River Ecology State and Trends in Tāmaki Makaurau / Auckland 2010-2019. State of the Environment Reporting

A Chaffe

February 2021 Technical Report 2021/05

Research and Evaluation Unit RIMU

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Opanuku Stream monitoring site, photograph taken by Ange Chaffe

Executive summary

Auckland Council's freshwater monitoring programmes are designed to increase understanding of the health of freshwater systems, habitats and organisms in the region. Through the collection of environmental data, we can determine the amount of natural variability which is likely to occur and use this to assess the performance of environmental control mechanisms and detect trends which may be attributed to land use change and/or climatic variation.

The River Ecology Monitoring Programme (REMP) commenced in 1999. Led by Auckland Council's Research and Evaluation Unit (RIMU), the programme involves the collection of macroinvertebrate community and stream habitat data and provides information on the condition of permanent, wadeable rivers and streams in the region. The programme aims to track council's progress in achieving environmental goals and forms part of the feedback loop necessary to confirm that environmental control strategies implemented under the Auckland Unitary Plan (Operative in part) are effective in sustaining river ecosystem function and opportunities for future use.

The purpose of this report is to assess the current condition of rivers and streams across the Auckland region using the macroinvertebrate community Index (MCI) and Stream Ecological Valuation (SEV), identify changes in river ecology over time and understand the pressures influencing overall health. State analysis was undertaken using MCI and SEV data from 68 monitoring sites across the region, while 10-year trends in macroinvertebrate data were also assessed across 30 sites and SEV data for 15 sites. This report is the first to include SEV data as a descriptor for stream habitat and function for council's monitored sites. This, and other information, will help decision-makers to assess the performance of existing plan controls and inform the direction of effective resource management and environmental policy.

Based on median MCI scores, 13 per cent of sites in the region were classified as being in the excellent quality class, indicating high water quality and habitat conditions. Results from 18 per cent of sites within the region were indicative of good habitat quality and possible mild pollution within associated streams. Sixty-nine per cent of sites were classified as poor to fair, with macroinvertebrate communities reflecting poor to fair water quality and/or instream habitat quality. Macroinvertebrate results showed strong correlations with SEV scores, land cover and water quality indices, indicating a general increase in MCI scores with improved stream function, habitat quality and water quality.

Trends in MCI were highly variable across all land cover categories, showing no obvious patterns in spatial distribution of MCI quality classes. Ten of the 30 sites suitable for trend analysis returned indeterminate trends, spanning all land cover types except exotic forest. Twenty-three per cent of sites recorded improving trends in MCI, while trends at 43 per cent of sites were found to be degrading. The trends observed spanned all land cover categories and National Policy Statement for Freshwater Management attribute bands.

Median SEV scores indicated 24 per cent of monitored sites in the region have excellent ecological function and habitat conditions, which are close to or at reference state. The majority of sites (60 per cent) in the region were classified as being in fair to good ecological condition, suggesting that most streams in the region are low to moderately impaired by anthropogenic pressures. Sixteen per cent of sites, all located in urban areas, were classified as poor. There was a strong relationship observed between median SEV score and land cover within the upstream catchment, indicating a pattern of reduced habitat quality and function with increased modification.

The indicators used to describe ecological health in this report provide a varying picture of the health of rivers in the Auckland region. Streams within native forest catchments tend to have the greatest ecological values, both in terms of macroinvertebrate community composition, stream habitat and overall function. Although there were no obvious patterns in the spatial distribution of observed state and trends, all measures showed a clear pattern of decline with increased land cover modification and intensification. As a result, urban sites were consistently found to be in the worst ecological health. An outcome which is largely influenced by the loss of riparian margin integrity and channel modification, as well as land cover modification within the upstream catchment. Results were comparable to previous regional reporting and show similarity with what is being observed at the national level.

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1.0 Introduction

1.1 Freshwater environments and the Auckland region

The Auckland region covers a land area of approximately 4894km^2 and encompasses a range of freshwater ecosystems, including lakes, rivers, streams, springs and wetlands. These ecosystems support a variety of indigenous flora and fauna, offer aesthetic and recreational values and are an integral part of Māori culture. Rivers and streams are central to Māori identity and well-being and are also a valued source of mahinga kai (NZ Conservation Authority, 2011). Ecological indicators of river health can also provide a tangible representation of a river system's mauri.

Auckland's river network consists of approximately 19,000km of permanently flowing rivers and streams, as well as an estimated combined length of 11,590km of intermittent and ephemeral streams (Auckland Council Geomaps V 3.2.1.1). These waterbodies are strongly influenced by the region's topography and underlying geology and, as a result, Auckland rivers are largely slow-flowing, low gradient and soft-bottomed in nature. Naturally occurring high gradient, hard-bottomed rivers are generally restricted to catchments within the Waitākere Ranges, Hunua Ranges and Aotea / Great Barrier Island. The Auckland area, particularly the central isthmus, is relatively narrow. As a result, the region's river catchments are generally small, often draining to the coast before larger river systems can form. Consequently, most rivers in Auckland are classified as first and second order streams (Snelder, et al., 2010; Storey & Wadhwa, 2009) which are characteristically short in length and no more than a few metres in width.

River ecology is in part regulated by natural environmental variability (i.e. geology, seasonal variation in rainfall and temperature); however, some are also heavily influenced by anthropogenic pressures (Allan & Castillo, 2007). Construction activities, such as stream realignment, piping and reclamation can have significant impacts on river ecosystems, including loss of river length and habitat, modification of instream habitat and riparian margins, interruption of natural functions and dispersal pathways, and altered flow regimes (Auckland Council, 2015). While land-based contaminants, such as sediment and nutrients, can enter rivers through overland run-off and groundwater seepage, reducing water and habitat quality and subsequently altering the makeup of biological communities. Rivers also form the interface between land and marine systems and are the primary mechanism for conveying land-based contaminants to these environments, where they can accumulate and disrupt natural processes and function.

Auckland’s freshwater monitoring programmes increase understanding of the health of freshwater systems, habitats and organisms in the region. Through the collection of environmental data, we can determine the amount of natural variability which is likely to occur and use this to assess the performance of management control mechanisms and detect trends which may be attributed to land use change and/or climatic variation.

1.2 National and regional directives

Auckland Council’s River Ecology Monitoring Programme (REMP) is led by the Research and Evaluation Unit (RIMU) and is designed to meet the following national and regional objectives:

- Satisfy Auckland Council’s obligations under section 35 of the Resource Management Act 1991 to monitor and report on the state of the region’s river environments.
- Contribute to Auckland Council’s ability to maintain and enhance the quality of the environment (Local Government Act 2002).
- Meet Auckland Council’s obligations under the National Policy Statement for Freshwater Management (NPS-FM), including monitoring and management of key attribute states aimed at improving the health of freshwater environments (MfE, 2020).
- Help inform the efficacy and efficiency of regional policy initiatives and strategies.
- Assist with the identification of large scale and/or cumulative impacts of land use activities and disturbance on biological communities and river ecological function.
- Supplement mātauranga Māori knowledge held by mana whenua and further support their role as kaitiaki to protect and enhance te mauri o te wai (the life supporting capacity of water).
- Provide baseline and regionally representative data to support the resource consent process and associated compliance monitoring for river environments.
- Continuously increase the knowledge base for Aucklanders and promote awareness of river ecology and habitat function in the region and how these might be managed.

These objectives are provided for under the Auckland Unitary Plan (Operative in Part) and fit under the “Environment and Cultural Heritage” component of the Auckland Plan 2050. A key challenge identified for the region is managing the effects of growth and development on our natural environment and ensuring environmental values are maintained for the benefit of future generations. These documents inform the direction of specific policies and rules for minimising and managing the adverse effects of present and future urban and rural intensification and population growth across the region, and seek to ensure that the values of Auckland's freshwater resources are restored, maintained and enhanced.

The parameters monitored in the REMP provide information on the condition of the region's river and stream systems, track council's progress in achieving environmental goals and provide feedback on the performance of management actions. The programme forms part of the feedback loop necessary to confirm that management strategies implemented under the Auckland Unitary Plan are effective in sustaining ecosystem function and opportunities for future use.

1.3 Report purpose and objectives

The purpose of this report is to assess the current condition of rivers and streams (collectively referred to as rivers henceforth) across the Auckland region, identify changes in river ecology over time and understand the pressures influencing overall health. This information helps decision-makers to assess the performance of existing management strategies and informs the direction of effective resource management and environmental policy.

The primary objectives of this report are to:

- Describe the current ecological condition of permanent, wadeable rivers in the region through the assessment of macroinvertebrate communities and river functional qualities.
- Identify temporal trends in key indicators and descriptors at sites considered to have robust long-term data.

1.4 Supporting information

This report has been produced alongside several others pertaining to the freshwater and marine environments in the Auckland region, including:

- *Auckland river water quality: annual reporting and National Policy Statement for Freshwater Management current state assessment, 2019* – TR2021/11
- *Coastal and estuarine water quality 2019 annual report* – TR2020/016
- *Coastal and estuarine water quality state and trends in Tāmaki Makaurau / Auckland 2010-2019. State of the environment reporting* – TR2021/02
- *Groundwater quality state and trends in Tāmaki Makaurau / Auckland 2010-2019. State of the environment reporting* – TR2021/03

- *Lake water quality state and trends in Tāmaki Makaurau / Auckland 2010-2019. State of the environment reporting* – TR2021/04
- *Marine ecology state and trends in Tāmaki Makaurau / Auckland to 2019. State of the environment reporting* – TR2021/09
- *Marine sediment contaminant state and trends in Tāmaki Makaurau / Auckland 2004-2019. State of the environment reporting* – TR2021/10
- *Rainfall, river flow, and groundwater level state and trends in Tāmaki Makaurau / Auckland 2010-2019. State of the environment reporting* – TR2021/06
- *River water quality state and trends in Tāmaki Makaurau / Auckland 2010-2019. State of the environment reporting* – TR2021/07.

The authors in this series have worked collectively to analyse current state and trend data over the same time periods (2010-2019). This is a new approach adopted by RIMU and aims to better identify potential linkages between biomes and disciplines and inform overall State of the Environment reporting in a more consistent manner.

All related reports (past and present) are available on Auckland Council's Knowledge Auckland website: www.knowledgeauckland.org.nz.

Further enquiries or data requests in relation to this or any other reports, including summary data outputs from analyses used in this report, can be directed to environmentaldata@aucklandcouncil.govt.nz.

2.0 River ecological monitoring programme

Council's REMP commenced in 1999 and involves the collection of macroinvertebrate and habitat data from permanent, wadeable rivers throughout the region. The programme has been largely focused on the collection of macroinvertebrate data and was initially designed to support the development of national sampling and assessment protocols (Maxted et al., 2003; Stark et al., 2001). Since development of standardised sampling protocols and reporting indices (Maxted et al., 2003; Stark , et al., 2001; Stark and Maxted, 2004; Stark & Maxted, 2007), annual macroinvertebrate data has been used to assess the ecological health of rivers in the region and support Auckland Council's State of the Environment reporting. Data have also been used for informing the consenting process and for developing interim guidelines for managing freshwater values until specific objectives and limits could be determined under the NPS-FM.

Due to the annual frequency of data collection, past reporting of REMP results has been limited. In 2005, a brief report summarised results from 41 sites used in the development of macroinvertebrate indices for soft-bottomed rivers (Maxted, 2005). This was followed by an in-depth state analysis of macroinvertebrate communities sampled across Auckland from 2003 to 2007 (Moore & Neale, 2008) and lastly, a state and trend analysis of 71 and 51 sites respectively was prepared for the period 2003 to 2013 (Neale, et al., 2017).

Since 2000, the macroinvertebrate component of the REMP has been supplemented by stream habitat assessments, initially using a rapid habitat assessment approach, followed by Stream Ecological Valuation (SEV) assessments (Appendix A). Rapid habitat assessment results were reported alongside macroinvertebrate data in 2008 (Moore & Neale, 2008), however, following report recommendations, this method was replaced with the SEV in 2009. SEV results have not previously been formally reported because of small sample sizes. This report will be the first to include this data as a descriptor for river habitat and function.

3.0 Methods

3.1 Monitoring network

The composition and structure of the monitoring network has varied over the years as programme objectives have changed (refer to Appendix A). The current monitoring network (Appendix B) is comprised of 76 sites which span each of Auckland Council's 10 geographically defined 'watersheds', including coverage of hard- and soft-bottomed substrate types (Table 3-1) and various stream orders (Snelder, et al., 2010). The watersheds reflect the region's major harbours and coastlines (Figure 3-1) and are aimed at providing an integrated catchment-level management approach that considers how land-based characteristics and activities may affect coastal receiving environments. Only sites within the current monitoring network were assessed in this report.

Table 3-1: Breakdown of River Ecology Monitoring Programme site representation across Auckland Council's watersheds and stream substrate types.

Watershed	No. of monitoring sites	No. of hard-bottomed stream sites	No. of soft-bottomed stream sites
Hauraki Gulf Islands	6	4	2
North East Coast	1	-	1
Mahurangi Harbour	8	1	7
South Kaipara Harbour	5	0	5
Hibiscus Coast	11	-	11
West Coast	3	3	-
Waitematā Harbour	22	9	13
Greater Tāmaki	6	3	3
Wairoa	5	3	2
Manukau Harbour	9	1	8
Total	**76**	**24**	**52**

Figure 3-1: Distribution of current River Ecology Monitoring Programme monitoring network sites (*n* = 76) across the Auckland region (inset map provides the location of sites on Aotea / Great Barrier Island).

3.2 Land cover categories

Catchment-scale land cover for each monitoring site was calculated using geospatial data obtained from the Land Cover Database (LCDB) v5.0 (Manaaki Whenua – Landcare Research, 2020b). Land cover descriptors were assessed and grouped according to four broad land cover types: native forest, exotic forest, rural, and urban. The dominant land cover categories (*n* = 5) used to describe upstream catchments in this report were determined according to the following criteria:

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

Sites not meeting the above criteria were classified as having predominantly rural land cover and divided into the following categories to describe rural catchments that have low versus high grassland or pastural cover:

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

Figure 3-2 describes the distribution of all 76 REMP monitoring sites across the five dominant land cover categories. For more details regarding the grouping of LCDB5 land cover descriptors and rationale for determining the dominant land cover categories described, refer to Appendix C.

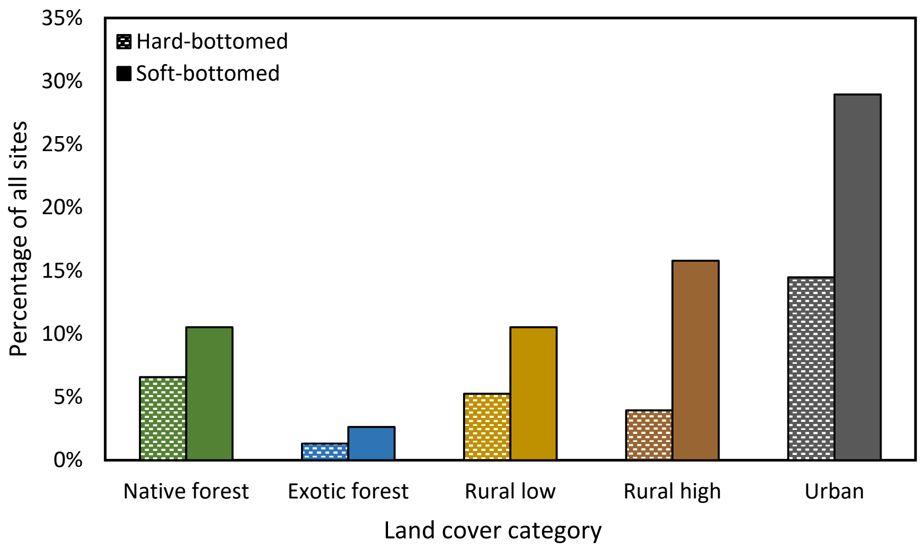

Figure 3-2: Distribution of current River Ecology Monitoring Programme sites across the five dominant land cover categories (derived from LCDB5).

3.3 River ecology data collection

Annual macroinvertebrate samples were collected by Auckland Council staff during the summer season (January-March) in accordance with standard sampling protocols for wadeable rivers and streams (Stark, et al., 2001). Samples were collected using semi-quantitative protocols C1 and C2 for hard-bottomed and soft-bottomed rivers respectively. A fixed area of river habitat (gravel, boulders or riffles in hard-bottomed rivers; and woody debris, macrophytes or bank margins in soft-bottomed rivers) was manually disturbed and dislodged organisms were swept into a handheld D-net (0.5mm mesh).

Composite samples were preserved in 70 per cent ethanol in the field and subsequently processed and identified by qualified macroinvertebrate taxonomists in accordance with protocol P1 (coded abundance). To ensure taxa were correctly identified, 10 per cent of all samples collected were subjected to quality control procedures in accordance with protocol QC1 (Stark et al., 2001). More information is provided in Appendix A.

River habitat and function data were collected approximately every four years and completed simultaneously with macroinvertebrate data in accordance with standard SEV methodologies (Rowe, et al., 2008; Neale, et al., 2011; Storey, et al., 2011). Observational cross section and reach scale measures were assessed along a sample reach of approximately 100m. Refer to Appendix D for more information.

3.4 River ecology data processing

To ensure taxonomic consistency between years, raw macroinvertebrate data were audited and standardised prior to analysis. The dataset was checked for any taxonomic changes or differences in identification levels that may have occurred between sample processors and adjusted accordingly. In general, the level of identification and assigned tolerance values aligned with those described in Stark and Maxted (2007b). Where taxa or tolerance values were previously unprescribed, these were assigned using professional judgement and based on standard guidelines (Stark & Maxted, 2007b) and values used to inform the NPS-FM (Clapcott, et al., 2017). Recorded taxa without corresponding 'macroinvertebrate community index (MCI)-level' tolerance scores (non-scoring taxa) were removed from all analyses.

In accordance with prior reporting, the following macroinvertebrate community metrics were calculated for all sites within the final dataset using the R statistical programme (R Core Team, 2020):

- Taxa richness (total number of scoring taxa).

- Per cent (%) Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness (percentage of total scoring EPT taxa in a sample) – excluding caddisflies from the Hydroptilidae family, namely *Oxyethira* and *Paraoxyethira*, in accordance with recommendations from Maxted, et al. (2003). These genera are often associated with filamentous algal growths and are generally abundant in degraded environments, and as a result can skew results.
- MCI: hard- and soft-bottomed variants were used and calculated according to corresponding substrate type (refer to Appendix E for index background and calculation).

Observational field SEV data were inputted into the respective calculators for each version of the SEV (Rowe, et al., 2008; Storey, et al., 2011). In accordance with assessment methodologies, corresponding macroinvertebrate presence-absence and Auckland-specific fish index of biotic integrity (IBI) data were also entered into the calculator, along with results from desktop geospatial analyses.

Raw data and score calculations were internally reviewed and quality checked to ensure consistency in data between years and correct calculation of scores. More information regarding the SEV methodology and comparability between SEV versions is provided in Appendix D.

Water quality data used for investigative analyses were derived from Auckland Council's River Water Quality Monitoring Programme. Calculated water quality index (WQI) scores for 18 paired river water quality-ecology monitoring sites were obtained (*pers. Comms.* R. Ingley 2020, 22 September) for comparison against the ecological indicators described above. For more information regarding specific water quality data and calculation of the WQI refer to the 2019 annual river water quality report (Ingley and Groom, 2021).

3.5 River ecology data analysis

3.5.1 State analysis

The current state of instream macroinvertebrate communities and the overall function of rivers is measured and described to provide an indication of the ecological function and condition of rivers within the Auckland region. Macroinvertebrate community state analysis was undertaken in accordance with Land, Air, Water Aotearoa (LAWA) guidelines for assessing river ecological health (Cawthron Institute, 2019b). Monitoring network macroinvertebrate data collected between 2015 and 2019 (inclusive) were filtered to remove sites with less than three sample events, resulting in a final reporting data set of 61 sites (80 per cent of possible total sites) across the region.

Due to the frequency at which historical SEV assessments have been undertaken, the overall sample sizes for each monitoring site are small (n = 2 – 5) and as a result, SEV data collected from 2015 to 2019 was considered insufficient to undertake a representative state analysis. As such, SEV data collected over the entire life of the programme (from 2009 to 2019 inclusive) were collated and sites with less than three data points were removed, resulting in a final dataset comprised of 68 sites (89 per cent of possible total sites) across the region.

Basic statistics, median, minimum and maximum, were calculated using the R package (R Core Team, 2020). Boxplots were used to describe the distribution of macroinvertebrate metrics (MCI, %EPT richness and taxa richness) and SEV results across the region. The boxplots were comprised of:

- a median, presented as the horizontal line in the middle of the box
- 25th and 75th percentiles presented as the lower and upper boundaries of the box
- 10th and 90th percentiles presented as the lower and upper extent of the whiskers (error bars)
- outliers presented as dots extending outside the whiskers.

The overall ecological state of rivers within the region was described using traditional MCI quality classes (Stark & Maxted, 2007b) (Table 3-2), including consideration of the ‘fuzzy boundaries’ or margin of error (±5 MCI units) recommended for interpreting results occurring on the boundary of class thresholds (Stark & Maxted, 2007b). The state of river habitat and function was described using professional interpretation (Table 3-3) of the upper and lower limit SEV score thresholds provided in Storey, et al. (2011). Results were summarised according to the dominant land cover categories described in Section 3.2.

Table 3-2: Interpretation of Macroinvertebrate Community Index scores (Stark & Maxted, 2007a).

MCI score	Quality Class	Description
>119	Excellent	River in excellent ecological condition. Indicative of excellent water quality and habitat conditions.
100-119	Good	River in good ecological condition. Indicative of possible mild pollution and/or good habitat conditions.
80-99	Fair	River in fair ecological condition. Indicative of probable mild pollution and/or fair habitat conditions.
<80	Poor	River in poor ecological condition. Indicative of probable severe pollution and/or poor habitat conditions.

Table 3-3: Table E-2: Interpretation of Stream Ecological Valuation scores.

SEV score	Class	Description
≥0.81	Excellent	River in excellent ecological condition. Indicative of ecological function and habitat conditions close to or at reference condition.
0.61-0.80	Good	River in good ecological condition. Indicative of good habitat conditions, few stream functions are impaired. Low deviation from reference state.
0.41-0.60	Fair	River in fair ecological condition. Indicative of fair habitat quality, some stream functions are impaired. Moderate deviation from reference state.
<0.40	Poor	River in poor ecological condition. Indicative of poor habitat condition, several stream functions are impaired. Substantial deviation from reference state.

Overall results were supported by a broad description of macroinvertebrate community composition and river characteristics identified in the SEV data. Relationships between SEV scores and land cover, and between macroinvertebrate community metric results, land cover, SEV scores, and WQI scores were assessed using Spearman rank correlation, with a significance threshold of $p < 0.05$.

3.5.1.1 Comparison against MCI thresholds

In order to gauge how MCI results perform against regional and national standards, MCI results recorded at the 61 sites used for state analysis were compared against Auckland Unitary Plan interim guideline values for MCI (native forest ≥123, exotic forest ≥111, rural ≥94 and urban ≥68) and the NPS-FM (MfE, 2020) National Objective Framework (NOF) MCI attribute bands (Table 3-4). In both cases consideration was given to the margin of error (±5 MCI units) recommended by Stark and Maxted (2007b); refer to Appendix E. In accordance with the NPS-FM (MfE, 2000), median state results were directly compared against NOF MCI attribute bands; however, Auckland Unitary Plan interim guideline values were developed using average MCI scores calculated across dominant land cover categories and, as such, comparisons against these thresholds took a different approach.

Table 3-4: Interpretation of macroinvertebrate community index scores in accordance with NPS-FM attribute bands and descriptions (MfE, 2020).

MCI score	Attribute band	Description
≥130	A	Macroinvertebrate community is indicative of pristine conditions, with almost no organic pollution or nutrient enrichment.
≥110 and <130	B	Macroinvertebrate community is indicative of mild organic pollution or nutrient enrichment and largely composed of taxa sensitive to organic pollution/nutrient enrichment.
≥90 and <110	C	Macroinvertebrate community is indicative of moderate organic pollution or nutrient enrichment, with a mix of taxa both sensitive and tolerant of organic pollution/nutrient enrichment.
90	**National bottom line**	
<90	D	Macroinvertebrate community is indicative of severe organic pollution or nutrient enrichment and largely composed of taxa tolerant of organic pollution/nutrient enrichment.

In order to align with the method used to develop the Auckland Unitary Plan interim guidelines for MCI (Neale, 2015), a five-year (2015 to 2019 inclusive) average MCI score was calculated for each monitoring network site to determine which are currently above/below the interim guideline values for their respective land cover category. To understand whether values have been maintained or enhanced over time (as required under Policy E1.3(2) of the Auckland Unitary Plan), current site averages were compared against a calculated 'previous state' which aimed to reflect the average MCI scores of analysed sites over the time period (2010 to 2014 inclusive) at which the interim guideline values were calculated. Sites with less than three data points were excluded from this analysis.

Performance of calculated average MCI scores against interim guidelines and changes in state over time were assessed using the margin of error (±5 MCI units) described by Stark and Maxted (2007b). As such, only average MCI scores occurring outside of the margin of error were considered to be above/below interim guideline values with certainty and only increases or declines which exceeded this threshold were considered to be meaningful and recorded as enhanced or degraded accordingly. Sites where the degree of change was less than the threshold (≤5 MCI units) were recorded as being maintained. The significance of changes were tested using simple *t*-tests assuming unequal variance, with a significance threshold of $p < 0.05$.

3.5.2 Trend analysis

Changes or trends in macroinvertebrate community composition and overall river function are evaluated to determine whether there has been notable improvement or degradation in biological indicators and overall river ecological health. Inference from longer-term trends is considered to be more reliable and can better account for the natural variability (i.e. the effects of natural drivers and seasonal variation) which may occur within ecological data.

As a result, trends in macroinvertebrate community metric data were assessed over a 10-year period, extending from 2010 to 2019 inclusive. Data requirements followed LAWA guidelines (Cawthron Institute, 2019a), whereby sites with less than eight data points over the 10-year period were excluded from the analysis. This resulted in a final dataset limited to 30 sites (51 per cent of possible total sites).

REMP SEV data were insufficient for assessing trends using the above criteria; however, reach-scale changes observed during SEV monitoring are likely to occur over longer timeframes than for those observed in macroinvertebrate communities (in the absence of modification or adjacent land cover change). Although sample sizes were small (n = 2 – 5), potential trends in data were assessed for the period 2009 to 2019 (inclusive) where possible. To provide more certainty in reporting, sites with less than five data points were excluded from analyses, resulting in a final dataset spanning 15 sites (20 per cent of possible total sites).

Trends were analysed using the non-parametric Mann-Kendall trend test and summarised according to described land cover categories. Test outputs were interpreted according to the methods described by Larned, et al. (2018). Trends were aggregated using the probablistic approach described in Stocker, et al. (2013); however, trends were categorised using a more simplified five-trend direction method to enable easier interpretation. This approach is used by LAWA (Cawthron Institute, 2019a) and indicates trend confidence using five descriptors: very likely degrading, likely degrading, indeterminate, likely improving, and very likely improving.

Degrading descriptors indicate declining trends in ecological values and improving descriptors indicate increasing trends in ecological values. A trend was classified as indeterminate when there was insufficient evidence to determine with confidence if the data was trending in a particular direction. Table 3-5 describes how the trend confidence levels provided in this report were determined. For more detail refer to Larned, et al. (2018).

Table 3-5: Trend confidence category levels used to determine the direction of ecological trends (Cawthron Institute, 2019a).

Trend confidence category	Mann-Kendall probability (P)
Very likely improving	>0.90
Likely improving	0.67-0.90
Indeterminate	0.33-0.67
Likely degrading	0.10-0.33
Very likely degrading	≤0.10

All trend categories are summarised in this report; however, there is higher confidence in very likely improving or degrading trends (probability <0.10 and >0.90) and, therefore, only these are discussed in detail. Where trends were found to be 'very likely', the magnitude of the trend was assessed to determine how much a metric was likely to decrease or increase annually. The magnitude of the trend was characterised by the slope of a linear trend line fitted using the Sen slope estimator (the annual Sen slope or SSE). The annual Sen slope is the median of all possible inter-observation slopes and is commonly used as an indicator of the rate (magnitude) of change. Following the approach used by Fraser and Snelder (2018), the trend magnitude (annual Sen slope) was assessed relative to the limit of precision (i.e. the measurement resolution) for each individual ecological metric.

The precision limit (±5 MCI units) used to assess the rate of change in very likely trends for MCI was derived from the 'fuzzy boundaries' or margin of error (refer to Appendix E) (Stark, 1998; Stark & Maxted, 2007b) used to describe the precision of MCI estimations. There was no information available regarding potential precision limits for taxa richness and %EPT richness. As such, the precision limit for these two metrics was considered to be one (taxa unit or per cent respectively) and reflected the numerical level to which these metrics are generally reported. Trend magnitude could only be estimated with confidence if trends were 'very likely'.

Analysis of similarities (ANOSIM) and similarity percentages (SIMPER) tests were undertaken using PRIMER (Clarke & Gorley, 2015). Tests were only completed on community composition data to identify significant compositional differences between years and understand which species might be contributing to that change. In order to understand how observed very likely trends may have changed overall ecological condition at specific sites, a comparison was made between MCI quality classes and NPS-FM NOF attribute bands calculated for a previous state (2010 to 2014 inclusive) and current state (2015-2019 inclusive) measures. Trajectories for the trend magnitudes were also assessed to determine how current trends might influence future projections for those sites.

Trend analyses were undertaken using purpose-written script designed for undertaking the trend analysis described in Larned, et al. (2018) in the R statistical package (R Core Team, 2020). The original script was obtained from Land Water People (LWP) and is readily available at https://landwaterpeople.co.nz/pdf-reports/.

3.6 Limitations

The macroinvertebrate and SEV data used in this report have been collected by numerous parties within Auckland Council throughout the life of the programme. Though standardised methods and operating procedures for sample collection and quality control are implemented, it is possible that this has caused some variation within the data which cannot be quantified. Furthermore, the assessment of state and trends in this report relies heavily on MCI. Although the metric responds appropriately to human-induced impacts and is known to be a good indicator of the multiple impact pathways, MCI is not stressor-specific or sensitive to all stressors (Clapcott, et al., 2017). Therefore, discussions around potential causative relationships should be viewed with caution.

4.0 Ecological current state results

4.1 Macroinvertebrate community metrics

4.1.1 Taxa richness

Regionally, taxa richness ranged from a minimum of six (urban site: Botany Creek) to a maximum of 43 (native forest sites: Wekatahi Stream and Wairoa Tributary), with a median of 22 taxa (Figure 4-1). Based on median taxa richness, native and exotic forest sites generally had the highest taxa richness, with a median of 27 and 30 respectively. Both rural low and rural high sites had a median taxa richness of 25. While the urban land cover class had the lowest, with a median of 17.

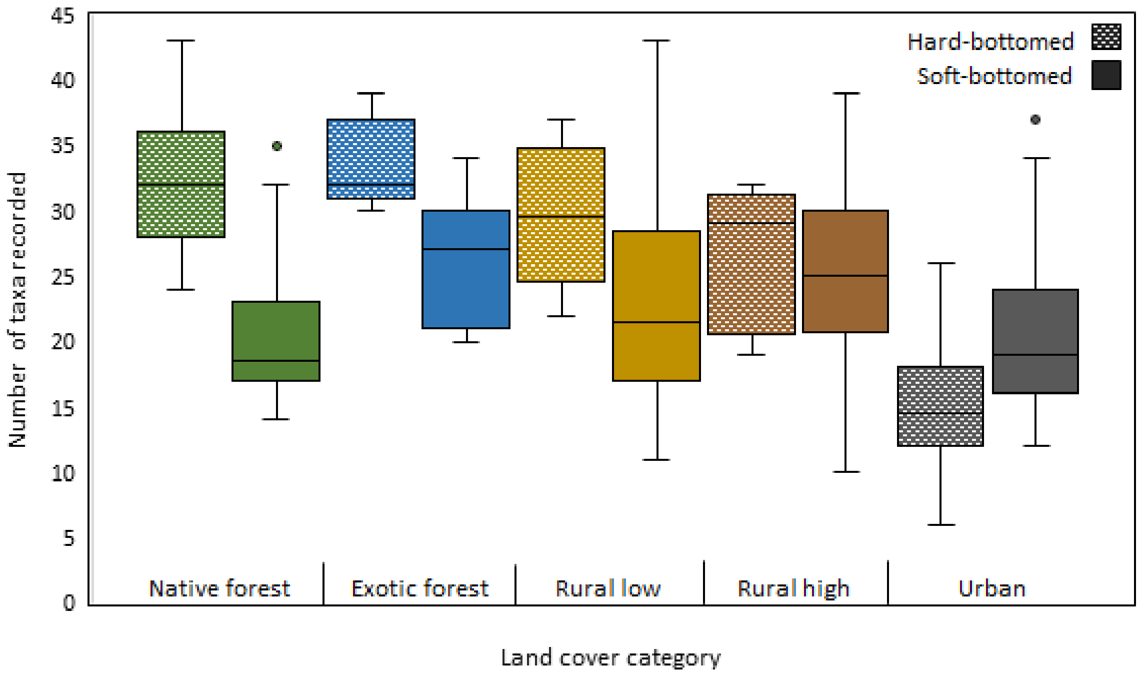

Figure 4-1: Boxplots of macroinvertebrate taxa richness recorded at 61 River Ecology Monitoring Programme sites across the Auckland region from 2015 to 2019, described according to land cover category and substrate type.

Hard-bottomed sites typically had higher taxa richness than their soft-bottomed counterparts (Figure 4-1); however, this was not true of urban hard-bottomed sites. Lower taxa richness at these sites is likely attributed to poor quality habitat and overall river function associated with a highly modified (i.e. artificially lined) river (refer to Section 4.3). Because taxa richness considers tolerant taxa (refer to Appendix E) and is not linearly related to the impacts of environmental stressors, this metric is not always an indication of higher or lower ecological quality (Stark & Maxted, 2007b; Casanovas, et al., 2019). However, there was a moderate positive correlation between these findings and corresponding SEV results (r_s = 0.51, p<0.001). There was also a strong negative correlation between taxa richness and the proportion of urban land cover in the upstream catchment (r_s = -0.66, p<0.001), suggesting catchment modification and habitat degradation may be having an influence on taxa richness.

4.1.2 Per cent (%) EPT richness

Regionally, %EPT richness ranged from a minimum of 0 per cent (recorded at several rural high and urban sites) to a maximum of 67 per cent (native forest site: Marawhara Stream), with a median of 12 per cent (Figure 4-2). Based on median %EPT richness, native forest and exotic forest sites generally had the highest %EPT richness, with a median of 41 per cent and 42 per cent respectively. Rural low sites had a median of 27 per cent, while rural high and urban sites had the lowest percentage of EPT, with a median of nine per cent and five per cent respectively.

Naturally hard-bottomed rivers generally had higher %EPT richness because these rivers provide more stable habitat and reflect the habitat preferences of most EPT taxa (i.e. well-aerated, riffle habitat and good water quality). This was supported by very strong positive correlations between %EPT richness and overall SEV score (r_s = 0.87, p<0.001) and the proportion of forest (native and exotic cover) in the upstream catchment (r_s = 0.83, p<0.001). A strong negative correlation was also identified between %EPT richness and the proportion of urban land cover in the upstream catchment (r_s = -0.69, p<0.001).

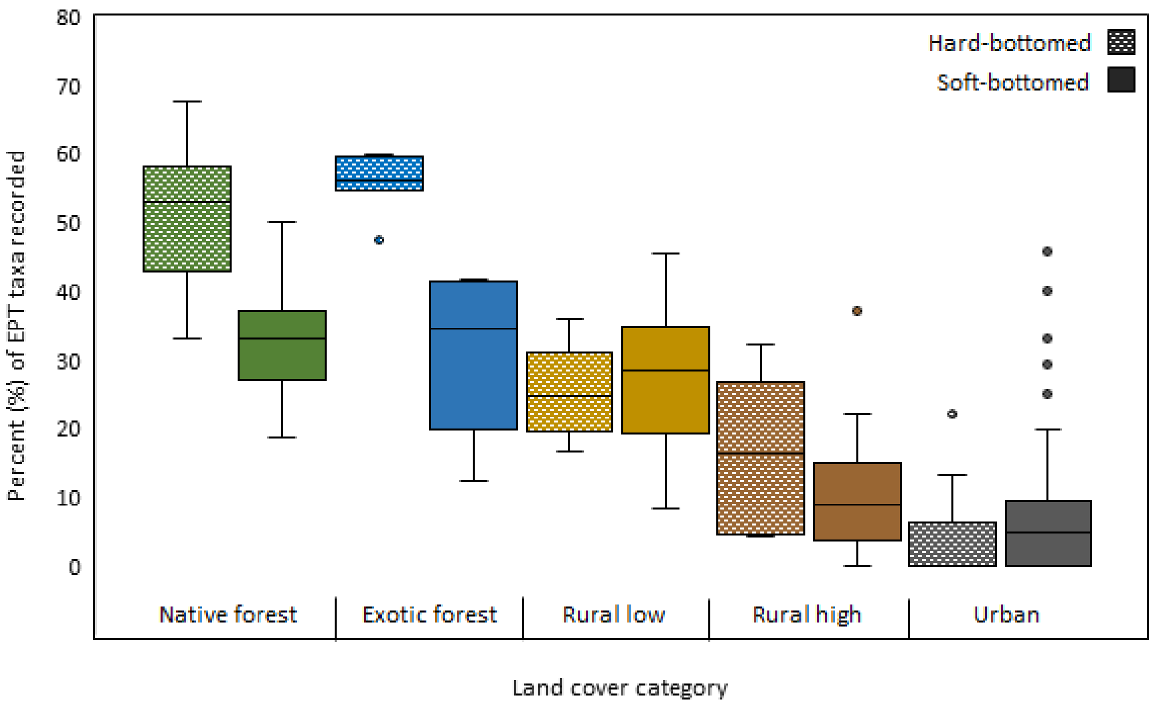

Figure 4-2: Boxplots of %EPT richness recorded at 61 River Ecology Monitoring Programme sites across the Auckland region from 2015 to 2019, described according to land cover category and substrate type.

4.1.3 Macroinvertebrate Community Index (MCI)

MCI scores across all sites (*n* =61) ranged from 38.1 (urban site: Tararata Creek) to 137.5 (native forest site: Wairoa Tributary), with a median of 81.3 (Figure 4-3). Overall, rivers within native forest recorded the highest MCI scores, with a range of 96.1 to 137.5 and a median of 119.7. Urban sites generally recorded the lowest scores, with a minimum of 38.1, maximum of 123.1 and a median of 65.9. Most sites (69 per cent) across rural low, rural high and urban land cover categories had median MCI scores ranging between 60.0 and 100.0 (Figure 4-3), and are indicative of macroinvertebrate communities reflecting poor to fair water quality and/or instream habitat quality.

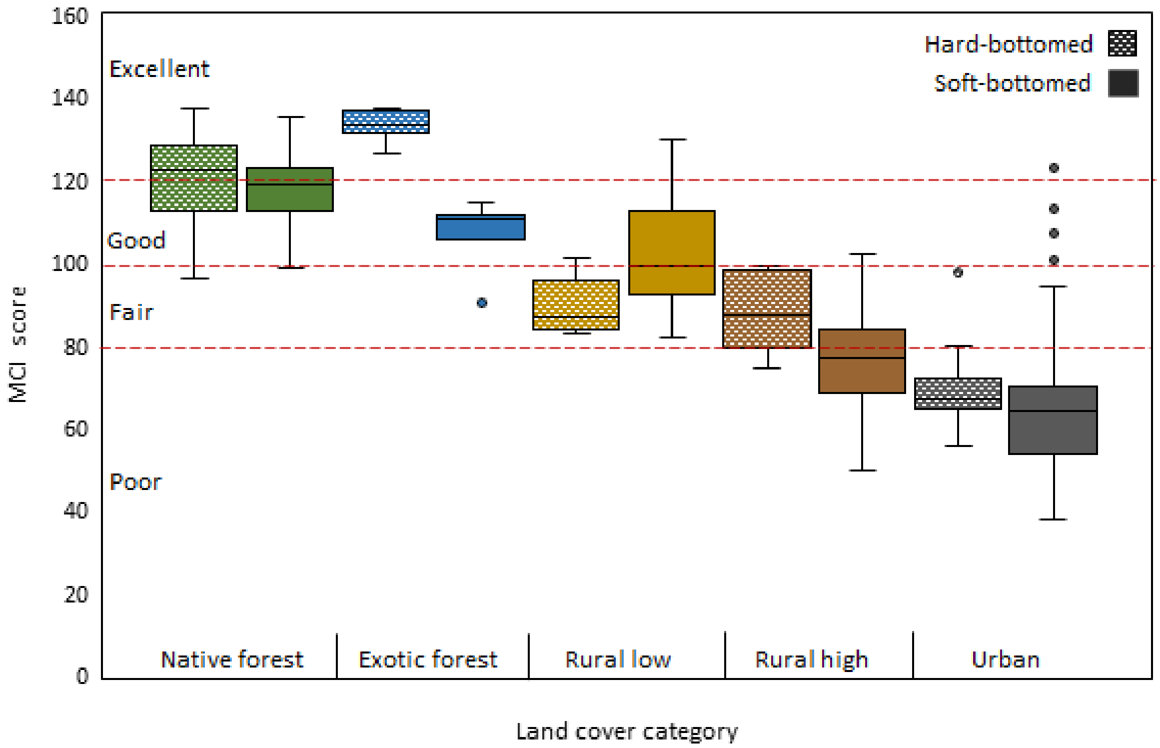

Figure 4-3: Boxplots MCI scores recorded at 61 River Ecology Monitoring Programme sites across the Auckland region from 2015 to 2019, described according to land cover category and substrate type (MCI quality thresholds are marked by red dashed lines).

Based on median MCI scores, 55 per cent of native forest sites were in the excellent quality class (Figure 4-4), with the remainder of native forest sites classified as good. These rivers were dominated by sensitive EPT taxa (refer to Section 4.1.2), a factor largely responsible for driving higher MCI scores. In addition to indicating high water quality, the taxa observed also reflect the habitat conditions (i.e. well-aerated, riffle habitat) which generally characterise these sites. For instance, sites with the highest MCI scores, Wairoa Tributary (median MCI of 132.1) and Marawhara Stream (median MCI of 128.2), had high abundances of mayfly (*Coloburiscus* and *Deleatidium*) and caddisfly (*Olinga* and *Pycnocentrodes*) taxa which typically inhabit cool, gravelly, fastflowing rivers in bush covered catchments. Such taxa were present across all native forest rivers; however, more tolerant caddisfly (*Oxyethira*) and midge (*Maoridiamesa*) taxa were also present at the Cascade Stream (Waitākere) site in relatively high abundance. This site recorded the lowest median MCI (102.1) of all native forest sites and the presence of such taxa may reflect the high abundance of streambed algae present at this site.

Median MCI scores recorded at exotic forest sites were comparable to native forest sites and reflected higher habitat quality (refer to Section 4.3). The sites with higher MCI scores, such as Orere Tributary (median MCI of 133.5), were dominated by similar taxa observed at native forest sites, reflecting good water quality and habitat; while increased abundances of the likes of water striders (*Microvelia*) and bivalve molluscs *Sphaeriidae* at the Riverhead site (median MCI of 108.3) are reflective of the soft-bottomed substrate and slower velocities present at this site. This land cover category is represented by just three sites located in forestry blocks in later stages of the forestry cycle. We would expect to see more deviation from native forest communities if different stages of the forestry cycle were represented in the network; however, the results indicate that once mature, rivers and streams within forestry blocks can support healthy macroinvertebrate communities similar to reference condition.

Sixty-three per cent of sites in the rural low land cover category were considered to be in the fair quality class (Figure 4-4); however, one site (Dyers Creek (Native)) had a borderline classification, occurring within the margin of error (5 MCI units) of the excellent/good threshold, with a median value MCI of 119.3. The macroinvertebrate communities recorded at these sites had fewer EPT taxa than forested sites and although mayflies were present in low abundances, EPT where largely comprised of the caddisflies *Pycnocentrodes*, *Hydropsyche* (*Aoteapsyche* group) and *Triplectides*. These taxa suggest moderate to good water quality; however, there is a caution that these are taxa not necessarily considered the best water quality indicators. There were also increased abundances of lower scoring Diptera taxa, such as *Tanytarsini* midges, which are most abundant in algae covered rivers and can be indicative of nutrient enrichment. This was further supported at Opanuku Stream, Tryphena Stream (GBI) and Wairoa River sites where limpets (*Ferrissia*) were recorded in relatively high abundance. This taxon commonly occurs in slow flowing farmland rivers with high macrophyte density and are indicative of moderate to poor water quality (Manaaki Whenua – Landcare Research, 2020a).

All sites within the rural high land cover category were in the poor to fair quality classes. Fifty-eight per cent of sites fell into the poor quality class; however, over half (57 per cent) of these were within five MCI units (error margin) of the poor/fair threshold (Figure 4-4), suggesting they could fluctuate between classes from year to year. Again, there were fewer EPT taxa recorded in these rivers and communities had higher abundances of lower scoring taxa. These included the caddisfly (*Triplectides)*, water strider (*Microvelia*), red damselfly (*Xanthocnemis*), midges (*Polypedilum* and *Tanypodinae*) and freshwater snail *Physa*, which are found in rivers and streams of varying water quality and are not overly good indicators of water quality (Manaaki Whenua – Landcare Research, 2020a). There were, however, some taxa which were more common to particular rivers and provided a better explanation of the taxa driving the MCI scores being observed and potential ecological condition.

For instance, unlike other sites in the rural high land cover category, the highest quality site, Puhinui Stream (median MCI of 98.1), had relatively high abundances of *Austroclima* mayfly and *Hydropsyche* (*Orthopsyche* group) caddisfly which are common in well-aerated, bush-covered rivers and indicative of moderate to good water and habitat quality (Manaaki Whenua – Landcare Research, 2020a). While poorer quality sites, such as Kumeu River (median MCI of 59.6) and Duck Creek (median MCI 69.7), had a high abundance of axehead caddis (*Oxyethira*) and chironomid midges *Orthocladiinae* and *Tanytarsini*. These taxa are generally abundant in unshaded rivers and streams with prolific algal growth, indicating poor habitat quality and nutrient enrichment.

As would be expected, urban river sites were found to have the lowest MCI scores, with 89 per cent of sites in the poor quality class (Figure 4-4). The upstream catchments are heavily modified, an aspect which is reflected in the composition of most sampled communities. Overall, urban sites have very few EPT taxa (refer to Section 4.1.2) and generally higher abundances of more tolerant taxa groups. Urban sites, particularly ones with the lower MCI scores, such as Tararata Creek (median MCI of 42.9) and Meola Creek (median MCI of 53.0), have high abundances of taxa which reflect limited shading, low oxygen levels, and an abundance of algae and macrophyte growth (Manaaki Whenua – Landcare Research, 2020). Such taxa include axehead caddis (*Oxyethira*), *Chironomus* midges, *Gyraulus* snails, and leeches (*Hirudinea*). Two sites (7 per cent of all urban sites), Auckland Domain (median MCI of 108.9) and Parahiku Stream (Upper) (median MCI of 100.8) are located within urban reserves and were classified as being in the good quality class. These sites had higher abundances of more sensitive taxa (i.e. mayfly *Zephlebia* and caddisfly *Polyplectropus*), indicating moderate to good habitat and water quality conditions.

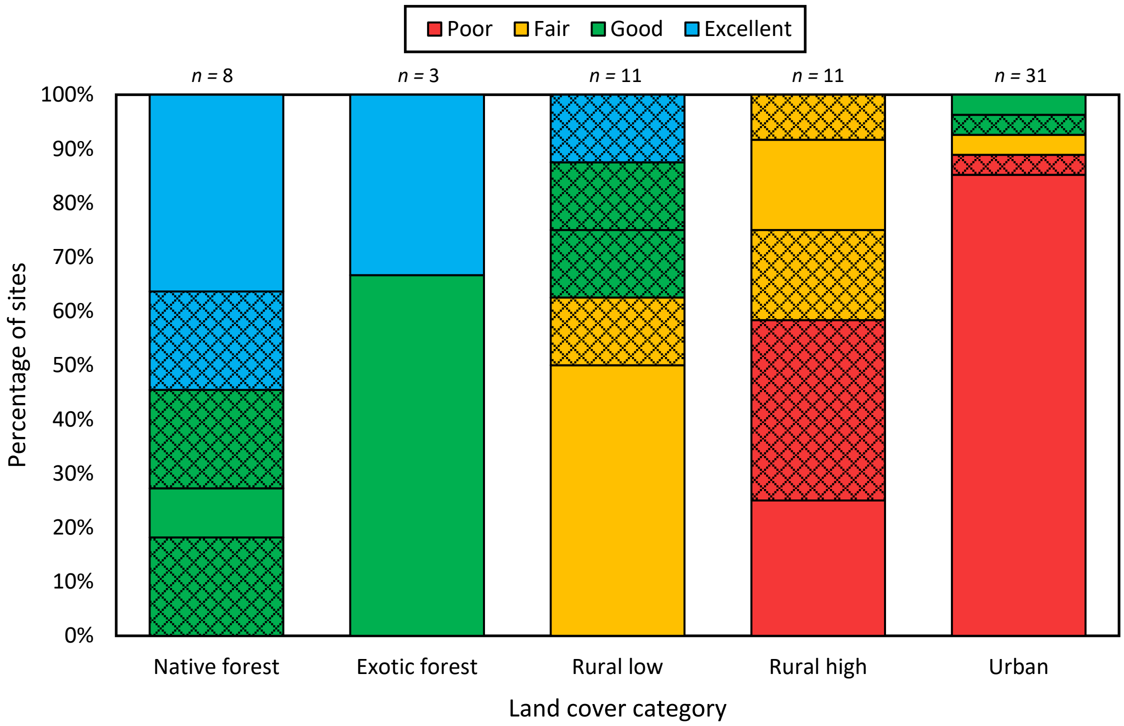

Figure 4-4: Percentage representation of River Ecology Monitoring Programme sites in each MCI quality class: poor <80, fair >80, good >100 and excellent >119 (Stark & Maxted, 2007b); described according to land cover category and based on median overall MCI scores (2015-2019). Hatched areas represent the percentage of sites which fall within the ±5 MCI units of each class threshold.

Based on median MCI scores, 13 per cent of all sites in the region were classified as being in the excellent quality class (Stark & Maxted, 2007b) and were indicative of excellent water quality and habitat conditions. The good and fair quality classes were each represented by 18 per cent of sites within the region, indicating moderate habitat quality and mild pollution within associated streams. Just over half (51 per cent) of the rivers sampled in the region were classified as being in the poor quality class. These were all in highly modified catchments and located in urban and rural high land cover classes. The spatial distribution of assigned MCI quality classes observed across network sites is provided in Figure 4-9. Summary statistics are also provided in Appendix F.

Hard-bottomed rivers generally recorded higher MCI scores. This is likely associated with higher water velocities, habitat diversity and riffle habitat at these sites which are favoured by higher scoring taxa. Stoneflies (*Plecoptera*) were rare throughout the region, while mud snail (*Potamopyrgus*) were by far the most abundant taxon across all land cover categories. This taxon is common throughout most rivers in New Zealand and is found in a variety of conditions, from highly polluted to pristine.

A very strong positive correlation (r_s = 0.81, p<0.001) was identified between median MCI score and the proportion of forest (native and exotic) cover in the upstream catchment, and a strong negative correlation (r_s = -0.69, p<0.001) was identified between median MCI and proportion of urban cover. There was no correlation (r_s = 0.01, p>0.05) with the proportion of rural pasture in the catchment. A very strong positive correlation (r_s = 0.82, p<0.001) was also identified between median MCI and SEV scores and there was a strong positive correlation (r_s = 0.76, p<0.05) with WQI scores at paired sites. As expected, there was also a very strong positive correlation between MCI score and %EPT richness (r_s = 0.92, p<0.001), while there was only a moderate relationship with taxa richness (r_s = 0.49, p<0.001).

4.2 Performance against MCI thresholds

Of the 61 sites used for state analysis, 43 had sufficient data to calculate average MCI scores for the period 2010 to 2014 (previous state) and allow comparisons with current (2015-2019) average state scores. Based on current (2015-2019) average MCI scores, 40 per cent of all sites are currently failing to meet their respective Auckland Unitary Plan interim guidelines, compared to 37 per cent for the previous state period (Table 4-1). Sixteen (37 per cent) previous state sites and 18 (42 per cent) current state sites fall within the margin of error of the thresholds (Figure 4-5) and could fluctuate above/below corresponding interim guidelines from year to year. As such, the performance of these sites against Auckland Unitary Plan interim guidelines could not be determined with certainty.

Table 4-1: Comparison of current River Ecology Monitoring Programme sites falling below Auckland Unitary Plan guidelines for MCI (native forest ≥123, exotic forest ≥111, rural ≥94 and urban ≥68) for previous (2010-2014) and current (2015-2019) state periods, including change over time across all sites (enhanced >5 MCI, maintained ≤5 and degraded >-5).

Land cover category	No. of sites with insufficient data	Sites below (>5 MCI units) interim guidelines (n = 43)		Change over time (> ±5 MCI units)		
		Previous	Current	Enhanced	Maintained	Degraded
Native forest	1	30% (3)	40% (4)	0% (0)	80% (8)	20% (2)
Exotic forest	0	33% (1)	33% (1)	33% (1)	33% (1)	33% (1)
Rural low	1	14% (1)	0% (0)	14% (1)	57% (4)	29% (2)
Rural high	2	80% (8)	80% (8)	10% (1)	80% (8)	10% (1)
Urban	14	23% (3)	31% (4)	15% (2)	62% (8)	23% (3)
Regionally (all sites)	18	37% (16)	40% (17)	12% (5)	67% (29)	21% (9)

Overall, sites within the rural high land cover category had the highest rate of failure at 80 per cent for both previous and current state periods. The failure rate also remained stable at 33 per cent for exotic forest sites across both periods. Native forest and rural low sites had the largest disparity between periods, which saw the failure rate of native forest sites increase by 10 per cent and rural low sites fall by 14 per cent. Overall, rural low sites had the highest rate of compliance.

Of the 43 sites analysed, 72 per cent have maintained average MCI scores (within five MCI units of previous state averages). Average MCI scores were enhanced at five sites; however, increases at four of these sites were within five MCI units (the margin of error) of the respective interim guideline values. Average MCI scores at Mahurangi River (Forestry) (exotic forest), Opanuku Stream (rural low) and Pakuranga Stream (urban) were just below the thresholds, and Papakura Tributary (urban) was just above the urban threshold. The average MCI score of Makarau River (rural high) increased between periods; however, this was still well below the rural threshold. Improvements in average MCI were largely found not to be significant ($p>0.05$), except enhanced average MCI scores at Makarau River and Pakuranga Stream sites which were found to be statistically significant ($p<0.05$).

The state of nine sites across all land cover categories were found to have degraded between time periods. The average MCI score of one rural low site, Dyers Creek (Pasture), dropped, but was still above the interim guideline values for rural areas. While the average MCI scores at four sites, Avondale stream (urban), Omaumau River (native forest), Okura Tributary 1 (rural high), and Wairoa River (rural low), fell below respective interim guidelines, they were within the margin of error (5 MCI units). Average MCI scores at Lucas Creek (urban), Otanerau Stream (native forest), Riverhead (exotic forest), and Vaughan lower (urban) have fallen well below the respective interim guidelines. The decline in average MCI score at all nine sites were not significant ($p>0.05$).

A number of sites in which average MCI scores have been maintained, currently fall below respective interim guidelines; however, MCI scores above the guidelines are also being maintained, indicating that existing resource management strategies are working to a degree. Furthermore, notable improvements at degraded sites, particularly Papakura Tributary, which is now above the corresponding interim guidelines (albeit within the margin of error), suggest that enhancement of degraded sites is occurring.

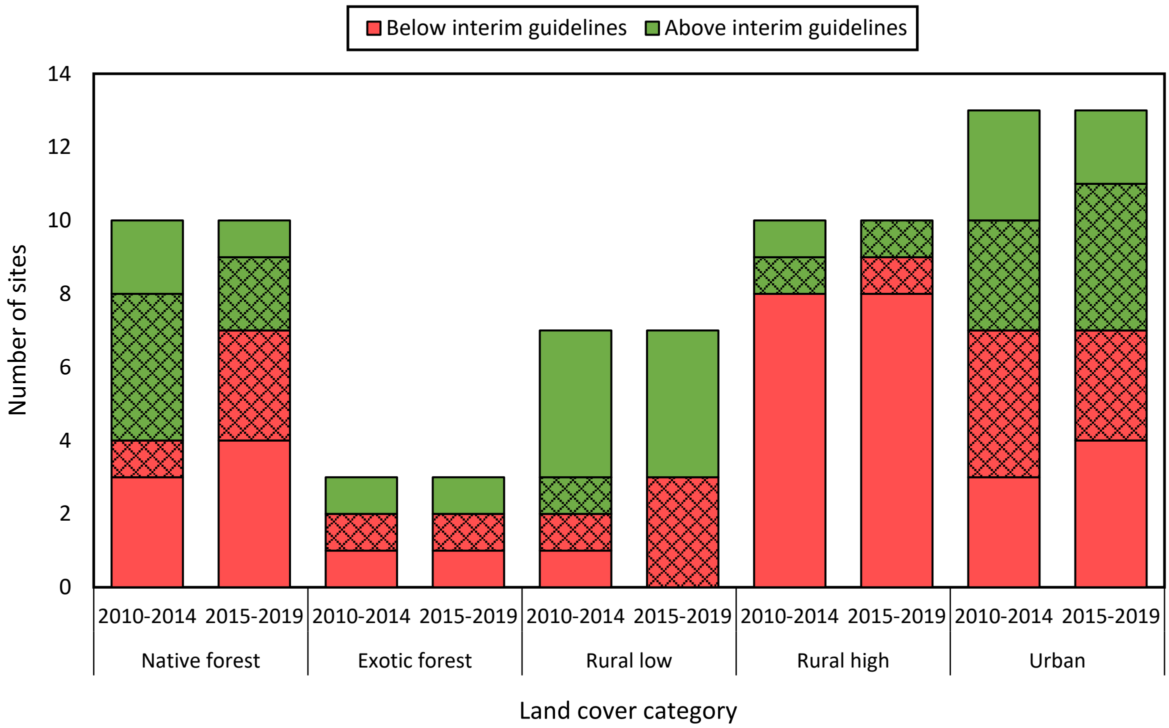

Figure 4-5: The number of River Ecology Monitoring Programme sites (*n* = 43) falling above and below Auckland Unitary Plan guidelines for MCI (native forest ≥123, exotic forest ≥111, rural ≥94 and urban ≥68) between the periods 2010 to 2014 and 2015 to 2019 inclusive. Hatched areas represent the number of sites which are within ±5 MCI units of the interim guideline threshold for each land cover class.

Results from the NPS-FM NOF MCI attribute band grading (Table 4-2) indicate that the majority of sites (61 per cent) fall into attribute band D and are below the national bottom line for MCI (i.e. the C/D band boundary). The vast majority of sites in band D are located within the more modified rural high and urban catchments, with 83 per cent and 93 per cent of sites respectively falling below the bottom line. The median of just three sites (8 per cent) in these two land cover categories fell within the margins of error (±5 MCI units) of both bands D and C (Figure 4-6). Two rural low sites, Opanuku Stream and Wairoa River, are within the lower boundary of the C band, suggesting that there is some uncertainty in this grading and that they may occasionally fall within the attribute band D. One site (Auckland Domain) was on the cusp of the upper boundary of the C band, suggesting that this site may fluctuate between bands C and B between years.

Native and exotic forest sites were of the highest quality, with the majority of sites, 74 per cent and 66 per cent respectively, falling into bands A and B. All attribute band A (*n* =1) and three band B native forest sites were within five MCI units (margin of error) of the band threshold, suggesting that there may some potential for future movement in the grading and, in particular, that those band B sites may fall within attribute band A on occasion. All three exotic forestry sites fell within the fuzzy boundaries of the respective attribute bands (refer to Figure 4-6), indicating that there may be some movement in grading of these sites between years.

As a result of the short timeframes between gazetting of the NPS-FM and production of this report, the NPS-FM NOF MCI attribute bands allocated to sites in this report are solely aimed at providing an indication of where Auckland's rivers currently sit against national standards. Until a thorough review of current data and processing practices can been undertaken, the grading provided is considered preliminary and should be viewed as such (refer to Appendix E).

Table 4-2: Percentage of River Ecology Monitoring Programme sites which fall into NPS-FM NOF MCI attribute bands: A ≥130, B >110, C >90 and D <90 (MfE, 2020).

Land cover category	NPS-FM MCI attribute band			
	A	B	C	D
Native forest	9% (1)	73% (8)	18% (2)	0% (0)
Exotic forest	33% (1)	33% (1)	33% (1)	0% (0)
Rural low	0% (0)	25% (2)	50% (4)	25% (2)
Rural high	0% (0)	0% (0)	17% (2)	83% (10)
Urban	0% (0)	0% (0)	7% (2)	93% (25)
Regionally (all sites)	3% (2)	18% (11)	18% (11)	61% (37)

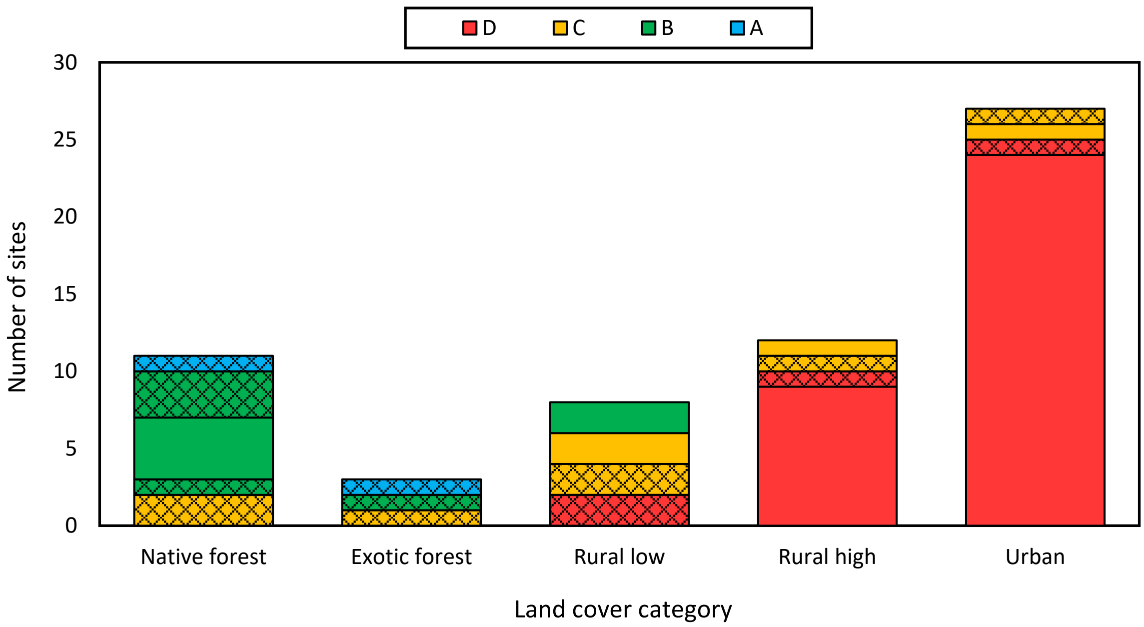

Figure 4-6: The number of River Ecology Monitoring Programme sites (*n* = 61) falling into NPS-FM NOF MCI attribute bands: A ≥130, B >110, C >90 and D <90 (MfE, 2020). Hatched areas represent the number of sites which are within ±5 MCI units of the interim guideline threshold for each land cover class.

4.3 Stream ecological valuation (SEV)

Overall SEV scores across all sites (*n* =68) ranged from a minimum of 0.21 (urban site: Botany Creek) to a maximum of 0.96 (native forest site: Wekatahi Stream), with a median of 0.59 (Figure 4-7). As expected, rivers within native forest were of the highest quality, with SEV scores ranging from 0.69 to 0.96 and a median of 0.84. Urban rivers were generally of the lowest quality, with SEV scores ranging from 0.21 to 0.83 and a median SEV score of 0.48. The majority of sites (60 per cent) in all land cover categories recorded median SEV scores between 0.41 and 0.80 (Figure 4-7), suggesting most streams in the region are in fair to good ecological condition, providing moderate habitat and showing varying (low to moderate) degrees of functional impairment.

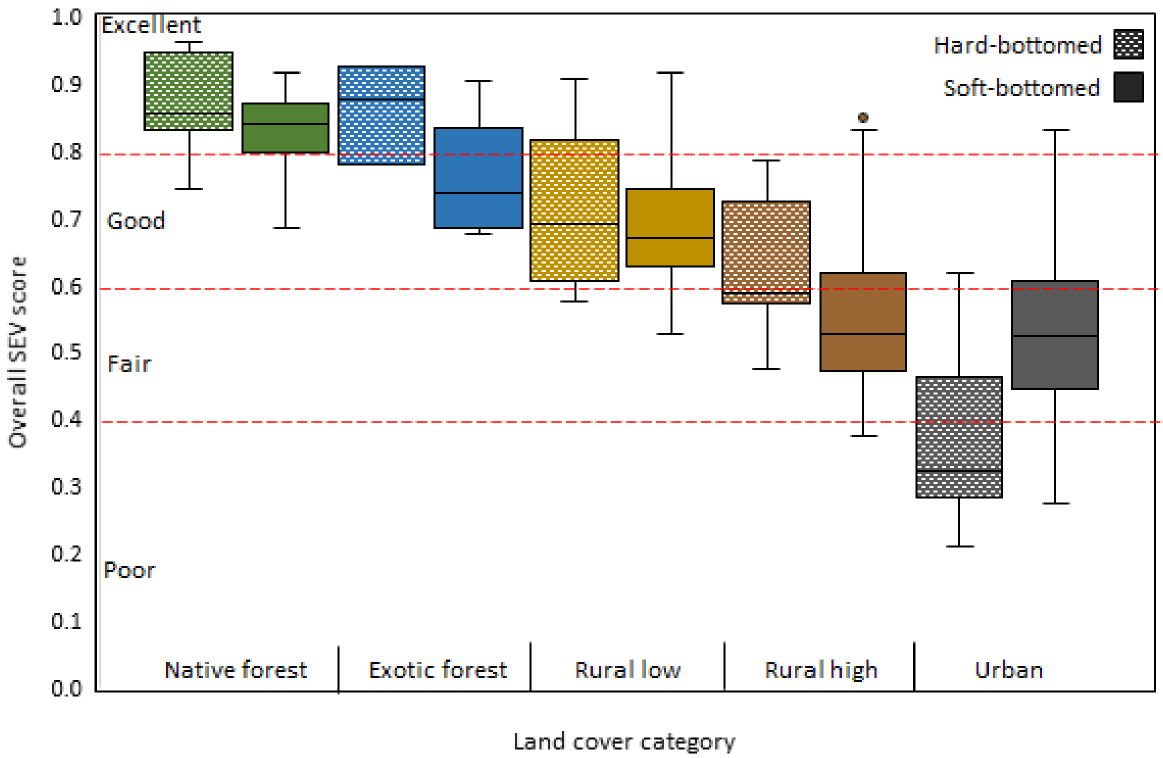

Figure 4-7: Boxplots of SEV scores recorded at 68 River Ecology Monitoring Programme sites across the Auckland region from 2009 to 2019, described according to land cover category (SEV category thresholds are marked by red dashed lines).

Based on median SEV scores, most (92 per cent) native forest sites were classified as excellent (Figure 4-8). The highest scoring sites, Wekatahi Stream (median of 0.95), Marawhara Stream (median of 0.94) and Cascade Stream in Waitākere (median of 0.92), are all located in low order, high gradient rivers within the Waitākere Ranges. These are hard-bottomed and located in catchments that are comprised predominantly, if not entirely (>99 per cent), of remnant and secondary native forest and scrub. The steep gradient channels are characterised by high oxygen producing processes (i.e. aeration), and high habitat diversity and abundances required to support a variety of instream fauna, including variable hydrologic conditions (i.e. riffles and pools), stable cobble habitat and woody debris. The native riparian margins are intact and largely undisturbed, providing ample stream shading, organic inputs and filtering of overland run-off.

One native forest site, Otanerau Stream (median of 0.79), was classified as being in good condition. This is a medium gradient, naturally soft-bottomed river located in a large native forest fragment. Although situated within reference conditions, the inherent qualities of this river meant that instream habitat quality and particular river functions are not performing at their optimal for some SEV variables. Like most soft-bottomed rivers in the region, this site naturally lacks characteristics, such as cobbled and riffle habitat, which encourage higher instream oxygen levels and are favoured by particular freshwater species. Channel incision resulting from flood flows was also observed at this site and is characteristic of rivers where the underlying geology is predominantly soft-sedimentary. Collectively, these factors are likely to be contributing to the lower SEV classification of this site.

The exotic forestry sites were classified as being in good to excellent condition, with median SEV scores ranging from 0.72 to 0.88. The highest quality site, Orere Tributary, shares similar characteristics to native forest sites and is located in the foothills of the Hunua Ranges. The lowest scoring site, Riverhead, is in a low-gradient, naturally soft-bottomed river and, although surround by established vegetation, SEV results suggest that the adverse effects of forest clearance at various locations in the upstream catchment over the last 15 to 20 years may have been compounded by the river's underlying geology (soft-sedimentary); resulting in a high incidence of channel incision from unmitigated flood flows and poorer instream habitat.

Sites within exotic forest were comparable to rivers in native forest catchments; however, it must be noted that this land cover category is only represented by three sites located in forestry blocks which are well into the recovery phases of the forestry cycle (i.e. felling and replanting occurred more than 15 years ago). Forestry sites have grow-harvest cycles of 25 to 30 years which result in fluctuations in the ecological health of streams within the catchment (Reid, et al., 2010; NZIER, 2017). Were there to be a higher number of sites in different stages of the forestry cycle we would expect to see greater disparity between sites.

Based on median SEV scores, 83 per cent of sites within the rural low land cover category had a median SEV score of between 0.62 and 0.70 and were classified as good (Figure 4-8), indicating good habitat provision with only minor function impairment. These sites are typically soft-bottomed, low gradient rivers with relatively intact riparian margins (20m or greater each side) directly adjacent to the sites and further upstream. The riparian margins were typically comprised of mature exotic trees and regenerating native vegetation, showing low to moderate impacts from human activities. These factors were considered to provide good shading and other processes to regulate instream properties (i.e. temperature and oxygen levels) and macrophyte growth. Instream habitat for native fauna and hydrologic heterogeneity were also relatively high in these streams. Lower scoring sites, such as Wairoa River (median of 0.62) and Aroaro Stream (median of 0.59), showed increased agricultural land use impacts, with reduced riparian margin width and integrity, and in some instances stock access to the river channel.

The catchments and riparian margins of rivers within the rural high land cover category have undergone more intensive modification. This was reflected in the results, with 73 per cent of rural high sites recording median SEV scores ranging from 0.43 to 0.51 (Figure 4-8). These sites were classified as fair and were generally characterised as having poor riparian margins largely comprised of pasture and low diversity shrubs, low shading, moderate instream macrophyte growth and fine sediment loading. These factors reduce habitat and impair the natural stream functions required to support healthy biological communities. Sites of higher value (Okura Tributary 1 and Puhinui Stream) were located in the gullies of native forest fragments and had median SEV scores greater than 0.70.

Urban sites were generally found to be the most compromised, with 38 per cent classified as poor and 45 per cent as fair (Figure 4-8). Lower scoring sites, such as Pakuranga Stream (median score of 0.28) and Pakuranga Creek (median score of 0.30), have been severely impaired by channel modification (i.e. straightening, artificial lining and bank widening) and substantial reductions in the quality of riparian margin vegetation and instream habitat. Where streams were not artificially contained, they were characterised by dense macrophyte growth, high sediment loading and littered with domestic rubbish. As a result, urban streams generally have poor habitat quantity and quality, lack of shading and altered hydrological cycles. Two sites, Onetangi Stream in Waiheke (median score of 0.81) and Parahiku Stream (Upper) (median score of 0.80), were the exception to this and classified as excellent and good respectively. Located in gully reserves within residential areas, the upstream catchments are small and largely (>75 per cent) comprised of regenerating native forest and scrub. As a result, these sites are substantially buffered from urban pressures and are able to function more naturally.

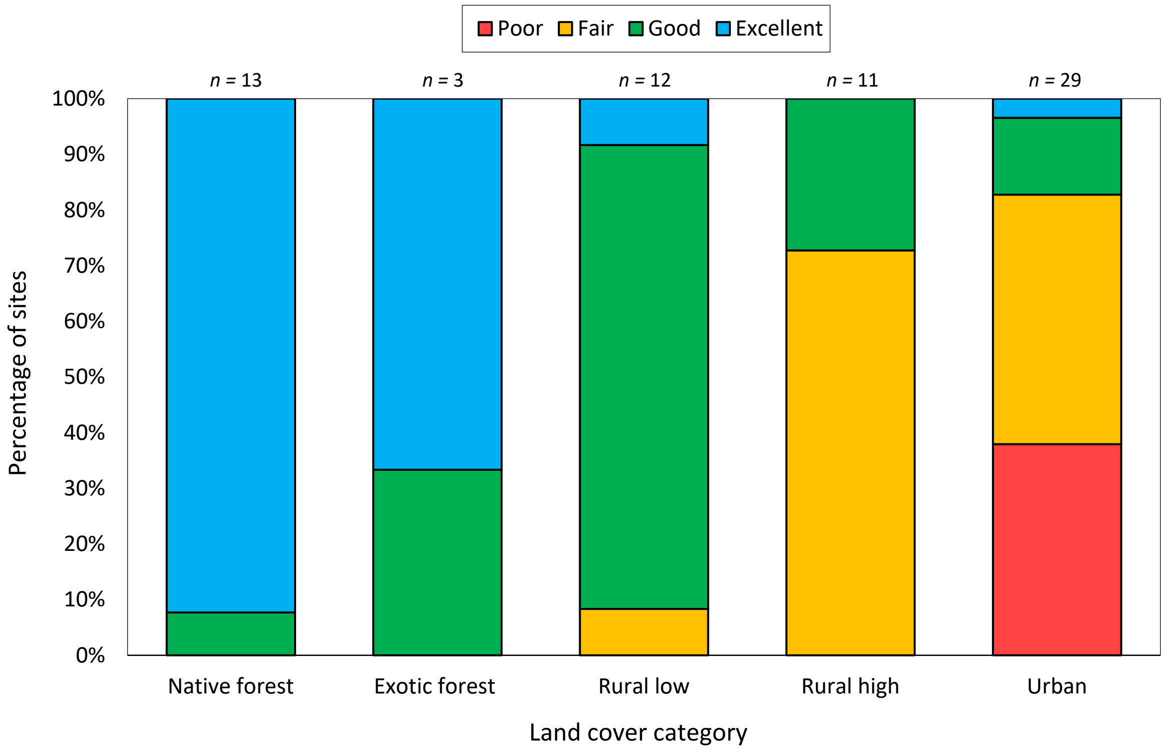

Figure 4-8: Percentage representation River Ecology Monitoring Programme sites in assigned quality classes (poor, fair, good and excellent) for interpreting SEV scores; described according to land cover category and based on median SEV scores (2009-2019).

Based on median SEV scores, 24 per cent of all sites in the region were classified as excellent, indicating ecological function and habitat conditions close to or at reference condition. The majority of sites (60 per cent) in the region were classified as fair (32 per cent) to good (28 per cent), suggesting low to moderate impairment by anthropogenic pressures. Sixteen per cent of all sites were classified as poor and were all located within urban areas. The spatial distribution of assigned SEV condition classes across sites is provided in Figure 4-9.

Naturally hard-bottomed rivers generally recorded higher SEV scores and this is linked to increased hydraulic function and instream habitat provision. A different pattern was observed within the urban land cover category, where most hard-bottomed rivers are artificially constructed and, as a result, many natural features have been removed and habitat is substantially reduced. There was a strong relationship observed between median SEV score and land cover within the upstream catchment, indicating a pattern of reduced habitat quality and function with increased modification (refer to Figure 4-7 and Figure 4-8). In particular, there was a very strong positive correlation (r_s = 0.89, p<0.001) between median SEV score and proportion of forest (native and exotic) cover and strong negative correlation between median SEV score and the proportion of urban cover upstream (r_s = -0.69, p<0.001).

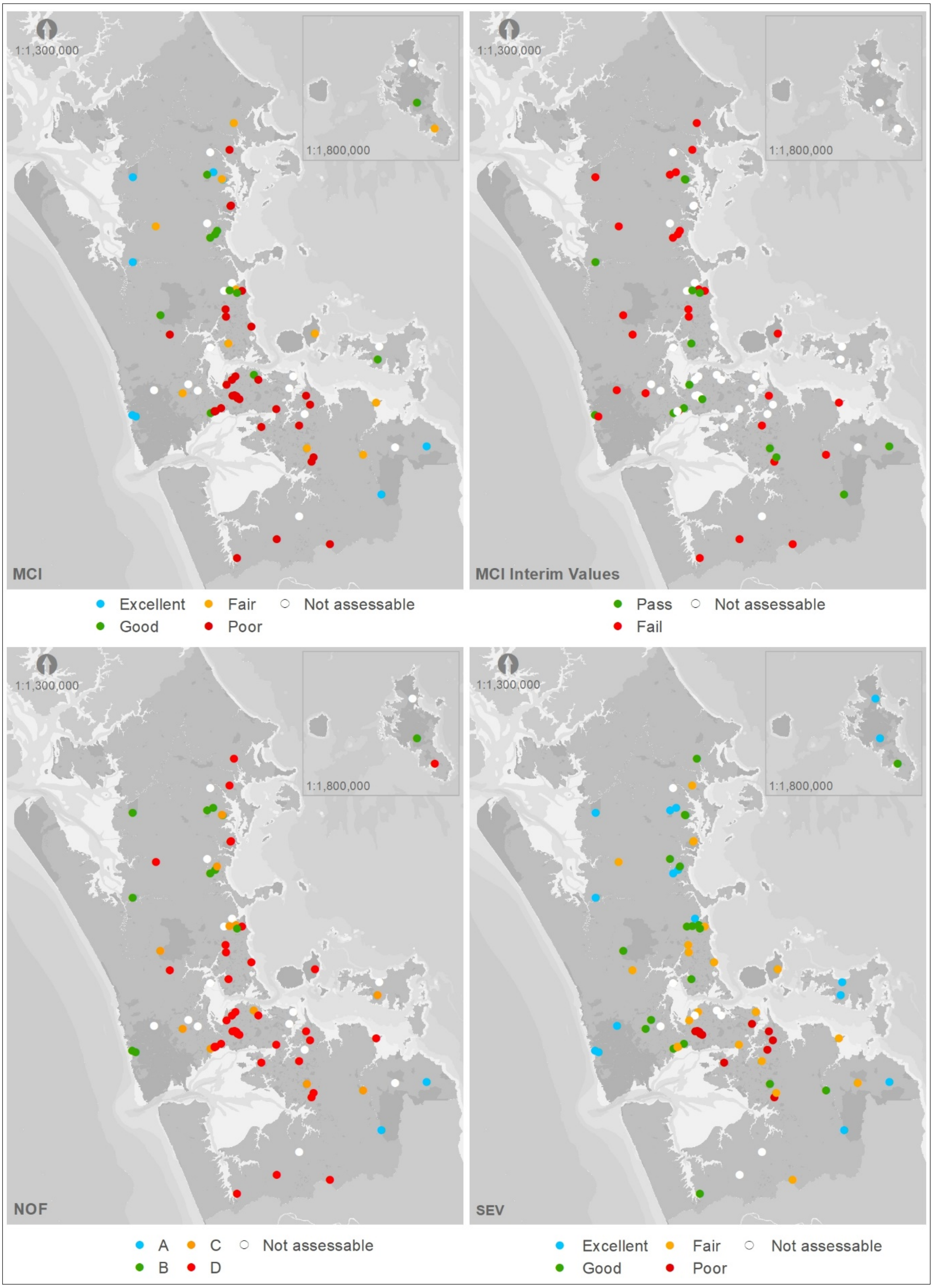

Figure 4-9: Map showing the spatial distribution of state (2015-2019) results: MCI quality class (Stark & Maxted, 2007a) (top left), Auckland Unitary Plan interim guideline values for MCI (top right), NPS-FM attributed bands for MCI (bottom left) and SEV condition classes (bottom right).

5.0 Ecological trend results

5.1 Macroinvertebrate community metrics

5.1.1 Taxa richness

Trends in macroinvertebrate taxa richness indicated that most sites (77 per cent) across the region and all land cover categories returned indeterminate or likely degrading trends (refer to Figure 5-1). While four sites, split between exotic forest (Orere Tributary), rural high (Duders Park) and urban (Papakura Tributary and Vaughan Lower) land cover categories, returned likely improving trends.

Only one site, Opanuku Stream in the rural low land cover category, returned a very likely improving trend, with an annual Sen slope of 1.4 taxa units which exceeded the measurement precision limit of one taxa unit. Two sites, Oakley Creek Lower and Otara Creek, located within urban catchments, returned very likely degrading trends, with an annual Sen slopes of -1.0 and -0.9 taxon units respectively.

Overall, taxa richness was found to be increasing (likely/very likely improving) at 17 per cent of sites and decreasing (likely/very likely degrading) at 15 per cent of sites over the 10-year period. Sites with improving trends were amongst those recording higher (≥25) median taxa richness, while sites with degrading trends generally recorded median taxa richness lower than 20 individuals (refer to Section 4.1.1).

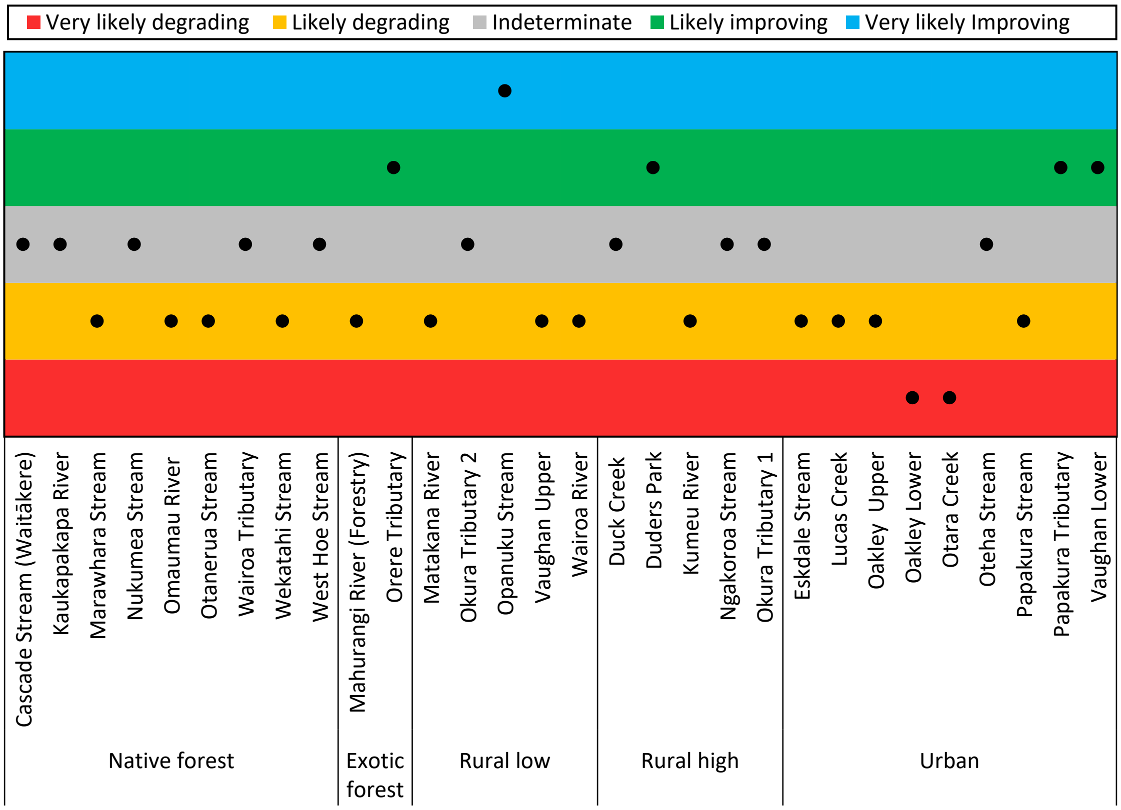

Figure 5-1: Summary plot of 10-year macroinvertebrate taxa richness trends (2010-2019) analysed across 30 sites in the River Ecology Monitoring Programme network; presented relative to the corresponding trend confidence category (see legend).

5.1.2 Per cent (%) EPT richness

Results indicate that trends in %EPT richness were highly variable across all land cover categories (Figure 5-2). Seven sites (23 per cent) returned indeterminate trends, five (17 per cent) likely degrading trends, and seven sites (23 per cent) likely improving trends. In total, six sites (20 per cent) returned very likely improving trends and five sites (17 per cent) very likely degrading trends. Overall, 43 per cent of sites recorded likely/very likely improving trends in %EPT richness, while likely/very likely degrading trends were recorded at 33 per cent of sites.

Very likely improving trends were observed across all land cover categories, except native forest, and most MCI quality classes. The annual magnitude of change at three sites, Eskdale Stream (urban), Mahurangi River (Forestry) (exotic forest) and Oakley Upper (urban), was above the measurement precision limit (one per cent EPT taxa) which correlated with a gradual increases in %EPT richness observed in the data over time.

Mahurangi River (Forestry) recorded the highest magnitude of annual improvement (annual Sen slope of 1.4 per cent). This was likely attributed to a dip in %EPT richness recorded in 2014 (9 per cent from 26 per cent in 2013), followed by incremental increases reaching 42 per cent in 2019. The higher %EPT richness recorded in later years could be associated with the natural recovery of macroinvertebrate communities in exotic forestry blocks following clearance. Aerial imagery indicates that a large portion (approximately 50 per cent) of the upstream catchment was clearfelled in the late 1990s, with replanting completed by 2001. Findings suggest that macroinvertebrate community recovery can take as long as 10 to 15 years, and even greater than 17 years in larger catchments, following forestry clearance, which fits the timeline for what is being observed at this site (Reid, et al., 2010; Neale, et al., 2017).

Very likely degrading trends were only observed at sites within the most modified catchments, representing sites with MCI quality classes of poor (60 per cent) and fair (40 per cent). The annual Sen slope recorded at three sites was above the measurement precision limit (one per cent EPT taxa). Okura Tributary 1 had the highest rate of change, with an annual Sen slope of -1.2 per cent and an overall change in %EPT richness between 2010 and 2019 of eight per cent.

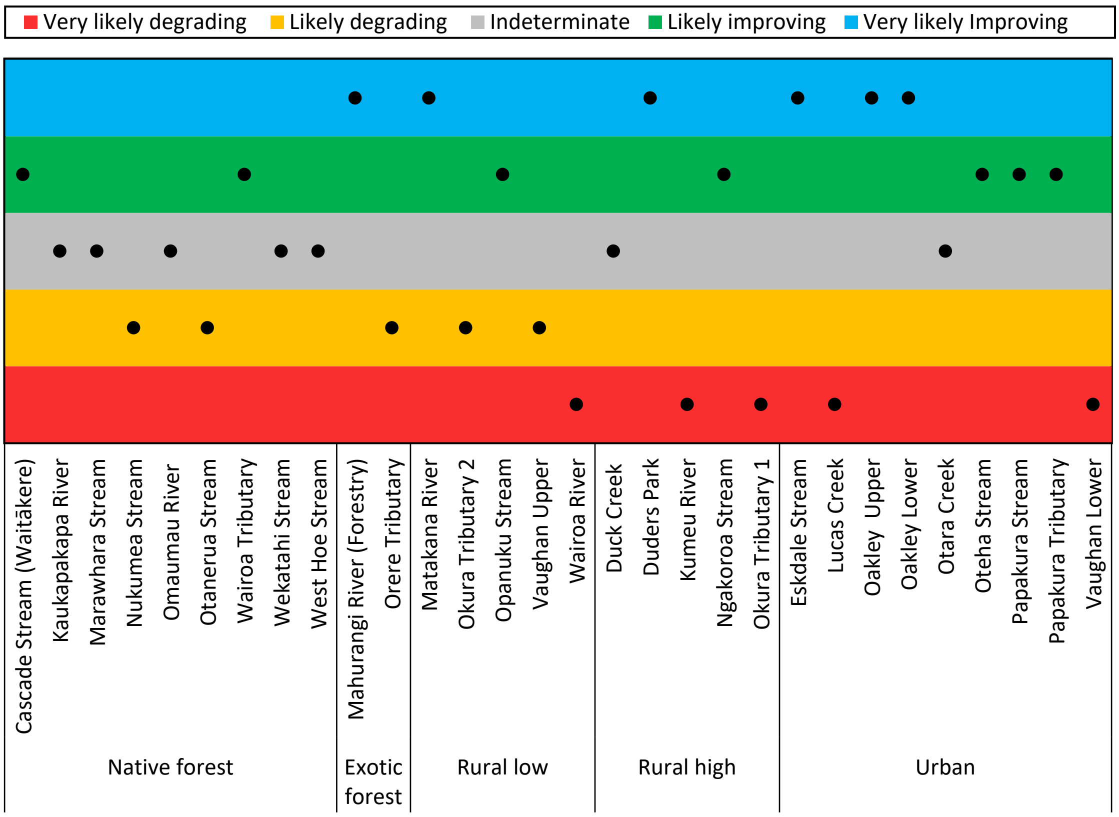

Figure 5-2: Summary plot of 10-year %EPT richness trends (2010-2019) analysed across 30 sites in the River Ecology Monitoring Programme network; presented relative to the corresponding trend confidence category (see legend).

5.1.3 Macroinvertebrate Community Index (MCI)

Results indicate that trends in MCI scores were highly variable across all land cover categories, with no obvious patterns in spatial distribution (refer to Figure 5-3). Ten of the 30 sites returned indeterminate trends (33 per cent), spanning all land cover types except exotic forest. Five sites (17 per cent) were likely improving and seven sites (23 per cent) had likely degrading trends. Very likely trends spanned most land cover categories (Figure 5-4) and include two very likely improving trends (7 per cent) and six very likely degrading trends (20 per cent).

Overall, 23 per cent of sites recorded likely/very likely improving trends in MCI and likely/very likely degrading trends were recorded at 43 per cent of sites. Although there were a number of sites showing indeterminate trends, identified likely/very likely improving trends indicate that sites within NOF attribute bands C and D are showing improvement (Figure 5-4). However, this is perhaps counterbalanced by the fact that degrading trends are also occurring across these and other attribute bands, including band A.

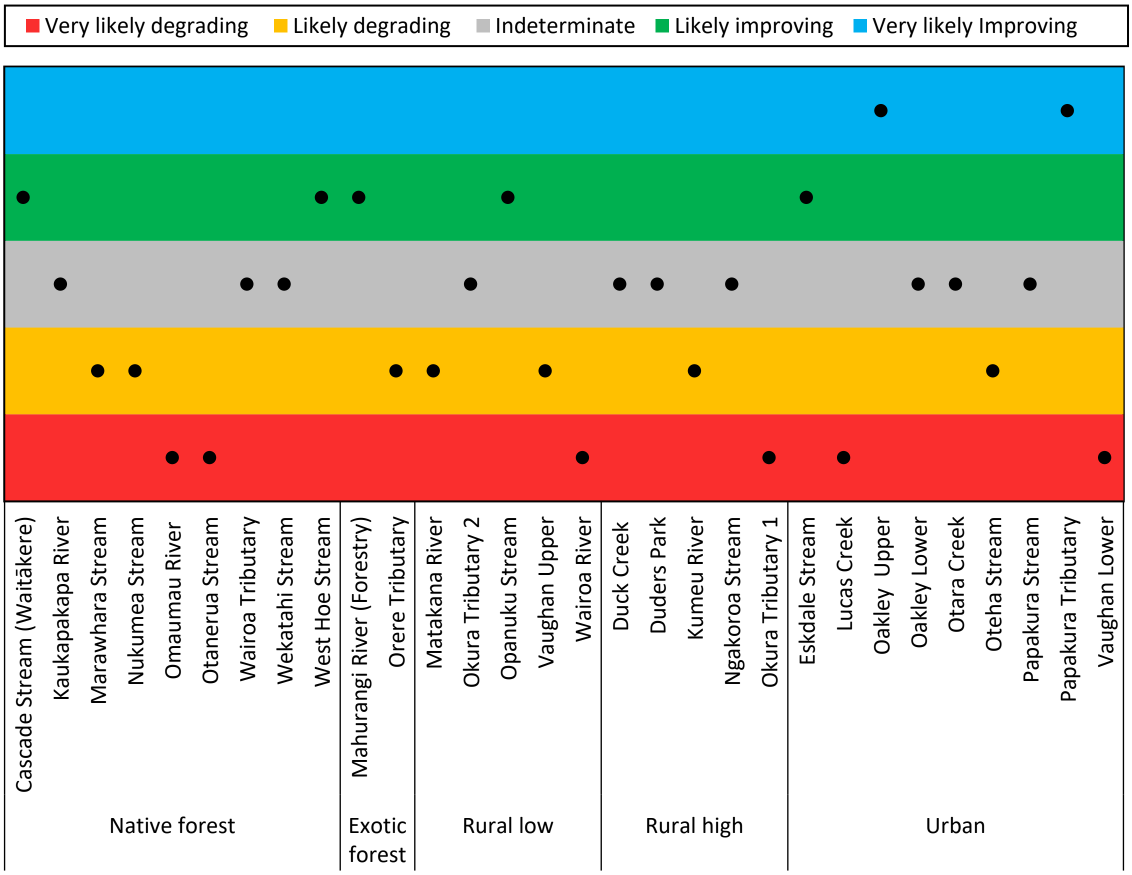

Figure 5-3: Summary plot of 10-year MCI trends (2010-2019) analysed across 30 sites in the River Ecology Monitoring Programme network; presented relative to the corresponding trend confidence category (see legend).

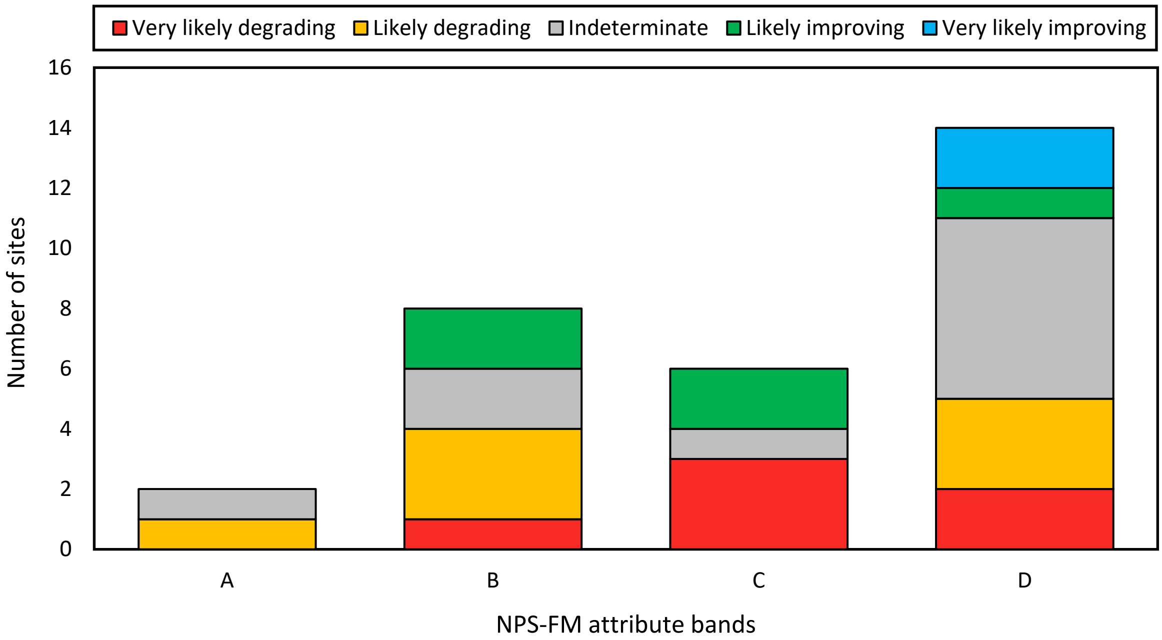

Figure 5-4: The number of sites in each trend confidence category, very likely degrading, likely degrading, indeterminate, likely improving and very likely improving, represented by the four NPS-FM NOF MCI attribute bands.

Two urban sites (Oakley Upper and Papakura Tributary) showed very likely improving trends, while two native forest sites (Omaumau River and Otanerua Stream), one rural low (Wairoa River), one rural high (Okura Tributary 1) and two urban sites (Lucas Creek and Vaughan Lower) returned very likely degrading trends (n = 7 total). The rate of annual change was below the measurement precision limit (±5 MCI units) for all trends (Table 5-1), suggesting that observed changes cannot be differentiated from the precision of MCI estimates.

Despite this, in most instances the very likely improving trends observed in MCI correlated with corresponding very likely improving trends in %EPT richness (refer to Figure 5-2). For example, very likely trends at Oakley Upper are potentially attributed to a higher incidence of more sensitive EPT taxa, suggesting that water quality or habitat may be improving at this location, while sites, including Lucas Creek, Wairoa River, Vaughan Lower and Okura Tributary 1, exhibited very likely degrading trends in both MCI and %EPT richness. This could be indicative of an overall change in community composition whereby sensitive taxa are being lost and replaced by more tolerant taxa as a result of declining water quality and/or habitat conditions at these locations.

Very likely trends in MCI at three sites (Omaumau River, Otanerua Stream and Papakura Tributary) did not correlate with trends observed in other metrics and, as such, potential causes for these trends were more challenging to determine. Although

ANOSIM tests identified a difference in community composition at some sites (e.g. Otanerua Stream), the dissimilarity was not found to be significant (p>0.05). Furthermore, the ANOSIM results did not always align with observed trends and taxa identified during SIMPER analysis as driving the change did not correlate with what was being seen in the MCI score.

For example, trends in MCI at Otanerau Stream were shown to be very likely degrading; however, there was very little change in the overall composition of taxa recorded, particularly EPT taxa. In general, most taxa over time remained indicative of good water quality and habitat conditions; however, an increase in axehead caddis (*Oxyethira*), chironomid midge (*Orthocladiinae*) and house fly (*Muscidae*) suggest an increase in algal content within the stream and may be indicative of nutrient enrichment within the catchment. This change in composition, however, was not identified during SIMPER analysis.

Comparison of MCI quality classes (Stark & Maxted, 2007b) and NPS-FM MCI attribute bands (MfE, 2020) indicate a decline in overall condition at three of the eight sites in which very likely trends have been identified (Table 5-1). Based on median MCI scores, NPS-FM attribute grading of Omaumau River (native forest) has fallen from band A to band B, and the NPS-FM banding and MCI quality class of Otanerua Stream (native forest) has changed from band B to band C, and excellent to good respectively. The MCI quality class of Okura Tributary 1 (rural high) has fallen from good to fair. The change in both the NPS-FM attribute banding and quality class of Otanerua Stream tends to support a decline in ecological condition at this site; however, the 2010 to 2014 median MCI scores of both Omaumau River (median of 130) and Okura Tributary 1 (median of 102) fall within the margin of error (±5 MCI units) of the respective attribute band/quality class estimates. This suggest that these sites may fluctuate between bands/quality classes or may have been in the lower band/class in the first instance.

Table 5-1: Comparison of quality classes (Stark & Maxted, 2007b) and NPS-FM NOF MCI attribute bands (MfE, 2020) at sites recording very likely degrading or improving trends; Interpretation is based on median MCI scores (2010-2014 and 2015-2019).

Site name	Land cover category	MCI quality class		NPS-FM attribute band		Difference in MCI score	Annual sen slope
		2010-2014	2015-2019	2010-2014	2015-2019		
Omaumau River	Native forest	Excellent	Excellent	A	B	-10.3	-1.6
Otanerua Stream	Native forest	Excellent	Good	B	C	-17.2	-2.0
Wairoa River	Rural low	Fair	Fair	C	C	-6.0	-1.4
Okura Tributary 1	Rural high	Good	Fair	C	C	-11.0	-2.2
Lucas Creek	Urban	Poor	Poor	D	D	-14.6	-3.0
Oakley Upper	Urban	Poor	Poor	D	D	+3.3	1.0
Papakura Tributary	Urban	Poor	Poor	D	D	+6.1	1.1
Vaughan Lower	Urban	Poor	Poor	D	D	-5.2	-1.6

Four out of the eight sites identified as showing very likely trends fall into NPS-FM attribute band D and are below the national bottom line (Table 5-1). Three of these sites had very likely degrading trends. Although this suggests that degraded sites are continuing to decline in some instances, the sites of the most interest in terms of the magnitude of change and what this might mean for future projections are those that have the potential to change bands over time, whether that means a positive or negative outcome.

Based on current median MCI state scores and assuming the trend directions continue at the corresponding rate of change (annual Sen slope) described for each site (Table 5-1) over consecutive years with no interventions, sites in band D with very likely improving trends, Oakley Upper (median MCI of 71.3 and annual Sen slope of 1.0) and Papakura Tributary (median MCI of 69.4 and annual Sen slope of 1.1), would take 20 years to rise above the national bottom line. Whereas it could take seven years for Omaumau River (median MCI of 119.7 and annual Sen slope of -1.6) to drop from band B to band C and Otanerua Stream (median MCI of 104.4 and annual Sen slope of -2.0) eight years to fall from band C to band D and below the national bottom line. The most concerning site is Wairoa River which has a current median MCI of 92.1 and trend magnitude (annual Sen slope of -1.4), with projections that suggest the site could fall below national bottom lines within just two years.

5.2 Stream ecological valuation (SEV)

The potential to detect trends in SEV score across network sites was compromised by a lack of data. Of the 15 sites assessed, four could not be analysed as a result of tied values, and six (55 per cent) returned indeterminate trends. Five sites from the rural high and urban land cover categories returned likely trends: three likely degrading (27 per cent) and two likely improving (18 per cent) (refer to Figure 5-5 and Figure 5-6). There were no very likely trends observed.

The indeterminate trends suggest that the observed changes cannot be differentiated from the precision of SEV estimates and that the changes in habitat quality and overall stream function at most analysed sites has been insubstantial over the past 11 years. One site (Duders Park) within the rural high category and one site (Oakley (Mid 4)) in the urban land cover category recorded likely improving quality. While three sites, Parahiku Stream (Upper), Avondale Stream (Lower) and Otara Creek in the urban land cover category, showed likely degrading trends.

Specific function data suggests that the likely improving trend recorded at Oakley (Mid 4) can be attributed to improvements in riparian margin integrity and habitat abundance. This stream reach is artificially lined with heavily managed riparian margins (mown with few trees), as a result it is likely that this trend is due to an error in observer perception rather than any actual improvement to these stream characteristics. In contrast, improving trends at Duders Park Stream are likely attributed to restoration of the river’s riparian margins, which has resulted in an overall reduction in fine sediment loads and macrophyte densities, as well as improvements in shading and general riparian margin function.

Parahiku Stream (Upper) and Avondale Stream (Lower) occur within the same catchment and each recorded likely degrading trends in SEV score. Specific function data suggests that the trends are associated with increased channel incision and fine sediment loading, as well as changes to fish spawning habitat quality and suitability. Similarly, Otara Creek has also been impacted by channel incision and changes in the quality habitat, in addition to changes in riparian vegetation and subsequent loss of shading, resulting in an overall decline in SEV score.

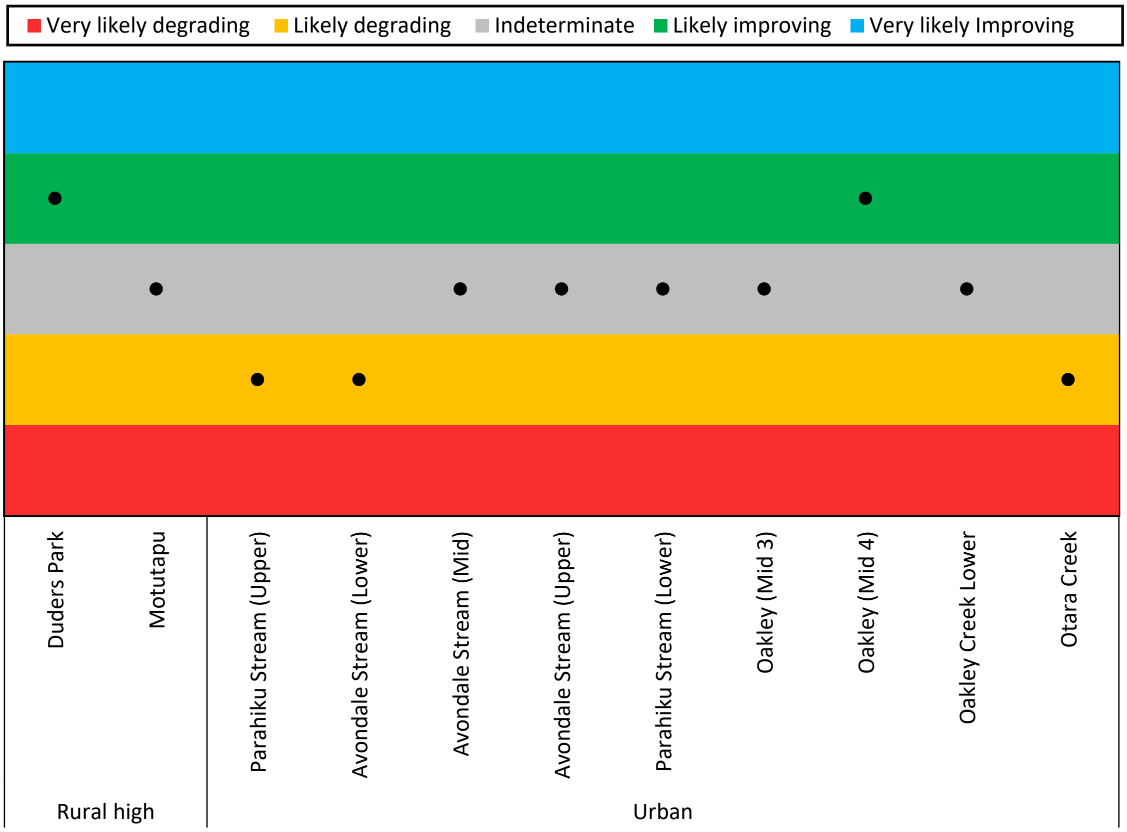

Figure 5-5: Summary plot of 10-year SEV trends (2010-2019) analysed across 11 sites in the REMP network, presented relative to the corresponding trend confidence category: very likely degrading, likely degrading, indeterminate, likely improving and very likely improving.

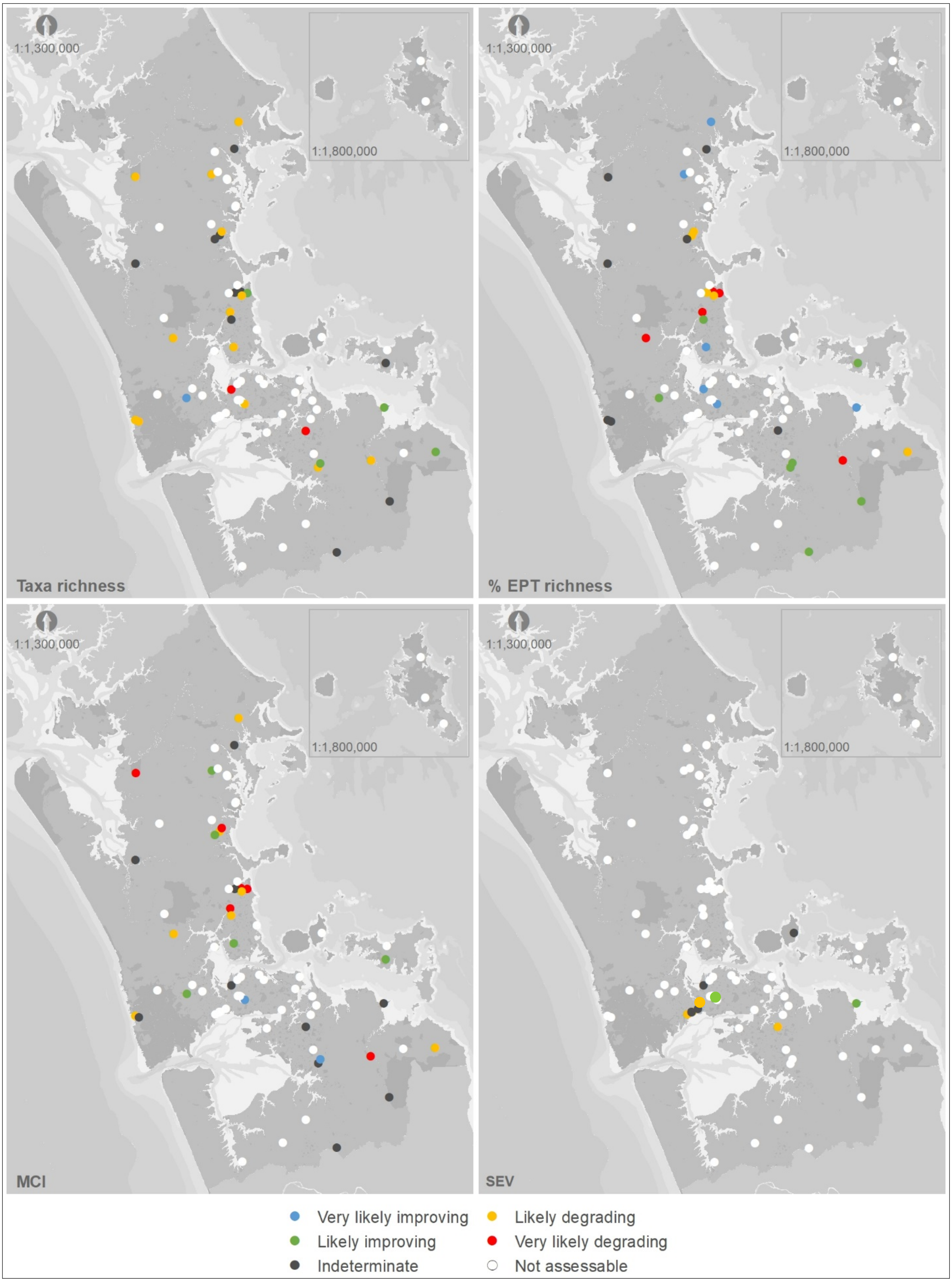

Figure 5-6: Map showing the geographic distribution of trend (2010-2019) results: taxa richness (top left), %EPT richness (top right), MCI score (bottom left) and SEV score (bottom right).

6.0 Summary discussion

The indicators used to describe ecological health in this report provide a varying picture of the overall health of streams across the Auckland region. As expected, rivers within native forest catchments tend to provide the greatest ecological values, both in terms of macroinvertebrate community composition and overall stream habitat and function. Although there were no obvious patterns in the spatial distribution of observed state and trends, all measures showed a clear pattern of decline with increased land cover modification. As a result, urban sites were consistently found to be in the worst ecological health.

State results for taxa richness and %EPT richness were consistent with results recorded during the last reporting period (Neale, et al., 2017), showing overall declines with increased land cover modification. In both instances results showed that taxa richness is generally higher in hard-bottomed rivers, except at more modified sites like those in the urban land cover categories. Furthermore, native and exotic forest sites were found to have the highest %EPT richness, while urban sites reported the lowest values, particularly at hard-bottomed sites.

Trends in the taxa richness and %EPT richness continue to show high spatial variability and a relatively high percentage of indeterminate trends. Neale, et al. (2017) reported improving trends in taxa richness at 41 per cent of sites for the period between 2003 and 2013 (inclusive), versus just 17 per cent of sites for this reporting period. Furthermore, just two per cent of sites in 2017 reported significant improving trends in %EPT richness, versus 20 per cent in this reporting period. Similarly, the magnitude of change was small (<3 units) in all instances.

MCI is considered one of the most integrative indicators used to describe ecological health in New Zealand rivers (Gadd, et al., 2020), particularly when compared against water quality or habitat measures alone. MCI state results indicate that 13 per cent of monitored rivers in the Auckland region are in excellent condition and 51 per cent of sites are in poor ecological condition. These results were comparable to those reported in the last river ecology state and trends report for the region (Neale, et al., 2017), with all native and exotic forest sites classified as having good to excellent ecological health, and more modified rural high and urban land cover category sites generally classified as poor to fair. There were some minor differences between results, such as rural categories recording lower numbers of higher quality sites; however, this is likely attributed to changes in the monitoring network that occurred between reporting periods (refer to Appendix A). Further investigations are recommended to determine whether dropped sites should be reintroduced into the programme (refer to Section 7.0).

Results presented in this report are also comparable to national reporting. Although expressed over different time periods, current state MCI quality classes were comparable to MCI band predictions used to describe the national picture (MfE and Stats NZ, 2020), particularly when viewed in the context of Auckland's modified landscape. Although modelled data in Our Freshwater 2020 (MfE and Stats NZ, 2020) indicated that over 75 per cent of rivers nation-wide fall within excellent and good quality classes (compared to just 31 per cent of sites identified in this report), overall results show similar declines in MCI score with increased land cover modification. LAWA (2020) estimates that 48 per cent of rivers in New Zealand are located within catchments predominantly comprised of native forest; however, urban sites account for 43 per cent of current REMP monitoring sites. This suggests urban rivers are over-represented in Auckland's existing monitoring network and helps to explain the lower percentage of higher-ranking sites recorded in the region. When compared against other more highly modified regions, such as Christchurch and north Waikato, Our Freshwater 2020 (MfE and Stats NZ, 2020) predictions for these areas are similar to Auckland; indicating a high percentage of rivers within fair to poor MCI quality classes.

Few regional council reports have yet assessed MCI results against NPS-FM (2020) attribute bands; however, comparisons were possible with two assessments recently undertaken by Gadd, et al. and LAWA (2020). National findings reported by LAWA (2020) correlate with what is being seen in Auckland, with the highest proportion of band D sites located within urban streams. For example, over 80 per cent of urban sites assessed by LAWA fall into band D, showing close similarity to the 93 per cent of urban sites recorded in this report. Results obtained by Gadd, et al. (2020) were also comparable, with 81 per cent of urban sites assessed across five regions (Auckland, Wellington, Christchurch, Waikato, Bay of Plenty and Taranaki) falling into band D and below the national bottom line. Furthermore, in this same study, 16 per cent of the total number of urban sites assessed were graded as band C, compared to seven per cent described in this report. The distribution of bands reported across land cover categories by LAWA (2020) was also similar to what has been seen in Auckland, reflecting the same gradient of degradation with increased land cover modification nationally.

Less than half of the river ecology monitoring network sites were found to have sufficient data to assess ecological trends across all metrics (taxa richness, %EPT richness, MCI and SEV). Furthermore, only a fraction of MCI results from those sites returned very likely trends through time, equating to 27 per cent of assessed sites (*n*= 30) and just 10.5 per cent of all current REMP network sites. Although the current configuration of network sites is not ideal, a review of the programme will ensure that reportability of site data is improved (refer to Section 7.0).

Trend assessments generally suggest that sites which are already in a degraded state are continuing to decline in ecological value. Although the trend slopes were generally considered to be minor/of a small magnitude for both reporting periods, there was an increase in accuracy provided by the probabilistic approach used in this report, meaning more trends could be identified. For example, Neale, et al. (2017) reported that trends in MCI were degrading at 25 per cent of sites and improving at eight per cent of sites (67 per cent indeterminate), while MCI was found to be degrading at 23 per cent of sites and improving at 43 per cent of sites (34 per cent indeterminate) for this reporting period. Trends reported in Our Freshwater 2020 (MfE and Stats NZ, 2020) did, however, show similarity with Auckland's results presented here, reporting comparable overall proportions of improving and degrading trends nationally.

This is the first time SEV results have been reported as part of State of the Environment monitoring for the Auckland region. Although the SEV was suggested as a method for measuring ecosystem function under the NPS-FM (Clapcott et al., 2018), there is currently no readily available information regarding the use of SEV for monitoring stream habitat and function at the national level. Therefore, comparison of any type is difficult. The SEV does, however, incorporate the assessment of instream habitat pressures and summarises a wider range of ecological functions which are not provided for in other more rapid habitat assessment types (Holmes, et al., 2018; Storey, et al., 2018) and is, therefore, considered to provide a more comprehensive snapshot of stream characteristics than other methodologies. Despite not having a point of comparison, the results are consistent with what might be expected, with native forest streams providing better quality habitat and higher stream function and urban streams generally showing the most impairment.

Overall, streams in the Auckland region, particularly those of poor quality, are being negatively impacted by loss of vegetation in the upstream catchment and surrounding riparian margins and the loss of habitat through channel modification, fine sediment loading and increased macrophyte growth. Streams with higher proportions of forest cover in the upstream catchment were consistently found to have higher ecological values, both in terms of habitat quality and biological communities. Close correlations were found between MCI and SEV results and WQI scores and forest cover in the upstream catchment.

Such relationships are commonly observed throughout New Zealand (Perrie, et al., 2012; Gadd, et al., 2020; MfE and Stats NZ, 2020), highlighting the complex nature of ecological evaluation and reinforcing that there are multiple factors contributing to observed ecological outcomes. The degradation occurring within many of the Auckland region's rivers is amplified by feedback loops which are occurring between various factors in the upstream catchment and it requires an integrated approach to their management. For instance, the poorest quality sites are characterised by poor riparian vegetation and shading, low instream oxygen levels, and the homogenisation of habitat through channel modification and high fine sediment content. These factors largely stem from land cover change and vegetation removal and are further compounded by activities within the wider catchment.

Results presented in this report indicate that urban sites (e.g. Parahiku Stream (Upper)) with large proportions of native forest cover in the upstream catchment can achieve good to excellent ecological values. Although the upstream catchments of such sites are relatively small, this suggests that with the right interventions it could be possible to improve ecological outcomes for some rivers; however, achieving results at the most degraded sites will be challenging. Although planting of riparian margins are known to provide a number of benefits at the local scale (i.e. channel shading, run-off filtration) and alleviate some of the issues present at a particular site (Collins, et al., 2013; Hughes, 2016; McKergow, et al., 2016), unless overaching issues such as land use practices and stormwater management (via water senitive urban design and hydrology mitigation) in the upstream catchment are addressed, the gains made are unlikely to be far reaching (Wahl, et al., 2013; Stanford, et al., 2020).

7.0 Monitoring limitations and knowledge gaps

The monitoring undertaken as part of the REMP programme provides a reasonable amount of information regarding the ecology of rivers in the region and their overall condition, however, there are some limitations and knowledge gaps associated with the data. The main limitations and recommendations are as follows:

- Monitoring network review – Urban sites are considered to be over-represented in the current network and often occur on the same river within relatively close proximity to each other. Many of these sites fail to tell us anything new about the current state of urban streams in the region and are often a legacy from specific monitoring projects. As a result, there is some underrepresentation in the network, particularly in areas towards the northern boundaries of the region. It is uncertain to what extent the current network is enabling us to assess the performance of Auckland Unitary Plan overlays and controls, such as stormwater management areas (SMAF 1 and 2), established to protect streams from further degradation. As a result, it is recommended a review of the network is undertaken to address these issues and ensure that river management objectives can be evidenced.
- Explanatory variables – The current network is such that there are very few sites which are paired with other monitoring programmes. As a result, there is little information available to us which might explain some of the results we are seeing beyond obvious habitat conditions. During the recommended river ecology monitoring network review, programme leads will look to integrate more sites with the stream water quality and periphyton monitoring network with the aim of providing more comprehensive reporting.
- Data continuity – One of the main challenges encountered during this reporting process was the number of network sites which lack the data required to complete the prescribed analysis, particularly in regard to the SEV data and overall trend analysis. This is largely due to inconsistent or irregular data collection throughout the years and as a result, only a subset of sites could be assessed. Because of this, overall trend assessments failed to provide full coverage at the regional scale. Therefore, it is recommended that the frequency of data collection is reviewed, and processes put in place to ensure adequate data is available in the future.
- New macroinvertebrate metrics – In addition to MCI, the NPS-FM (MfE, 2020) also includes NOF attribute states for two additional metrics: the quantitative variant of MCI (QMCI) and Average Score Per Metric (ASPM). Due to the short time frame between gazetting of the NPS-FM 2020 and preparation of this

report, these metrics could not be included in this report. The appropriate steps will be taken to ensure data processing requirements described in the NPS-FM are met and these metrics are included in future reporting, where appropriate, as well as potentially removing the less relevant metrics, taxa richness and %EPT richness.

- Additional monitoring – Macroinvertebrate and SEV data provide valuable information about the function and condition of instream habitat and water quality in Auckland's permanent, wadeable streams; however, little is known about intermittent streams in the region or the ability of river systems in to support native fish. Controls to protect intermittent streams are included in the Auckland Unitary Plan and fish monitoring is a new requirement under the NPS-FM (MfE, 2020). As such, it is recommended that monitoring of these aspects of ecology are initiated to fill this gap.

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Appendix A Programme history

Monitoring network

Auckland Council's Research and Evaluation Unit's (RIMU) River Ecological Monitoring Programme (REMP) was established in 1999 and commenced with the collection of macroinvertebrate samples from 19 river locations throughout the region between 1999 and 2001. Over the following years the monitoring network increased substantially from seven sites in 1999 to 88 at its peak in 2012 and 2013, with the number and composition of active sites varying between years in response to changing programme objectives (Figure A-1Figure).

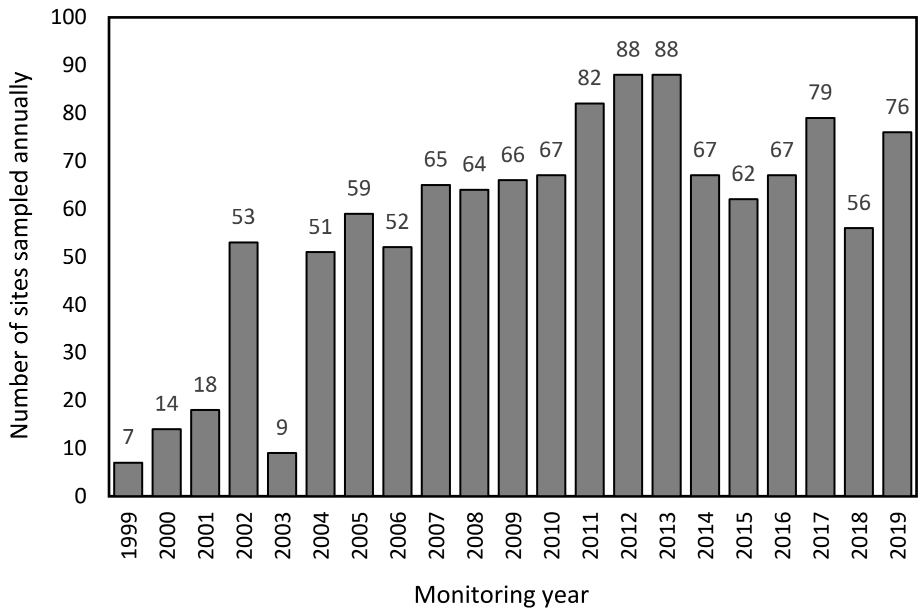

Figure A-1: Number of sites sampled as part of the River Ecological Monitoring Programme.

The programme was initially started to facilitate the development and standardisation of methods for macroinvertebrate sampling. Sites were selected to capture the natural variation in the macroinvertebrate communities present within hard- and soft-bottomed rivers in the region and provide an understanding of differing land use impacts. Results obtained between 1999 and 2003 contributed to the development of national protocols for sampling of both hard- and soft-bottomed streams (Maxted, et al., 2003; Stark , et al., 2001), as well as indices values for soft-bottomed streams (Stark & Maxted, 2004; Stark & Maxted, 2007).

In total, 121 sites have been sampled as part of continuous or intermittent monitoring efforts throughout the lifetime of the programme. Sites have been added to the network for a variety of reasons, including:

- To assess the impacts of land use intensification;
- To provide better representation of local wards in the region and improve spatial reporting;
- To support district action plans;
- To monitor the effects of stream restoration or other projects; and
- To form a freshwater-marine monitoring site network and promote cross programme linkages for State of the Environment reporting.

Conversely, some sites (*n* = 15) were only sampled once, largely for reasons unknown to the author, while others (*n* = 30) have been dropped from the network as a result of ongoing programme reviews. The reason why sites have been dropped is not always clear, however, some reasons include:

- Identified health and safety issues for monitoring staff (i.e. sites too deep to be considered wadeable);
- Poor data yield; and
- Changes in sampling substrate and/or stream profiles which have made obtaining representative samples difficult.

The last review was undertaken in 2018, resulting in the selection of the current network of 76 sites. A breakdown of why these sites were selected is provided in Table A-1. Sampling of this network commenced in 2019.

Table A-1: Breakdown of the freshwater monitoring sites selected in the 2018 programme review and included in the current network.

Reason for inclusion	Number of sites
Long-term monitoring site	31
Reference site	10
Local Board reporting	23
Project monitoring	11
Monitor land use effects	1
Total	**76**

Additional data collection

In addition to the annual macroinvertebrate sampling, council staff have also collected information regarding the quality of instream and riparian habitat at each site.

Initially (2000-2008), this consisted of rapid habitat quality assessments which were carried out concurrently with macroinvertebrate sampling. The assessment was developed in-house and was based on the principles described in the United States Environmental Protection Agency (US EPA) habitat assessment methodology, HABSCORE (Barbour, et al., 1999), and used a scoring system to assess seven habitat quality measures. Results from habitat quality assessments were reported in the first freshwater ecology report (Moore & Neale, 2008), however, analysis indicated that the assessment was of little value for identifying land use impacts on stream ecology. As such, recommendations were made to introduce Stream Ecological Valuation (SEV) (Rowe, et al., 2008; Storey, et al., 2011) into the programme as an alternative.

Following these recommendations, the SEV methodology was adopted into the programme in 2009, firstly using the second edition methodology (Rowe, et al., 2008), followed by the latest revision (Storey, et al., 2011). Completing an SEV is a much lengthier process than the initial scoring system used to assess habitat and, as a result, were undertaken on a more *ad hoc* basis until 2019. Due to the sporadic nature of data collection and small sample sizes, prior reporting of SEV data has not been possible.

Taxonomic processing

A number of agencies have been used to process and identify macroinvertebrate taxa during the programme’s lifespan. From 1999 to 2007, samples were processed by the Cawthron Institute, followed by Manaaki Whenua – Landcare Research from 2008 to 2013. In 2014, the processing switched to EOS Ecology Limited under a collective agreement with four other councils.

Quality control has always been undertaken by National Institute of Water and Atmospheric Research (NIWA).

Appendix B Current monitoring network

Table B-1: List and details of monitoring sites (*n* = 76) currently included in Auckland Council's River Ecological Monitoring Programme.

Water shed	Site ID	FWM site no.	Site name	Reporting/stream name	Easting (NZTM)	Northing (NZTM)	Year initiated	Substrate type	Dominant land cover
Greater Tamaki	8268	FWM102	Botany Creek @ Tangello Place	Pakuranga Stream	1769802	5915087	2011	HB	Urban
	8267	FWM100	Glendowie Stream @ Athlone Road	Glendowie Stream	1766987	5919411	2011	SB	Urban
	8249	FWM107	Omaru Ck @ Maybury	Omaru Creek	1766030	5916762	2011	SB	Urban
	8241	FWM038	Otara LTB	Otara Creek	1768326	5908371	2002	SB	Urban
	8217	FWM106	Pakuranga @ Botany Rd	Botany Creek	1770688	5913038	2011	HB	Urban
	8215	FWM105	Pakuranga Ck @ Greenmount Dr	Pakuranga Creek	1769462	5910964	2011	HB	Urban
Hauraki Gulf Islands	74701	FWM108	Cascades @ Whakanewha	Cascade Stream (Waiheke)	1785942	5923254	2011	HB	Rural low
	6990	FWM112	Kaitoke Creek @ Hotsprings Tk	Kaitoke Creek (GBI)	1817856	5987872	2013	HB	Native forest
	6989	FWM116	Mabey Rd	Mabey Stream (GBI)	1816457	6000276	2013	SB	Native forest
	7407	FWM084	Motutapu	Motutapu	1771846	5929049	2007	HB	Rural high
	74401	FWM109	Onetangi @ Waiheke Rd	Onetangi Stream	1786242	5926203	2011	SB	Urban
	6931	FWM113	Tryphena @ Medlands Rd	Tryphena Stream (GBI)	1823430	5979941	2013	HB	Rural low
Hibiscus Coast	7308	FWM061	Awanohi Lower	Awanohi Steam	1751424	5938711	2003	SB	Rural low
	7548	FWM110	Castor @ Braemar	Castor Stream	1757497	5930670	2011	SB	Urban
	7171	FWM047	Nukumea Upper	Nukumea Stream	1749411	5951400	2000	SB	Native forest
	7313	FWM075	Okura Reserve	Okura Reserve	1753241	5940408	2005	SB	Native forest
	7314	FWM062	Okura Trib 1	Okura Tributary 1	1754059	5939002	2002	SB	Rural high
	7315	FWM063	Okura Trib 2	Okura Tributary 2	1752669	5938790	2002	SB	Rural low
	7172	FWM052	Otanerua	Otanerua Stream	1749829	5952217	2002	SB	Native forest
	7527	FWM041	Vaughan Lower	Vaughan Lower	1755414	5938729	2000	SB	Urban

Water shed	Site ID	FWM site no.	Site name	Reporting/stream name	Easting (NZTM)	Northing (NZTM)	Year initiated	Substrate type	Dominant land cover
	7526	FWM014	Vaughan Upper	Vaughan Upper	1754271	5938178	2000	SB	Rural low
	7173	FWM103	Waiwera R @ Waiwera Rd	Waiwera River	1747580	5953924	2011	SB	Rural low
	7213	FWM046	West Hoe LTB	West Hoe Stream	1748300	5950608	2001	SB	Native forest
Mahurangi Harbour	6606	FWM076	Duck Creek @ Trotters	Duck Creek	1752605	5970451	2005	SB	Rural high
	6847	FWM087	Dyers Creek @ Bush	Dyers Creek (Forest)	1751076	5963704	2007	SB	Rural low
	6852	FWM088	Dyers Creek @ Mid Paddock	Dyers Creek (Pasture)	1750910	5963846	2007	SB	Rural low
	6862	FWM089	Mahu Ref @ Trappit	Mahurangi River (Native)	1748961	5965371	2008	SB	Native forest
	6869	FWM140	Mahurangi @ college FWM	Mahurangi River (Pasture)	1748269	5969810	2019	HB	Rural high
	6850	FWM028	Mahurangi LTB	Mahurangi River (Forestry)	1747626	5964882	2002	SB	Exotic forest
	6996	FWM137	Te Muri @ Fenceline	Te-Muri-Ō-Tarariki Stream	1752857	5957744	2014	SB	Rural high
	6995	FWM136	Te Muri @ Weir	Te-Muri-Ō-Tarariki Stream	1752915	5957910	2014	SB	Rural high
Manukau Harbour	44030	FWM098	Anns Creek @ Hamlins Hill	Anns Creek	1763107	5912095	2011	SB	Urban
	1043824	FWM037	Ngakoroa LTB	Ngakoroa Stream	1775165	5881618	2002	SB	Rural high
	1043825	FWM033	Papakura LTB	Papakura Stream	1771066	5900274	2002	SB	Urban
	1043835	FWM104	Papakura Trib @ Alfriston Rd	Papakura Tributary	1771523	5901203	2011	SB	Urban
	1043828	FWM015	Puhinui Upper (hard)	Puhinui Stream	1770055	5903290	2002	HB	Rural high
	43929	FWM097	Tararata Creek @ Elmdon Street	Tararata Creek	1759795	5908043	2011	SB	Urban
	43601	FWM093	Waitangi Stream	Waitangi Stream	1754347	5878524	2009	SB	Rural high
	104300	FWM095	Whangamarie Stream @ Hunter Rd	Whangamaire Stream	1763241	5882752	2011	SB	Rural high
	43968	FWM141	Whangapouri @ Paerata	Whangapouri Creek	1768327	5887871	2019	SB	Rural high
North East Coast	6604	FWM031	Matakana LTB	Matakana River	1753615	5976422	2002	SB	Rural low

Water shed	Site ID	FWM site no.	Site name	Reporting/stream name	Easting (NZTM)	Northing (NZTM)	Year initiated	Substrate type	Dominant land cover
South Kaipara Harbour	45416	FWM086	Kaukapakapa Ref	Kaukapakapa River	1730803	5945157	2007	SB	Native forest
	45369	FWM021	Kumeu @ Weza	Kumeu River	1739216	5928819	2002	SB	Rural high
	45505	FWM091	Makarau @ Rail Bridge	Makarau River	1736090	5953237	2009	SB	Rural high
	45605	FWM056	Mt Auckland	Omaumau River	1730852	5964294	2001	SB	Native forest
	45371	FWM008	Riverhead	Riverhead	1737125	5933216	2002	SB	Exotic forest
Wairoa	8557	FWM068	Aroaro @ Phillips	Aroaro Stream	1789897	5903472	2004	HB	Rural low
	8407	FWM069	Duders	Duders Park	1785588	5913500	2006	SB	Rural high
	8609	FWM019	Orere B	Orere Tributary	1796917	5903677	2002	HB	Exotic forest
	8569	FWM092	Wairoa @ Caitchen Rd Trib	Wairoa Tributary	1786762	5892804	2009	HB	Native forest
	8553	FWM032	Wairoa LTB	Wairoa River	1782680	5901828	2002	SB	Rural low
Waitematā Harbour	108123	FWM121	Auckland Domain @ Lower Domain Dr	Auckland Domain	1758082	5919748	2013	SB	Urban
	8023	FWM114	Avondale @ Reserve	Parahiku Stream (Upper)	1748402	5911129	2012	SB	Urban
	8019	FWM099	Avondale @ Shadbolt Park	Avondale Stream (Lower)	1750685	5912301	2011	SB	Urban
	8022	FWM115	Avondale @ Thuja Pl	Avondale Stream (Mid)	1749503	5911643	2012	SB	Urban
	10713	FWM111	Edgar @ Maxwell Av	Edgars Creek	1753970	5919393	2011	SB	Urban
	7722	FWM071	Eskdale Lower	Eskdale Stream	1752448	5926772	2005	SB	Urban
	8027	FWM131	La Rosa Reserve TL (North Stream)	Avondale Stream (Upper)	1749288	5911619	2013	HB	Urban
	8026	FWM130	La Rosa Reserve TR (South Stream)	Parahiku Stream (Lower)	1749303	5911539	2013	HB	Urban
	7899	FWM040	Lucas LTB @ Tennis	Lucas Creek	1751752	5934493	2004	SB	Urban
	8106	FWM125	Meola Ck @ Motions Rd	Meola Creek	1753212	5918641	2013	SB	Urban
	8176	FWM120	Newmarket Stream @ Ayr Street	Newmarket Stream	1759114	5918641	2013	HB	Urban
	107892	FWM139	Nimrod Stream @ Scott Point	Nimrod Stream	1748221	5925949	2019	SB	Rural high
	108144	FWM138	Oakley @ Beagle Road	Oakley Creek (Mid 2)	1753792	5915208	2017	HB	Urban

Water shed	Site ID	FWM site no.	Site name	Reporting/stream name	Easting (NZTM)	Northing (NZTM)	Year initiated	Substrate type	Dominant land cover
	8128	FWM132	Oakley @ Richardson Road	Oakley Creek (Mid 1)	1753326	5915131	2014	HB	Urban
	108127	FWM134	Oakley @ Walmsley Park	Oakley (Mid 3)	1754146	5914953	2014	HB	Urban
	108126	FWM133	Oakley @ War Memorial Park	Oakley (Mid 4)	1754457	5914549	2014	HB	Urban
	10812	FWM101	Oakley Creek @ May Road	Oakley Upper	1754919	5914268	2011	HB	Urban
	8177	FWM035	Oakley LTB	Oakley Lower	1751936	5917508	2002	SB	Urban
	7925	FWM034	Opanuku LTB	Opanuku Stream	1742087	5915597	2002	HB	Rural low
	7911	FWM126	Oratia @ Millbrook	Oratia Stream	1745528	5916176	2013	SB	Urban
	107801	FWM013	Oteha LTB	Oteha Stream	1751903	5932876	2002	SB	Urban
	7939	FWM096	Paramuka Stream @ Brookwood Drive	Paramuka Stream	1743365	5917644	2011	SB	Urban
West Coast	44618	FWM048	Cascade LTB	Cascade Stream (Waitākere)	1735633	5916371	2001	HB	Native forest
	44460	FWM049	Marawhara	Marawhara Stream	1730774	5910762	2000	HB	Native forest
	44470	FWM050	Wekatahi	Wekatahi Stream	1735633	5916371	2000	HB	Native forest

Appendix C Land cover breakdown

Table C-1: Land cover breakdown for each monitoring site as a percentage of the upstream catchment (less waterbodies and freshwater vegetation), including total catchment area (derived from LCDB5). ** denotes sites in which dominant land cover classification was determined according to prior land cover delineation (Neale, et al., 2017) and site knowledge (see explanation below).

Site name	Native forest (per cent cover)			Exotic forest (per cent cover)			Rural (per cent cover)						Urban (per cent cover)				Total area (km^2)
	Indigenous forest	Broad-leaved indigenous hardwoods	Manuka/ kanuka	Exotic forest	Forest - harvested	Deciduous hard woods	High producing grassland	Low producing grassland	Short-rotation cropland	Orchard, vineyard, perennial crop	Mixed exotic shrub-land	Gorse/ broom	Urban park/ open space	Mine/ Dump	Transport infra-structure	Built-up area	
Anns Creek	0.0	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.2	0.0	0.0	41.0	0.13
Aroaro Stream	46.7	3.6	5.8	8.0	0.0	0.0	35.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.40
Auckland Domain	0.0	0.0	0.0	0.0	0.0	27.4	0.0	0.0	0.0	0.0	0.0	0.0	64.1	0.0	0.0	8.5	0.39
Avondale Stream (Lower)	9.8	0.0	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	66.1	1.98
Avondale Stream (Mid)	7.4	0.0	11.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5	0.0	0.0	63.0	3.43
Avondale Stream (Upper)	0.0	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.8	0.0	0.0	68.2	0.76
Awanohi Stream	24.6	7.3	28.2	6.8	0.0	0.0	31.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	5.53
Botany Creek	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	92.7	6.64
Cascade Stream (Waiheke)	25.9	0.0	28.7	0.0	0.0	0.0	44.3	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.64
Cascade Stream (Waitākere)	96.9	0.2	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.88
Castor Stream	0.0	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	83.6	0.48
Duck Creek	0.0	0.0	0.5	7.9	0.0	0.0	81.7	0.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.32

Site name	Native forest (per cent cover)			Exotic forest (per cent cover)			Rural (per cent cover)						Urban (per cent cover)				Total area (km^2)
	Indige-nous forest	Broad-leaved indigenous hardwoods	Manuka/ kanuka	Exotic forest	Forest - harvested	Decid-uous hard woods	High producing grassland	Low producing grassland	Short-rotation cropland	Orchard, vineyard, perennial crop	Mixed exotic shrub-land	Gorse/ broom	Urban park/ open space	Mine/ Dump	Transport infra-structure	Built-up area	
Duders Park	16.3	0.0	0.0	0.0	0.0	0.0	83.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.20
Dyers Creek (Forest)	43.4	1.3	0.2	7.1	0.0	0.0	47.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.71
Dyers Creek (Pasture)	40.3	1.4	0.2	7.9	0.0	0.0	50.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.04
Edgars Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	95.7	0.58
Eskdale Stream	34.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	0.0	0.0	57.4	3.83
Glendowie Stream	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	0.0	0.0	80.1	2.42
Kaitoke Creek (GBI)	49.8	1.9	48.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.23
Kaukapakapa River	24.1	8.5	64.4	0.3	0.0	0.0	0.1	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.62
Kumeu River	1.8	2.8	7.2	5.0	0.4	0.2	74.1	0.1	1.7	3.8	0.3	0.4	0.4	0.1	0.0	1.8	45.66
Lucas Creek	2.6	1.9	8.1	1.5	0.0	0.0	15.7	0.3	0.0	0.0	0.0	0.0	14.2	0.0	2.0	53.7	5.53
Mabey Stream (GBI)	67.5	0.0	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.54
Mahurangi River (Forestry)	1.0	0.0	0.0	60.9	37.8	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.63
Mahurangi River (Native)**	58.8	0.0	0.0	25.4	1.9	0.0	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.17
Mahurangi River (Pasture)	18.4	2.4	3.7	17.8	5.9	0.1	48.6	0.4	0.0	0.6	0.0	0.4	0.0	0.0	0.2	1.5	46.80
Makarau River	7.5	2.5	5.8	18.1	0.3	0.1	63.1	2.1	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	48.41
Marawhara Stream	83.1	0.0	16.3	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.93
Matakana River	26.3	15.1	8.3	8.8	0.1	1.0	39.3	1.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	13.88

Site name	Native forest (per cent cover)			Exotic forest (per cent cover)			Rural (per cent cover)						Urban (per cent cover)				Total area (km^2)
	Indigenous forest	Broad-leaved indigenous hardwoods	Manuka/ kanuka	Exotic forest	Forest - harvested	Deciduous hard woods	High producing grassland	Low producing grassland	Short-rotation cropland	Orchard, vineyard, perennial crop	Mixed exotic shrub-land	Gorse/ broom	Urban park/ open space	Mine/ Dump	Transport infra-structure	Built-up area	
Meola Creek	0.5	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2	1.4	0.8	84.3	7.87
Motutapu	0.0	5.0	0.0	0.0	0.3	3.5	89.1	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.71
Newmarket Stream	0.6	0.0	0.0	3.9	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.8	86.1	6.24
Ngakoroa Stream	0.6	1.5	0.0	3.2	0.6	0.4	63.1	0.6	26.2	2.5	0.0	1.1	0.0	0.3	0.0	0.0	4.68
Nimrod Stream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
Nukumea Stream	45.7	0.0	52.3	0.0	0.0	0.0	0.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.99
Oakley Creek Lower	1.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.1	0.0	0.0	81.1	11.26
Oakley (Mid 3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	0.0	81.8	5.02
Oakley (Mid 4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	0.0	0.0	81.0	4.63
Oakley Creek Upper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	99.4	0.10
Oakley Creek (Mid 1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.2	0.0	0.0	82.8	5.88
Oakley Creek (Mid 2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	82.0	5.19
Okura Creek	40.6	0.0	57.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.31
Okura Tributary 1	6.5	3.8	10.1	5.1	0.0	1.0	72.2	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.69
Okura Tributary 2	3.4	5.2	37.1	5.7	0.0	0.0	39.7	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	5.4	1.24
Omaru Creek	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	26.2	0.0	0.0	71.8	4.65
Omaumau River	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.72
Onetangi Stream	25.8	7.8	49.8	0.3	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.5	0.68

Site name	Native forest (per cent cover)			Exotic forest (per cent cover)			Rural (per cent cover)						Urban (per cent cover)				Total area (km^2)
	Indige-nous forest	Broad-leaved indigenous hardwoods	Manuka/ kanuka	Exotic forest	Forest - harvested	Decid-uous hard woods	High producing grassland	Low producing grassland	Short-rotation cropland	Orchard, vineyard, perennial crop	Mixed exotic shrub-land	Gorse/ broom	Urban park/ open space	Mine/ Dump	Transport infra-structure	Built-up area	
Opanuku Stream	61.9	0.5	19.6	0.8	0.0	0.0	13.9	0.1	0.2	1.2	0.2	0.0	0.0	0.0	0.0	1.6	15.66
Oratia Stream	26.3	4.2	15.7	1.6	0.0	0.0	10.6	0.1	0.1	6.0	0.0	0.2	3.4	0.0	0.0	31.7	27.68
Orere Tributary	0.0	0.0	0.5	99.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.28
Otanerua Stream	64.4	0.0	35.5	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22
Otara Creek	4.5	1.2	0.1	1.6	0.0	0.2	31.3	0.0	0.0	0.0	0.0	0.0	13.8	0.1	0.0	47.3	18.28
Oteha Stream	3.3	0.3	0.5	2.1	0.0	0.0	5.4	0.0	0.0	0.0	0.6	0.0	21.8	0.0	2.7	63.2	9.75
Pakuranga Creek Trib	0.0	0.1	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	91.4	2.16
Pakuranga Stream	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	0.0	91.2	2.01
Papakura Stream	5.9	1.3	1.5	5.2	1.2	0.2	69.5	0.0	2.6	1.7	0.4	0.6	1.9	1.3	0.6	5.8	47.14
Papakura Tributary	2.5	0.0	0.0	1.8	0.0	0.0	37.2	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	57.9	2.01
Parahiku Stream (Lower)	17.9	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	61.6	1.09
Parahiku Stream (Upper)	53.7	0.0	37.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	6.8	0.25
Paramuka Stream	1.0	9.8	0.2	1.7	0.0	0.0	34.1	0.0	0.0	7.8	0.0	0.0	5.0	0.0	0.0	40.4	1.81
Puhinui Stream **	9.5	2.3	0.0	5.0	0.0	0.0	58.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	24.8	3.43
Riverhead	0.0	0.0	0.1	99.6	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.10
Tararata Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	1.3	85.8	0.93
Te-Muri-Ō-Tarariki Stream (Lower)	3.2	0.0	3.1	0.0	0.0	0.0	93.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.20

Site name	Native forest (per cent cover)			Exotic forest (per cent cover)			Rural (per cent cover)						Urban (per cent cover)				Total area (km^2)
	Indigenous forest	Broad-leaved indigenous hardwoods	Manuka/ kanuka	Exotic forest	Forest - harvested	Deciduous hard woods	High producing grassland	Low producing grassland	Short-rotation cropland	Orchard, vineyard, perennial crop	Mixed exotic shrub-land	Gorse/ broom	Urban park/ open space	Mine/ Dump	Transport infra-structure	Built-up area	
Te-Muri-Ō-Tarariki Stream (Upper)	3.7	0.0	3.7	0.0	0.0	0.0	92.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.27
Tryphena Stream (GBI)	0.4	44.0	41.4	0.0	0.0	0.0	13.7	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	2.96
Vaughan Lower	2.1	2.2	24.0	5.2	0.0	0.0	49.8	0.0	0.0	0.0	0.7	0.0	2.6	0.0	0.0	13.4	2.39
Vaughan Upper	0.5	3.6	36.1	8.8	0.0	0.0	43.8	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	6.6	1.05
Wairoa River	15.5	7.0	5.7	22.2	0.5	0.0	48.1	0.1	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.1	148.84
Wairoa Tributary	58.5	17.3	24.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.18
Waitangi Stream	3.6	0.2	0.1	1.2	0.0	0.0	81.5	0.0	11.4	1.9	0.0	0.0	0.0	0.0	0.0	0.2	18.99
Waiwera River	29.3	4.7	20.9	4.1	0.4	0.0	38.8	0.0	0.3	0.0	0.0	1.5	0.0	0.0	0.0	0.0	15.55
Wekatahi Stream	99.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.24
West Hoe Stream	0.0	39.1	60.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.53
Whangamarie Stream	2.0	0.0	0.0	0.0	0.0	0.0	28.5	0.0	59.6	7.6	0.0	0.0	0.0	0.0	0.0	2.2	4.75
Whangapouri @ Paerata	0.0	0.0	0.0	2.2	0.0	0.0	97.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.88

Assigning dominant land cover categories

The five land cover categories used to describe dominant land cover within upstream catchments in this report are derived from the approach used in the most recent and only state and trend report for freshwater ecology (Neale, et al., 2017). This method diverged from the four category (native and exotic forest, rural and urban) scale generally used nationally and was done in an effort to provide greater granularity in reporting for rural areas across the region (M. Neale 2020, *pers. comm.*, 14 May).

The thresholds for delineating land cover categories (Neale, et al., 2017) were determined using professional judgment. While native forest, exotic forest and urban categories were found to be fairly well described and relatively narrow in terms of their MCI scores, the rural category was found to be a “catch all” category with a wide range of land cover types, environmental quality and, subsequently, MCI scores. As a result, the rural category was split according to the extent of forested and urban cover within the catchment. The categories where described as ‘rural low intensity’ and ‘rural high intensity’ to indicate the level of environmental pressure potentially associated with the amount of modification in the catchment.

These categories were continued through to this report to maintain consistency and allow for comparison between reports. The methods used to classify native forest, exotic forest and urban categories were maintained; however, closer analysis of macroinvertebrate results in rural areas found that communities were more heavily influenced by the extent of forested area in the catchment than urban cover, and provided increased differentiation between MCI scores in rural categories. As such, delineation of the two rural catchments was altered and determined based on percentage of forested land cover within the catchment alone (the urban component was removed as a decision rule). It was also found that the use of ‘intensity’ in the naming of rural categories was often misinterpreted as an indication of the intensity of land use practices or activities occurring within the catchment. As a result, the wording was changed to remove any confusion.

Appendix D Stream Ecological Valuation background and methodology

In 2009, RIMU adopted the SEV methodology into the ecological monitoring programme, replacing the rapid habitat scoring system used in previous years (refer to Appendix A). The latest edition of the SEV methodology (Storey, et al., 2011) was developed following a series of revisions and workshops (Rowe, et al., 2006; 2008) and now provides a standardised method for quantifying the ecological condition or value of wadeable stream and river systems in the Auckland region.

This method places emphasis on ecological function as a proxy for the provision of ecosystem services. As a result, the ecological value of a stream is viewed as a measure of the overall intactness of stream functions relative to an expected reference state. The SEV uses transect- and reach-scale observations, combined with biological (macroinvertebrate and fish community indices) and catchment-scale data, to assess the performance of 14 key stream ecological functions. These are divided into four main function categories (refer to Table D-1).

Table D-1: Summary of the ecological functions assessed during Stream Ecological Valuation.

Function category	Ecological functions	Description
Hydraulic function	Natural flow regime (NFR) Floodplain effectiveness (FLE) Connectivity for natural species migrations (CSM) Natural connectivity to groundwater (CGW)	Processes associated with water storage, movement and transport.
Biogeochemical function	Water temperature control (WTC) Dissolved oxygen levels (DOM) Organic matter input (OMI) In-stream particle retention (IPR) Decontamination of pollutants (DOP)	Relates to the processing of minerals, particulates and water chemistry.
Habitat provision function	Fish spawning habitat (FSH) Habitat for aquatic fauna (HAF)	The types, amount and quality of habitats that the stream reach provides for flora and Fauna.
Biodiversity provision function	Fish fauna intact (FFI) Invertebrate fauna intact (IFI) Riparian vegetation intact (RVI)	The occurrences of diverse populations of native plants and animals that would normally be associated with the stream reach.

Through a series of algorithms and formulae, 28 function variable inputs are used to produce an overall SEV score (ranging from 0 to 1) which is used to describe overall habitat and ecological function within a given stream reach (refer to Table 3-3 in Section 3.5.1).

The main objectives for updating earlier versions of the SEV method was to reduce repetition and redundancy amongst functions, reduce application time and ensure definitions of natural conditions were applied more consistently across functions. Although most variables remained unchanged, embedded algorithms were changed in some instances to amend variables and the more redundant variables were removed altogether. Neale, et al. (2017) compared earlier (Rowe, et al., 2006; 2008) and revised (Storey, et al., 2011) versions of the SEV methodology, analysing the relationship between output scores. Results indicated that the scores from the revised version are better able to discriminate impacted from reference conditions; however, a strong correlation was observed between mean function and overall SEV scores across land cover types, with any differences found not to be significant. Although the study cautions users against comparing individual variable function scores from the different versions, there was confidence that mean function and overall SEV scores are directly comparable.

The SEV is now widely accepted as standard practice amongst environmental management practitioners for assessing stream ecological function in Auckland and is gaining traction in other regions, including Wellington and Hawkes Bay. The SEV is largely recognised as a consenting tool and is the recommended method for assessing stream ecological effects and calculating ecological compensation requirements in resource consent applications (refer to Chapter E3 of the Auckland Unitary Plan), however, the production of a single SEV score also allows the method to be incorporated into regional environmental reporting.

Appendix E Macroinvertebrate community metric background and methodology

The use of macroinvertebrates in freshwater monitoring

Freshwater macroinvertebrates are typically visible with the naked eye and commonly found living on or under rocks, logs, aquatic vegetation and organic debris. Examples include insects and their larvae, crustaceans, molluscs and worms. These organisms play an integral role in the aquatic food chain, feeding on organic matter (i.e. leaves and algae) and providing a food source for higher order organisms, such as fish, birds and carnivorous insects.

Macroinvertebrate community assemblages are largely dependent on instream water and habitat quality, as well as the terrestrial habitat requirements and dispersal capabilities of some adult lifeforms. The ecological traits of macroinvertebrate species mean that changes in these features can influence community structure and, as a result, are a well-known indicator of a river's ecological health. Such traits include:

- Generally common and abundant in most freshwater habitats. Even in smaller habitats, such as first and second order streams, where larger fauna are generally limited.
- Communities are comprised of a broad range of trophic levels, offering a spectrum of potential responses to environmental stressors.
- Limited migration patterns and relatively sedentary life modes make them good indicators of localised conditions.
- Complex life cycles (typically ranging from months to a year) mean sensitive life stages respond quickly to environmental stressors, while overall community response is relatively slow, providing an integrated record of temporal changes in environmental quality.
- Relatively easy and inexpensive to identify to family or lower taxonomic levels.

Macroinvertebrate taxa have unique habitat preferences and respond differently to changes in water quality. Some are highly sensitive and can only survive in water with little to no pollution, low temperatures and high oxygen levels (i.e. fast-moving rivers with abundant riffle habitat), such as Ephemeroptera, Plecoptera, and Trichoptera. These taxa include the mayflies, stoneflies and caddisflies respectively, and are referred to as EPT taxa. High EPT taxa richness is indicative of clean water and structurally complex invertebrate habitat, and diversity has been shown to decline in response to impaired water and habitat quality in New Zealand (Casanovas, et al., 2019). As a result, these taxa in particular are considered to be a good gauge of river health.

Some taxa, such as mud snails (*Potamopyrgus*), are moderately sensitive to pollution and are adapted to a variety of habitat and stream types and, as such, are not overly useful as water quality indicators. While others, such as chironomid midges (i.e. *Chironomus*), are highly tolerant and have biological mechanisms adapted to surviving in homogenous, low-oxygen environments, making them good indicators of poor water quality and habitat conditions.

This information is commonly summarised into biological indices which produce a single score or grade and help communicate complex information to the general public. Indices can detect and simplify differences occurring in species composition to allow for relatively quick comparisons amongst numerous sites. The most commonly used biological index for assessing the ecological health of rivers in New Zealand is the Macroinvertebrate Community Index (MCI) (Stark, 1985) and its variants (Stark & Maxted, 2007a).

The MCI is calculated from taxon-specific tolerance scores and is recognised as a good metric for assessing ecosystem health with respect to nutrient enrichment, organic pollution and sedimentation (Casanovas, et al., 2019; Stark & Maxted, 2007a). The MCI is also known to detect changes in community composition relative to land use activities occurring in the upstream catchment, thus providing strong information for interpreting cumulative effects from multiple stressors. The MCI (and its variants) is an approach used consistently amongst regional and district councils for assessing the condition of rivers throughout New Zealand.

Total taxa richness is also commonly used when assessing macroinvertebrate community results. On its own it is considered a poor indicator of ecological health. This is largely because it includes pollution tolerant taxa and there is no definitive evidence to suggest that high taxa richness is indicative of good health and low taxa richness of bad health (Casanovas, et al., 2019; Stark & Maxted, 2007b). However, when used in combination with the above metrics it can help explain or support observed results.

Macroinvertebrate Community Indices

MCI, and its quantitative variant (QMCI), were originally developed to measure the effects of nutrients on macroinvertebrate communities in hard-bottomed streams in New Zealand (Stark, 1985) and was derived from the Biological Monitoring Working Party (BMWP) aquatic macroinvertebrate scoring system used in United Kingdom (BMWP, 1978). This work was later expanded to include the development of biotic indices (MCI-sb and QMCI-sb) specifically designed for assessment of soft-bottomed streams (Stark & Maxted, 2007a) and a semi-quantitative alternative of the QMCI

(SQMCI) (Stark, 1998). Semi-quantitative and quantitative methods are used for Auckland Council's state and trends reporting, however, the inclusion of QMCI as a required NPS-FM ecosystem attribute means that it will be included in future reporting.

The MCI and its variants follow the same principles in which a tolerance value ranging from 1 to 10 is assigned to macroinvertebrate taxa recorded in freshwater samples. The tolerance value given to each taxon relates to stream condition or an environmental gradient and reflects a perceived sensitivity to environmental pressures, with a value of 1 indicative of highly tolerant taxa and a value of 10 highly sensitive taxa. The values were determined through calculations relating to changes in community composition along a disturbance gradient and professional judgment.

The tolerance values of each taxa identified within a sample are then used to calculate an overall score which is indicative of stream condition. MCI scores are determined using presence-absence data and calculated using the formula provided below:

$$MCI = \frac{\sum_{i=1}^{i=S} a_i}{S} \times 20$$

Where:

S = the total number of scoring taxa in the sample

a_i = the tolerance value for the ith taxon

The scaling factor of 20 is used to distinguish MCI scores from its quantitative and semi-quantitative variant scores, which consider taxon counts. Soft-bottom (-sb) versions are analogous with hard-bottomed indices and are calculated and interpreted in the same manner.

It was initially proposed that certain ranges of MCI scores would indicate a particular level of pollution, however, revised versions recognise that macroinvertebrate communities are not solely determined by pollution. More sensitive, higher scoring taxa can be displaced by a number of other factors, such as a reduction in riffle habitat, an increase in stream temperature and fine sediment deposition, decreases in dissolved oxygen levels, reduced riparian vegetation quality, and a lack of recruitment. As such, the index scores and standardised quality classes (Stark & Maxted, 2007a) are now considered a measure of general water quality and habitat quality combined. These are described in Table 3-2 of Section 3.5.1. Stark and Maxted (2007b) note that there should be some flexibility when interpreting the thresholds or boundaries between described quality classes and that is best to view the boundaries as 'fuzzy'. In order to account for observed error associated with MCI estimations (Stark, 1998), they suggest a ‘fuzzy boundary’ of ±5 MCI units either side of the thresholds to account for this variability.

Auckland Unitary Plan (Operative in part) interim NPS-FM guideline values

Chapter E1 of the Auckland Unitary Plan outlines the provisions for freshwater management under legacy versions of the NPS-FM, including interim freshwater quality guidelines for MCI (Table D-2). These were developed objectively using a combination of REMP data, River Environment Classification (REC) data (Snelder, et al., 2010) and modelling outputs (Clapcott, et al., 2011), and were included at the policy level with the objective of maintaining river ecological values at their current state until specific objectives and limits could be determined in accordance with the NPS-FM (Neale, 2015).

Table E-1: Macroinvertebrate Community Index interim guidelines for Auckland rivers (Table E1.3.1 of the Auckland Unitary Plan (Operative in part)).

Land cover	MCI guidelines
Native forest	123
Exotic forest	111
Rural areas	94
Urban areas	68

National Policy Statement (NPS-FM 2020) attribute bands

Traditionally, MCI scores have been interpreted using the quality classes described above, refer to Table D-1 (Stark & Maxted, 2007b), however, with the introduction of MCI to the National Objective Framework (NOF) under the NPS-FM (MfE, 2020), the thresholds and descriptors have changed. Although similar to the traditonal quality classes (Stark & Maxted, 2007b), the thresholds for NPS-FM attribute bands have been set higher to encourage improvement of New Zealand’s rivers and prevent further degradation of sites that are at higher risk. As a result, when interpreted, they can indicate lower quality than traditional classes. The descriptions of the attribute bands also lean solely towards the land-based pollutants as the factor predominantly influencing community composition (refer to Table 3-2 and Table 3-4 in section 3.5.1). Other metrics, QMCI and Average Score Per Metric (ASPM), have also been added as required NOF attributes under the NPS-FM (MfE, 2020), however, these metrics have not been included in this report. It is likely these metric will be included in future recording.

2020 river ecology state and trends reporting

To align with prior reporting, the state and trends assessments undertaken in this report have been summarised according to the quality classes described in Stark and Maxted (2007b) for MCI (in addition to taxa richness and %EPT richness). This method provides a more pragmatic approach for describing the actual ecological condition of rivers in the region and considers the implications on both water quality and habitat quality. In order to understand how the region is currently stacking up against regional and national objectives, MCI results were also assessed against Auckland Unitary Plan interim guidelines, as well as the corresponding NPS-FM attribute bands and thresholds for MCI only (MfE, 2020).

It is important to note that the NPS-FM sets standard guidelines regarding expectations around processing of macroinvertebrate samples and the specific tolerance values used for calculating the MCI. Due to historic protocols used to process samples and the short timeframes between gazetting of the NPS-FM and production of this report, it is currently unclear as to whether RIMU's MCI data meets these standards completely. As a result, calculated NOF attribute grades for MCI are considered preliminary and should be viewed as such.

Appendix F Summary statistics

Table F-1: Summary state statistics for all ecological indicators, includes the minimum, maximum and five-year median for each metric, and quality/condition classes where applicable. The MCI summary also includes Auckland Unitary Plan and NPS-FM NOF attribute grades for MCI – indicates there is no data against the analysis of interest, "insufficient data" indicates that analyses could not be completed.

Site name	Overall SEV score				Macroinvertebrate community metrics											
					Taxa richness			%EPT richness			MCI					
	Min.	Max.	5-year median	Class	Min.	Max.	5-year median	Min.	Max.	5-year median	Min.	Max.	5-year median	Quality Class	Below AUP interim values	NOF grade
Anns Creek	0.39	0.51	0.48	Fair	15	17	16	0.0	6.2	0.0	50.2	64	61.5	Poor	Yes	D
Aroaro Stream	0.59	0.61	0.59	Fair	Insufficient data											
Auckland Domain	Insufficient data				15	17	15	29.4	40	33.3	107.3	112.9	108.9	Good	No	C
Avondale Stream (Lower)	0.48	0.68	0.56	Fair	17	26	22	0.0	13.6	5.9	58.3	79.1	59.3	Poor	Yes	D
Avondale Stream (Mid)	0.57	0.67	0.65	Good	20	24	20	5	8.3	5	65.2	69.2	69.2	Poor	No	D
Avondale Stream (Upper)	0.44	0.56	0.53	Fair	8	18	12	0.0	22.2	5.6	63.3	97.5	67.8	Poor	No	D
Awanohi Stream	0.63	0.73	0.68	Good	Insufficient data											
Botany Creek	0.21	0.36	0.25	Poor	6	10	8	0.0	0.0	0.0	63.3	72	70	Poor	No	D
Cascade Stream (Waiheke)	0.78	0.91	0.82	Excellent	Insufficient data											
Cascade Stream (Waitākere)	0.74	0.93	0.92	Excellent	27	38	31	38.7	44.4	42.1	96.1	112.5	102.1	Good	Yes	C
Castor Stream	0.36	0.52	0.44	Fair	18	24	20	0.0	5	0.0	45.2	65.7	56.4	Poor	Yes	D
Duck Creek	0.52	0.61	0.56	Fair	28	36	33	3.6	9.1	5.6	69.6	79.9	69.7	Poor	Yes	D
Duders Park	0.44	0.64	0.53	Fair	24	33	25	4.2	15.2	8	83.4	90.5	86.1	Fair	Yes	D
Dyers Creek (Forest)	0.77	0.83	0.78	Good	18	29	27	37	44.4	43.3	113.6	129.8	119.3	Excellent	No	B

Site name	Overall SEV score				Macroinvertebrate community metrics											
					Taxa richness			%EPT richness			MCI					
	Min.	Max.	5-year median	Class	Min.	Max.	5-year median	Min.	Max.	5-year median	Min.	Max.	5-year median	Quality Class	Below AUP interim values	NOF grade
Dyers Creek (Pasture)	0.77	0.83	0.63	Good	27	43	27	25.9	45.5	29.6	98.9	119.3	99.2	Fair	No	C
Edgars Creek	0.45	0.66	0.54	Fair	16	22	17	0.0	4.5	0.0	55.2	64.1	59.3	Poor	No	D
Eskdale Stream	0.57	0.67	0.61	Good	12	25	20	10	25	16	75.5	93.5	87.6	Fair	No	D
Glendowie Stream	0.40	0.51	0.46	Fair	Insufficient data											
Kaitoke Creek (GBI)	0.82	0.85	0.83	Excellent	24	31	25	33.3	52	41.9	102.5	127.2	116.8	Good	Yes	B
Kaukapakapa RIver	0.78	0.90	0.84	Excellent	18	35	26	26.3	48.4	35	119.5	128.8	122.3	Excellent	Yes	B
Kumeu River	0.42	0.51	0.46	Fair	11	26	21	0.0	4.8	0.0	49.9	62.9	59.6	Poor	Yes	D
Lucas Creek	0.50	0.65	0.56	Fair	12	21	18	5	14.3	8.3	50.9	78	54.1	Poor	Yes	D
Mabey Stream (GBI)	0.83	0.87	0.85	Excellent	Insufficient data											
Mahurangi River (Forestry)	0.69	0.90	0.81	Excellent	27	34	30	34.5	41.9	39.8	105.4	114.4	110.75	Good	No	B
Mahurangi River (Native)	0.74	0.91	0.81	Excellent	17	23	17	23.5	33.3	33.3	112.5	128.0	126.5	Excellent	No	B
Makarau River	0.51	0.57	0.55	Fair	33	39	33	12.1	37.1	20.5	78.2	102.1	84.4	Fair	Yes	D
Marawhara Stream	0.83	0.95	0.94	Excellent	32	37	34	53.1	67.6	60.5	120.0	133	128.2	Excellent	No	B
Matakana River	0.53	0.68	0.63	Good	14	34	20	18.8	42.9	21.7	81.8	96.8	88.6	Fair	Yes	D
Meola Creek	Insufficient data				16	17	17	16	17	17	0.0	5.9	0.0	52.7	56.9	53
Motutapu	0.48	0.60	0.57	Fair	19	29	21	4.5	9.7	4.8	74.7	81.9	80.7	Fair	Yes	D
Newmarket Stream	Insufficient data				9	14	13	9	14	13	0.0	0.0	0.0	55.6	65.7	63.1

Site name	Overall SEV score				Macroinvertebrate community metrics											
					Taxa richness			%EPT richness			MCI					
	Min.	Max.	5-year median	Class	Min.	Max.	5-year median	Min.	Max.	5-year median	Min.	Max.	5-year median	Quality Class	Below AUP interim values	NOF grade
Ngakoroa Stream	0.43	0.55	0.52	Fair	22	33	26	8.7	22.2	14.8	72.6	83.2	76.8	Poor	Yes	D
Nukumea Stream	0.84	0.85	0.85	Excellent	16	23	20	34.8	37.5	34.8	109.2	118.5	112.7	Good	Yes	B
Oakley (Lower)	0.43	0.55	0.47	Fair	13	23	16	4.3	7.7	6.2	62.2	69.7	69.5	Poor	No	D
Oakley (Mid 3)	0.29	0.39	0.36	Poor	12	17	14	0.0	8.3	2.95	63.3	70	66.7	Poor	Yes	D
Oakley (Mid 4)	0.26	0.31	0.28	Poor	7	22	17	0.0	6.2	4.5	62	67.5	67.1	Poor	Yes	D
Oakley (Upper)	0.30	0.40	0.32	Poor	12	20	19	0.0	10.5	6.65	67	76.7	71.3	Poor	No	D
Oakley Creek (Mid 1)	0.25	0.32	0.31	Poor	12	19	15	0.0	6.7	0.0	60	69.3	61.1	Poor	Yes	D
Oakley Creek (Mid 2)	0.29	0.55	0.30	Poor	14	20	16	0.0	0.0	0.0	65	67.1	65	Poor	Yes	D
Okura Creek	0.69	0.92	0.88	Excellent	Insufficient data											
Okura Tributary 1	0.67	0.85	0.79	Good	19	30	21	15	21.1	16.7	82.2	98	90.8	Fair	Yes	C
Okura Tributary 2	0.63	0.68	0.68	Good	11	21	16	8.3	13.3	11.1	93.6	106.6	101.3	Good	No	C
Omaru Creek	0.27	0.42	0.37	Poor	Insufficient data											
Omaumau River	0.79	0.89	0.82	Excellent	17	32	19	25.0	50.0	36.4	115.3	135.2	119.7	Excellent	Yes	B
Onetangi Stream	0.73	0.83	0.81	Excellent	Insufficient data											
Opanuku Stream	0.70	0.84	0.79	Good	26	37	34	23.1	35.9	27.8	83.1	101.1	93.7	Fair	No	C
Orere Tributary	0.78	0.93	0.88	Excellent	30	39	32	47.5	60	56.2	126.2	137.3	133.5	Excellent	No	A
Otanerua Stream	0.71	0.84	0.79	Good	14	23	16	18.8	43.5	21.4	98.5	119.7	104.4	Good	Yes	C
Otara Creek	0.43	0.54	0.46	Fair	16	27	17	0.0	3.7	0.0	43.1	58.5	51.8	Poor	Yes	D

Site name	Overall SEV score				Macroinvertebrate community metrics											
					Taxa richness			%EPT richness			MCI					
	Min.	Max.	5-year median	Class	Min.	Max.	5-year median	Min.	Max.	5-year median	Min.	Max.	5-year median	Quality Class	Below AUP interim values	NOF grade
Oteha Stream	0.55	0.60	0.57	Fair	12	27	16	3.7	18.8	7.7	52.9	75.3	66.8	Poor	Yes	D
Pakuranga Creek Trib	0.28	0.37	0.30	Poor	Insufficient data											
Pakuranga Stream	0.25	0.39	0.28	Poor	14	19	17	0.0	0.0	0.0	65.9	67.4	67.1	Poor	Yes	D
Papakura Stream	0.36	0.42	0.37	Poor	12	22	22	4.3	8.3	4.5	51.7	65	57	Poor	Yes	D
Papakura Tributary	0.42	0.58	0.51	Fair	24	37	29	3.4	12.5	9.4	67.4	72.5	69.4	Poor	No	D
Parahiku Stream (Lower)	0.48	0.62	0.52	Fair	10	26	15	0.0	13.3	10	72.5	80	75.4	Poor	No	D
Parahiku Stream (Upper)	0.78	0.82	0.80	Good	19	25	24	15.8	45.8	20	94.2	123.1	100.8	Good	No	C
Paramuka Stream	0.59	0.68	0.66	Good	Insufficient data											
Puhinui Stream	0.69	0.78	0.73	Good	29	32	31	23.3	32.3	25	92.5	99.3	98.1	Fair	No	C
Riverhead	0.68	0.75	0.72	Good	20	23	21	12.5	23.8	18.2	90.1	111.4	108.3	Good	Yes	C
Tararata Creek	0.28	0.41	0.33	Poor	14	15	15	0.0	0.0	0.0	65.6	79.7	75.0	Poor	Yes	D
Te-Muri-Ō-Tarariki Stream (Lower)	0.45	0.55	0.47	Fair	25	32	26.5	0.0	11.5	4.8	65.6	79	70.9	Poor	Yes	D
Te-Muri-Ō-Tarariki Stream (Upper)	0.37	0.48	0.43	Fair	21	26	24.5	4	11.1	6.9	76.4	91.7	78.6	Poor	Yes	D
Tryphena Stream (GBI)	0.57	0.68	0.67	Good	22	26	24	16.7	22.7	18.5	83.6	87.5	86.2	Fair	Yes	D
Vaughan Stream (Lower)	0.49	0.59	0.54	Fair	22	34	25	0.0	3.7	0.0	48.8	64.7	59.8	Poor	Yes	D
Vaughan Stream (Upper)	0.66	0.92	0.78	Good	18	29	21	27.8	33.3	31	109.7	117.3	115.5	Good	No	B
Wairoa River	0.55	0.62	0.62	Good	17	36	26	23.7	34.8	33.3	86.6	92.6	92.1	Fair	Yes	C

Site name	Overall SEV score				Macroinvertebrate community metrics											
					Taxa richness			%EPT richness			MCI					
	Min.	Max.	5-year median	Class	Min.	Max.	5-year median	Min.	Max.	5-year median	Min.	Max.	5-year median	Quality Class	Below AUP interim values	NOF grade
Wairoa Tributary	0.83	0.96	0.87	Excellent	28	43	32	47.1	60.7	57.6	122.3	137.5	132.1	Excellent	No	A
Waitangi Stream	0.57	0.64	0.62	Good	10	16	13	0.0	7.1	0.0	53.9	62.3	56.4	Poor	Yes	D
Waiwera River	0.64	0.71	0.66	Good	Insufficient data											
Wekatahi Stream	0.80	0.96	0.95	Excellent	24	43	36	45.5	58.1	55.6	114.9	126.5	125.0	Excellent	No	B
West Hoe Stream	0.83	0.90	0.86	Excellent	17	27	21	29.4	33.3	32.7	112.7	123.4	116.9	Good	Yes	B
Whangamarie Stream	Insufficient data				15	22	19	6.2	10.5	9.1	74.0	75.5	74.5	Poor	Yes	D

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