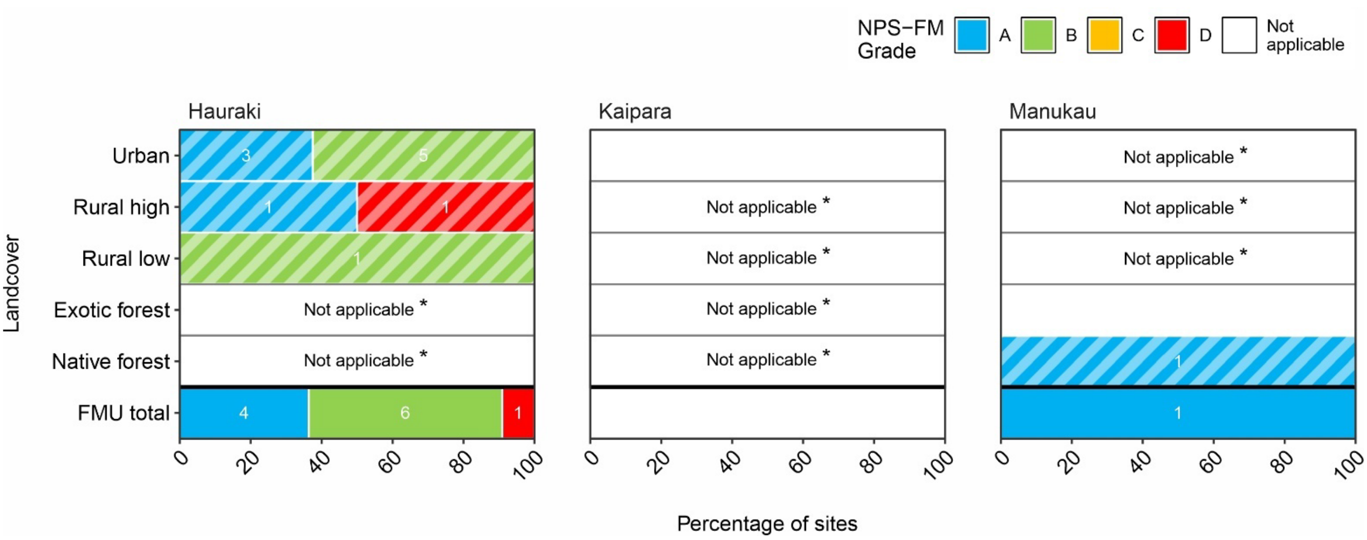

Figure 19: Interim grading for the periphyton attribute for aquatic life in all rivers, across five dominant land cover classes and FMUs over the period 2020-2023. Sites in band D are below the national bottom line. Not applicable* refers to land use categories that do not have hard bottomed streams. The numbers in bars are the number of sites.

Dissolved oxygen

Baseline state for the dissolved oxygen (all rivers) attribute was successfully established for 11 sites based on state of the environment monitoring data. One site, Rangitopuni River, did not meet the internal Auckland Council minimum data requirements for state reporting of at least two years of data. The state assessment is shown in Table 8 below. Both statistics in the DO attribute are consistently below the national bottom line, for this site. Based on this assessment, an overall D band grading is recommended for the baseline state for this site. A provisional assessment of NOF grades for the DO attribute across FMU and land cover classes including this interim grade is provided in Figure 20.

Table 8. NOF grading for Rangitopuni River Monitoring site for the Dissolved Oxygen (all rivers) attribute through time, based on five years of data. Grades based on less than two years of data are considered insufficient.

Hydrological year	Number of years with available data	DO One day min (mg/L) – Median NOF band	DO Seven day mean min (mg/L) – Median NOF band	Overall NOF band
2011	3	D	D	D
2012	4	D	D	D
2013	3	D	D	D
2014	3	D	D	D
2015	2	D	D	D
2016	2	D	D	D
2017	1	D	D	D
2018	1	D	D	D
2019	2	D	D	D
2020	2	D	D	D

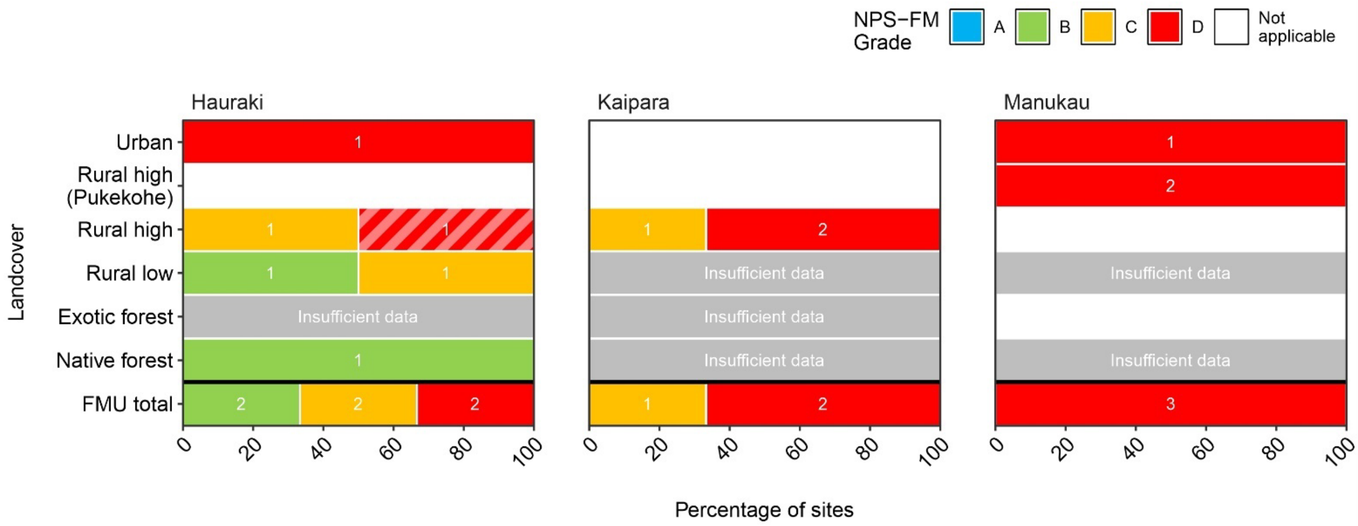

Figure 20: Grading for the Dissolved oxygen (DO) attribute across five dominant land cover classes and FMUs over the baseline period. Overall grade displayed. Sites in D band are below the national bottom line. Striped bars indicate interim grading based on less than two years of data. Number in bars are the number of sites.

Auckland Council has recently increased the number of continuous DO monitoring sites (with monitoring focusing on the summer period (November to April) improving coverage across a range of land cover and nutrient gradients. Thirteen additional sites were established in November 2021. Significant flood events in summer 2023 have disrupted this monitoring programme leading to delayed reporting. Therefore, results from new monitoring sites will be included in the next iteration of this report.

Suspended sediment

Until regional verification of the national turbidity to visual clarity conversion can be made, grading of suspended fine sediment (visual clarity) is considered interim.

There was **no clear difference in visual clarity state between rural and urban land cover classes within each FMU** (Figure 21). There was a higher proportion of sites in bands C and D in both urban and rural rivers compared to exotic and native forest rivers. All sites within native forested catchments were in bands A and B. Exotic forestry sites varied from B to C.

One urban site and one rural site within the Hauraki FMU failed the national bottom line (D band) for visual clarity. The rural river that failed the bottom line has been observed to have brown coloured water and further work is needed to identify if this is due to naturally occurring processes. **No monitored rivers in the Kaipara or Manukau FMUs were found to fail the national bottom line.**

The wide variation in visual clarity baseline state within land cover classes suggests that there are processes driving visual clarity in Auckland rivers that are not explained by land cover alone. The main sources of sediment to rivers are erosion and wash off from land, landslides, and riverbank erosion[40]. These sediment sources can vary depending on the size and shape of the waterway, soil and underlying catchment geology, the slope of the land, rainfall, and land cover and land use practices. Thus, further classifications of rivers in future, other than just by land cover, may better explain variation in the state of visual clarity in rivers and help to support identifying appropriate objectives and targets in future.

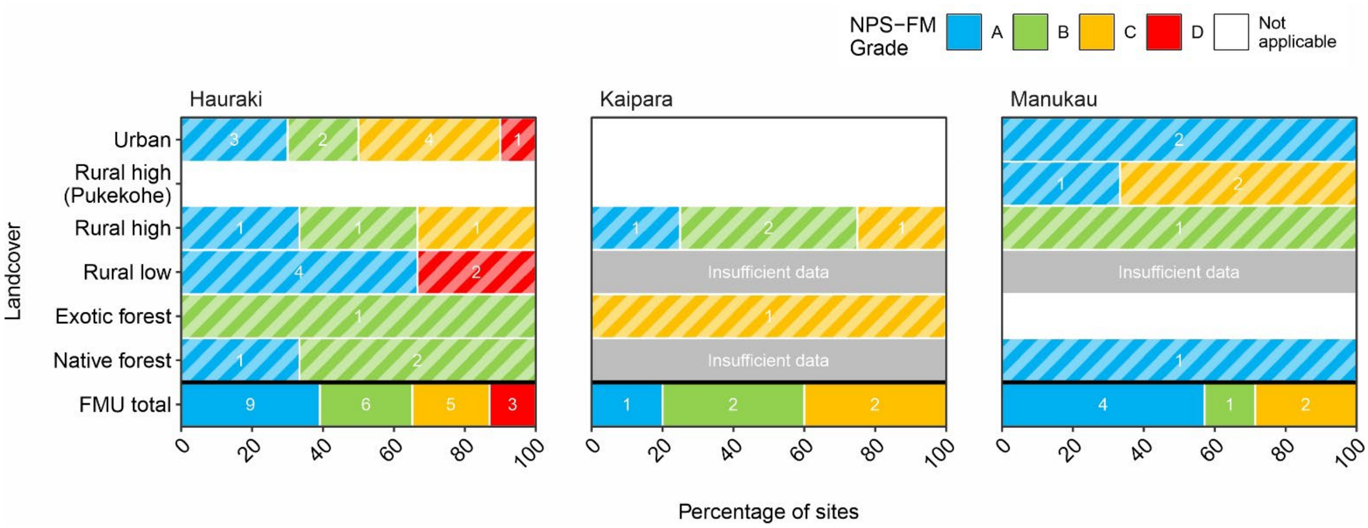

Figure 21: Interim grading for the Suspended Fine Sediment (visual clarity) attribute for water quality in all rivers, across five dominant land cover classes and FMUs over the baseline period (2012-2017). Grading based on converted turbidity data. Sites in band D are below the national bottom line. Numbers in bars are the number of sites.

[40] Hughes, A.O., Huirama, M.K., Owens, P.N., Petticrew, E.L. (2021) Stream bank erosion as a source of sediment within New Zealand catchments, *New Zealand Journal of Marine and Freshwater Research*, DOI: 10.1080/00288330.2021.1929352

Lakes

In 2020, additional lakes (Figure 22) were added to Auckland Council's SOE monitoring network to improve representation of lakes across Auckland FMUs. These include lakes across land cover classes of native forest (Kawaupaku), rural high (Pokorua, Slipper, Spectacle and Whatihua) and rural low (Kereta, Okaihau and Te Kanae).

The interim grades presented in this section are calculated from available measured monthly data from July 2020 to June 2023 inclusive, as limited, or no, measured, or modelled data is available for these lakes over the baseline period. It is important to note that the additional lakes score lower for most compulsory attributes, and therefore the five lakes with confirmed baselines are likely not representative of the condition of all lakes in the Auckland region. For more information on lake attributes refer to the Lake Baseline State section in this report.

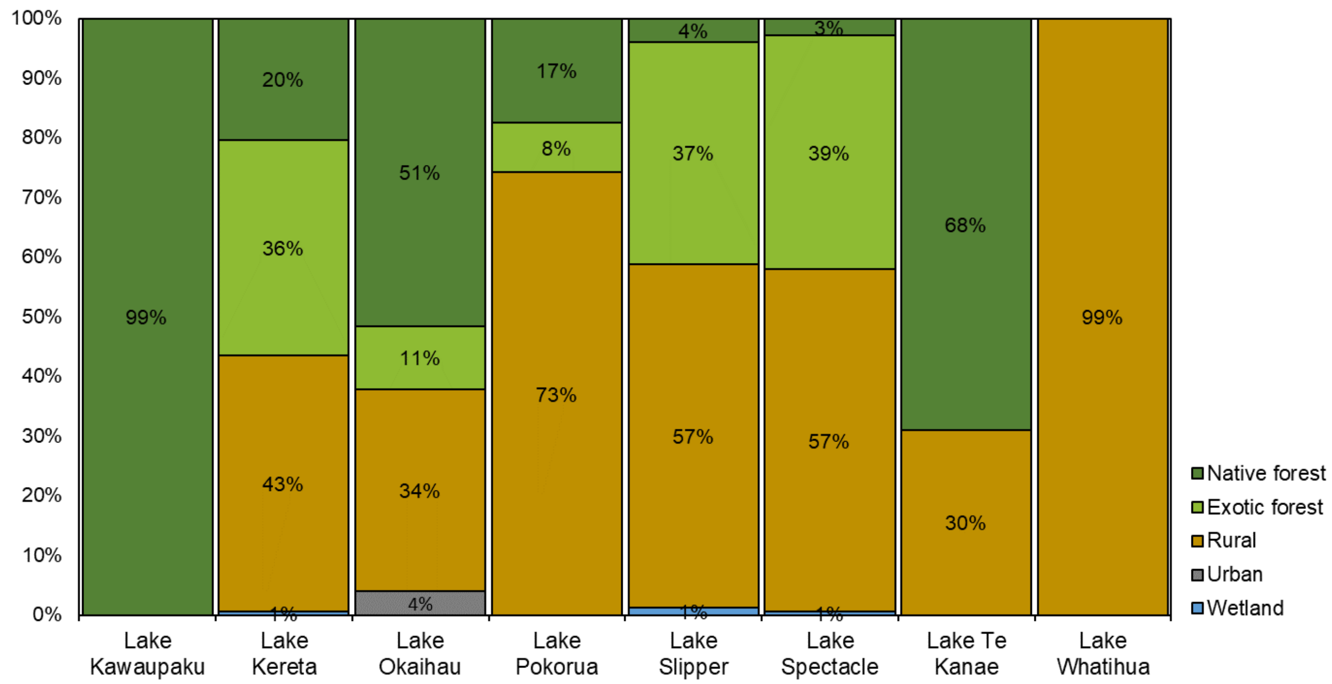

Figure 22: Proportions of catchment land cover for lakes added to SOE monitoring programme in 2020, based on 2018 LCDB5 medium level class data.

Aquatic Life

All interim-grade lakes are below the national bottom line (Band D) for the phytoplankton attribute except Lake Te Kanae (Band C) (Figure 23). The consistently elevated concentrations of chlorophyll-*a* suggest all lakes are impacted by excess nutrient enrichment. **Most interim grade lakes are also below the national bottom line for the submerged plants (native) attribute, and all lakes are in band C or D for the submerged plants (invasive) attribute** (Figure 23).

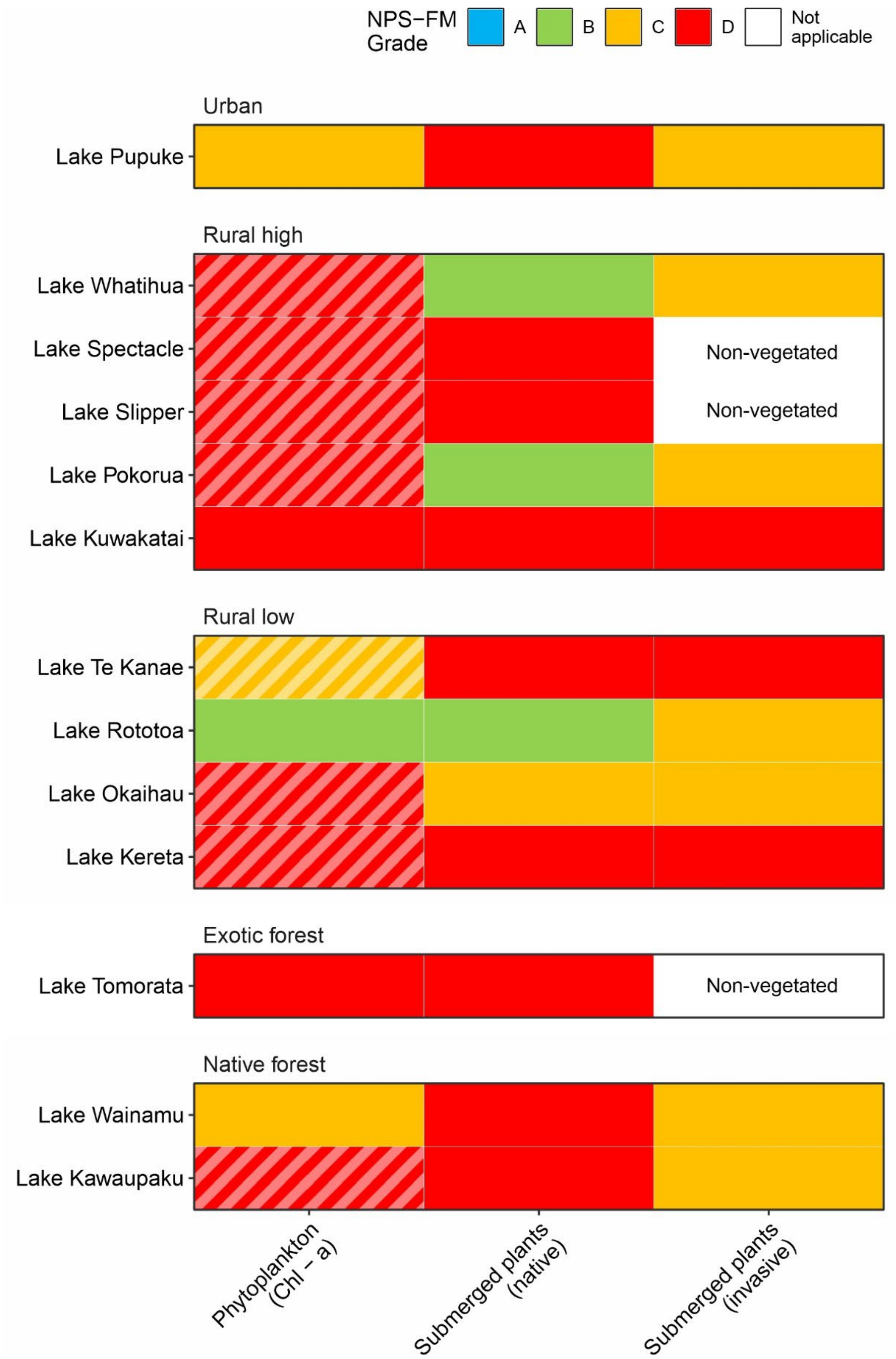

Figure 23: Baseline and interim baseline grading for the Phytoplankton and Submerged Plants (native and invasive) attributes for aquatic life in the monitored lakes in the Auckland region. Overall grade displayed for the phytoplankton attribute. Striped bands indicate interim grading based on available recent data (between 2020-2023). Sites in band D are below the national bottom line. Note: Lake Wainamu was last monitored for submerged plants in 2007 and is included here as phytoplankton and submerged plants are ecologically interrelated and it is best to interpret them together.

Water Quality

All water quality attributes have the national bottom line set below band C, except for the ammonia attribute (toxicity) set below band B. The interim bands for TP and TN are all in band C or D with the exception for TP at Lake Te Kanae. **All interim-baseline lakes failed both dissolved oxygen attributes except Lake Kereta and Lake Pokorua** (Figure 24). The lakes that did not fail the dissolved oxygen attribute are too shallow for water for top and bottom waters to remain separated and become anoxic.

All lakes with interim-baseline are above the national bottom line (Band A and B) for the ammonia attribute except for Lake Kereta (Band C) (Figure 24), suggesting species are protected from chronic toxicity effects in these lakes.

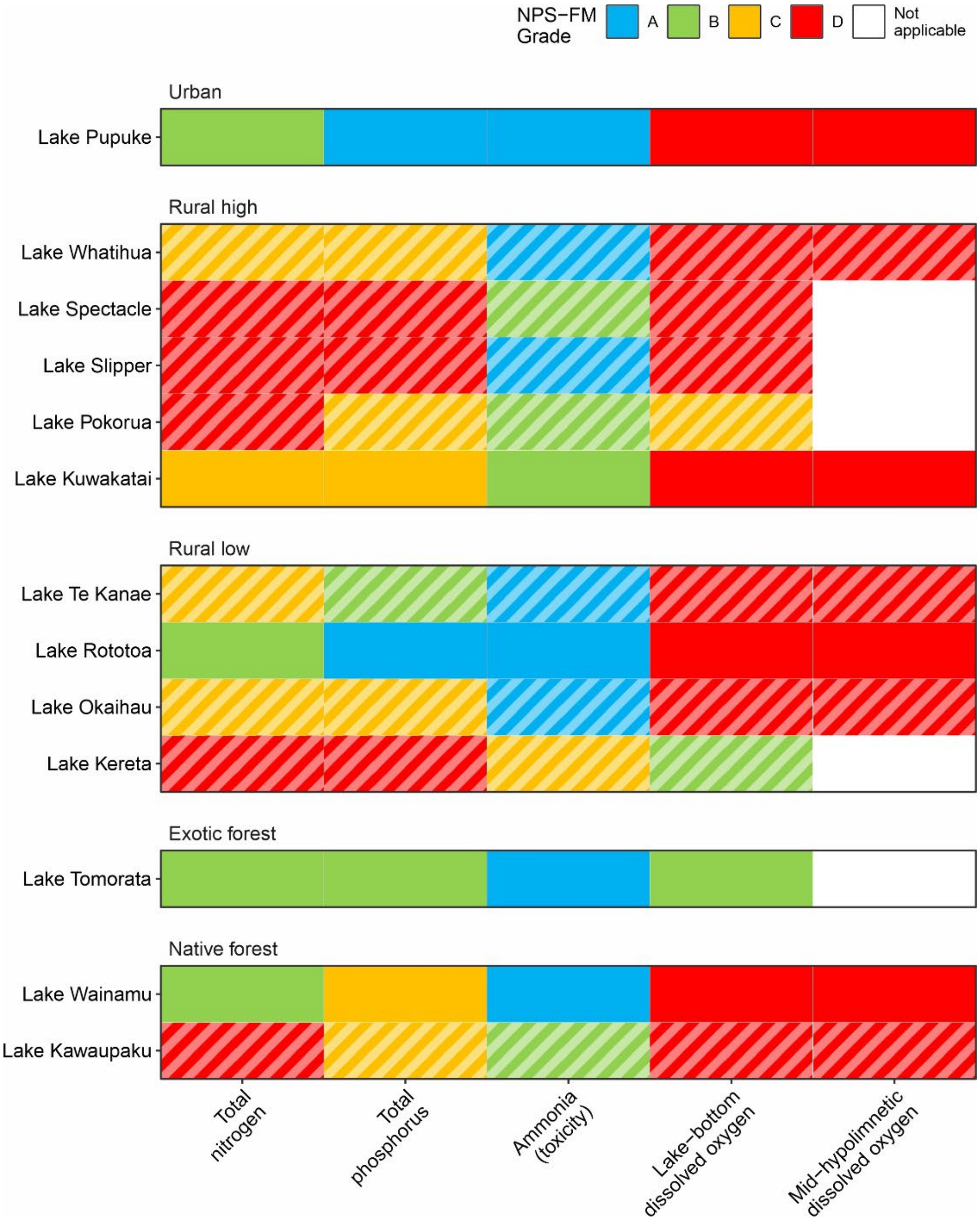

Figure 24: Baseline and interim baseline grading for the Total Nitrogen, Total Phosphorus, Ammonia (toxicity), Lake-bottom Dissolved Oxygen and Mid-Hypolimnetic Dissolved Oxygen attributes for water quality in monitored lakes in the Auckland region (2012-2017). Overall grade displayed for the ammonia (toxicity) attribute. For Ammonia (toxicity) sites in band C and D are below the national bottom line. For all other attributes, sites in band D are below the national bottom line. Striped bands indicate interim grading based on available recent three years of data (2020-2023).

Human Contact

The cyanobacteria and *E. coli* attribute are considered interim baseline state as there is no data before January 2020 that meet band calculation data requirements. **All lakes with sufficient data are in band A for the cyanobacteria attribute, except for Lake Slipper (band B)** (Figure 25), which is above the national bottom line of below band C. Interim baseline state for the remaining lakes range from band A to band D. Lakes Kereta, Kuwakatai, Whatihua and Kawaupaku are all below the national bottom line in band D.

All sites except for Lake Okaihau and Lake Pokorua score as band A for the *E. coli* attribute (Figure 25). This indicates a minimal risk of *E. coli* infection during human contact at most Auckland lakes.

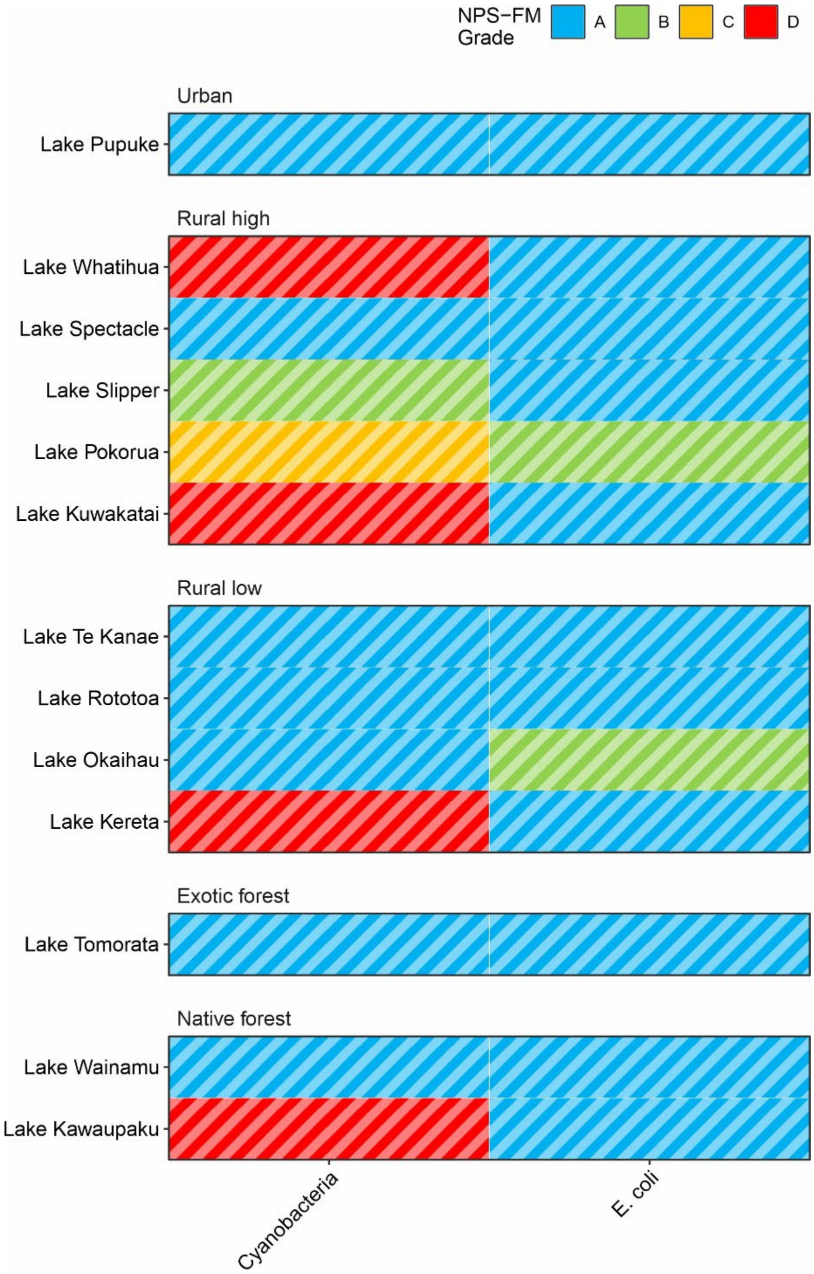

Figure 25: Interim baseline grading for the *E. coli* and Cyanobacteria attributes for human contact at monitored lakes in the Auckland region. Interim grading based on available recent three years of data (2020-2023) for *E. coli* and two years of data (2021-2023) for cyanobacteria.

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