Trends analysis for selected indicators of Waikato River health and wellbeing 2010-2019

Prepared for Waikato River Authority

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Executive summary

Te Ture Whaimana

Te Ture Whaimana (the Vision and Strategy) is the primary direction-setting document for the Waikato River. It contains a set of objectives and strategies for the restoration and protection of the health and wellbeing of the Waikato River for present and future generations. In giving effect to Te Ture Whaimana, the Waikato River Authority (WRA) supports strengthening policy provisions to include a clear directive that current contaminant levels shall not increase, that existing and new discharges are regulated to ensure there is no further degradation of water quality, and that monitoring and review provisions are strengthened to ensure progress towards these objectives can be measured.

WRA legislative responsibility and Waikato River Report Card

The WRA is required, as part of its enabling legislation, to report at least every five years to the Crown, Waikato-Tainui, and other appointers (i.e., Tūwharetoa, Te Arawa, Raukawa and Maniapoto). The first Five-Year Report was delivered in 2015. As part of the body of evidence the WRA assembled they released the first whole of catchment Report Card[1] for the Waikato and Waipā rivers as a pilot. The pilot report card combined 62 scores or grades derived from available datasets and best professional judgement (BPJ) collated under eight taura (key themes) to describe whether certain combinations of indicators corresponded to a healthy state, as defined by Te Ture Whaimana. In order to communicate the spatial variability in the health and wellbeing of the Waikato River, the catchment was divided into Report Card Units (RCUs).

Scope of this report

The next Report Card is not due until 2025 (covering a ten-year period). In preparation for the WRA's forthcoming Five-Year Report, due for release in June 2021, NIWA was engaged to provide an interim assessment of trends in indicators since the 2015 Report Card. The brief did not require attribution of observed trends to possible causes. Five- and ten-year trend periods were deliberately chosen to align with the WRA's reporting cycles. Whilst our brief was to focus on identifying trends over the 5-year period since the Report Card (2015-2019 inclusive), having a 10-year dataset enabled us to place these trends in context with the period preceding it and to perform longer-term trend analysis. This interim assessment was restricted to those Report Card indicators where suitable datasets were available. The trends presented in this report are for the Waikato River mainstem and its tributary streams. It does not report on trends for lakes in the river catchment.

Data sets and trend analysis

Trend analyses were conducted for 21 indicators that have been collected in a consistent manner between 2010 and 2019. The indicators assessed for trends were water clarity (black disk), *E.coli*, total nitrogen (TN), dissolved oxygen (DO), phytoplankton (using chlorophyll *a* as a surrogate), water temperature, ammoniacal nitrogen, arsenic (As), macroinvertebrates (MCI, QMCI, %EPT abundance, % EPT taxa), periphyton (cover of long filaments, cover of thick mats), macrophytes (channel clogged by macrophytes, exotic cover, native cover) and riparian health (channel shade, riparian vegetation protection, riparian width). The results were grouped into five spatial zones and 10 Report Card Units (RCUs) covering the Waikato River mainstem and tributaries.

[1] The 2015 pilot Waikato River Report Card (Williamson et al. 2016) was a combination of 62 scores or grades derived from available datasets and best professional judgement, which were collated under eight taura (Kai, Water Quality, Ecological Integrity, Experience, Water Security, Effort, Economics and Sites of Significance) to describe whether certain combinations of indicators corresponded to a healthy state, as defined by the 13 objectives of Te Ture Whaimana, the Vision and Strategy for the Waikato River.

The datasets used in trend analyses were sourced from the Waikato River Water Quality Monitoring Programme, the Regional Rivers Water Quality Monitoring Programme, and the Regional Ecological Monitoring of Streams Programme maintained by Waikato Regional Council (WRC), and the National River Water Quality Network maintained by NIWA. The water quality and experience indicators analysed generally had larger and more robust datasets, with data gathered monthly or quarterly. The ecological indicators were based on data sets derived from annual sampling, the minimum resolution acceptable for inclusion in the trend analyses.

Trend analyses followed current best practice (Fraser et al. 2021), using methods employed by the Ministry for the Environment and Statistics New Zealand to assess state and trends under the Environmental Reporting Act 2015. The trend analyses were conducted on data representing relatively short time periods. Trends derived from ten years' of data (or less) are known to be influenced by both sampling errors (i.e., a limited subset of data not reflecting the entire population) and natural fluctuations in environmental drivers, such as flow and climate cycles, and should therefore be interpreted with caution.

Summary of key findings:

For the five-year period since the Report Card (2015-2019):

1. A total of 751 trend analyses were performed across all combinations of indicators and sites, of which 22% (169 of 751) were improving trends, 37% (275 of 751) were deteriorating trends and 41% (307 of 751) were as likely improving as deteriorating trends.

2. **Water quality indicators** were dominated by deteriorating trends, with exceptions being improving trends for dissolved oxygen, arsenic, and chlorophyll *a* (Table i).

3. **Ecological indicators** were dominated by as likely improving as deteriorating trends, but where a trend could be detected with confidence, improving trends were more common than deteriorating trends for seven of the nine indicators. The dominance of as likely improving as deteriorating trends is perhaps not surprising given the combination of annual sampling frequency and the short time period (5 years) for trend analyses. However, the riparian indicators showed a 'mixed bag', with the riparian channel shade indicator dominated by as likely improving as deteriorating trends and riparian vegetation and riparian width indicators showing more deteriorating trends than improving trends (Table i).

4. Trends were also examined for each RCU individually. In general, trends varied between indicators and time periods, and similar patterns across all indicators within an RCU were not observed. However, some spatial variation was observed between RCUs, with trend patterns more similar within RCUs than between up-river, mid-river, and down-river RCUs (Tables ii and iii).

The trend analyses undertaken here provides 'mixed signals' in terms of changes in the health of the river and its tributaries since the 2015 Report Card was produced. There are strong signals of widespread deterioration in the water quality taura indicators, with fewer signals of improvement, or at least maintenance, of the ecological integrity taura indicators. Overall, more deterioration was detected than improvement in both the last five years and over the ten-year period.

Table i: Summary of water quality and ecological indicators trends at Waikato River sites over a 5-year period from 2015 to 2019. All trends have been grouped under three categories (deteriorating, improving, and as likely improving as deteriorating), with the number of sites in each category shown as a percentage of the total. The number of sites used in these assessments varied between indicators. All percentages have been rounded to the nearest whole number.

Indicator	% Deteriorating trend	% Improving trend	% as likely improving as deteriorating trend	*No. of sites*
Water Quality Indicators				
Water clarity	78%	4%	18%	*50*
E. coli	71%	11%	18%	*61*
Total nitrogen	70%	18%	12%	*60*
Total phosphorus*	55%	29%	16%	*62*
Chlorophyll *a*	0%	40%	60%	*10*
Dissolved oxygen	21%	56%	23%	*62*
Temperature	50%	19%	31%	*62*
Ammonia	37%	11%	52%	*62*
Arsenic	0%	50%	50%	*10*
Ecological Indicators				
MCI	23%	33%	44%	*27*
QMCI	4%	33%	63%	*27*
% EPT abundance	11%	26%	63%	*27*
% EPT taxa	26%	15%	59%	*27*
Periphyton filament cover	0%	28%	72%	*25*
Periphyton thick mat cover	0%	12%	88%	*25*
Macrophyte clogginess	8%	28%	64%	*25*
Exotic macrophytes	0%	28%	76%	*25*
Native macrophytes	20%	4%	76%	*25*
Riparian channel shade	12%	16%	72%	*25*
Riparian vegetation protection	44	26	30	*27*
Riparian width	33	23	44	*27*

*The data and trends for total phosphorus are considered provisional due to analytical method changes that may have influenced results (see Vant 2013, 2018 for further explanation).

Table ii: Summary of the nine water quality indicators presented by RCU over a 5-year period from 2015 to 2019. All trends for each RCU have been grouped under three categories (deteriorating, improving, and as likely improving as deteriorating), with the number of site/indicator combination in each category shown as a percentage of the total. The number of sites used in these assessments varied between indicators. All percentages have been rounded to the nearest whole number.

RCU	% Deteriorating trend	% Improving trend	% as likely improving as deteriorating trend	Total no. of trends
OW - Huka to Ōhakuri	38%	19%	42%	26
OWT - Huka to Ōhakuri Tributaries	42%	40%	17%	52
KW - Ōhakuri to Karāpiro	53%	12%	35%	17
KWT - Ōhakuri to Karāpiro Tributaries	42%	31%	27%	62
MW - Karāpiro to Ngāruawāhia	50%	22%	28%	18
MWT - Karāpiro to Ngāruawāhia Tributaries	60%	19%	21%	42
Wp – Waipā	62%	19%	19%	26
WpT - Waipā Tributaries	55%	22%	23%	73
LW - Ngāruawāhia to Te Pūaha	31%	19%	50%	26
LWT - Ngāruawāhia to Te Pūaha Tributaries	62%	16%	22%	97

Table iii: Summary of the twelve ecological indicators presented by RCU over a 5-year period from 2015 to 2019. All trends for each RCU have been grouped under three categories (deteriorating, improving, and as likely improving as deteriorating), with the number of site/indicator combination in each category shown as a percentage of the total. The number of sites used in these assessments varied between indicators. All percentages have been rounded to the nearest whole number.

RCU	% Deteriorating trend	% Improving trend	% as likely improving as deteriorating trend	Total no. of trends
OWT - Huka to Ōhakuri Tributaries	21%	29%	50%	24
KWT - Ōhakuri to Karāpiro Tributaries	10%	33%	57%	42
MWT - Karāpiro to Ngāruawāhia Tributaries	18%	28%	54%	96
WpT - Waipā Tributaries	17%	18%	66%	90
LWT - Ngāruawāhia to Te Pūaha Tributaries	18%	7%	75%	60

Trends derived from data representing relatively short time periods (fewer than ten years), and trends derived from single annual data (i.e., macroinvertebrate, macrophyte, periphyton, and riparian metrics) need to be considered cautiously.

- Observed changes in direction and/or rate of change between the two five-year periods may be the result of sampling errors or differences in number of sites analysed in each time period.
- Observed trends could reflect the influence of variation in natural environmental drivers, such as climate factors, including rainfall (which influences stream flow) and temperature, which fluctuate over similar time scales.
- Furthermore, it must be noted that trend analysis provides information on change over time alone. It does not test or attribute causation, or even correlation, with potential drivers of change, either natural or anthropogenic.

1 Introduction

1.1 Te Ture Whaimana

The vision of Te Ture Whaimana o te Awa o Waikato (hereafter "Te Ture Whaimana") is:

> "*…for a future where a healthy Waikato River sustains abundant life and prosperous communities who, in turn, are all responsible for restoring and protecting the health and wellbeing of the Waikato River, and all it embraces, for generations to come*".

Te Ture Whaimana, the Vision and Strategy, is the primary direction-setting document for the Waikato River and has the status of a National Policy Statement, prevailing over inconsistent provisions in any other National Policy Statement and the New Zealand Coastal Policy Statement, where there is a conflict. Te Ture Whaimana encompasses all people of the River and their relationships with it and contains a set of objectives and strategies for the restoration and protection of the health and wellbeing of the Waikato River for present and future generations.

Te Ture Whaimana responds to four fundamental issues (Waikato River Authority 2019):

1. The degradation of the Waikato River and its catchment has severely compromised Waikato River iwi in their ability to exercise mana whakahaere or conduct their tikanga and kawa.
2. Over time, human activities along the Waikato River and land uses through its catchments have degraded the Waikato River and reduced the relationships and aspirations of communities with the Waikato River.
3. The natural processes of the Waikato River have been altered over time by physical intervention, land use and subsurface hydrological changes. The cumulative effects of these uses have degraded the Waikato River.
4. It will take commitment and time to restore and protect the health and wellbeing of the Waikato River.

Objectives of Te Ture Whaimana to which this trend analysis report is particularly relevant include:

- restoration and protection of the health and wellbeing of the Waikato River,
- avoidance of adverse cumulative effects,
- recognition that the Waikato River is degraded and should not be required to absorb further degradation, and
- restoration of water quality so that it is safe for people to swim in and take food from.

1.2 Purpose of this report

The Waikato River Authority (WRA) acknowledges that the changes required to achieve Te Ture Whaimana will take commitment and time, requiring the Waikato and wider New Zealand community to work together collaboratively and cooperatively in a coordinated approach. The WRA supports strengthening policy provisions to include a clear directive that current contaminant levels shall not increase, that existing and new discharges are regulated to ensure there is no further degradation of water quality, and that monitoring and review provisions are strengthened to ensure they consider progress against implementation and giving effect to Te Ture Whaimana[2].

The WRA is required, as part of its enabling legislation, to report at least every five years to the Crown, Waikato-Tainui and other appointers (i.e., Tūwharetoa, Te Arawa, Raukawa and Maniapoto) on:

- the carrying out, effectiveness and achievement of its principal function,
- the implementation, effectiveness and achievement of the Te Ture Whaimana, and
- the implementation, effectiveness and achievement of the clean-up initiatives funded by the Waikato River Clean-up Trust.

The first Five-Year Report to the Crown and Waikato River iwi was delivered in 2015 (Waikato River Authority 2015). As part of the body of evidence assembled in the 2015 report, the WRA released the first whole-of-catchment Report Card[3] for the Waikato and Waipā rivers. The Report Card is the first of its kind internationally and seeks to communicate, in a more holistic way, the health and wellbeing of Waikato waterways and their communities (Williamson et al. 2016). WRA expressed that the Report Card "will serve as an enduring measure of our progress" (Waikato River Authority 2015), with the next Report Card due to be delivered in 2025 (i.e., cover 10-year periods).

In preparation for the WRA's forthcoming Five-Year Report due for release in June 2021, NIWA was engaged to provide an interim assessment of data to determine improving or deteriorating trends in the Waikato River and its tributaries for a subset of Report Card indicators, where suitable datasets were readily available. Only river (and not lake) indicators were included in the scope of this report. The brief did not require attribution of observed trends to possible causes. The WRA also requested the production of high-quality graphics that they can uplift from this report and insert directly into the forthcoming Five-Year Report.

[2] 2018-09-17-PPC1-Healthy-Rivers-Further-Submission.pdf (waikatoriver.org.nz)

[3] The 2015 pilot Waikato River Report Card (Williamson et al. 2016) was a combination of 62 scores or grades derived from available datasets and best professional judgement, which were collated under eight taura (Kai, Water Quality, Ecological Integrity, Experience, Water Security, Effort, Economics and Sites of Significance) to describe whether certain combinations of indicators corresponded to a healthy state, as defined by the 13 objectives of Te Ture Whaimana, the Vision and Strategy for the Waikato River.

1.3 Structure of this report

This report is divided into the following sections, where:

- Section 1 introduces Te Ture Whaimana and the purpose and structure of this report.
- Section 2 introduces the 2015 pilot Waikato River Report Card framework which directed the selection of a subset of indicators and the spatial scales (called Report Card Units) used.
- Section 3 identifies how elements of the 2015 report were adopted in this report to assess trends using readily available, suitable datasets, and outlines the statistical methods used to undertake the trend analysis.
- Section 4 describes the results of the statistical analysis (trends over time) by indicator, then by Report Card Unit.
- Section 5 discusses the key findings of the analysis.

This report also includes detailed technical appendices (Appendices A-B) and a list of all the report tables and figures (Appendix C).

2 Pilot Waikato River report card

A report card is essentially a report on combined scores derived from monitoring data, which are used to summarise whether or not certain prescribed values correspond to a healthy state. The key purpose of environmental report cards is to engage stakeholders in environmental management by communicating information from a range of measures in a condensed, relevant and simple message (Williamson et al. 2016). In 2013 Waikato Raupatu River Trust (WRRT), Diffuse Sources Ltd and NIWA were funded by the WRA to prepare report cards for the Waikato River catchment to assist the WRA and Waikato Clean-up Trust to evaluate the success of restoration activities and to guide future restoration activities, and to enable river communities and the public to actively engage in the restoration of the river (Williamson et al. 2016).

The pilot Waikato River Report Card was designed to communicate the state of the cultural, social, environmental and economic health and wellbeing of the catchment and was linked to the vision set out in Te Ture Whaimana. The Report Card is divided into sections or themes of importance to Waikato communities with regard to the Awa, and for guiding its restoration. These are called 'taura' (threads or ropes), where the taura are 'plaited' (taura whiri) by the Report Card to communicate the state of the Awa. The Waikato River Report Card is structured around eight taura (key themes) that are underpinned by Waikato River Iwi values and captures the aspirations of Te Ture Whaimana, including:

- **Experience** – We have a flourishing and nurturing connection with the river, and we are empowered to pursue and maintain our positive interaction.
- **Ecological Integrity** – Aquatic life has access to healthy habitats protected from adverse effects due to land use and contaminants.
- **Kai** – Kai are healthy and have a strong whakapapa, are safe to eat, locally abundant and can be harvested according to our traditional practices.
- **Water Quality** – Land use and land development practises support water bodies that have water that is safe to physically interact with.
- **Water Security** – Our land use practices, and land development supports communities and taonga species having access to life sustaining supplies of water.
- **Effort** – Communities, businesses and individuals are engaged in comprehensive contaminant control and rehabilitation to achieve Te Ture Whaimana.
- **Sites of Significance** – Our sites of significance are forever recognised and celebrated as areas of historical and cultural importance and are safe for us to interact with and support a heathy Awa.
- **Economics** – Communities are prosperous, as shown by high levels of employment, housing affordability, gross domestic product and income equality.

Each taura essentially equates to a high level or 'mega-value set' (e.g., Kai – species that support cultural, recreational and commercial harvest) which is then broken down into smaller strands or value sub-sets (e.g., abundance and distribution of species, for example, tuna). Below this level are a number of indicators that in combination can be used to describe the state of each value subset (e.g., tuna are able to be sourced locally, in the quantities required, and are safe to eat) (Williamson et al. 2016).

Over 248 potential indicators were assessed and rationalised during the development of the Pilot Report Card. Indicators were categorised as: (1) relatively easy to score, appropriate datasets available, (2) very difficult to score as further research or significant work to create the dataset(s) is required, (3) only appropriate for hapū/iwi to develop the method and gather/interpret the dataset(s) required, and (4) yes/no indicators of specific management actions, and not appropriate for tracking changes in state/condition over time.

An additional feature of the process for selecting indicators was the use of a Māori-aspirations framework. The aspirations of Māori and communities as captured under the Waikato River Independent Scoping Study (NIWA 2010) were used to underpin each of the taura. Suggestions for indicators (e.g., biophysical/scientific) that were deemed relevant to best measure the state/condition of the taura were then back-analysed against these aspirations to evaluate their ability to provide a better 'picture' on progress towards achieving those aspirations. In other words, if an aspiration for Māori communities was for 'safe and healthy kai' as captured under the 'Kai' taura, it was important to ensure that the indicators selected would cumulatively be able to show how those aspirations were (or were not) being met (Williamson et al. 2016, Tipa et al. 2017).

The resulting product combined 62 scores or grades derived from available datasets and best professional judgement (BPJ) collated under the eight taura to describe whether certain combinations of indicators corresponded to a healthy state, as defined by Te Ture Whaimana. In order to help communicate the spatial variability in the health and wellbeing of the Waikato River, the catchment was also divided into Report Card Units (RCUs), for the mainstem and tributaries, as well as seven lakes that were selected to represent the diversity of lake types that occur within the hydrological catchment area (Figure 1). The RCUs were:

- Huka to Ōhakuri – Mainstem, Tributaries, Lake Ngāhewa (volcanic lake).
- Ōhakuri to Karāpiro – Mainstem, tributaries.
- Waipā – Mainstem, Tributaries, Lake Ngāroto (peat lake), Lake Rotopiko (Serpentine lakes).
- Mid Waikato (Karāpiro to Ngāruawāhia) – Mainstem, Tributaries, Lake Rotoroa (Hamilton City lake).
- Lower Waikato (Ngāruawāhia to Te Pūaha) – Mainstem, Tributaries, Lake Waikare, Lake Whangape, Lake Waahi (lower Waikato riverine lakes).

As the Waikato River Report Card framework evolves and the wider community starts to become familiar with, and engage in this product, it is anticipated that future versions will rely less on BPJ as more collaborators co-develop the appropriate methodologies, particularly additional mātauranga Māori-informed indicators which can only be determined by Waikato River Iwi, and gather the long term datasets required to measure progress towards achieving Te Ture Whaimana (Williamson et al. 2016).

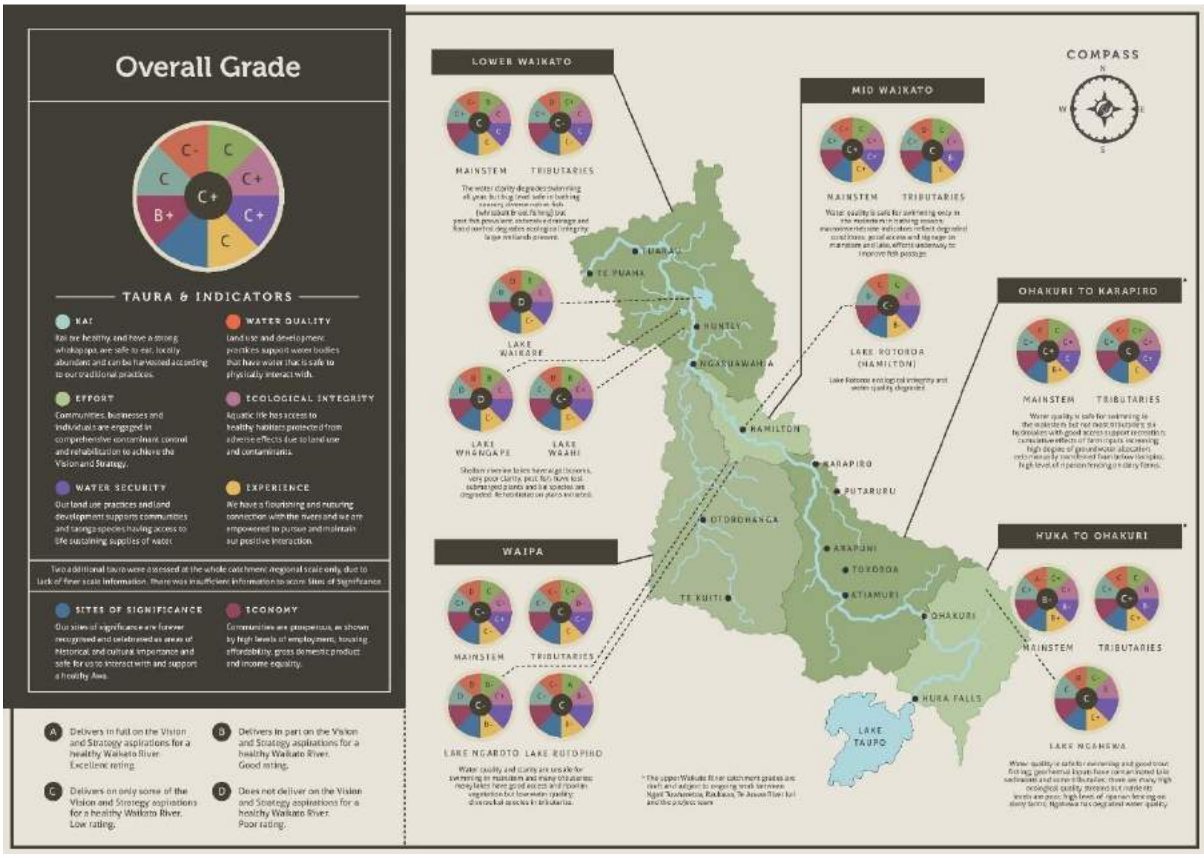

Figure 1: 2015 Pilot Waikato River Report Card, showing the eight taura and five RCUs. Source: WRA.

3 Methods

To inform the forthcoming Five-Year Report, WRA seek to understand any trends that can be observed in accessible datasets since the production of the pilot Waikato River Report Card.

3.1 Selection of indicators and RCUs for trend analyses

In addition to aligning with the indicators and spatial RCUs of the pilot report card (Section 2), the indicators selected needed to be suitable for temporal trend analysis, according to current best practise (Fraser et al. 2021). This required data to have been gathered monthly or annually for the period between 1 January 2010 and 31 December 2019. These dates were chosen in order to align with the 2015 report card five-year reporting period and the subsequent five years since the 2015 report card was published. Additionally, the trends analysis could not accommodate indicators that were assessed less frequently than annually, using BPJ or “one-off” data analyses undertaken to specifically inform the pilot report card.

Applying the above criteria significantly reduced the number of potential indicators that could be used to inform an interim trends analysis. The remaining indicators that met the criteria for analysis were related to the experience, water quality and ecological integrity taura of the pilot report card (Table 3-1). Only river (and not lake) indicators were included in the scope of this report.

Datasets for trends analyses were collated from long-term records gathered by the Waikato Regional Council (WRC) and NIWA, including:

- The Waikato River Water Quality Monitoring Programme, which includes 10 sites on the mainstem of the Waikato River monitored by WRC.
- The Regional Rivers Water Quality Monitoring Programme, which includes 51 tributary sites within the Waikato region monitored by WRC.
- The National River Water Quality Network, which includes 2 Waikato River sites and 2 Waipā river sites monitored by NIWA.
- The Regional Ecological Monitoring of Streams Programme, which includes more than 240 wadeable stream/river sites within the Waikato region (Collier and Hamer 2012), 74 of which are monitored annually. A further 180 sites are sampled on a three-year rotation, where 60 sites are sampled per year (Pingram et al. 2016). Forty-nine WRC monitoring sites are situated within the Waikato River RCUs. Of the 49 sites within the Waikato River RCUs, 27 were monitored annually and suitable for trend analysis. The remaining 22 were sampled every three years and therefore were not included in our short-term (5-10 year) trend analyses. Therefore, the number of sites used in this analysis are a subset of the wider network due to the specific requirements of this project, rather than a reflection of the overall network design. The aquatic insects (benthic macroinvertebrates), aquatic plants (macrophytes and periphyton), riparian vegetation and stream shading datasets were provided by the Regional Ecological Monitoring of Streams Programme. Data on macroinvertebrates, macrophytes, periphyton cover and riparian condition were not collected at the mainstem Waikato River sites because the mainstem is too wide and deep for wadeable stream sampling protocols to be undertaken.

See Appendix A for individual site names, numbers and locations.

Table 3-1: Indicators of Waikato River health and wellbeing that were selected for trends analysis in the current study. Headings in bold indicate indicator alignment with the Waikato River Report Card taura.

No.	Indicator	Where measured	Measurement frequency (per site)	Method	Measurement unit
	EXPERIENCE and WATER QUALITY				
1	Water clarity	Mainstem & tributaries	Monthly	Field measurement with a black disk. Horizontal water transparency (20mm, 60mm, 100mm, 200mm disk) in river or trough (20mm only). (Tulagi 2018).	metre
2	*E. coli*	Mainstem & tributaries	Monthly	Laboratory analysis of water sample. Membrane Filtration (mFC Agar) confirmation by MUG Agar. APHA method 9222 G. (Tulagi 2018).	Number of *E.coli* cells per100 ml
	WATER QUALITY				
3	Phytoplankton (chlorophyll *a*)	Main stem	Monthly	Laboratory analysis of water sample. Acetone extraction. Spectroscopy. APHA method 10200 H (modified). (Tulagi 2017).	grams of chlorophyll a per cubic metre (g/m^3)
4	Total nitrogen	Mainstem & tributaries	Monthly	Laboratory analysis of water sample. Calculated from NNN + TKN (Nitrite/Nitrate Nitrogen + Total Kjeldahl-Nitrogen). NNN: Automated Cadmium reduction. Flow injection analyser. APHA method 4500 – $NO3^-$ I(modified). TKN: Acid digestion. Phenol/Hypochlorite colorimetry. Discrete analyser. APHA method 4500-Norg D. (Tulagi 2018).	grams of nitrogen per cubic metre (mg/m^3)
5	Total phosphorus	Mainstem & tributaries	Monthly	Laboratory analysis of water sample. Acid persulphate digestion, Colorimetry. Discrete Analyser. APHA method 4500-P B & E (modified). Also modified to include the use of reductant to eliminate interference from arsenic present in the sample. NAWASCA Pub 38, 1982. (Tulagi 2018).	grams of phosphorus per cubic metre (mg/m^3)
	ECOLOGICAL INTEGRITY				
6	Ammoniacal- nitrogen (NH_4-N)	Tributaries	Monthly	Laboratory analysis of water sample. Filtration, Phenol/Hypochlorite Colorimetry. Discrete analyser. APHA method 4500-NH3 F (modified). (Tulagi 2018).	grams of ammoniacal-nitrogen per cubic metre (mg/m^3)
7	Arsenic (total) in water	Mainstem	Monthly	Laboratory analysis of water sample. Nitric acid digestion, ICP-MS, APHA method 3125 B / USEPA 200B. (Tulagi 2017).	grams of arsenic per cubic metre (mg/m^3)

Table 3-1: Continued.

No.	Indicator	Where measured	Measurement frequency (per site)	Method	Measurement unit
8	Dissolved oxygen (spot measurement)	Mainstem & tributaries	Monthly	Field measurement with calibrated instrument (Hach DO meter, model HQ 30d). (Tulagi 2018).	Percent of saturation (%)
9	Water temperature (spot measurement)	Mainstem & tributaries	Monthly	Field measurement with calibrated instrument (Hach DO meter, model HQ 30d). (Tulagi 2018).	Degrees Celsius (°C)
10	Macroinvertebrate - Macroinvertebrate community index (MCI)	Tributaries	Annually	Net sample of fixed area of stream bed (Pingram et al. 2016).	MCI score (0-200) based on taxa presence-absence
11	Macroinvertebrate - Quantitative macroinvertebrate community index (QMCI)	Tributaries	Annually	Net sample of fixed area of stream bed (Pingram et al. 2016).	QMCI score (0-10) based on quantitative or percentage data
12	Macroinvertebrate - Ephemeroptera, Plecoptera and Trichoptera (EPT) – taxa	Tributaries	Annually	Net sample of fixed area of stream bed (Pingram et al. 2016).	% of macroinvertebrate taxa belonging to EPT taxa
13	Macroinvertebrate - Ephemeroptera, Plecoptera and Trichoptera (EPT) – abundance	Tributaries	Annually	Net sample of fixed area of stream bed (Pingram et al. 2016).	% of macroinvertebrate individuals belonging to EPT taxa
14	Periphyton - thick mats cover	Tributaries	Annually	Visual observations of the stream bed (Collier et al. 2014).	Percent cover of stream bed by thick mats (%)
15	Periphyton - long filaments cover	Tributaries	Annually	Visual observations of the stream bed (Collier et al. 2014).	Percent cover of stream bed by long filaments (%)
16	Macrophyte - channel clogginess	Tributaries	Annually	Visual observations of the stream (Collier et al. 2014).	Percent clogginess of the stream by all macrophytes (%)
17	Macrophyte - native cover	Tributaries	Annually	Visual observations of the stream (Collier et al. 2014).	Percent cover of stream by native macrophytes (%)
18	Macrophyte - exotic cover	Tributaries	Annually	Visual observations of the stream (Collier et al. 2014).	Percent cover of stream by exotic macrophytes (%)
19	Riparian metrics - Stream shade	Tributaries	Annually	Densiometer reading of overhead canopy cover (channel centre) (Harding et al. 2009).	Percent shade (%)
20	Riparian metrics - Riparian vegetation score	Tributaries	Annually	Visual observations of the stream banks (Collier and Kelly 2005).	Score from 0 (poor) to 20 (optimal)
21	Riparian metrics - Riparian width score	Tributaries	Annually	Visual observations of the stream banks (Collier and Kelly 2005).	Score from 0 (poor) to 20 (optimal)

3.2 Data processing

Prior to analysis, each dataset was filtered for missing, duplicate, and censored data. Following Larned et al. (2018b), to ensure the dataset was representative, only site and variable combinations which had measurements for at least 90% of the years and at least 90% of seasons were included in the trend analysis for monthly data and 80% of years for annual data. When there was more than one value per season or year, the median value for the season or year was calculated and used in the trend analysis[4].

Censored data refers to values above (right-censored) or below (left-censored) a detection limit. Censored values were handled in the trend analysis as described in Section 3.3. below.

Notes on specific datasets:

E. coli were sampled quarterly (in March, June, September, and December) in the regional river sites between 2010 and 2012 and monthly thereafter. To avoid biasing the trend analyses with more data in later years, only corresponding quarterly data from 2013-2019 were included in the *E. coli* trend analyses, following Vant 2018. The ten mainstem river sites were sampled monthly during the entire time series between 2010 and 2019 and therefore all monthly data was included.

Chlorophyll *a* was only monitored monthly in the ten mainstem river sites between 2010 and 2019. Between 2010 and 2014, duplicate measurements were taken by WRC and NIWA. When multiple measurements were taken on the same day, the mean value was taken. If one or both values were below detection limits, adjusted values (0.5 x detection limit) were used to calculate means.

Total nitrogen (TN) was calculated as NNN (Nitrite/Nitrate Nitrogen) + TKN (Total Kjeldahl-Nitrogen). If either NNN or TKN was missing, TN was also considered missing. If either value was below detection limit, adjusted values (0.5 x detection limit) were used to calculate TN (Tulagi 2017).

Flow adjustment

Less than half the water quality sites had corresponding daily flow data. Therefore, flow adjustment was considered out of scope in order to keep analytical methods consistent across all sites.

3.3 Trend analysis

A "trend" is an upwards or downwards shift over time. Trends were analysed for each site x indicator combination.

In this report, trends in water quality indicators and macroinvertebrate indicators were assessed following the trend direction assessment (TDA) procedure outlined in McBride (2019) and implemented using the LWP-Trends library in R (Snelder and Fraser 2019, Larned et al. 2018b). In this method, trend direction is determined using Kendall S statistics and p-values. The Kendall test is a nonparametric correlation coefficient which measures the monotonic (single direction) association between a variable y and, in temporal trend analysis, time x. The Kendall p-value can be interpreted as the probability that the trend is decreasing by:

$P(S<0) = 1 - 0.5 \times \text{pvalue}$ $P(S>0) = 0.5 \times \text{pvalue}$

[4] In New Zealand water quality is commonly sampled monthly to account for seasonal variability, while periphyton, macrophytes, and macroinvertebrates are typically sampled annually in summer because the sampling effort required for these indicators is greater, and this approach targets the high risk period for harmful impacts.

Where pvalue is the p-value returned by a seasonal or non-seasonal Kendall test, S is the S statistic returned by the Kendall test, and P is the probability that the trend was decreasing (Fraser and Snelder 2018). The trend direction is then interpreted as decreasing when P > 0.5 and increasing when P < 0.5 (Fraser and Snelder 2018).

If there were significant differences in measurements between seasons, a seasonal Kendall S statistic was calculated. This requires first calculating the S statistic for data from each season individually and then summing over all seasons (Fraser et al. 2021). The probabilities derived from the Kendall test statistics were then used to assign a confidence in trend direction category to each trend following the framework introduced by the Intergovernmental Panel on Climate Change (IPCC), with nine categories ranging from "virtually certain" to "exceptionally unlikely" (Table 3-2), following McBride (2019) and Fraser and Snelder (2018). Note that an "exceptionally unlikely" improving trend is the same as a "virtually certain" deteriorating trend and have been relabelled as such for this report (see Table 2).

However, whether an increasing or decreasing trend represents an ecological 'improvement' varies by parameter, for example, an increase in water clarity is an ecological improvement, whereas a decrease in *E. coli* is an ecological improvement. Therefore, to avoid confusion, trends will be referred to as either 'improving' or 'deteriorating' rather than 'increasing' or 'decreasing' or 'declining.'

Table 3-2: Intergovernmental Panel on Climate Change likelihood categories (Stocker 2014). IPCC categories are listed first in italics, whilst the modified descriptions used in this study are listed below them in bold.

Categorical level of confidence	Probability (%)
Virtually certain **Virtually certain improving**	99-100
Extremely likely **Extremely likely improving**	95-99
Very likely **Very likely improving**	90-95
Likely **Likely improving**	67-90
About as likely as not **As likely improving as deteriorating**	33-67
Unlikely **Likely deteriorating**	10-33
Very unlikely **Very likely deteriorating**	5-10
Extremely unlikely **Extremely likely deteriorating**	1-5
Exceptionally unlikely **Virtually certain deteriorating**	0-1

Censored values used to calculate the Kendall S statistic and p-values were handled within the LWP-Trends software following methods recommended by Helsel (2005, 2012). Pairwise slopes that were based on one or more censored values were identified as either increases or decreases (i.e., a change from a censored entry of <1 to 10 would be considered an increase, and vice versa) (Larned et al. 2018b). Changes between two censored values are considered ties. This information was then used in the calculation of the Kendall S statistic and its variance, thus providing a robust calculation of the p-value (Larned et al. 2018b). However, as the proportion of censored values and ties increases, the confidence in the trend direction decreases (Larned et al. 2018b). Consequently, trends for site x variable combinations with high proportions of censored data tend to be categorised as indeterminant (Larned et al. 2018b).

Trend rates were calculated using non-parametric Sen slope regression. The Sen slope estimator (SSE) is calculated as the median of the slopes of all lines through all pairs of points. If data were seasonal, a seasonal version of the SSE (SSSE) was calculated by determining the median slope for each season and then taking the median of the seasonal values (Fraser et al. 2021). Seasonality was determined using a Kruskal-Wallis test with season as an explanatory categorical variable (Snelder and Fraser 2019).

To calculate the Sen slopes, the censored values were replaced by their corresponding raw numeric values (i.e., the detection limit) multiplied by an adjustment factor of 0.5 for left-censored and 1.1 for right-censored data. Individual pairwise slopes based on these replacement values are imprecise. However, Sen slopes are based on the median of all pairwise slopes, so they are minimally affected by small proportions of censored data (Larned et al. 2018b). As the proportion of censored values increase, the probability that the Sen slope is affected will also increase (Larned et al. 2018b).

Uncertainty in trend rates is assessed by the ranking 100 (1-a) % two-sided symmetrical confidence intervals around the SSE and determining the lower and upper confidence limits. The slopes associated with these observations are then applied as the confidence intervals (Fraser et al. 2021).

For some indicators, particularly chlorophyll *a*, ammonia, and arsenic, all or most of reported data points were below the detection limit. Because the entire dataset was therefore considered ‘tied,’ it was not possible to perform a trend analysis for these site x indicator combinations using the LWP-Trends library. In these cases, trends were manually assigned a slope of zero and to be “as likely improving as deteriorating,” given that we can be confident all data remains within the small range between zero and the detection limit over time.

The constraints on tied values also prevented analysis of several of the ecological indicators (macrophytes and periphyton cover and riparian shade) with the LWP-Trends library. However, unlike ties in solute concentrations, which are primarily due to data censoring, ties in ecological indicators reflected that for many sites the indicator values remained the same over time. For example, there was often zero percentage cover of periphyton and macrophytes within a site every year. Therefore, these indicators were analysed using the kendallTrendTest function from the EnvStats package in R, and the Kendall p-values used to determine categorical confidence levels as described above. Sites which did not contain tied values for these indicators were also analysed using the same method for consistency of analytical approach within indicators.

3.4 Graphics

To help communicate the spatial variability in the results the trends data analysis was grouped into RCUs covering the Waikato River mainstem and tributaries (Figure 2):

- Huka to Ōhakuri Mainstem (OW).
- Huka to Ōhakuri Tributaries (OWT).
- Ōhakuri to Karāpiro Mainstem (KW).
- Ōhakuri to Karāpiro Tributaries (KWT).
- Waipā Mainstem (Wp).
- Waipā Tributaries (WpT).
- Mid Waikato (Karāpiro to Ngāruawāhia) Mainstem (MW).
- Mid Waikato (Karāpiro to Ngāruawāhia) Tributaries (MWT).
- Lower Waikato (Ngāruawāhia to Te Pūaha) Mainstem (LW).
- Lower Waikato (Ngāruawāhia to Te Pūaha) Tributaries (LWT).

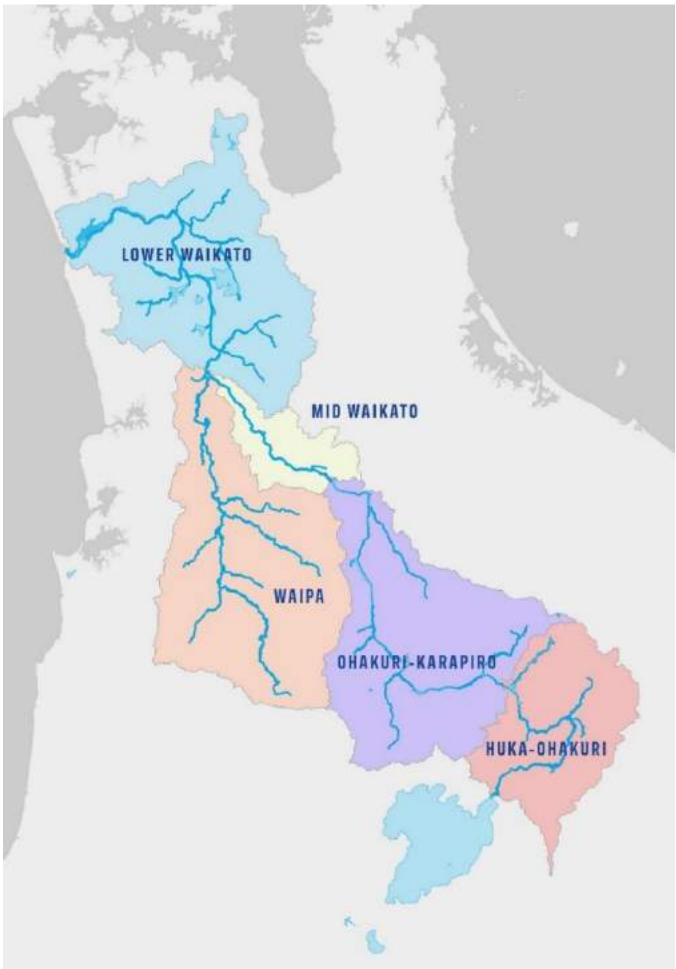

Figure 2: The Waikato-Waipā River catchment showing spatial extends of the RCUs used for analyses.

Five types of graphics (three in the body of the report, pie charts, dot plots, and heatmaps, and two in the technical appendices, Sen slope regression plots and box-and-whisker plots) are used to visualise the trend results by indicator and by RCU:

Graphic style 1 (Section 4.1) –

A pie chart (e.g., Figure 3) is a type of graph that allows data to be presented in a circular manner where each piece of the pie represents the proportion of the whole. In this report the site trends for each confidence category are tallied and then displayed as a proportion of the total number of sites showing trends for that indicator. The colour of the segments indicates the confidence that the trend is improving or deteriorating (as per the chart key below), with the number of sites in each category noted on the outside of the pie.

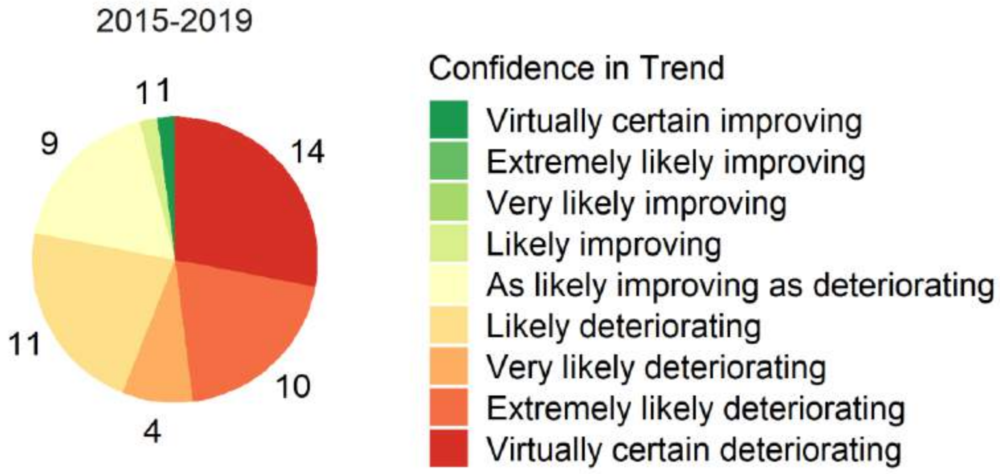

Figure 3: Example of a pie chart used to present Waikato River trends results. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside. In this example the analysis indicates that we can be *virtually certain* that water quality trends in 14 Waikato River monitoring sites are *deteriorating*.

Graphic style 2 (Section 4.1) –

To help communicate the spatial variability of the results, the sites were plotted as a **dot on a base map** of the Waikato River catchment (e.g., Figure 4). The RCUs are shaded (Huka to Ōhakuri – peach, Ōhakuri to Karāpiro – purple, Mid Waikato – Yellow, Waipā – orange, Lower Waikato – blue). The trend for each site is displayed as an individual dot with the colour corresponding to the confidence in trend (as per the map key).

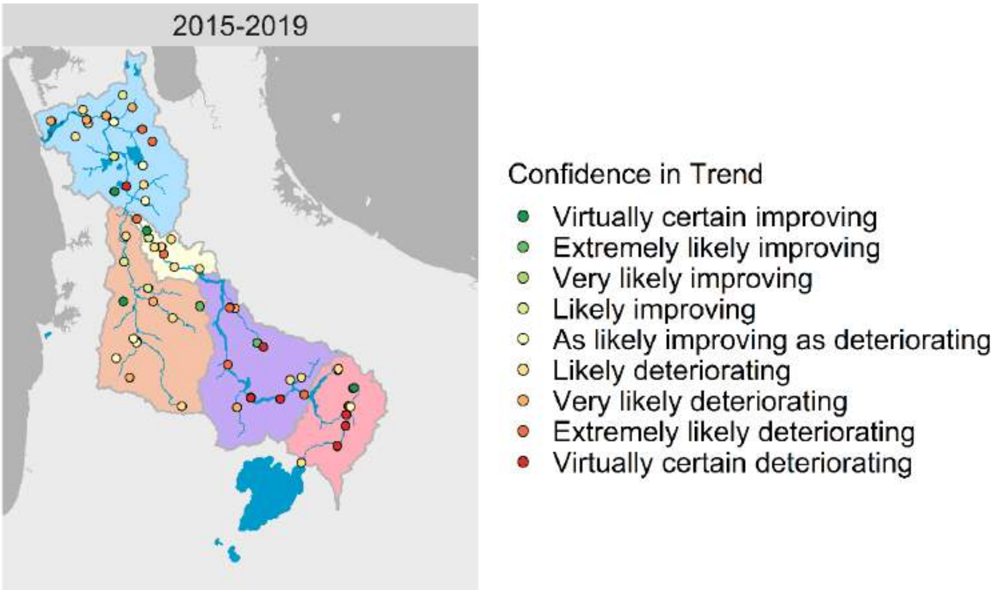

Figure 4: Example of dot plot used to spatially present Waikato River trend results. The colour of the dot indicates the confidence that the trend is improving or deteriorating at a particular monitoring site within an RCU.

Graphic style 3 (Section 4.2) –

The **heatmaps** (e.g., Figure 5) have a panel for each RCU/indicator combination, with individual sites listed longitudinally on the y-axis from upstream to downstream along the length of the Waikato River. Tributaries are ordered in downstream direction. The x-axis shows the three different trend analysis periods: 2010-2014, 2015-2019, and 2010-2019. The colour of each cell indicates the confidence in the trend, in that indicator, for that site, in that time period. Where the cell is grey, insufficient data exist to conduct a trend analysis. Further site information (i.e., locations) can be found in Appendix A.

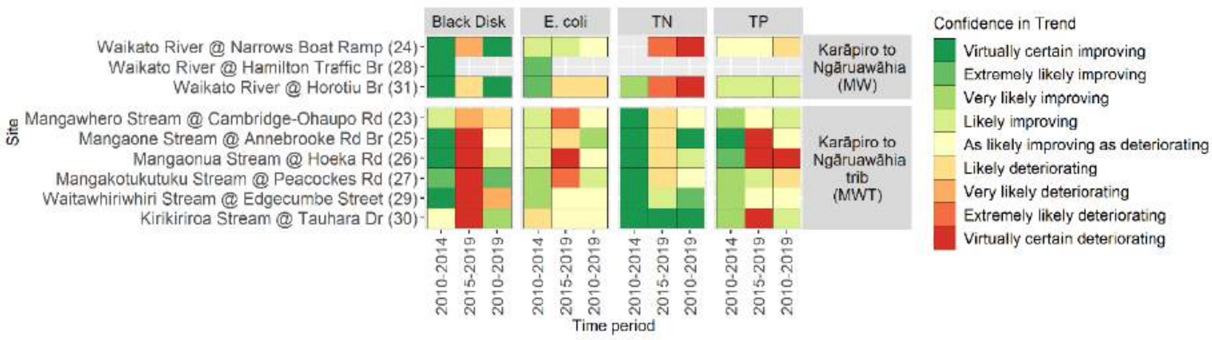

Figure 5: Example of a heatmap used to present Waikato River trends results spatially and temporally. Individual sites are listed down the left-hand y-axis. The three trend assessment periods are listed on the x-axis. Each row represents a monitoring site, with the different indicators shown in columns, except for the last column which lists the RCUs. Thus, each cell is a site x indicator combination, the colour of the cell indicates the confidence in trend. Where the cell is grey, insufficient data exist to conduct a trend analysis.

Graphic style 4 (Appendix B) –

The **Sen slope regression plots** (e.g., Figure 6) have a panel for each RCU/indicator combination, with the trend for each site within an RCU displayed as an individual line with colour corresponding to the confidence in assignment of trend category. Green indicates an improving trend, red indicates a deteriorating trend, and yellow indicates the trend is as likely improving as deteriorating. Whether an increasing or decreasing trend represents an 'improvement' varies by parameter, for example, an increase in water clarity is an improving trend, whereas a decrease in *E. coli* is an improving trend.

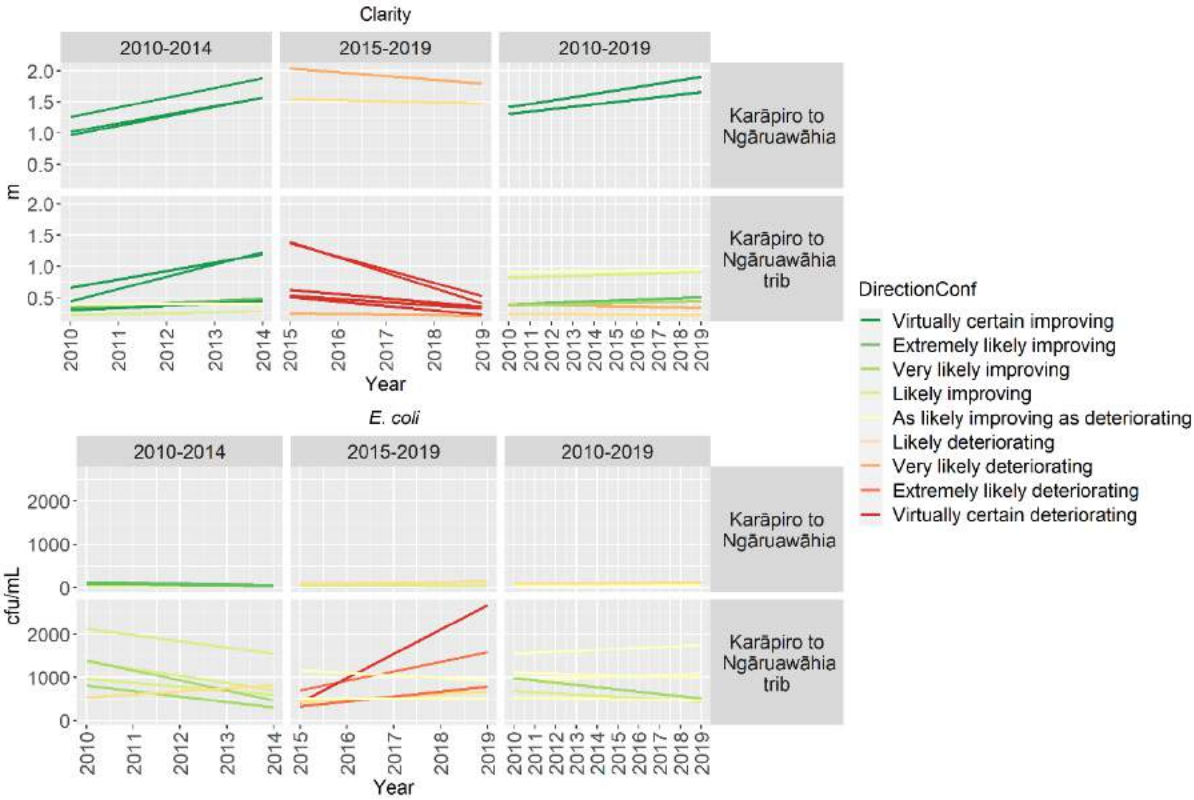

Figure 6: Example of Sen slope regression plot used to spatially and temporally present Waikato River trends results. Each row represents an RCU (e.g., MW and MWT) and each column represents a trend assessment time period. Thus, each panel is an RCU/time period combination. The lines represent the trend (Sen Slope) for individual sites within the RCU, where the colour of the lines indicates the confidence in trend.

Graphic style 5 (Appendix B) –

The **box-and-whisker plots** (e.g., Figure 7) show the distribution of site medians and trend rates (Sen Slope Estimates) for each time period. The black horizontal line within each box indicates the median and the lower and upper hinges of the box indicate the 25th and 75th percentiles, respectively. The whiskers extend from the percentile values to the largest value no larger than 1.5 * IQR (interquartile range). Outliers beyond the end of the whiskers are plotted as individual points. The median box-and-whisker plots show the range in measured values in each time period. The slope plots show the variability in rate of change, slopes close to zero indicate small changes over the time period whereas larger slopes indicate greater change.

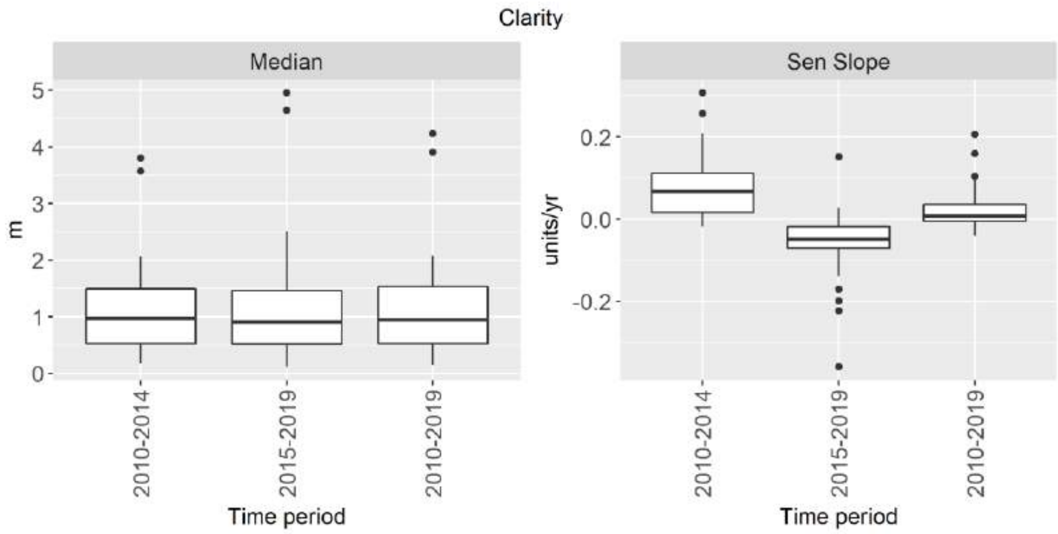

Figure 7: An example of a box-and-whisker plot used to present the medians and trend rates. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range (25th-75th percentiles), the whiskers values within 1.5 * inter-quartile range, and the points indicate outliers.

4 Trend results

The trend results are presented in two different ways, by indicator (Section 4.1) and by RCU (Section 4.2). This repetition is to allow the reader the option to focus on individual indicators of interest or on either a particular geographic area or the overall spatial variability in the trend results.

4.1 Trend results summary by indicator

Five indicators that are components of the water quality taura were able to be analysed for trends in this report:

- water clarity (measured using the black disk method),
- *E. coli, (*counts per 100 mL),
- phytoplankton (measured as Chlorophyll *a*, in mainstem river sites only),
- total nitrogen, and
- total phosphorus.

Two of these indicators, water clarity and *E. coli*, are shared with the experience taura.

Sixteen indicators that align with the Ecological Integrity taura, including four water quality indicators, were analysed:

- dissolved oxygen (percent saturation),
- water temperature,
- ammoniacal nitrogen, and
- arsenic (in mainstream river sites only).

Four macroinvertebrate indicators were analysed:

- macroinvertebrate community index – MCI,
- quantitative macroinvertebrate community index – QMCI,
- percent EPT abundance (percent of sensitive Ephemeroptera – mayflies, Plecoptera – stoneflies, and Trichoptera – caddisflies),
- percent EPT taxa.

Two periphyton indicators were analysed:

- percent cover by long filaments, and
- percent cover by thick mats.

Three macrophyte indicators were analysed:

- percent cover by native vegetation,
- percent cover by exotic vegetation, and
- percent channel clogginess.

And three riparian indicators were analysed:

- stream shading,
- riparian vegetation cover score, and
- riparian width score.

4.1.1 Combined meta-analysis

To provide a high-level summary of trends in the Waikato River and its tributaries, we combined the results of the analyses for all 21 indicators. In the 5-year period since the Report Card (2015-2019), this provided a meta-data set of 751 trends, of which 22% (169 of 751) were improving trends, 37% (277 of 751) were deteriorating trends, and 41% (305 of 751) were as likely improving as deteriorating (Figure 8). It is important to reiterate that an "improving" trend refers to ecological condition, and therefore an improving trend can indicate either an increase in indicator values (i.e. water clarity) or a decrease in indicator values (i.e. *E. coli*). Furthermore, the number of total trends analysed varies between time periods due to data availability which met the selection criteria.

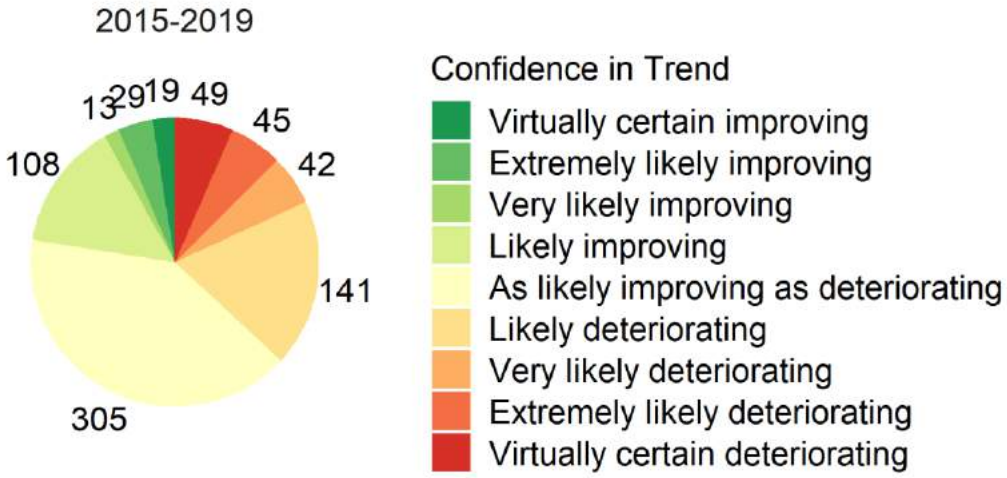

Figure 8: Combined results of Waikato River trend analyses for 21 indicators, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

In the 5-year period immediately preceding (2010-2014) the report card, 40% (260 of 642) of the meta data set trends were improving, 22% (136 of 642) were deteriorating trends and 38% (246 of 642) were as likely improving as deteriorating trends (Figure 9).

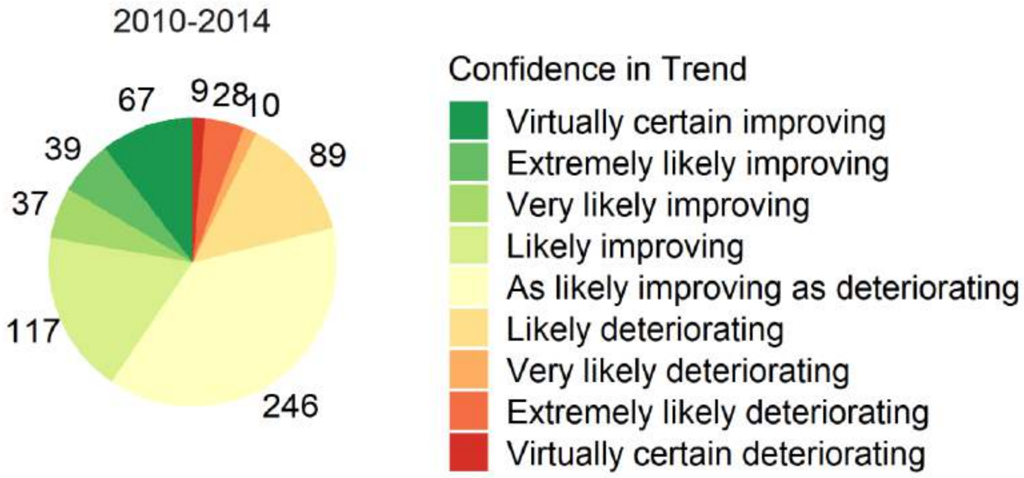

Figure 9: Combined results of Waikato River trend analyses for 21 indicators, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the ten-year period 2010-2019, 25% (161 of 650) of the meta data set trends were improving, 45% (295 of 650) were deteriorating, and 30% (194 of 650) were as likely improving or degrading trends (Figure 10).

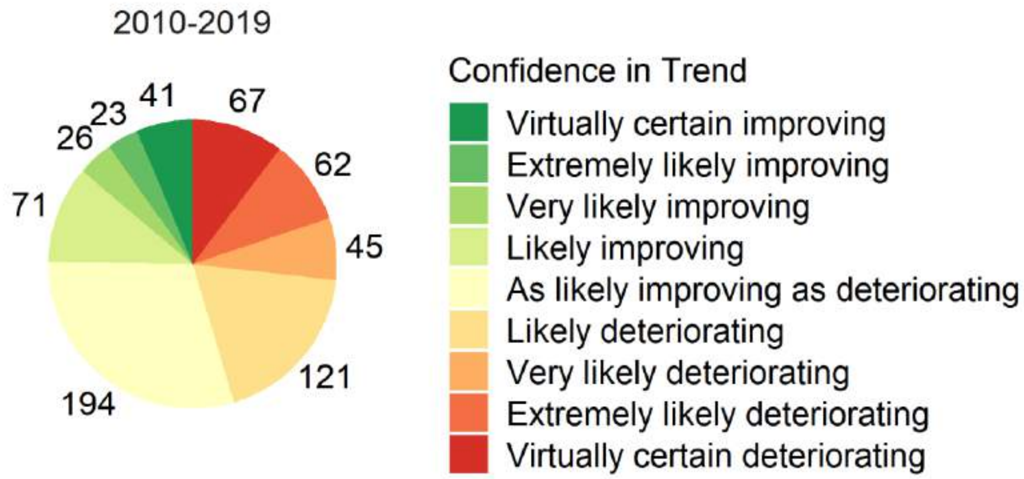

Figure 10: Combined results of Waikato River trend analyses for 21 indicators, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

This meta-analysis shows that deterioration in the health of the river and its tributaries continues to occur and the number of deteriorating trends appears to have increased in the five years since the Report Card was produced. The following sections provide the summary results of the trend analysis by indicator. Further details, including median states and trend rates for each indicator are provided in the Technical Appendix (Appendix B).

4.1.2 Water clarity (black disk measurement)

Why measure it?

Water clarity is a direct measure of light attenuation, which is largely determined by the concentration of particulate matter suspended in the water column. It is conveniently measured as the horizontal siting distance of a 100 mm diameter black disk. Visual clarity is important for both human and ecological values, hence it is included in both the Experience and Water Quality taura. Most people prefer to see clear water in our rivers and lakes and clear water enhances the experience of recreational activities such as swimming, water-skiing, and waka ama. Water clarity is also important from an ecological health perspective, directly affecting the capture efficiency of visual feeders such as birds and fish and impacting on food quality for filter and particle feeders (e.g., kākahi/freshwater mussels) via the concentration, physical, chemical and biological characteristics of sediment particles. Increases in water clarity are considered improving trends.

What are the trends?

In the five-year period since the Report Card (2015-2019), water clarity deteriorated at 78% of the sites analysed (39 of 50), with improving trends detected at 4% of sites (2 of 50). The remaining 18% of sites (9 of 50) were as likely to be improving as deteriorating (Figure 11).

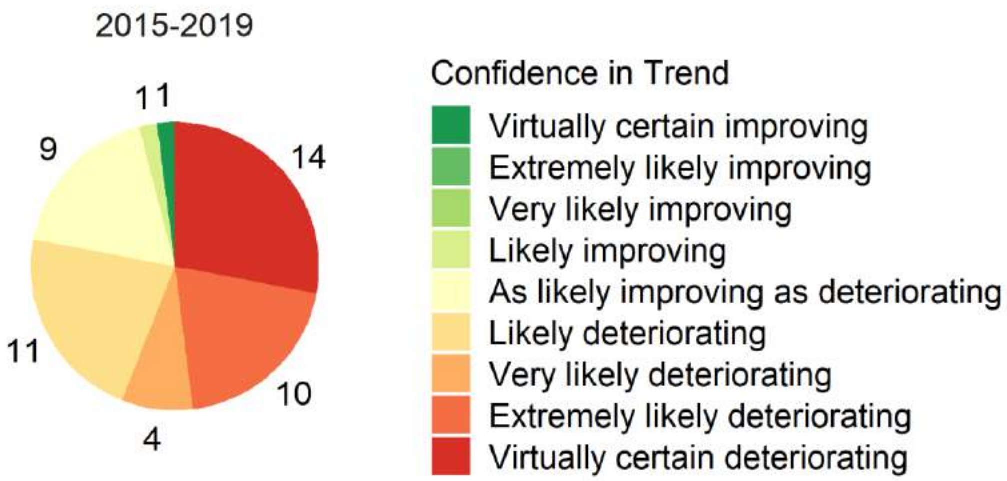

Figure 11: Trends in Waikato River water clarity, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Deteriorating water clarity trends were apparent across all RCUs (Figure 12). Improving trends were observed at Otamakokore Stream, a tributary in the Huka to Ōhakuri RCU (likely improving) and Little Waipā Stream, Arapuni, a tributary in the Ōhakuri to Karāpiro RCU (virtually certain improving).

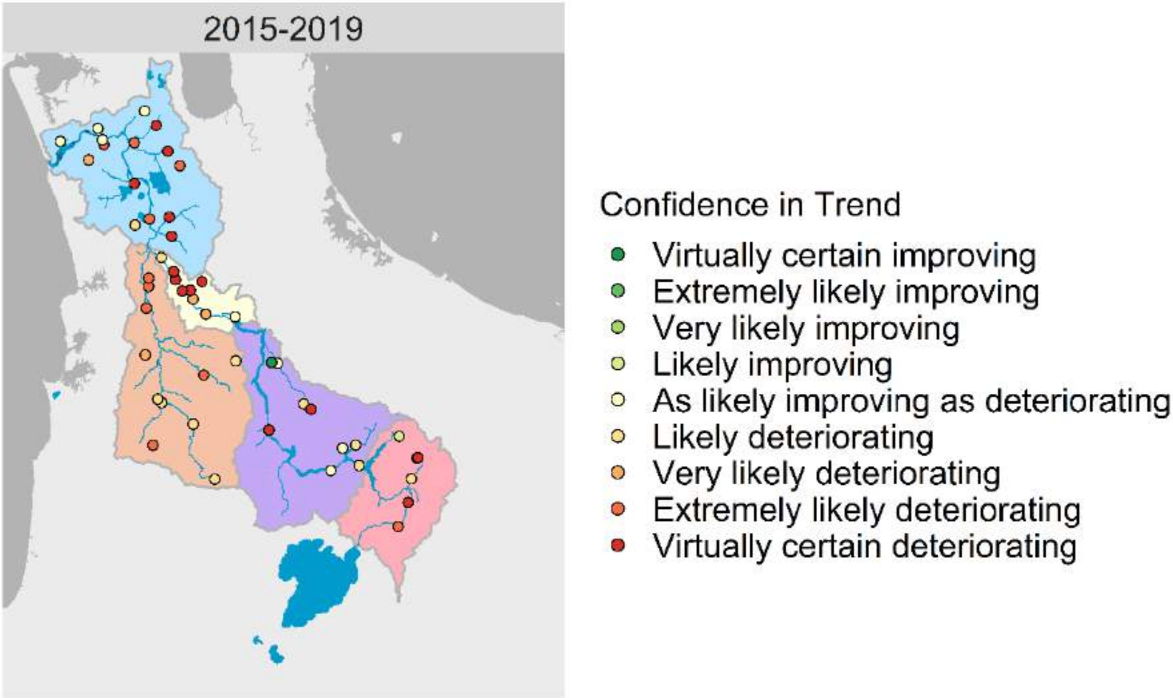

Figure 12: Trends in Waikato River water clarity, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

The predominantly deteriorating trend over the 2015-2019 period contrasts with the trends over the 5-year period immediately preceding the report card (2010-2014) where water clarity was improving at 89% (47 of 53) of the sites (Figure 13), and only one site had a deteriorating water clarity trend (Mangatangi River – Lower Waikato Tributary). The remaining 9% of sites (5 of 53) had as likely improving as deteriorating trends. Thirty-eight sites switched trend direction from improving to deteriorating across these two five-year periods. It is important to note here that while five-year trends provide a useful preliminary assessment of recent conditions, short-term trends (up to ten years) are less robust due to the low number of data points used to determine each trend. The observed differences in trend direction between the two 5-year periods could also be due to statistical sampling errors or natural fluctuations in environmental drivers, such as flow and climate cycles, as well as anthropogenic drivers such as land-use change or ecological restoration. Therefore, the presented five-year trends are indicative only and should be interpreted with caution (see Section 5 for further discussion).

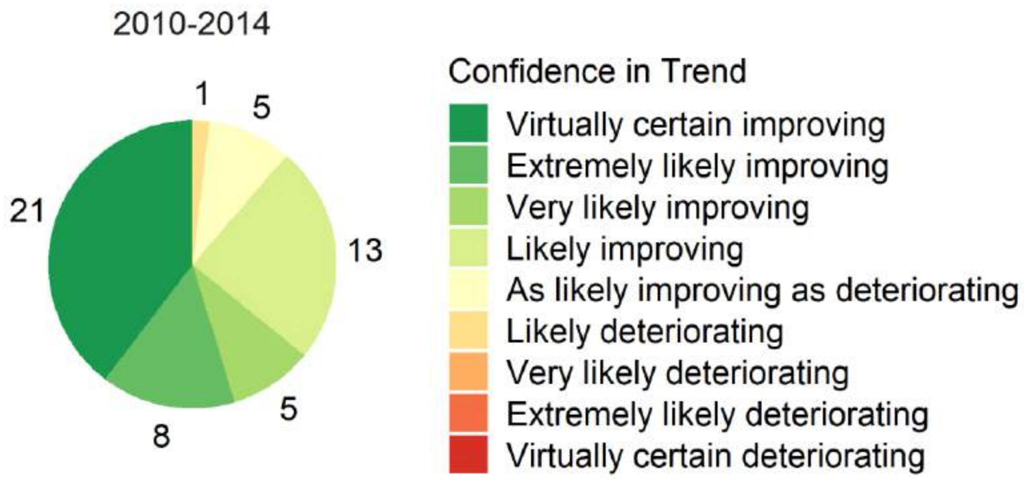

Figure 13: Trends in Waikato River water clarity, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Given the trend 'switching' described above, it is unsurprising that the trend analysis for the whole 10-year period (2010-2019) shows a mix of improving and deteriorating trends, with 52% of sites (26 of 50) improving and 36% deteriorating (18 of 50). The remaining 12% (6 of 50) were as likely improving as deteriorating (Figure 14).

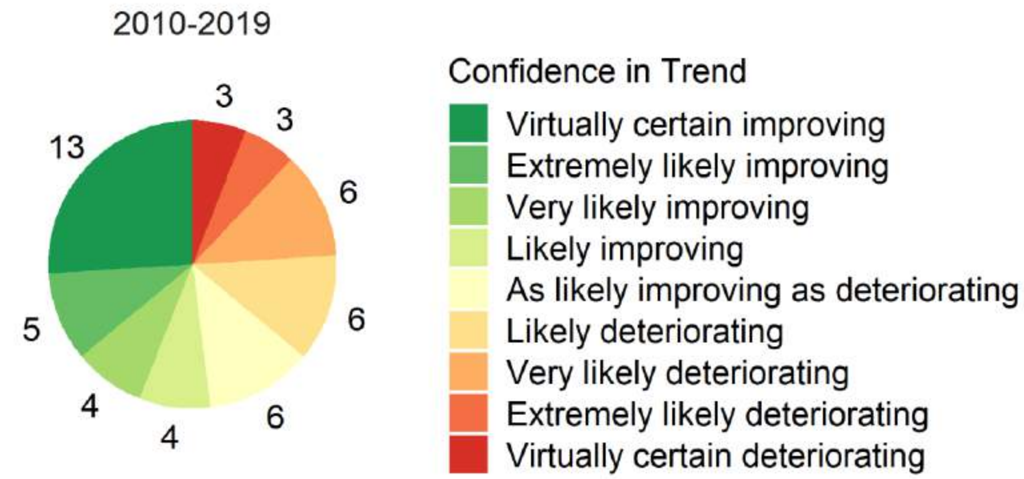

Figure 14: Trends in Waikato River water clarity, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.3 *E. coli*

Why measure it?

E. coli is a faecal indicator bacteria. High numbers infer increased human health risk (greater risk of infection and illness) following ingestion of waterborne pathogens such as campylobacter and viruses. The quality of water in which contact recreation activities occurs (such as swimming, water skiing, and waka ama) needs to be such that the health risk posed is low. The National Policy Statement for Freshwater Management (2020) relates threshold concentrations to risk of infection and illness. Reducing the human health risk during recreation requires faecal indicator bacteria concentrations to be below specified *E.coli* levels. Decreases in *E. coli* concentrations over time indicates improving trends.

What are the trends?

In the five-year period since the Report Card (2015-2019), deteriorating *E. coli* trends were detected at 70% of the sites analysed (43 of 61), with improving trends detected at 11% (7 of 61) of sites. The remaining 18% (11 of 61) of sites were as likely improving as deteriorating (Figure 15).

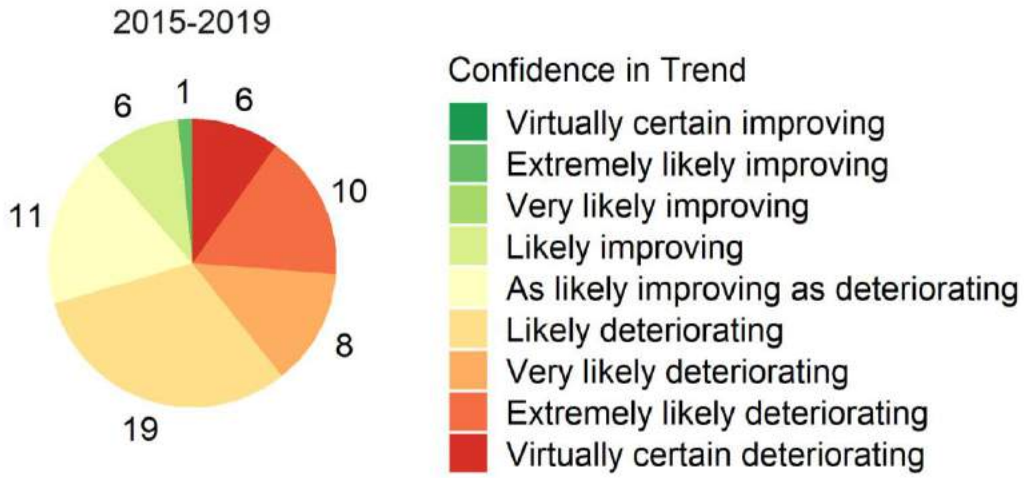

Figure 15: Trends in Waikato River *E.coli*, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Deteriorating trends in *E. coli* occurred across all RCUs, with strong trends occurring in the tributaries of the Middle Waikato (Karāpiro to Ngāruawāhia), Waipā, and Lower Waikato (Figure 16). Of the seven improving trends that were detected, four were in the Waipā River catchment. Sites where improving trends were detected included Whangape Stream at Rangiriri and Whangamarino River at Jefferies Road in the lower Waikato, Mangaokewa Stream at Lawrence Street Bridge, Kaniwhaniwha Stream at Wright Road, Waitomo Stream at SH31 and Waipā River at Otewa in the Waipā River catchment and the Waikato River at Narrows Boat Ramp (MW).

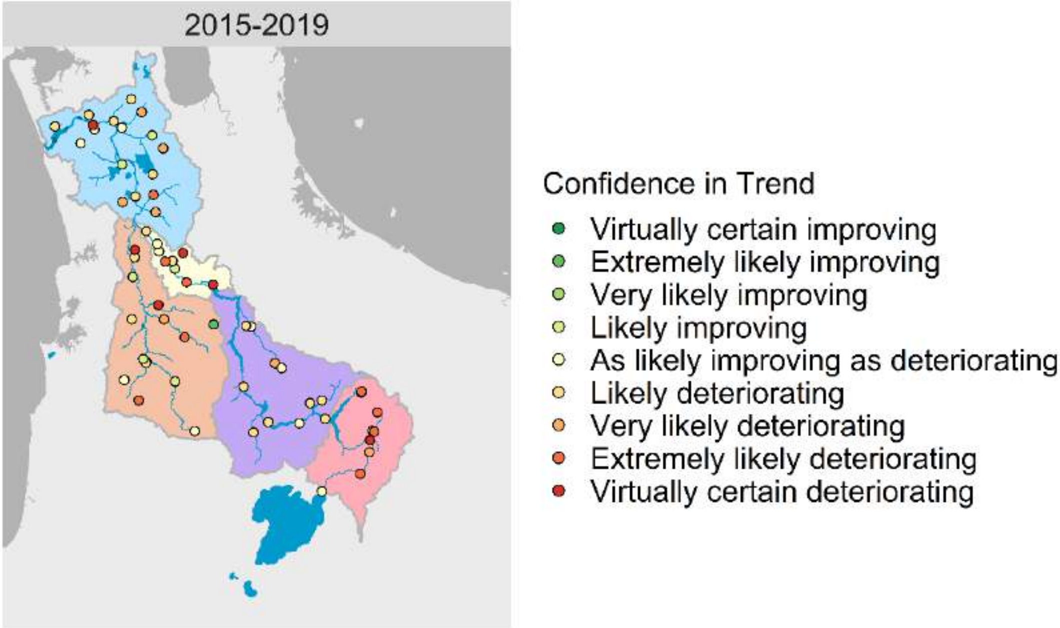

Figure 16: Trends in Waikato River *E. coli*, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

This predominance of deteriorating trend in the 2015-2019 period contrasts with the trends over the five-year period immediately preceding the report card (2010-2014) where *E. coli* was improving at 56% (25 of 45) of the sites, and only 16% of sites (7 of 45) had a deteriorating trend. The remaining 29% (13 of 45) of sites were as likely improving as deteriorating (Figure 17). However, 16 more trends were analysed in 2015-2019 than in 2010-2014, therefore, the increase in proportion of negative trends could be due to the additional sites having all or mostly deteriorating trends rather than the 2010-2014 sites switching from improving to deteriorating trends.

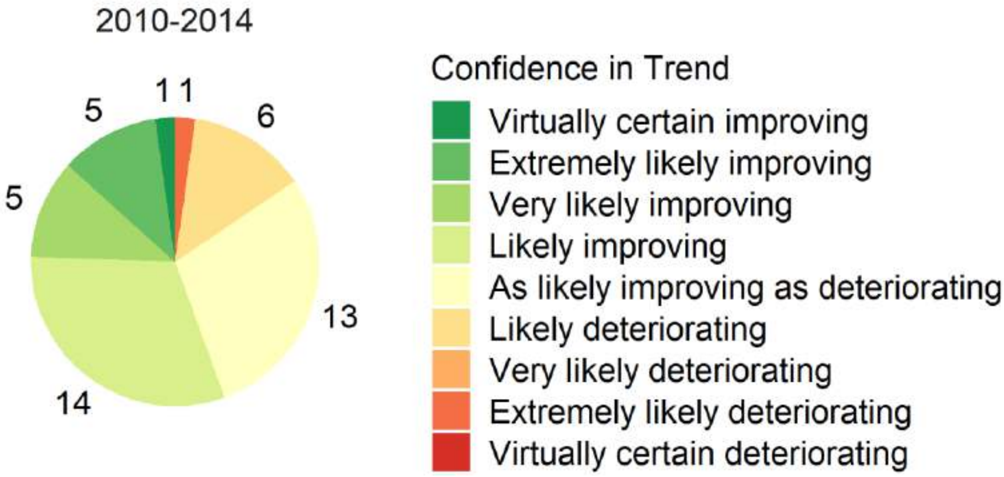

Figure 17: Trends in Waikato River *E. coli*, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

For the 2010 to 2019 time period, 42 of the 65 sites were able to be analysed for a temporal trend. Fifty percent (21 of 42) of *E. coli* trends in this time period were deteriorating, with only 19% (8 of 42) improving and 31% (13 of 42) as likely improving as deteriorating (Figure 18). The Mangaokewa Stream at Lawrence Street Bridge however has shown an improving trend for the five-year time period (2015-2019) and the 10-year (2010-2019) time period.

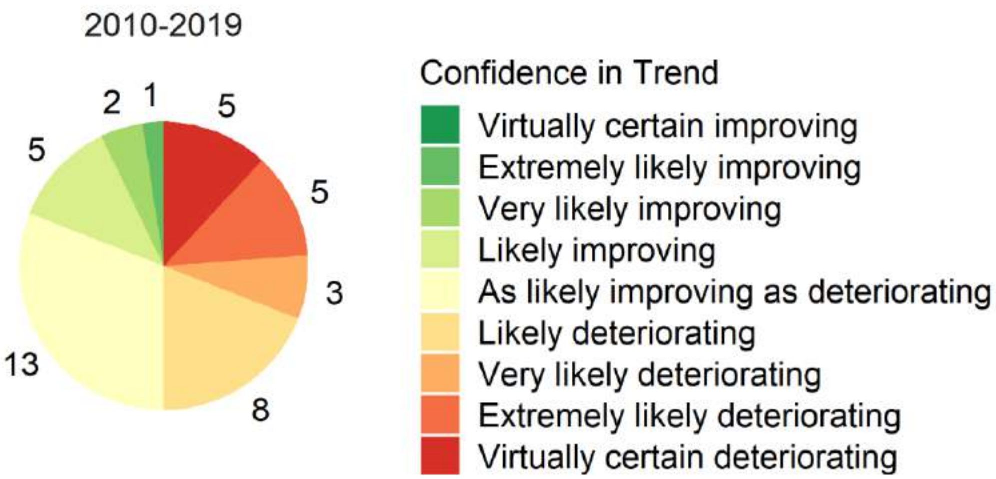

Figure 18: Trends in Waikato River *E. coli*, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.4 Total nitrogen (TN)

Why measure it?

Nitrogen is a key nutrient for aquatic plants. Small amounts are required for healthy rivers – excessive amounts can encourage the growth of aquatic plants, especially algae, to nuisance levels. Total nitrogen includes all forms of nitrogen found in freshwater: nitrate-nitrogen, nitrite-nitrogen, ammoniacal-nitrogen, and organic nitrogen. Elevated TN concentrations are often a direct consequence of land use intensification (including urbanization), and land management practices. Common sources of nitrogen include fertilizer use followed by soil leaching and run-off from agricultural lands, wastewater treatment plants, and industrial discharges (LAWA 2019a). Decreases in total nitrogen over time indicate an improving trend.

What are the trends?

In the five-year period since the Report Card (2015-2019), deteriorating total nitrogen trends were observed at 70% of the sites analysed (42 of 60), with improving trends detected at 18% (11 of 60) of sites. Trends at the remaining 12% (7 of 60) of sites had an as likely improving as deteriorating trend direction (Figure 19).

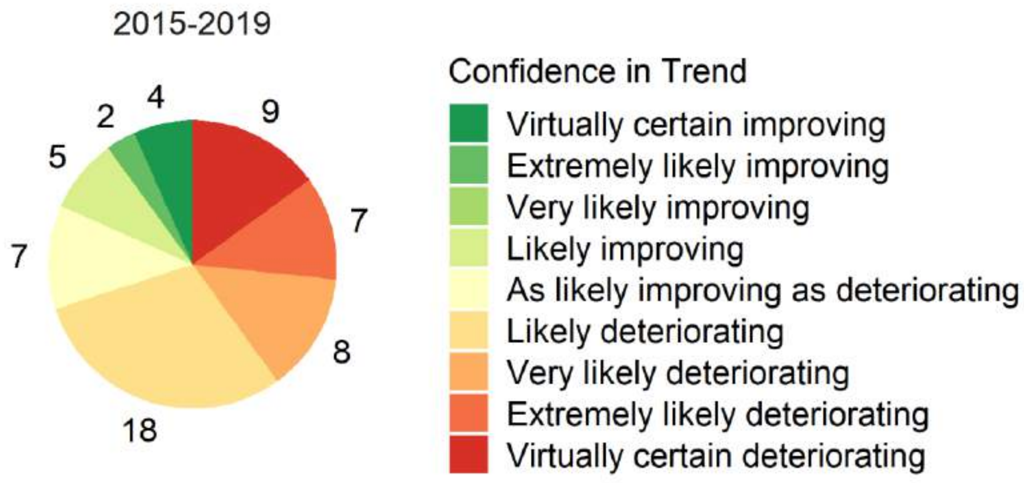

Figure 19: Trends in Waikato River total nitrogen, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

Total nitrogen data was collected across all RCUs. Trends varied between RCUs, with the Middle Waikato, Waipā and Lower Waikato Tributary RCUs having more improving and/or fewer deteriorating trends than the other RCUs (Figure 20), particularly over the ten-year time period. Sites showing virtually certain improving trends over the 2015 to 2019 time period include Waiotapu Stream at Campbell Road Bridge (OWT), Kirikiriroa Stream at Tauhara Drive (MWT), Mangauika Stream at the Te Awamutu Borough W/S Intake (WpT) and Awaroa Stream (Rotowaro) at Sansons Bridge (LWT).

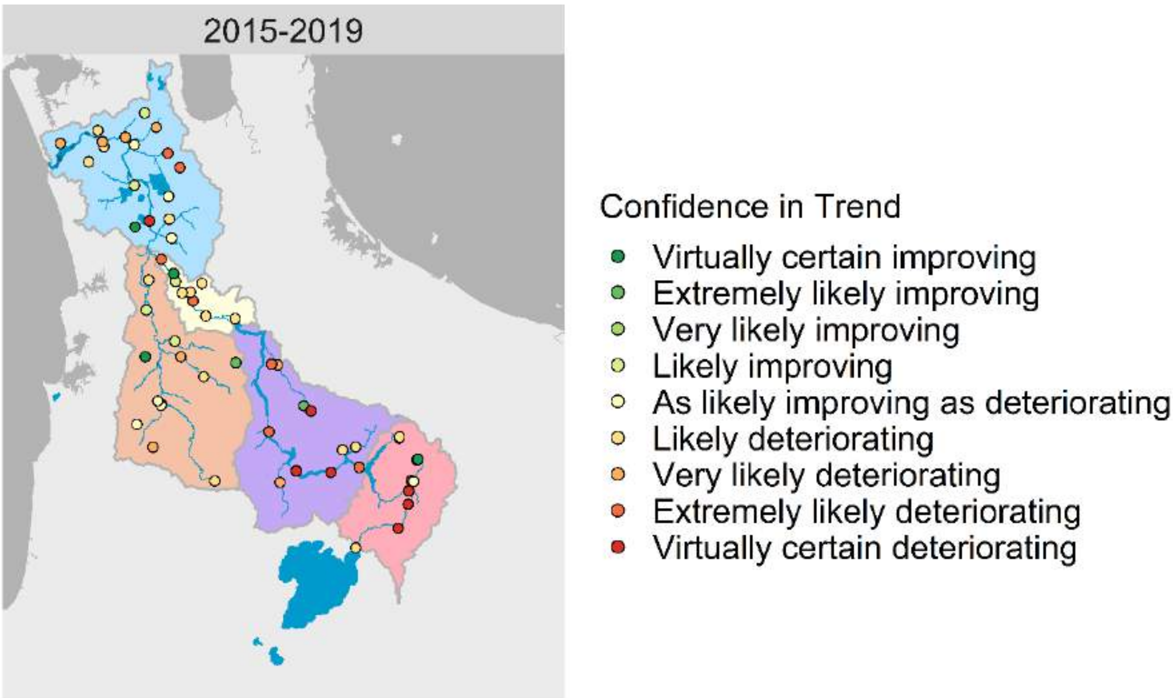

Figure 20: Trends in Waikato River total nitrogen, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the confidence that the trend is improving or deteriorating.

This predominantly deteriorating trends for the 2015-2019 period contrasts with the trends over the five-year period immediately preceding the Report Card (2010-2014) where total nitrogen was improving at 85% (52 of 61) of the sites. The remaining sites had 5% (3 of 61) of sites with trends that were as likely improving as deteriorating and 10% (6 or 61) of sites had deteriorating trends (Figure 21).

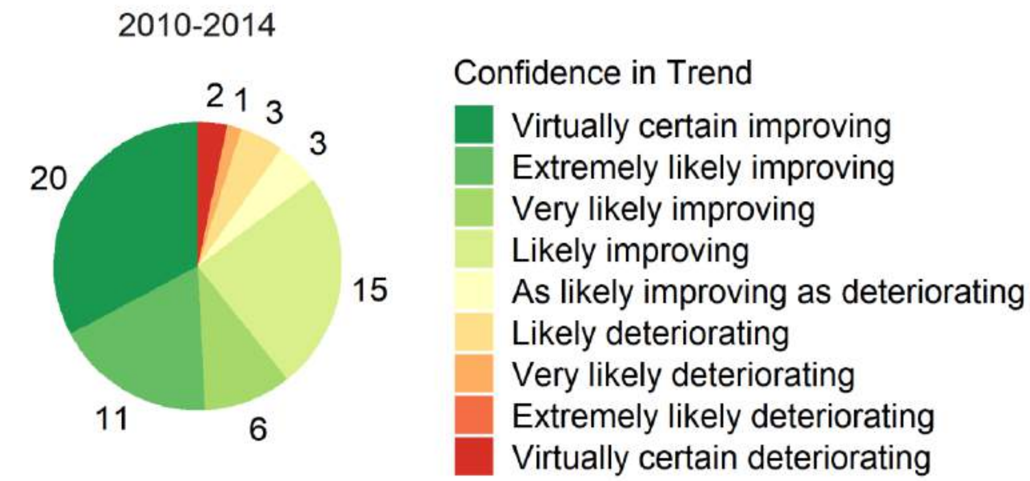

Figure 21: Trends in Waikato River total nitrogen, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the entire 2010-2019 time period, 67% (40 of 60) of total nitrogen trends were deteriorating, although there were also 17% (10 of 60) as likely improving as deteriorating trends and 17% (10 of 60) improving trends (Figure 22).

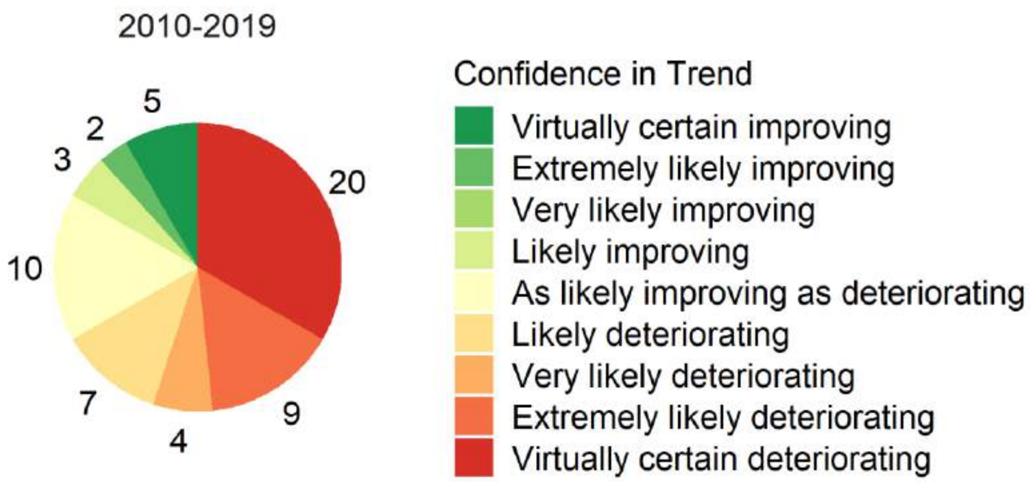

Figure 22: Trends in Waikato River total nitrogen, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.5 Total Phosphorus (TP)

Why measure it?

Phosphorus is a key nutrient for aquatic plants, and like nitrogen, excessive amounts can encourage the growth of aquatic plants (including algae) to nuisance levels. Total phosphorus includes phosphorus that is bound to sediment and dissolved reactive phosphorus (DRP) in the water column. The bulk of phosphorus enters river ecosystems attached to sediment in surface run-off. Phosphorus can also enter waterways as discharge from wastewater treatment plants and in runoff from agricultural lands containing animal waste (LAWA 2019b).

The presence of arsenic in water can interfere with the accurate measurement of TP using some analytical methods. Arsenic of geothermal origin occurs across much of the Waikato River catchment. To account for interference in the analytical method, WRC applied a correction factor to TP results generated in 2010-2012, when laboratory processing procedures did not account for the presence of arsenic (Vant 2013, 2018).

Ongoing discussion regarding comparison of TP results derived from varying methods of analysis mean that TP data and trends should be considered provisional (Vant 2013, 2018). Decreases in total phosphorus concentration over time are considered to indicate an improving trend.

What are the trends?

In the five-year period since the Report Card (2015-2019), 55% of sites analysed (34 of 62) show a deteriorating trend in total phosphorus, while 29% (18 of 62) show an improving trend and 16% (10 of 62) are as likely improving as deteriorating trends (Figure 23).

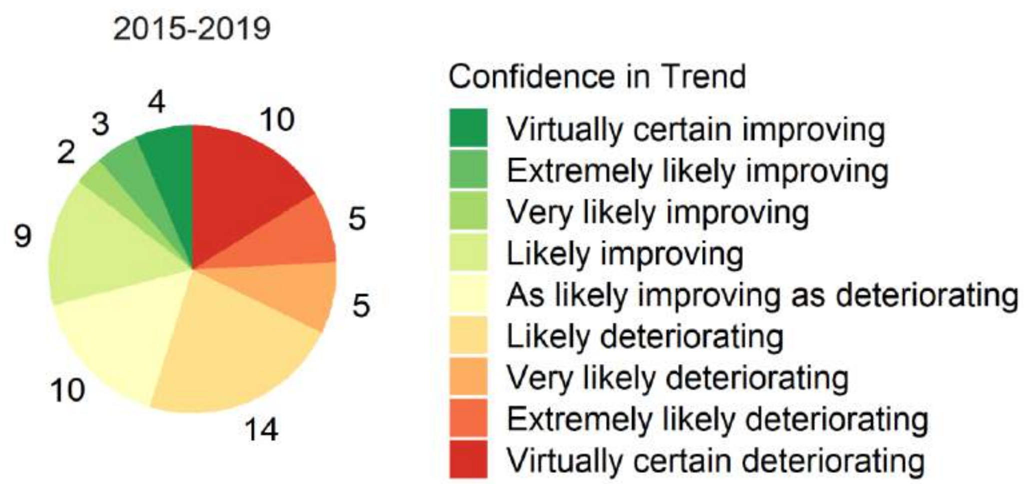

Figure 23: Trends in Waikato River total phosphorus, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Total phosphorus data was gathered across all 10 RCUs. Trends varied somewhat between the RCUs, with more deteriorating trends in the lower river (LW) than elsewhere. The majority of improving trends for the 2015-2019 time period were observed in the Huka to Ōhakuri tributaries (6 of 18) and Ōhakuri to Karāpiro tributaries (6 of 18) (Figure 24).

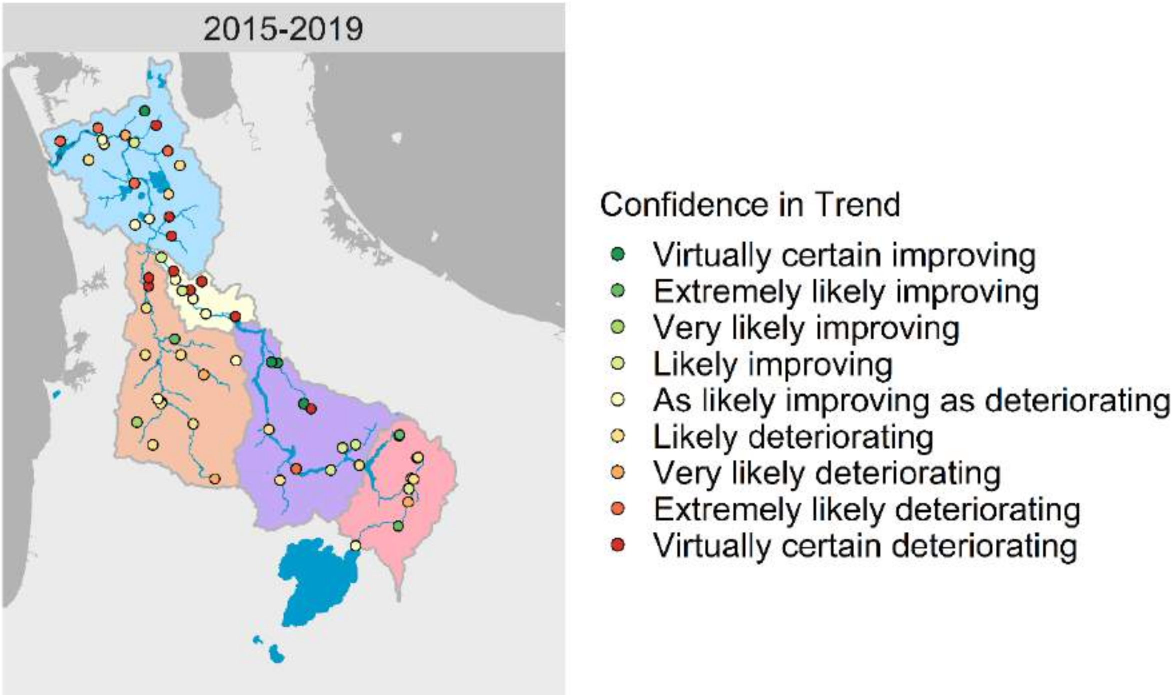

Figure 24: Trends in Waikato River total phosphorus, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In the five-year period that preceded the Report Card (2010 to 2014), 71% (41 of 58) of trends were improving, 17% (10 of 58) were as likely improving as deteriorating and 12% (7 of 58) were deteriorating trends (Figure 25).

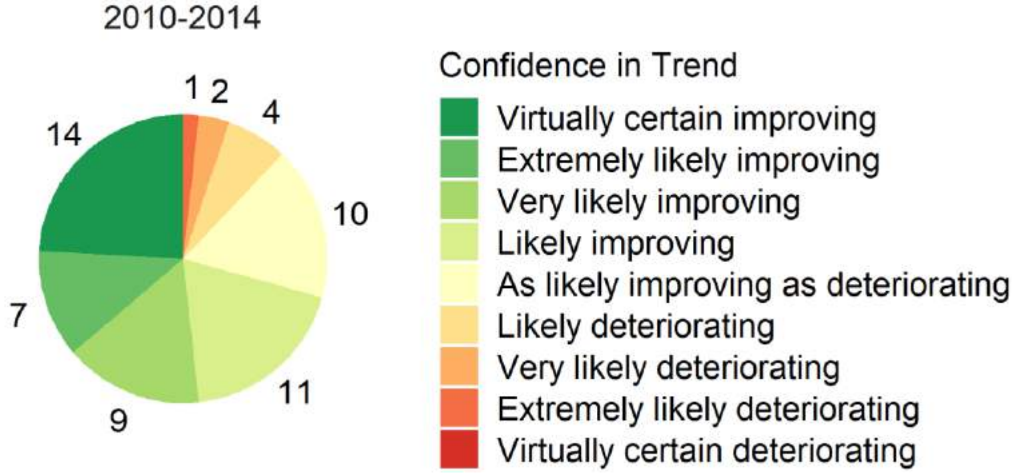

Figure 25: Trends in Waikato River total phosphorus, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

For the 2010-2019 time period the total phosphorus trend directions and confidence were mixed, with 40% improving (23 of 58) and 40% deteriorating trends (23 of 58). The remaining 20% (12 of 58) of sites had as likely improving as deteriorating trends (Figure 26). All five sites analysed in the OWT (5) and LW (3) RCUs showed improving trends for the 10-year period.

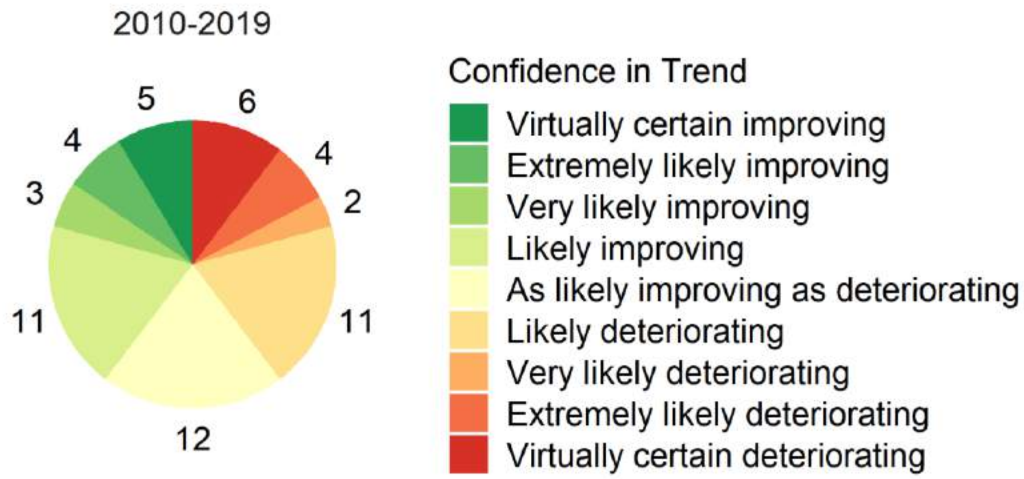

Figure 26: Trends in Waikato River total phosphorus, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.6 Phytoplankton (Chlorophyll *a*)

Why measure it?

Algae occur naturally in our rivers, lakes and streams. Chlorophyll *a* in a water sample is used as a surrogate measure of total algal biomass (phytoplankton), which is free-floating in the water column of lakes, reservoirs or large, slow-moving rivers. High levels of algae can affect aesthetics, clarity and colour and be indicative of cyanobacteria (blue-green algae) blooms. Decreases in chlorophyll *a* concentrations are considered improving trends.

What are the trends?

The concentration of phytoplankton (Chlorophyll *a*) was only measured in the 10 mainstem Waikato River sites by WRC. It is worth noting that there were a large number of censored values in the phytoplankton dataset (indicating concentrations which were below detection limits).

For the 2015 to 2019 time period, 60% (6 of 10) of trends were as likely improving as deteriorating and 40% (4 of10) were improving (Figure 27). All improving trends were in the lower river (LW and MW) (Figure 28).

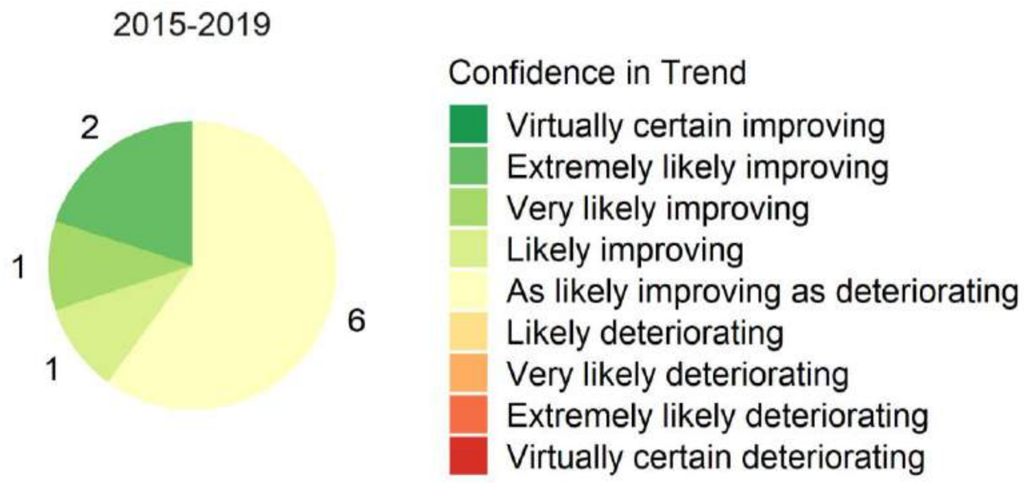

Figure 27: Trends in Waikato River Chlorophyll *a*, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

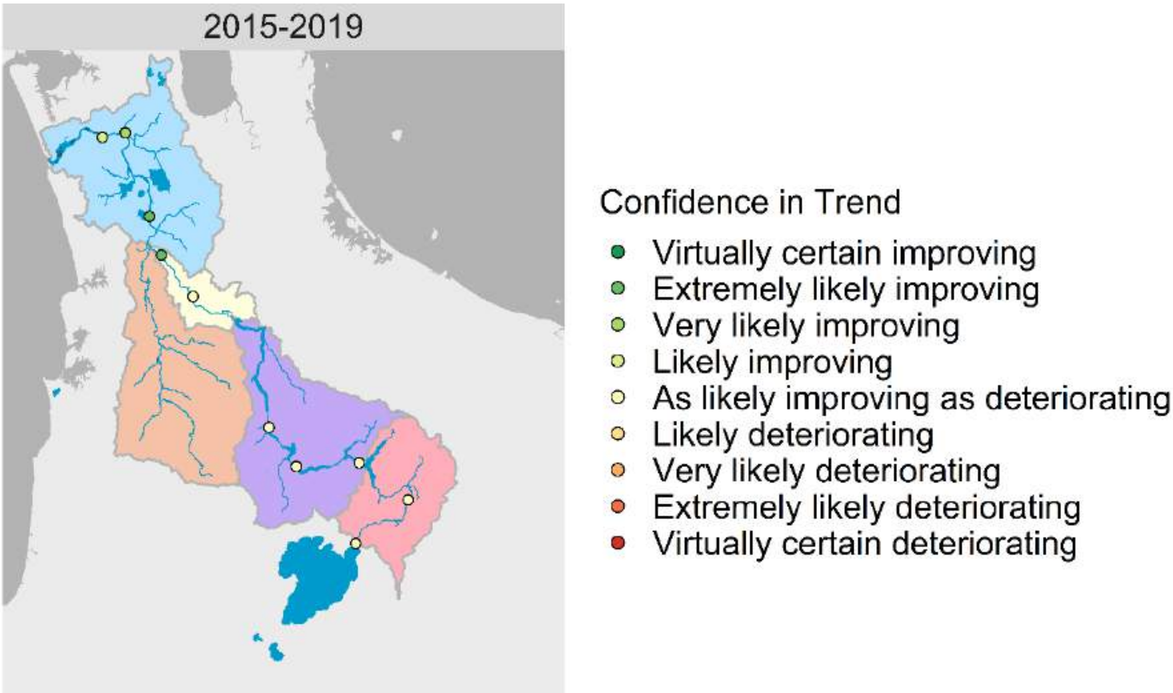

Figure 28: Trends in Waikato River Chlorophyll *a*, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In 2010-2014, improving trends were observed at 30% (3 of 10) of sites, 20% (2 of 10) were deteriorating and 50% (5 of 10) were as likely improving as deteriorating (Figure 29).

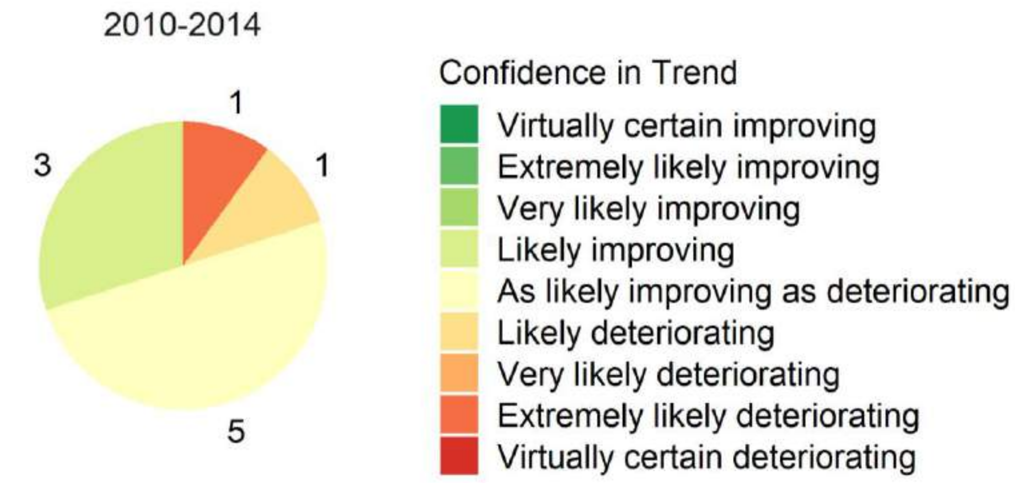

Figure 29: Trends in Waikato River Chlorophyll *a*, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

When assessed over the ten-year period most sites were improving (70%, 7 of 10), with trend at the remaining 30% (3 of 10) as likely improving as deteriorating (Figure 30).

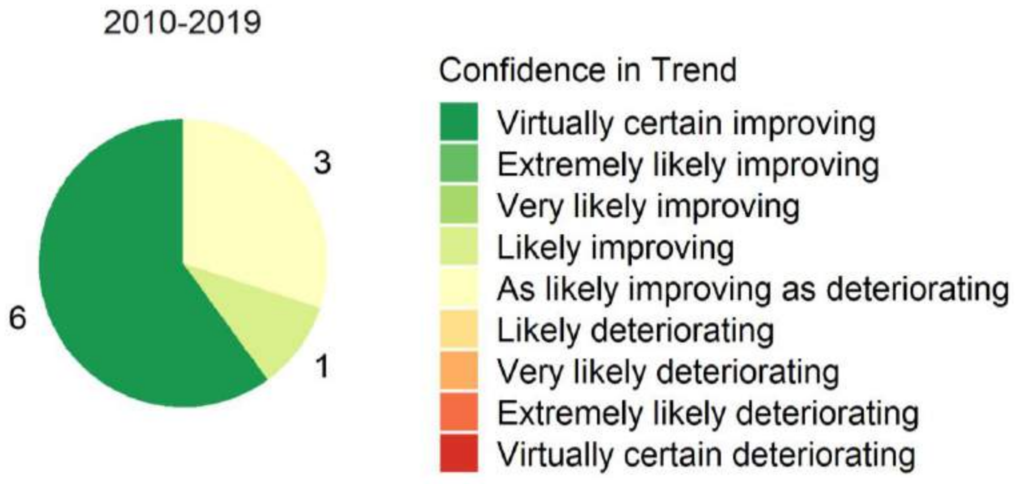

Figure 30: Trends in Waikato River Chlorophyll *a*, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.7 Dissolved oxygen (DO)

Why measure it?

Adequate dissolved oxygen (DO) concentrations are critical for healthy aquatic systems and current guidelines seek to maintain dissolved oxygen at sufficiently high concentrations to prevent adverse effects on freshwater organisms. Reduced dissolved oxygen levels (hypoxia) can impair the growth and/or reproduction of aquatic organisms and very low or zero dissolved oxygen levels (anoxia) will kill organisms.

Low DO levels in freshwater can occur due to discharge of organic or inorganic substances that deplete oxygen (e.g., wastewater discharges containing biodegradable organic materials or ammoniacal-N), or as a result of die-off of algal blooms. Nutrient enrichment (eutrophication) and high light levels can also potentially impact on DO through excessive growths of aquatic plants and high night-time respiration. Respiration results in DO minima immediately prior to sunrise daily. Unacceptably low DO concentrations can be managed by controlling discharges and eutrophication.

It is important to note that the dissolved oxygen data analysed consisted of instantaneous spot measurements, which are recorded during daylight hours. DO varies according to a reasonably pronounced daily cycle, which will not be represented by a single spot measurement.[5] WRC visits each site at the same time of day (± 1 hour) on each sampling visit to minimise effects of diurnal variation this makes it possible to use these data for trend analysis (Vant 2018). Increases in dissolved oxygen are considered improving trends.

What are the trends?

In the 2015-2019 time period, 56% (35 of 62 sites) of DO trends were improving, 23% (14 of 62 sites) were as likely improving as deteriorating, and 21% (13 of 62 sites) were deteriorating (Figure 31).

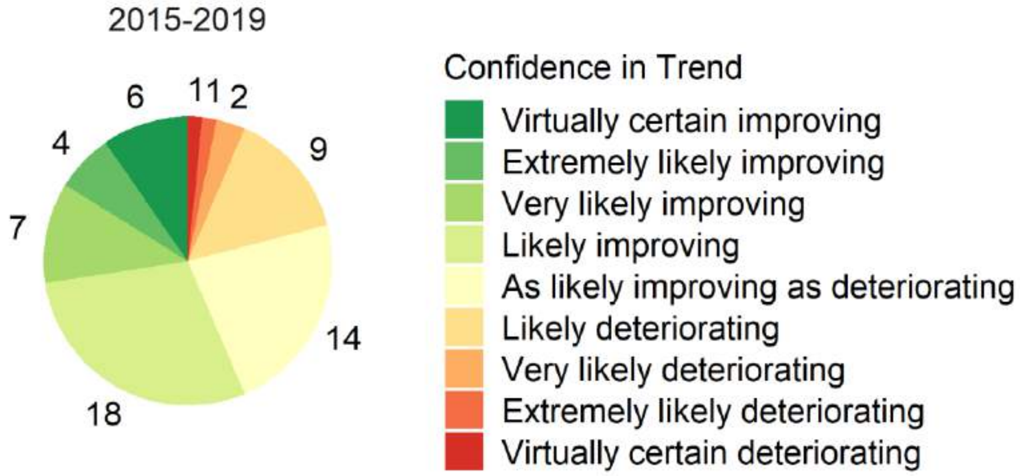

Figure 31: Trends in Waikato River dissolved oxygen, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Dissolved oxygen data was gathered for all 10 RCUs. Trends were similar across RCUs, with most sites showing likely improving or as likely improving as deteriorating trends (Figure 32). The 13 deteriorating sites were spread across most RCUs, while the Waipā River had two deteriorating sites, the Waipā River at Ngutunui road bridge (virtually certain deteriorating) and the Mangauika Steam at the Te Awamutu Borough W/S Intake (extremely likely deteriorating).

[5] Determining daily minimum DO concentrations requires use of a meter and logger that is able to record DO concentrations automatically, at regular intervals over a representative 24-hour period.

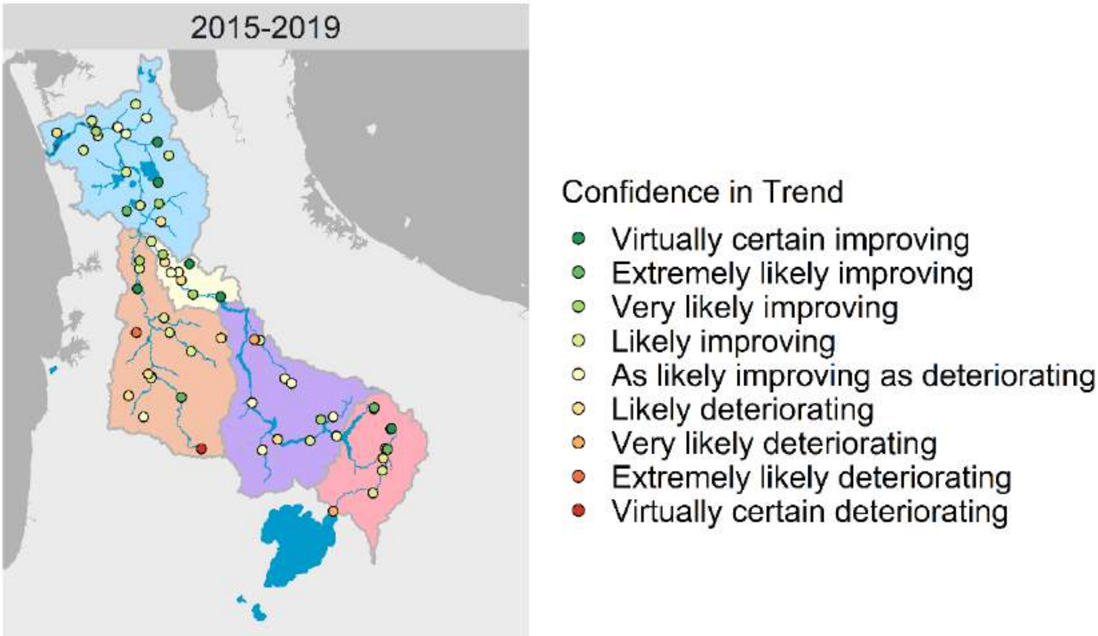

Figure 32: Trends in Waikato River dissolved oxygen, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

For the 2010 to 2014 time period, dissolved oxygen trends were also mixed but with slightly more deteriorating than improving trends. Thirty-three percent (22 of 65) of trends were as likely improving as deteriorating, 26% (17 of 65) of trends were improving and 40% (26 of 65) of trends were deteriorating (Figure 33).

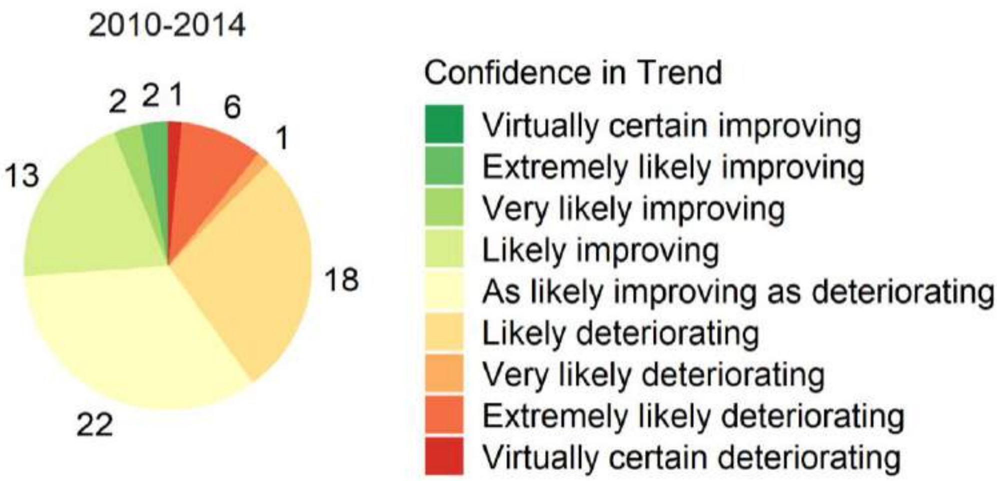

Figure 33: Trends in Waikato River dissolved oxygen, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

For the 10-year time period (2010-2019) 71% of trends were deteriorating (44 of 62 sites), with only 13% (8 of 62) improving trends and 16% (10 of 62) as likely improving as deteriorating trends (Figure 34).

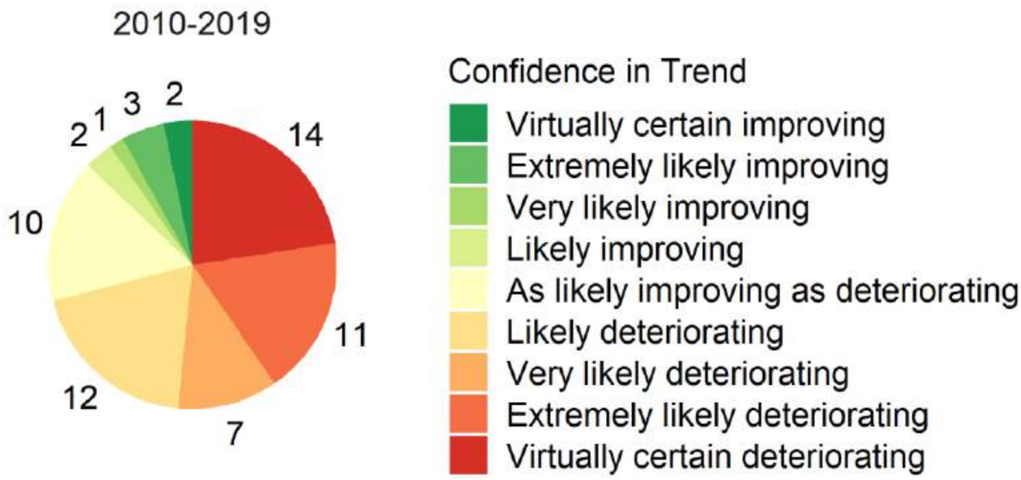

Figure 34: Trends in Waikato River dissolved oxygen, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.8 Water temperature

Why measure it?

Water temperature plays an important role in the functioning of aquatic ecosystems. Importantly, it affects the growth of most aquatic organisms. Temperatures above the growth optimum impose a thermal stress on organisms, and lethal effects are reached only slightly higher than the growth optimum temperature. Water temperature also influences oxygen solubility and hence availability (cooler water holds more oxygen) and it can affect the toxicity of other contaminants (e.g., ammoniacal nitrogen).

Temperature varies seasonally, with the fastest heating, and therefore fastest rate of temperature rise, occurring near the summer solstice (22 December). Maximum temperatures are typically achieved a little later, in late January to early February. Stream and river temperatures also vary diurnally, with temperature reaching a maximum in the mid to late afternoon with fairly rapid cooling through the remainder of the day and through the night, so that minimum water temperatures occur near dawn.

Water temperature data were instantaneous spot measurements, which will vary with the time of day samples are collected. However, because WRC visits each site at the same time of day (± 1 hour) on each sampling visit, the effects of diurnal variation should be minimised (Vant 2018). Decreases in water temperature are considered improving trends.

What are the trends?

In the five-year period since the Report Card (2015-2019), water temperature has deteriorated at 50% (31 of 62) of the sites analysed, while 31% (19 of 62) of sites had as likely as improving as deteriorating trends and the remaining 19% (12 of 62) of sites had improving trends (Figure 35).

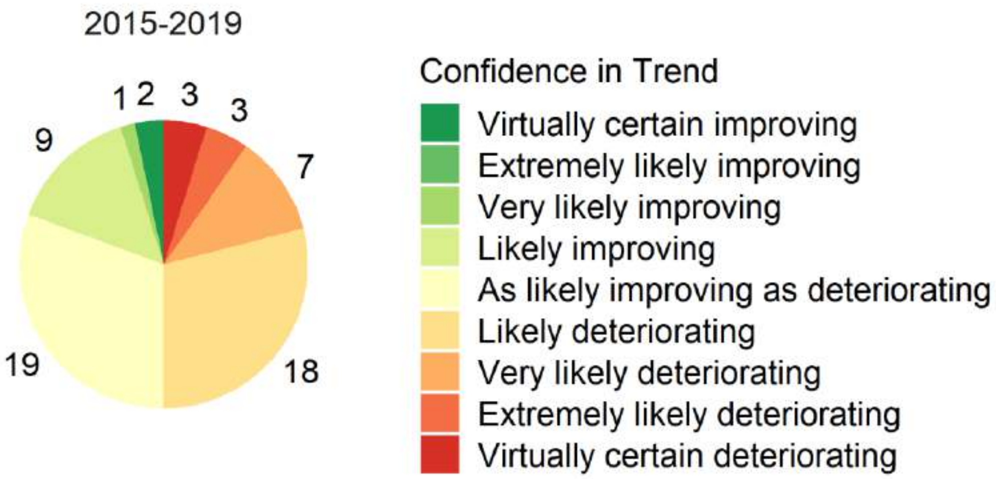

Figure 35: Trends in Waikato River water temperature, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or declining, with the number of sites showing trends in each category noted on the outside.

Water temperature was gathered for all 10 RCUs. Trends varied between the RCUs, with upstream Huka to Ōhakuri mainstem and tributaries RCUs showing more improving trends and downstream RCUs Mid Waikato, Waipā and Lower Waikato tributaries showing more deteriorating trends (Figure 36).

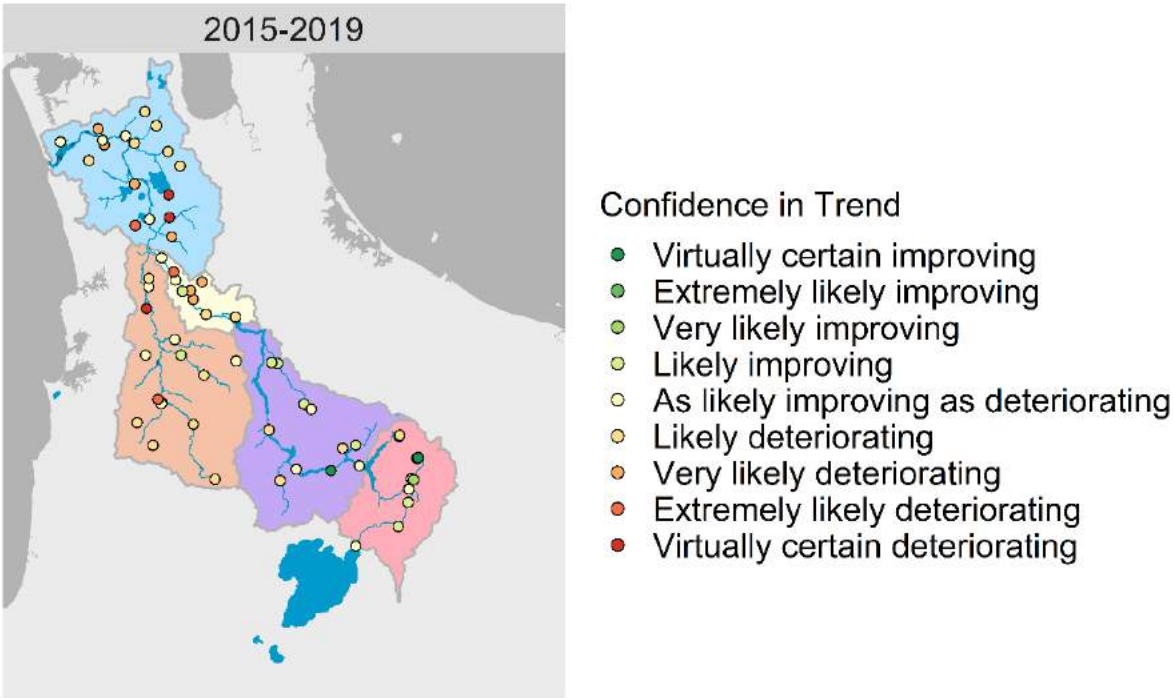

Figure 36: Trends in Waikato River water temperature, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

The predominantly deteriorating trend over the 2015-2019 period contrasts with the trends over the five-year period immediately preceding the Report Card (2010-2014) where water temperature was improving at 42% (27 of 65) of the sites, as likely improving as deteriorating at 32% (21 of 65) of sites and deteriorating at the remaining 26% (17 of 65) of sites (Figure 37).

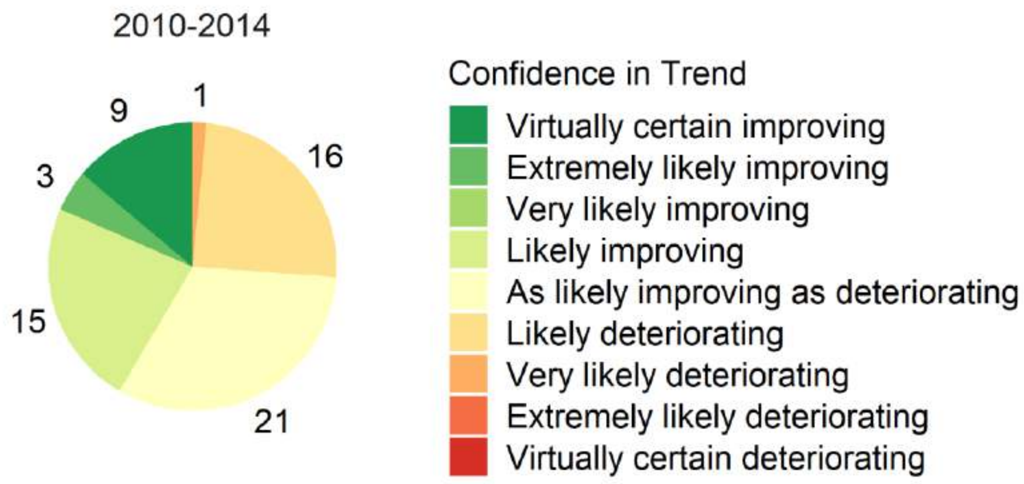

Figure 37: Trends in Waikato River water temperature, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

For the 10-year period of 2010 to 2019, 47% (29 of 62) of water temperature trends were deteriorating, with 26% (16 of 62) improving and 27% (17 of 62) as likely improving as deteriorating (Figure 38).

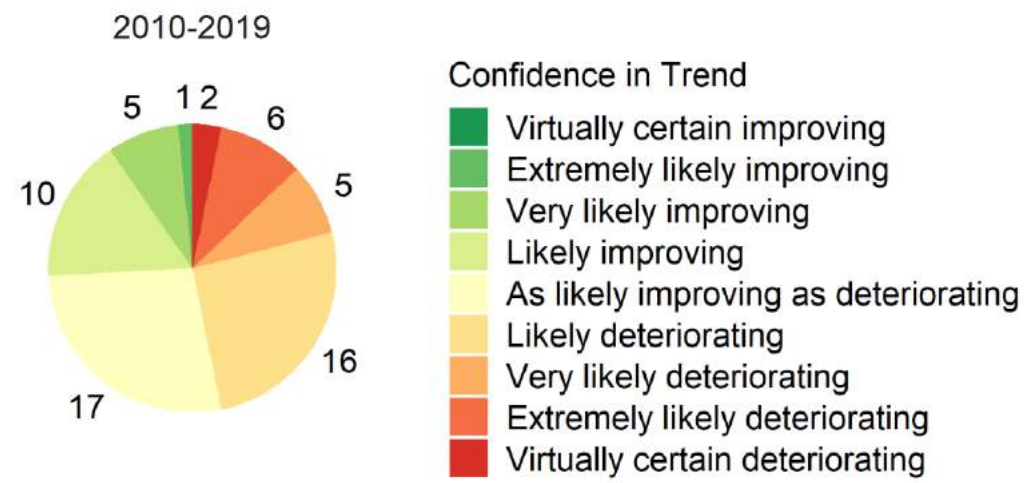

Figure 38: Trends in Waikato River water temperature, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.9 Ammoniacal nitrogen

Why measure it?

"Ammonia" exists in water as either ammonia (NH_3) or ammonium ion (NH_4^+), with the proportion of each determined by the temperature and pH of the water. Current analytical methods do not permit measurement of NH_3 and NH_4 separately (Williamson et al. 2016). Ammoniacal nitrogen primarily enters waterways through point source discharges, such as raw sewage or dairy shed effluent (LAWA 2019a). It commonly occurs in catchment runoff and receiving waters in the Waikato region, but usually at low, non-toxic concentrations. The main concerns are associated with elevated levels in human and animal wastes and in enriched sediments (Williamson et al. 2016). It can be toxic to aquatic life at low concentrations, with the toxicity dependent on the proportion of free ammonia. The toxicity of a solution containing ammoniacal-N increases with pH (LAWA 2019a). Decreases in ammoniacal nitrogen are considered improving trends.

What are the trends?

A large proportion of analytical results were reported as being below detection limits. Fifty-two percent (32 of 62) of ammoniacal nitrogen trends for the 2015-2019 time period were as likely improving as deteriorating. Eleven percent (7 of 62) sites had improving trends and 37% (23 of 62) sites had deteriorating trends (Figure 39).

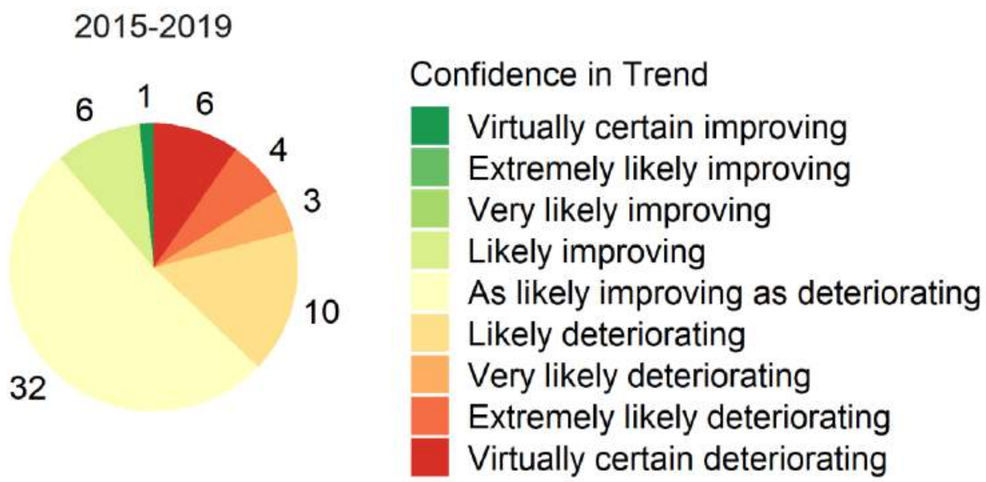

Figure 39: Trends in Waikato River ammoniacal nitrogen, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Ammoniacal nitrogen data was measured at sites across all 10 RCUs, and deteriorating trends were observed in all five zones (Figure 40). The mid- and upper-Waikato tributaries had more improving trends in ammoniacal nitrogen compared to the other RCUs, while the lower Waikato tributaries exhibited more deteriorating trends.

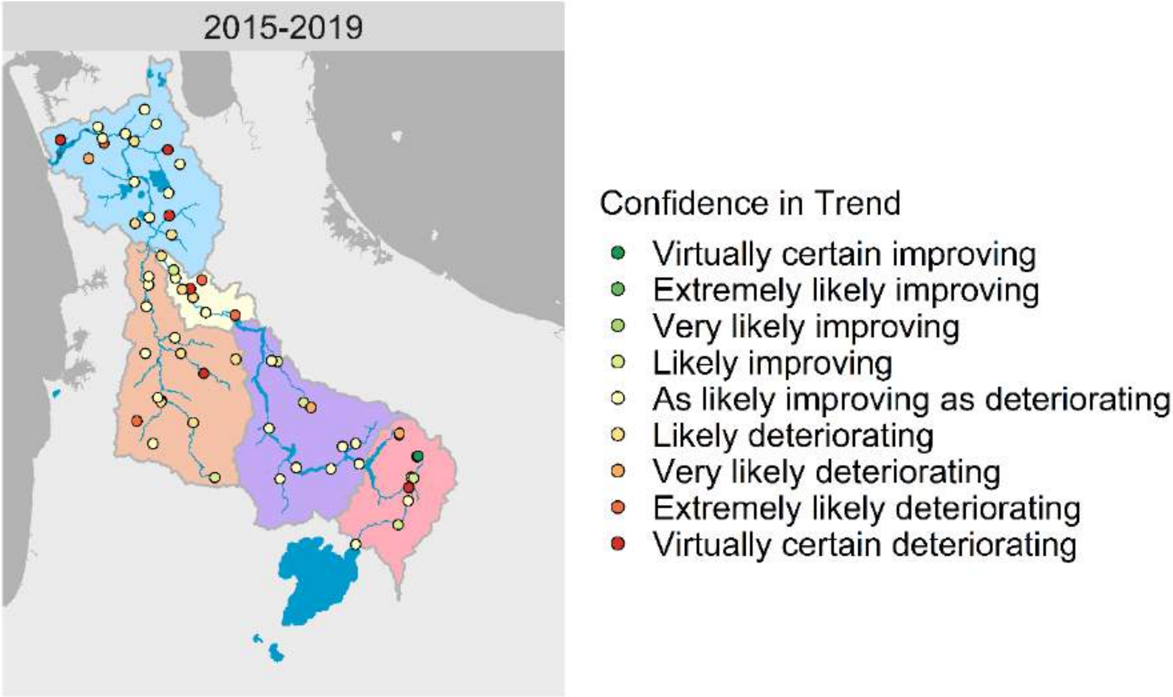

Figure 40: Trends in Waikato River ammoniacal nitrogen, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

Similar to the preceding five-year period, 43% (28 of 65) of ammoniacal nitrogen trends were as likely improving as deteriorating, with 28% (18 of 65) improving and 29% (19 of 65) deteriorating trends (Figure 41).

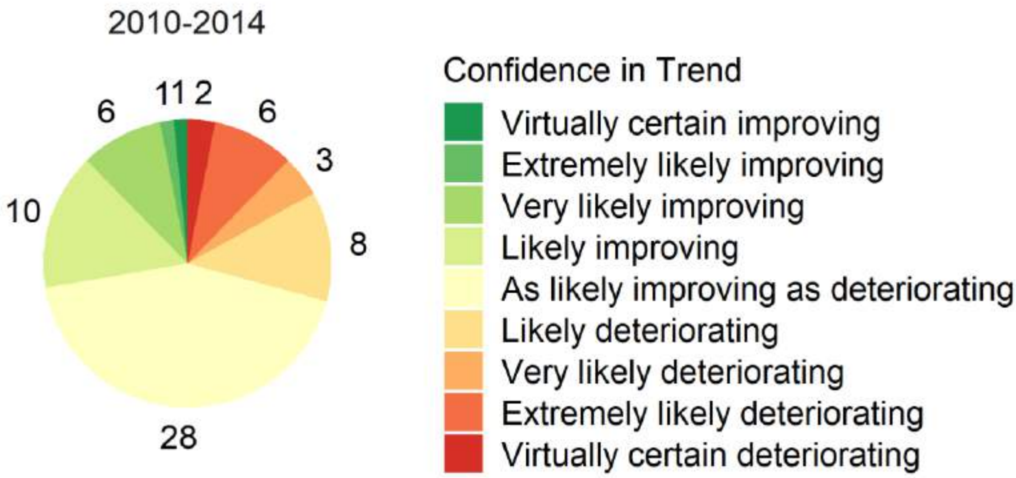

Figure 41: Trends in Waikato River ammoniacal nitrogen, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010-2019, 52% of trends in ammoniacal nitrogen were deteriorating (32 out of 62), with 13% (8 out of 62) improving and the remaining 35% (22 out of 62) as likely improving as deteriorating (Figure 42).

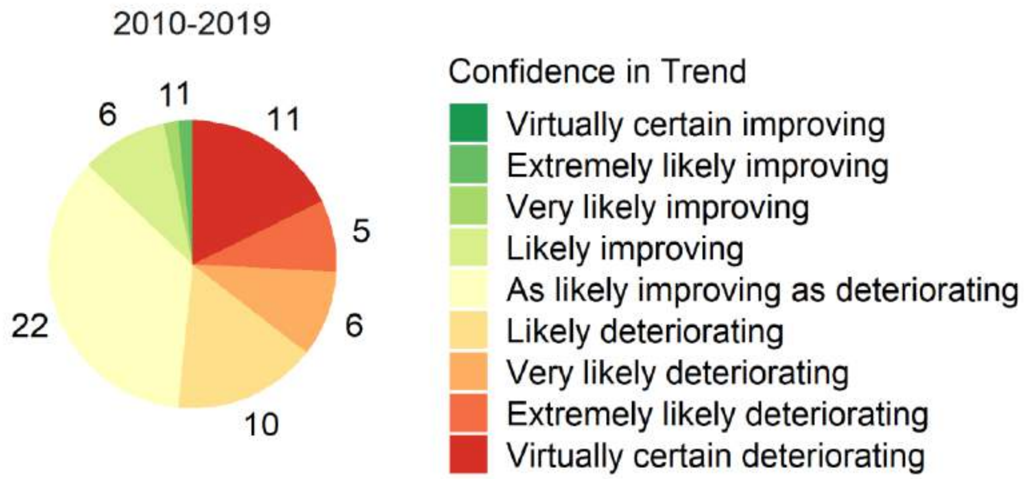

Figure 42: Trends in Waikato River ammoniacal nitrogen, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.10 Arsenic (As)

Why measure it?

Arsenic (As) is elevated in natural and/or anthropogenic geothermal discharges in the Waikato region, leading to contamination of waterways. Most of the arsenic in the Waikato River comes from geothermal condensate discharged from the Wairākei geothermal power station. Arsenic occurs in inorganic and organic forms. Inorganic arsenic is found in minerals, rocks and mine tailings. Organic arsenic is found in fish and shellfish and is sometimes called 'fish arsenic'. Organic arsenic is less harmful than inorganic arsenic (MoH 2015). WRC measures total arsenic (organic plus inorganic) in water. Water for human consumption should contain less than 0.01 parts per million (ppm = g/m^3). Arsenic may be toxic to aquatic organisms at concentrations below the drinking water guideline value (Williamson et al. 2016). Decreases in arsenic concentration are considered improving trends.

What are the trends?

Arsenic concentrations were measured at 10 Waikato River mainstem sites. Fifty percent (5 of 10) of the trends for the 2015-2019 time period were as likely improving as deteriorating and the remaining 50% (5 of 10) were improving (Figure 43). This contrasted with the preceding five-year period where 50% (5 of 10) of trends were deteriorating, 30% (3 of 10) were improving, and 20% (2 of 10) were as likely improving as deteriorating (Figure 45). Improving trends were recorded at sites in the upper Waikato River, while the as likely improving as deteriorating trends were recorded at sites in the mid-lower Waikato River (Figure 44).

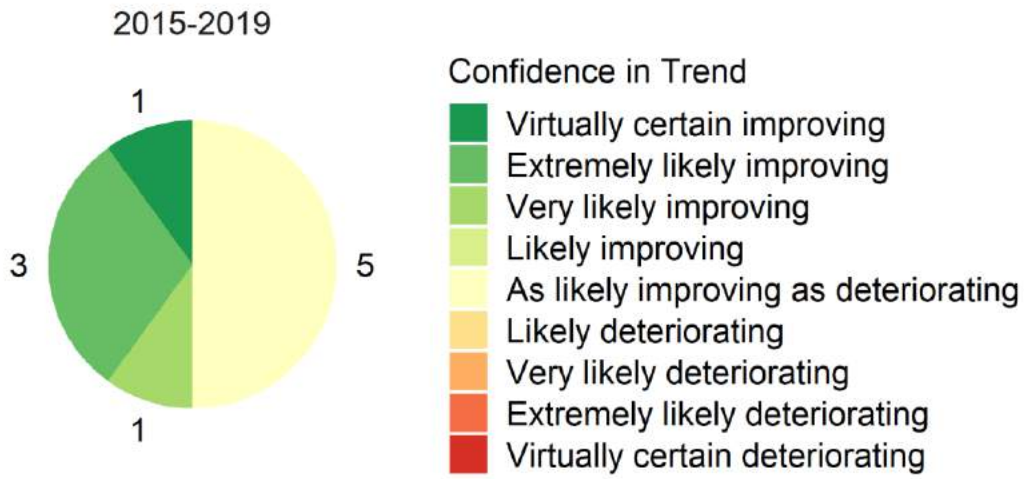

Figure 43: Trends in Waikato River arsenic, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

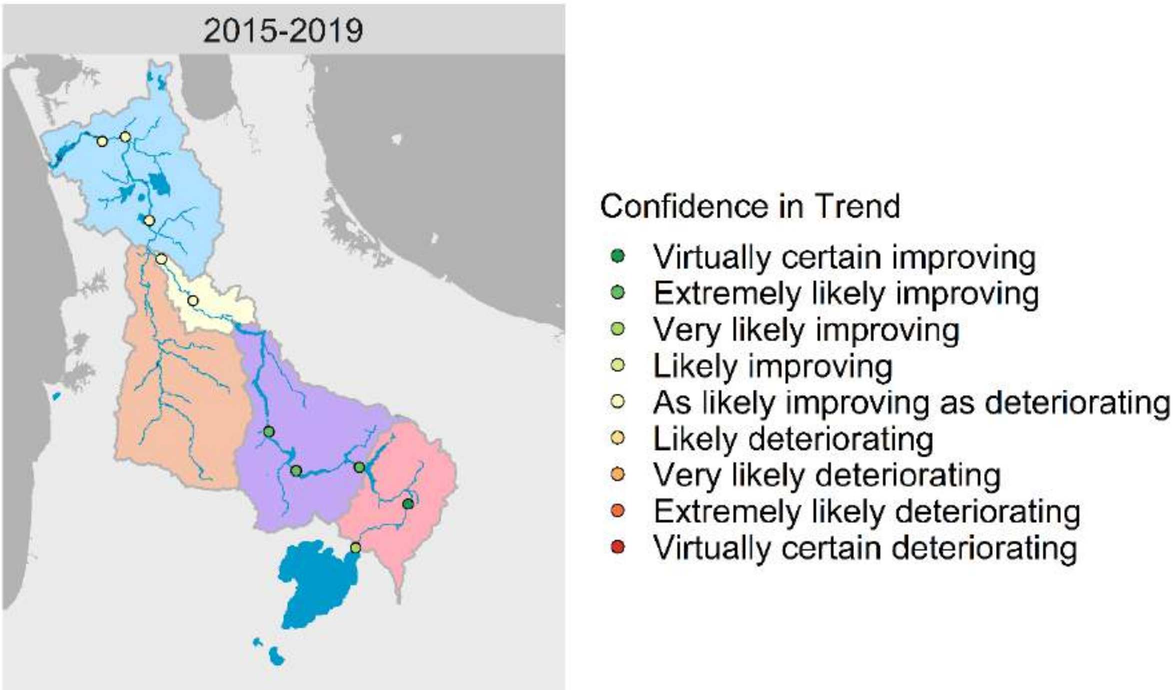

Figure 44: Trends in Waikato River arsenic, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

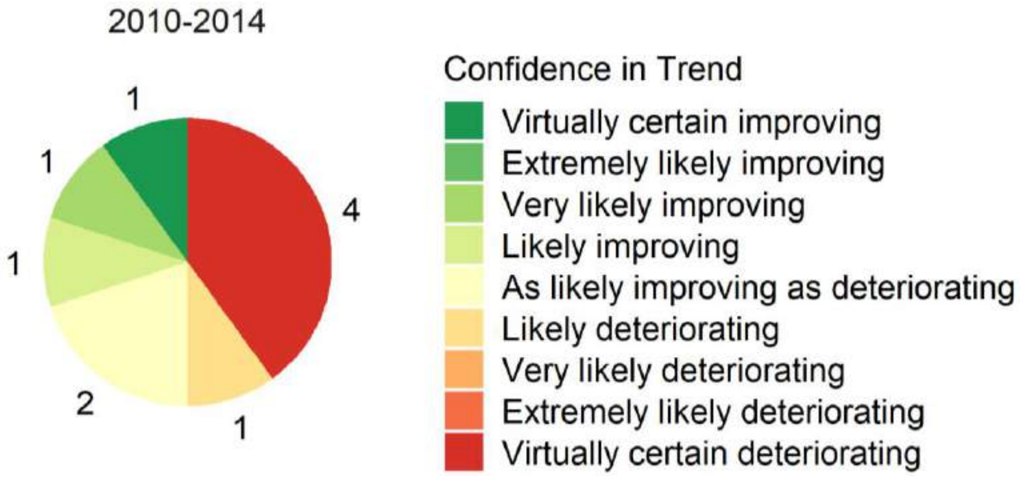

Figure 45: Trends in Waikato River arsenic, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

While the two five-year time periods show a mix of improving and deteriorating trends , the 10-year time period shows improving trends for all ten sites (Figure 46).

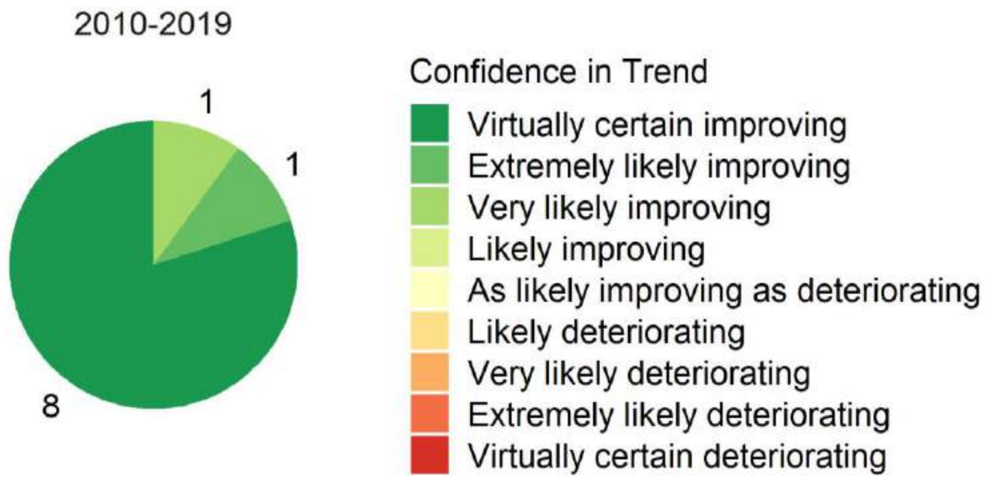

Figure 46: Trends in Waikato River arsenic, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.11 Macroinvertebrates

Why measure it?

Freshwater macroinvertebrates include insects, molluscs, crustaceans and worms. Macroinvertebrate species have varying tolerances to pollution (primarily organic enrichment) and habitat conditions (Moore and Neale 2008, Wagenhoff et al. 2016). In addition to organic enrichment, other factors known to affect macroinvertebrate community composition and abundance include temperature, flow, dissolved oxygen, and amounts of fine sediment (Moore and Neale 2008). Macroinvertebrates live in the water for prolonged periods and therefore provide an integrated picture (over a period of time), which provides additional information to spot measurements and samples for chemical analyses. Thus, the types and numbers of invertebrates living in a river can be used to provide information about water and habitat quality. Increases in macroinvertebrate metric scores are considered improving trends.

What are the trends?

Four macroinvertebrate indicators were considered in the trends analysis: The Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI), Percent EPT abundance and Percent EPT taxa. The MCI and QMCI are scores calculated based on the sensitivity of the different species present to the effects of organic pollution and stream habitat conditions Clapcott et al. 2017), using methods for hard and soft-bottomed streams. Measurement of these indicators is now a requirement of the NPS-FM 2020. MCI scores can be calculated from simple records of species presence or absence. The QMCI score requires count data for each species present. Where both hard and soft-bottomed habitats were sampled at a single site, the mean of the hard-bottomed and soft-bottomed scores was used. Percent EPT taxa and Percent EPT abundance represent river health based on the proportion of particularly sensitive species present - the mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera).

Percent EPT taxa is the proportion of these taxa of a count of all taxa collected at a site. Percent EPT abundance is the proportion of specimens of these taxa present out of all individual invertebrates collected at a site. Degraded streams typically have fewer EPT (Wagenhoff et al. 2016). While these metrics are often correlated, they do not always show the same trends and therefore all four are presented for comparison. Invertebrate data were only collected at sites in five tributary RCUs: OWT, KWT, MWT, WpT, and LWT.

Macroinvertebrate Community Index (MCI)

Forty-one percent (11 of 27) of the MCI trends over the 2015-2019 time period were as likely improving as deteriorating, with the remaining trends split between 33% (9 of 27) improving and 26% (7 of 27) deteriorating (Figure 47).

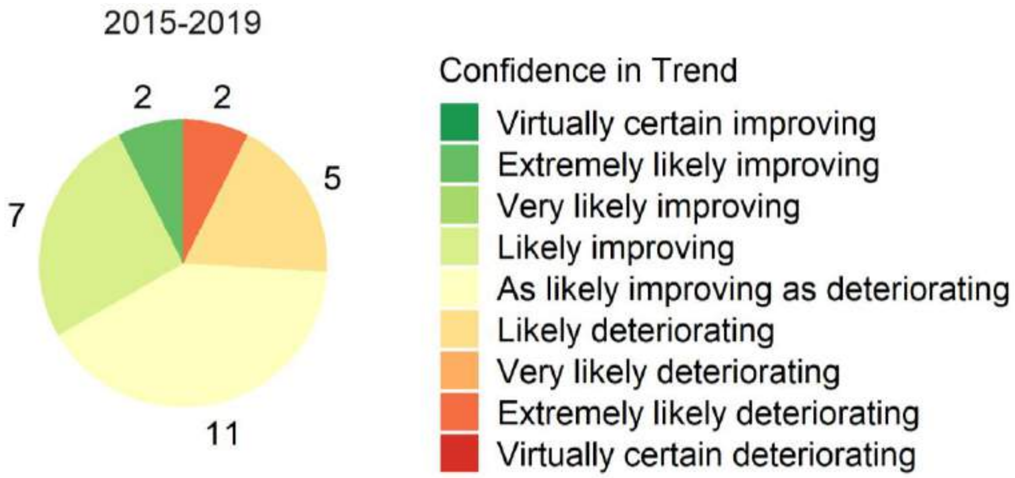

Figure 47: Trends in Waikato River Macroinvertebrate Community Index (MCI), 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

There were no strong differences in trends between RCUs, although there were more improving trends in the Ōhakuri to Karāpiro and Waipā tributaries in the 2015-2019 time period (Figure 48).

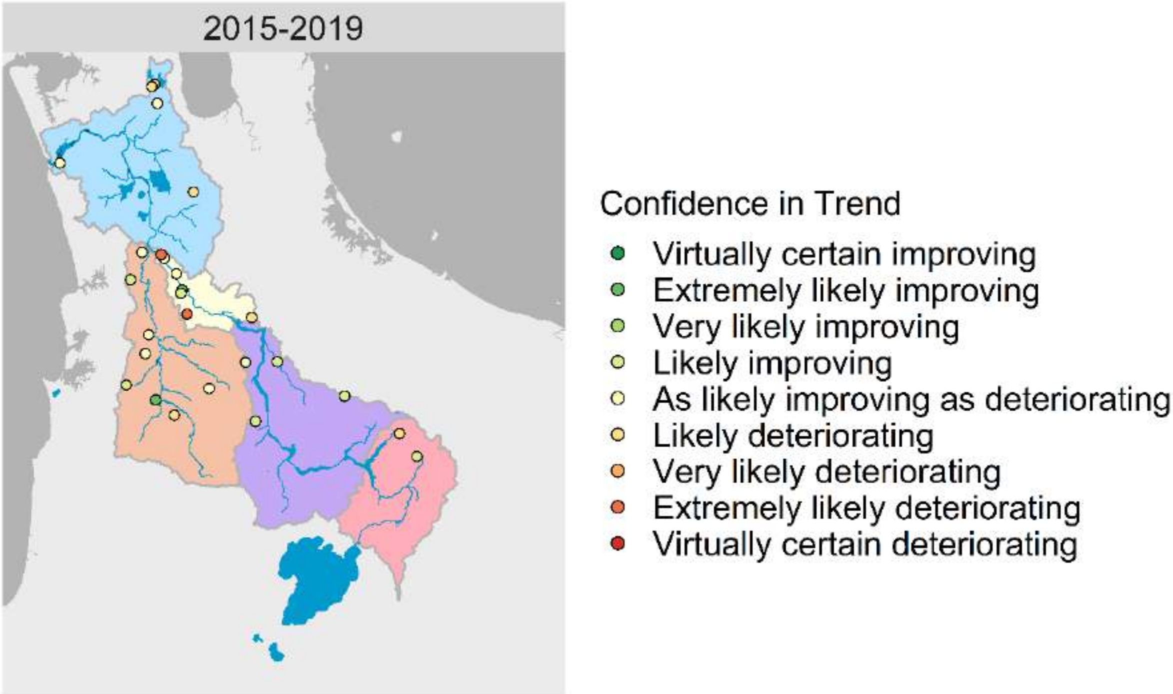

Figure 48: Trends in Waikato River Macroinvertebrate Community Index (MCI), 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

For the previous five-year time period (2010-2014), 70% (14 of 20) of MCI trends were as likely improving as deteriorating, with 5% (1 of 20) improving and 25% (5 of 20) deteriorating (Figure 49).

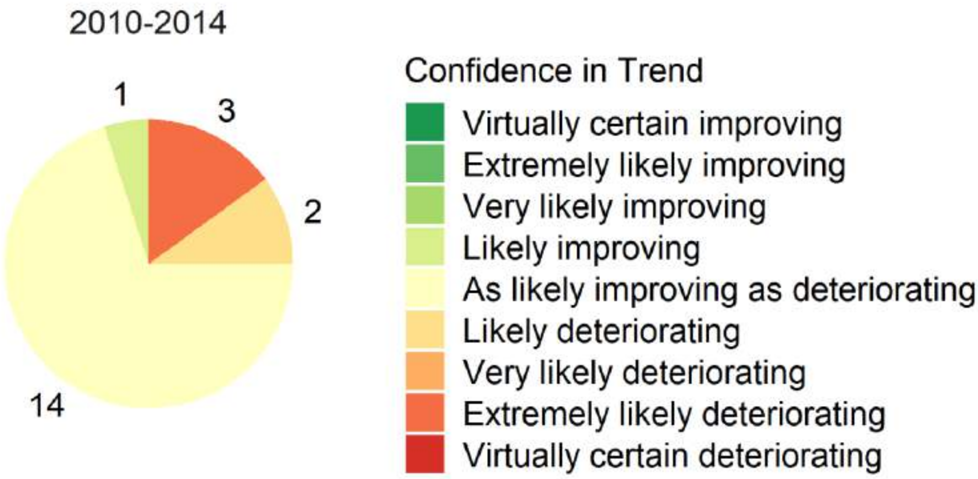

Figure 49: Trends in Waikato River Macroinvertebrate Community Index (MCI), 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010-2019, 41% (9 of 22) of trend results were as likely improving as deteriorating. Eighteen percent (4 of 22) of MCI trends in this time period were improving and 41% (9 of 22) were deteriorating (Figure 50).

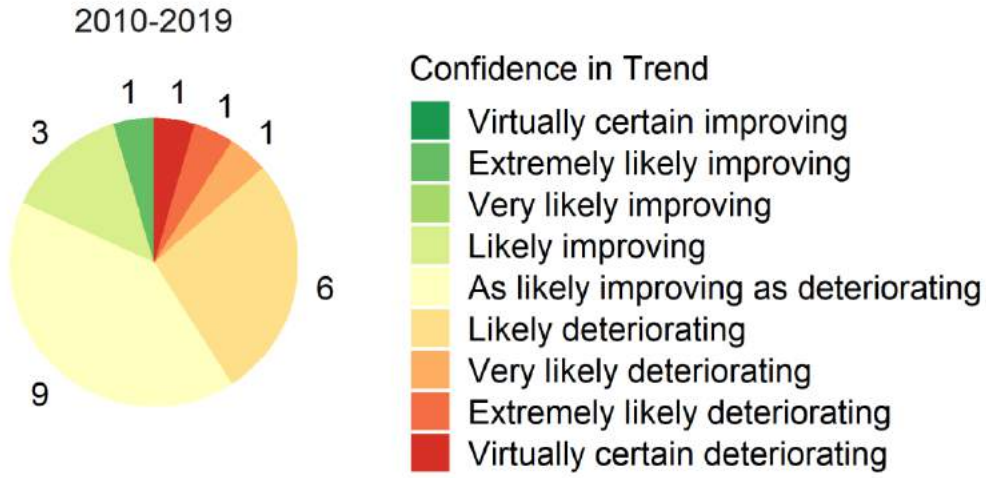

Figure 50: Trends in Waikato River Macroinvertebrate Community Index (MCI), 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Quantitative Macroinvertebrate Community Index (QMCI)

Fifty-nine percent (16 of 27) of QMCI trends over the five-year reporting period from 2015 to 2019 were as likely improving as deteriorating, with 33% (9 of 27) improving and two (8%) deteriorating (Figure 51).

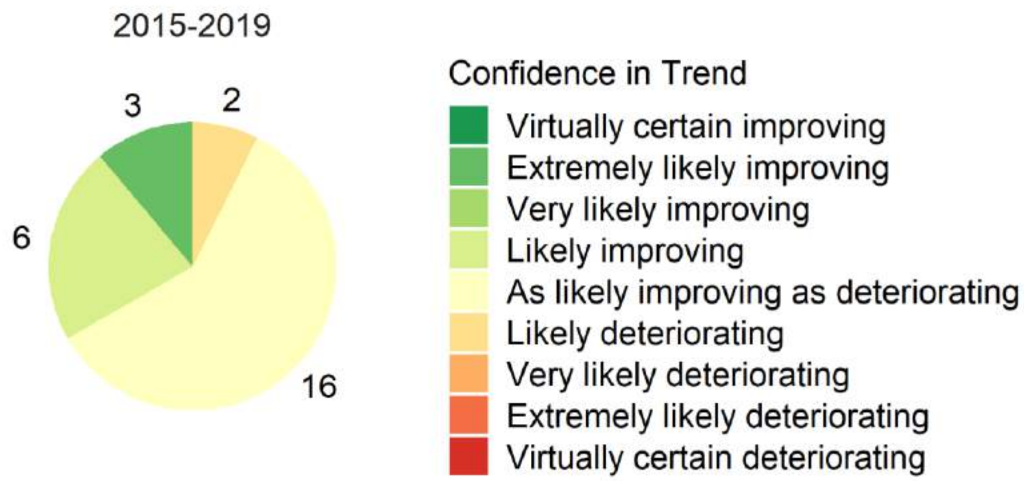

Figure 51: Trends in Waikato River Quantitative Macroinvertebrate Community Index (QMCI), 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Improving trends were mostly located in the Ōhakuri to Karāpiro tributaries and Waipā tributaries, with mostly as likely improving as deteriorating trends in the mid- and lower-Waikato RCUs (Figure 52).

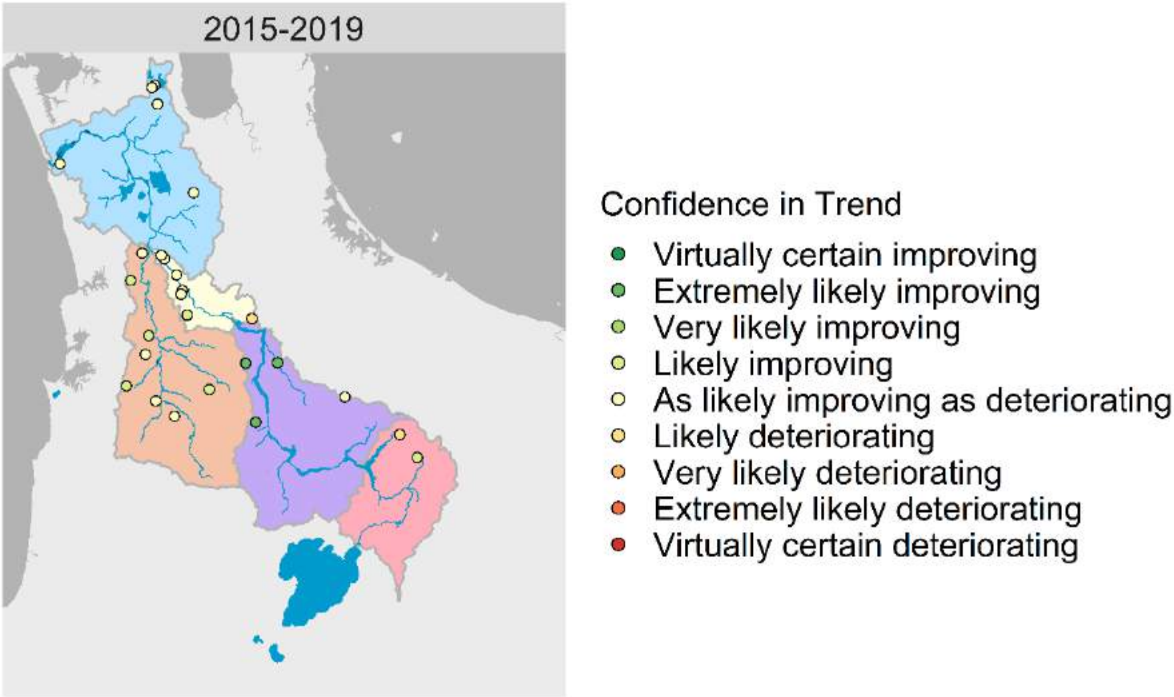

Figure 52: Trends in Waikato River Quantitative Macroinvertebrate Community Index (QMCI), 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In the preceding five-year time period (2010 to 2014), QMCI trends were largely split between 40% (8 of 20) as likely improving as deteriorating and 40% (8 of 20) deteriorating, although there were also 20% (4 of 20) improving trends (Figure 53).

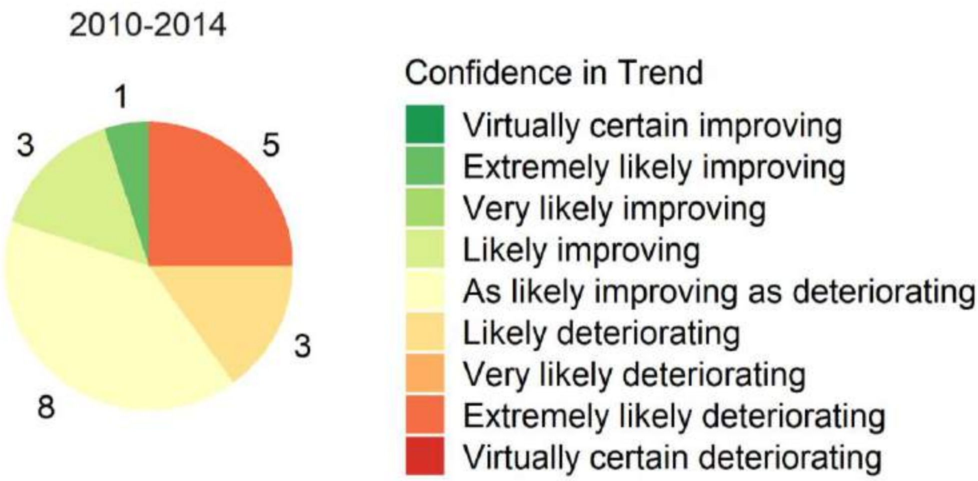

Figure 53: Trends in Waikato River Quantitative Macroinvertebrate Community Index (QMCI), 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010 to 2019, 68% of trends (15 of 22) were deteriorating, with 18% (4 of 22) improving and 13% (3 of 22) as likely improving as deteriorating (Figure 54).

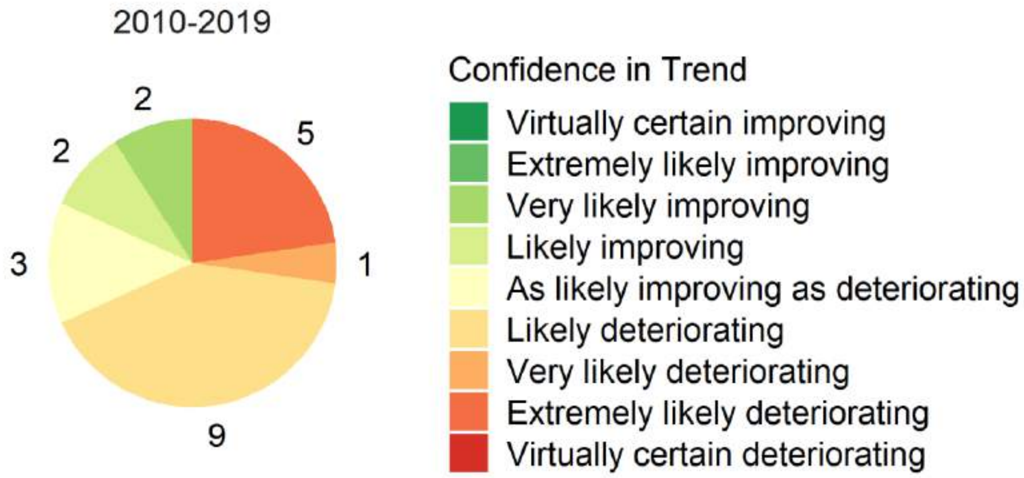

Figure 54: Trends in Waikato River Quantitative Macroinvertebrate Community Index (QMCI), 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the no. of sites showing trends in each category noted on the outside.

Percent EPT abundance

Percent EPT abundance trends over the 2015 to 2019 period were 59% (16 of 27) as likely improving as deteriorating, 22% (6 of 27) improving, and 19% (5 of 27) deteriorating (Figure 55).

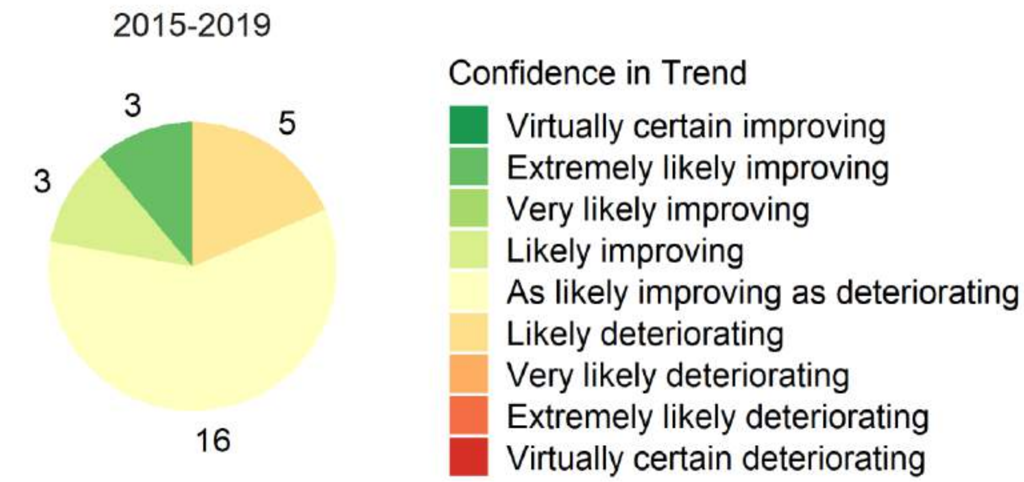

Figure 55: Trends in Waikato River percent EPT abundance, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

The improving trends in percent EPT abundance were spread across the Huka to Ōhakuri, Ōhakuri to Karāpiro, Waipā, and Karāpiro to Ngāruawāhia tributaries (Figure 56).

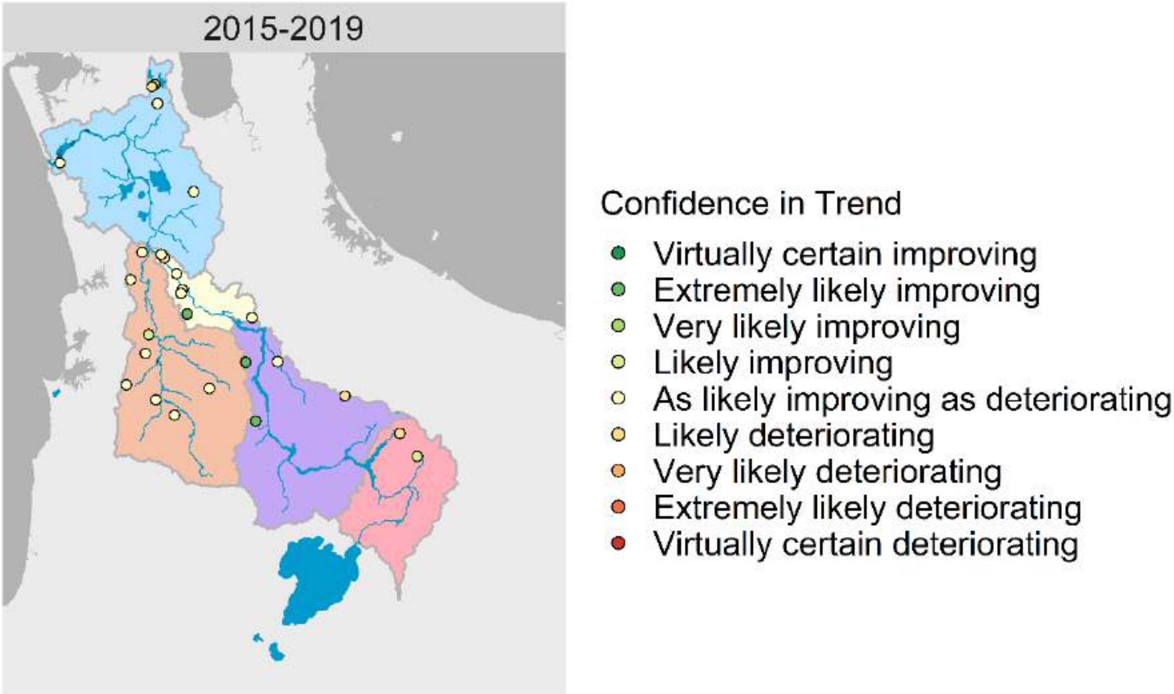

Figure 56: Trends in Waikato River percent EPT abundance, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In the preceding five-year time period, from 2010-2014, there were no improving trends in percent EPT abundance, instead 65% (13 of 20) of trends were as likely improving as deteriorating and 35% (7 of 20) of trends were deteriorating (Figure 57).

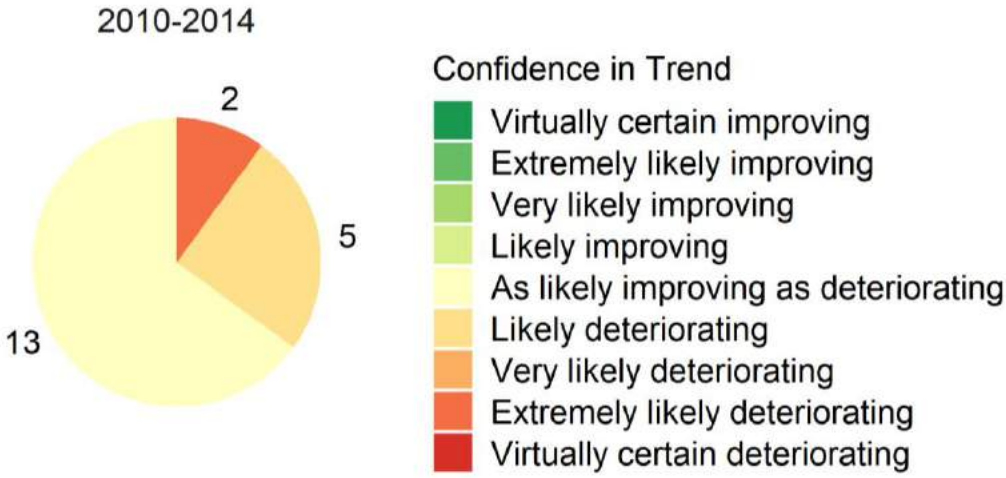

Figure 57: Trends in Waikato River percent EPT abundance, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the ten-year period from 2010 to 2019, seventy-seven percent (17 of 22) of trends in percent EPT abundance were deteriorating, with only 9% (2 of 22) improving and 13% (3 of 22) as likely improving as deteriorating (Figure 58).

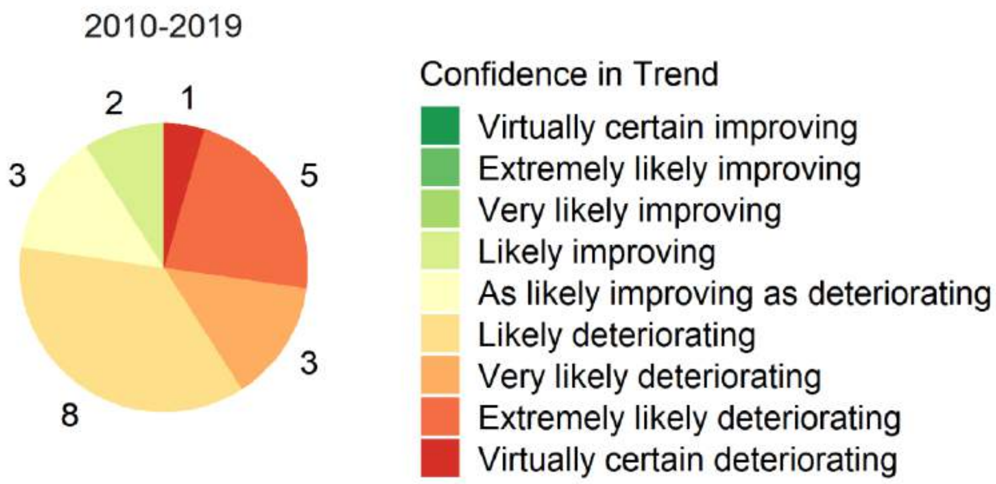

Figure 58: Trends in Waikato River percent EPT abundance, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the no. of sites showing trends in each category noted on the outside.

Percent EPT taxa

Sixty-three percent (17 of 27) of trends in percent EPT taxa were as likely improving as deteriorating for the 2015-2019 reporting period. Fifteen percent (4 of 27) were improving and 22% (6 of 27) of trends were deteriorating (Figure 59).

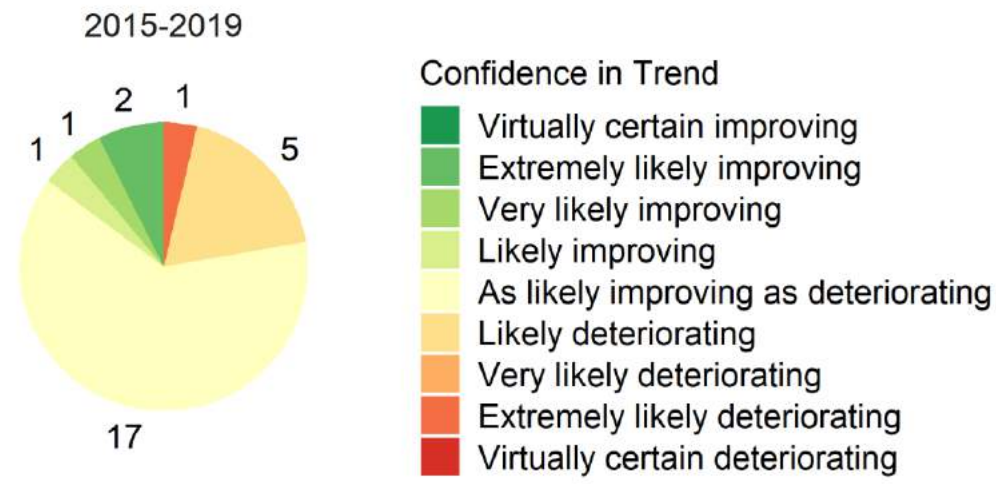

Figure 59: Trends in Waikato River percent EPT taxa, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Two of the improving trends were located in the Karāpiro to Ngāruawāhia RCU, one was in each of the Ōhakuri to Karāpiro and the Waipā RCUs. The majority of deteriorating trends were located in the Ngāruawāhia to Te Pūaha RCU (Figure 60).

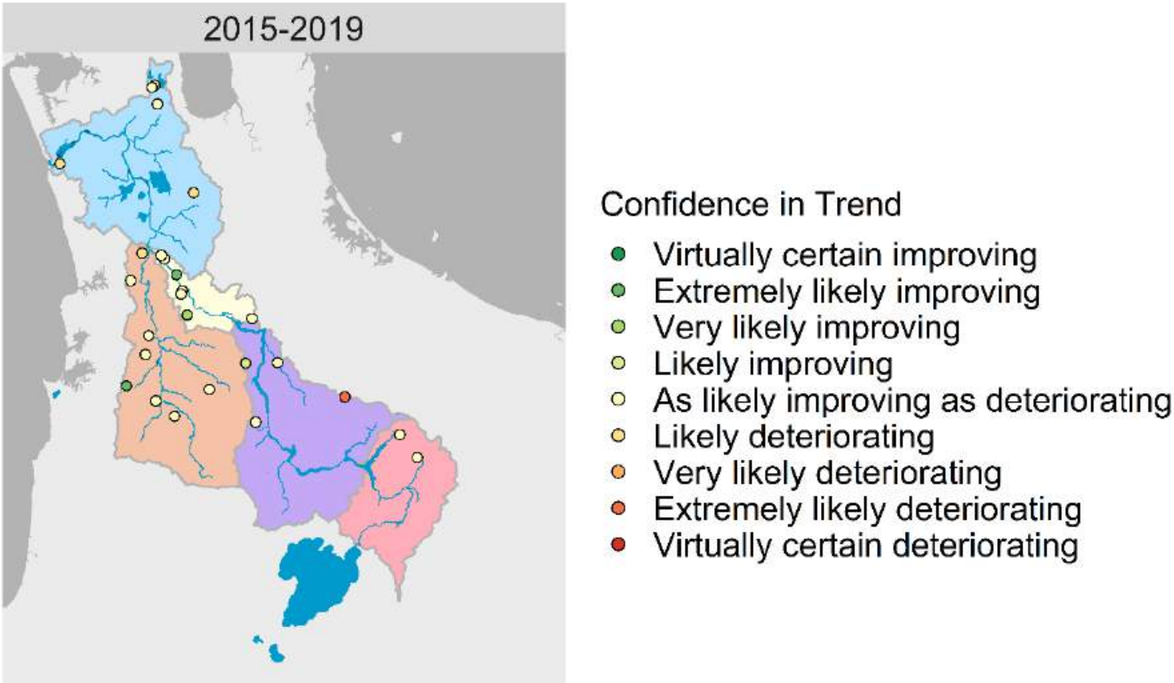

Figure 60: Trends in Waikato River percent EPT taxa, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

Over the preceding five-year period, from 2010-2014, trends in percent EPT taxa were again largely as likely improving as deteriorating (55%, 11 of 20), with 20% of trends improving (4 of 20) and 25% of trends deteriorating (5 of 20) (Figure 61).

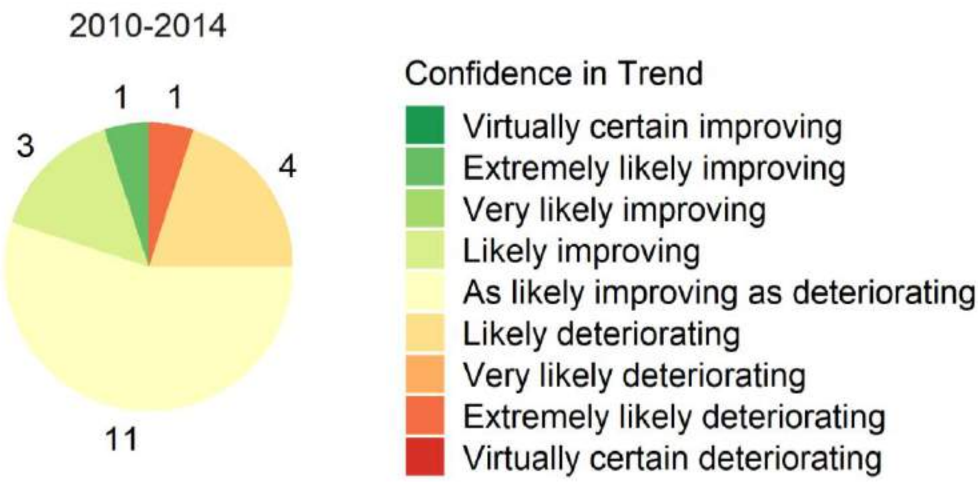

Figure 61: Trends in Waikato River percent EPT taxa, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Trends in percent EPT taxa over the 10-year period (2010 to 2019) were more mixed, with more than half (59%, 13 of 22) deteriorating, 14% (3 of 22) improving, and 27% (6 of 22) as likely improving as deteriorating (Figure 62).

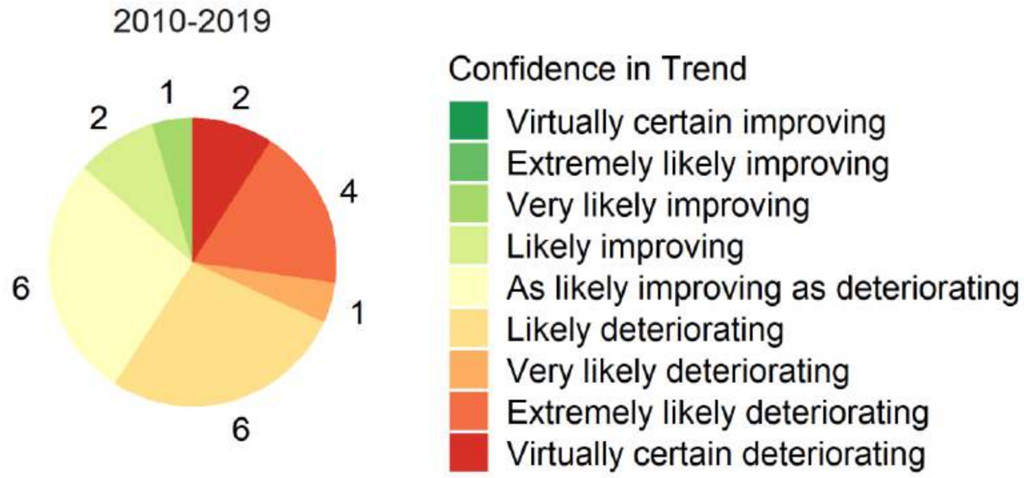

Figure 62: Trends in Waikato River percent EPT taxa, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.12 Periphyton

Why measure it?

Periphyton are the algae that grow on riverbeds, usually attached to rocks but also wood, aquatic plants and sometimes finer sediments. They play an important role in the natural functioning of stream and river ecosystems, influencing nutrient and oxygen cycles. Periphyton growth is the result of primary production, and underpins the food web, providing an important food source and habitat for living creatures, especially aquatic insects. However, where nutrient levels are elevated and where there is plenty of light and flow conditions are stable for long periods of time, periphyton can proliferate, impair aesthetic values, and impact negatively upon aquatic life and reduce biodiversity.

Periphyton is generally more abundant and more frequently monitored at hard-bottom river sites – those with beds consisting of gravels, cobbles or boulders, than at sites dominated by silt and sand. Results for two periphyton indicators were analysed: areal cover of long filamentous algae and cover of thick mats. These are key indicators of periphyton nuisance growths which detrimentally impact upon stream aesthetic, recreational and ecological values (Biggs 2000, Matheson et al. 2012). Periphyton is deemed a nuisance when stream coverage exceeds 30% for long filaments, and 60% for thick mats (Biggs 2000). Decreases in periphyton long filament and thick mat covers are considered improving trends. We note, however, that many sites had consistently low (or no) stream bed coverage with periphyton, resulting in many as likely improving as deteriorating trends.

What are the trends? – Cover of long filaments

Trends in periphyton long filament cover were discernible at 25 sites from 2015 to 2019. Trends were either likely improving (7 of 25, 28%) or as likely improving as deteriorating (17 of 25, 68%) over this reporting period, with 1 deteriorating trend (Figure 63).

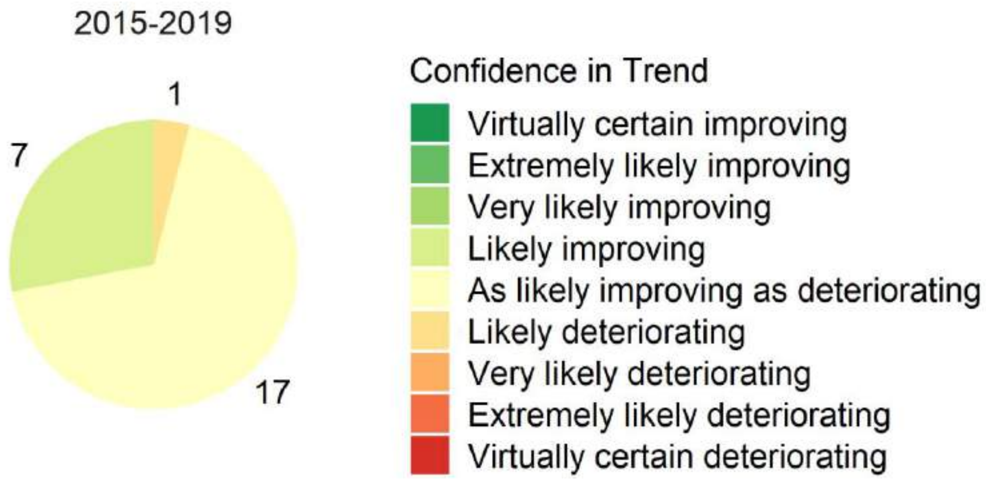

Figure 63: Trends in Waikato River periphyton long filament cover, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Improving trends in periphyton long filament cover were spread across all RCUs except the Huka to Ōhakuri RCU, which contained one as likely improving as deteriorating trend and one deteriorating trend (Figure 64).

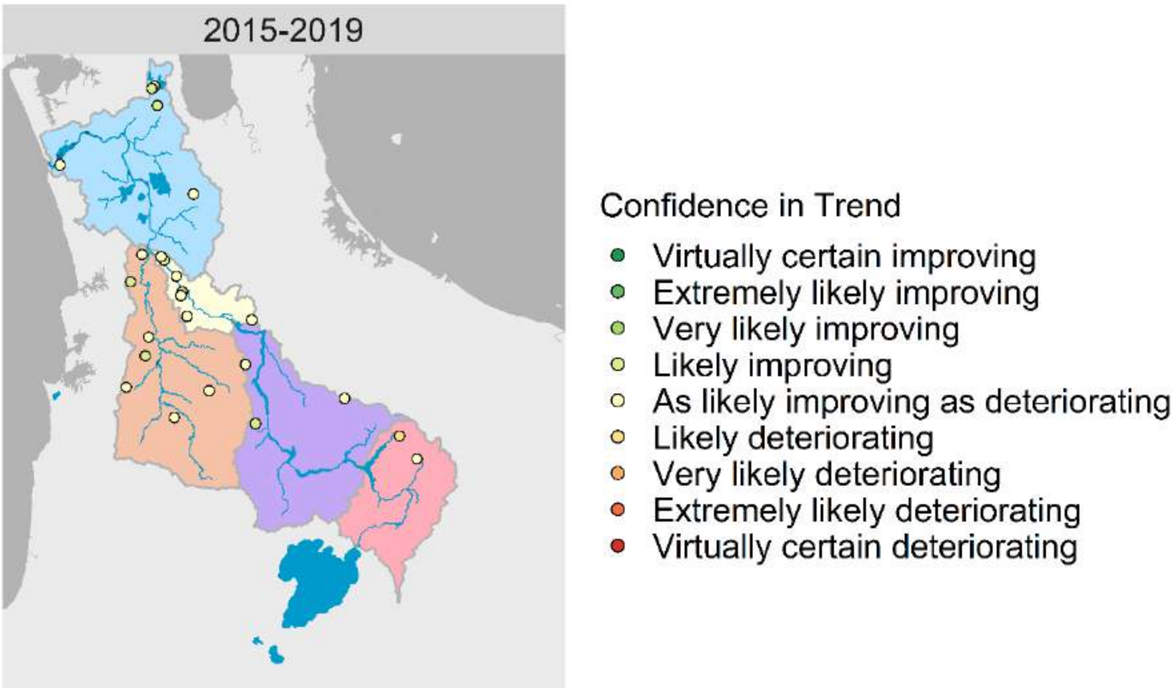

Figure 64: Trends in Waikato River periphyton long filament cover, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

Trends in periphyton long filament cover were also largely as likely improving as deteriorating over the 2010-2014 time period, with 83% (15 of 18) of trends as likely improving as deteriorating, 6% (1 of 18) improving, and 11% (2 of 11) deteriorating (Figure 65).

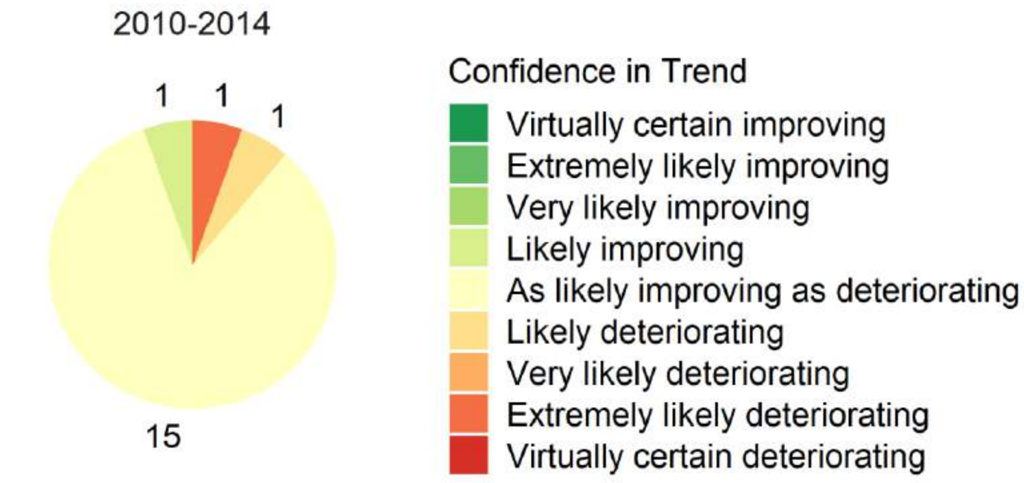

Figure 65: Trends in Waikato River periphyton long filament cover, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010-2019, 29% (6 of 21) of trends were improving, 14% (3 of 21) were deteriorating, and 57% (12 of 21) were as likely improving as deteriorating (Figure 66).

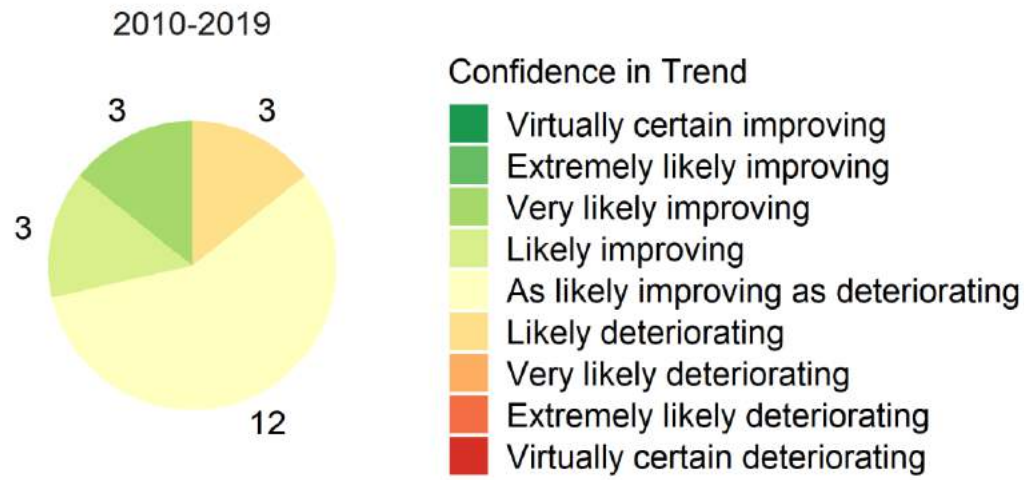

Figure 66: Trends in Waikato River periphyton long filament cover, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

What are the trends? – Cover of thick mats

Ninety-two percent (23 of 25) of trends in periphyton thick mat cover were as likely improving as deteriorating over the 2015-2019 reporting period (Figure 67). The remaining 8% (2 of 25) of trends were improving.

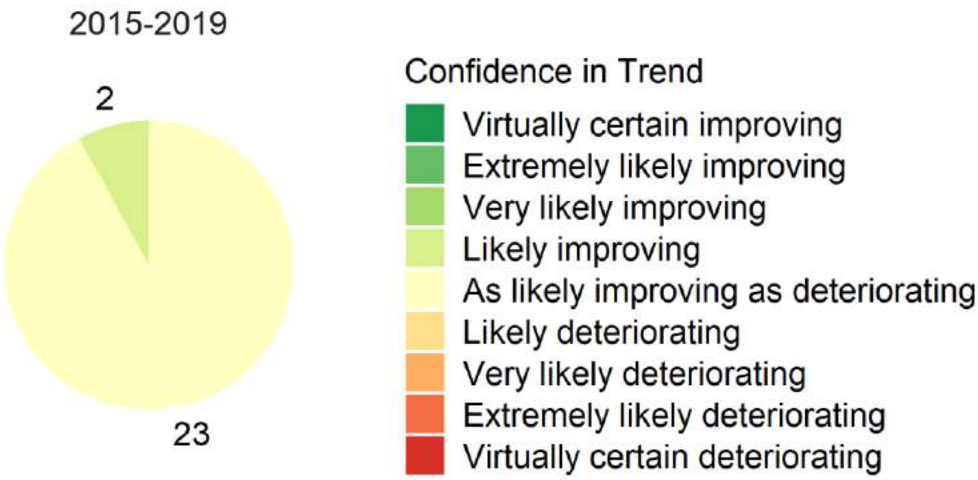

Figure 67: Trends in Waikato River periphyton thick mat cover, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

There was one improving trend located in the Ōhakuri to Karāpiro RCU and one in the Karāpiro to Ngāruawāhia RCU (Figure 68).

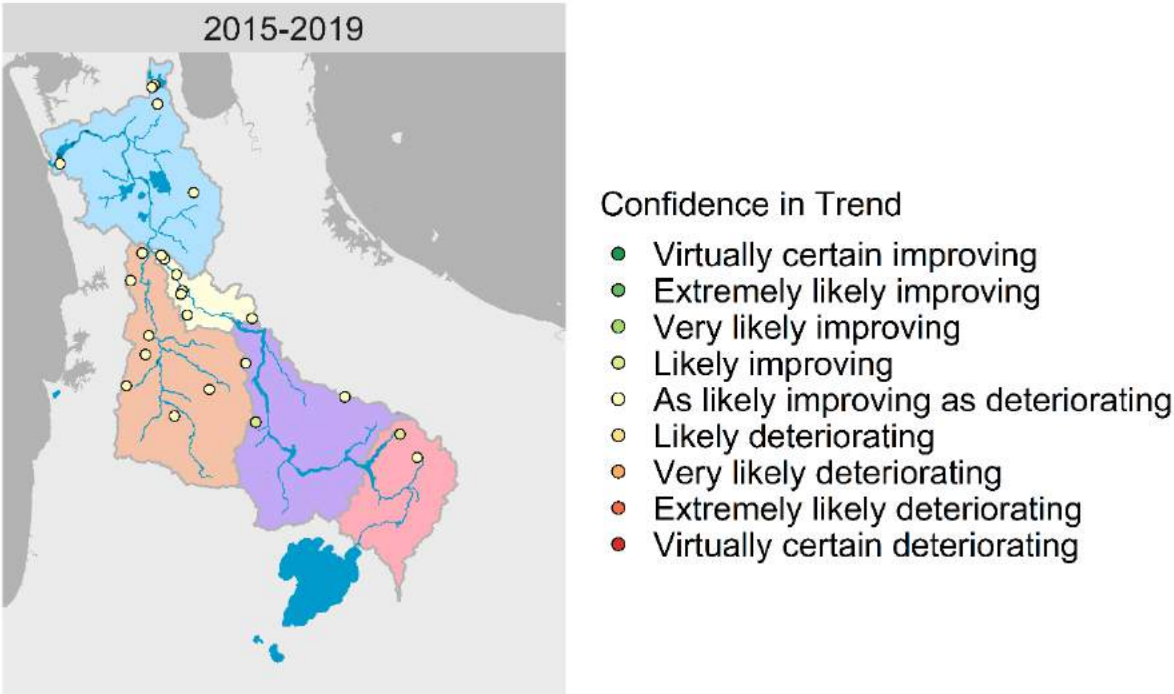

Figure 68: Trends in Waikato River periphyton thick mat cover, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In the preceding five-year period, from 2010-2014, 83% of trends in periphyton thick mat cover were again as likely improving as deteriorating (15 of 18), along with 27% (3 of 18) deteriorating trends (Figure 69).

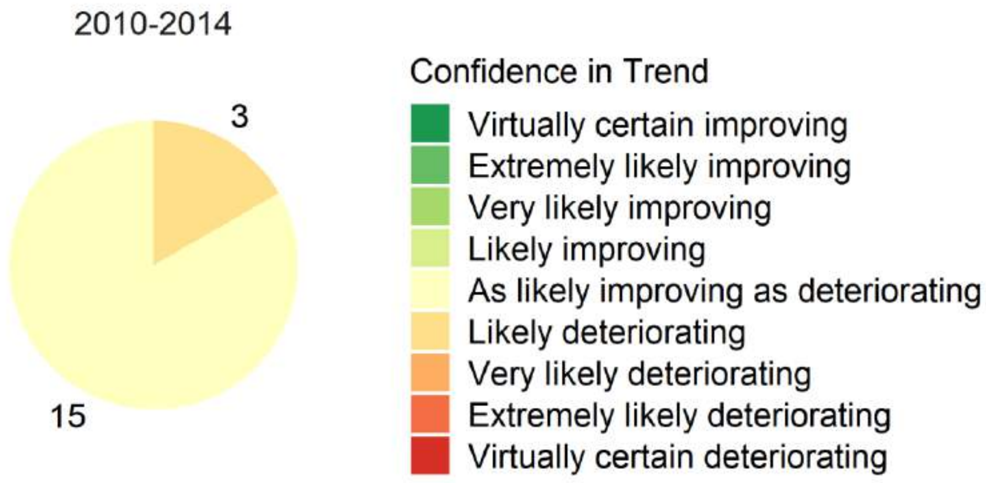

Figure 69: Trends in Waikato River periphyton thick mat cover, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010 to 2019, 10% (2 of 21) of trends in periphyton thick mat cover were improving, 19% (4 of 21) were deteriorating, and the majority (71%, 15 of 21) were as likely improving as deteriorating (Figure 70).

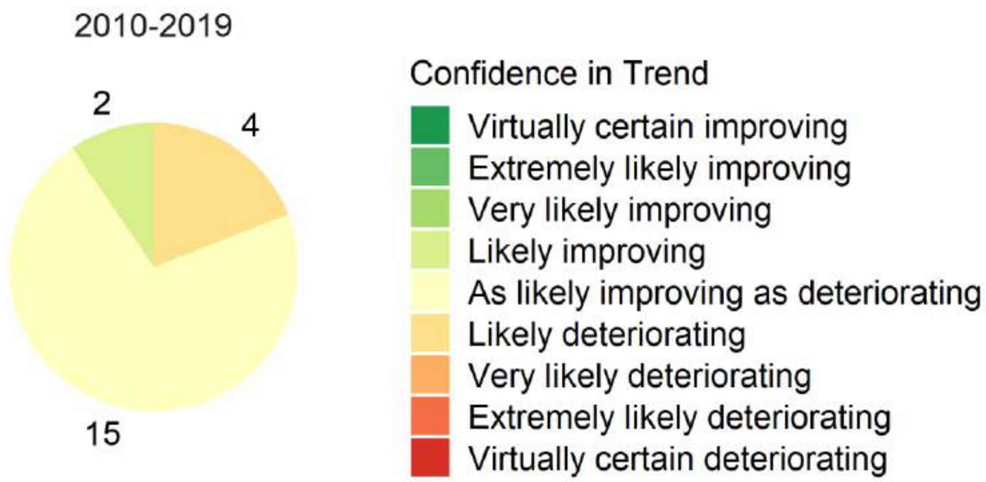

Figure 70: Trends in Waikato River periphyton thick mat cover, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.13 Macrophytes

Why measure it?

Macrophytes are rooted aquatic plants that grow in streams and rivers. They also occur in lakes, but lake macrophyte indicators are not considered in this report. Macrophytes often grow abundantly in lowland rivers where there are fine sediments into which they can easily root, but some species (such as watercress) can also grow from the riverbanks and sprawl across the water surface. In like manner as periphyton, macrophytes are important components of waterways, providing habitat and influencing stream hydraulics, nutrient and oxygen cycles. Stable flows, high light levels, and nutrient availability encourage their growth. However, some species (mostly exotic) can grow to problem levels when conditions are favourable, creating channel blockages, increasing flooding risk and replacing native vegetation.

Macrophytes are most common, and therefore monitored, at soft-bottom river sites – those with sandy or silty beds. Three macrophyte indicators were considered in the trends analysis:

- the percentage of stream channel water depth clogged by macrophytes (**channel clogginess**),
- the percentage of stream bed covered by exotic species (**exotic cover**), and
- the percentage of stream bed covered by native species (**native cover**).

These three indicators provide important information on different aspects of the macrophyte community. The "clogginess" indicator tells us how much of the stream or river channel is occupied by aquatic plants, this is an important indicator of potential flow impedance (and thus flooding risk), and how much the aquatic plants present may trap fine sediments and contribute to reducing oxygen levels in the river water overnight. The "exotic" and "native" cover indicators tell us how impacted the river site is by introduced aquatic plant species, with a low or no exotic cover status and a higher native cover status being more desirable outcomes.

Macrophyte data were sufficient to enable trends determination for 23 sites in five RCUs: OWT, KWT, MWT, WpT, and LWT. Overall, macrophyte clogginess and coverage (native or exotic) were relatively high (>50%) at few sites. Decreases in channel clogginess and exotic cover are considered improving trends, while increases in native cover are considered improving trends.

What are the trends? – Channel clogged by macrophytes

Trends in macrophyte channel clogginess over the 2015-2019 reporting period were largely as likely improving as deteriorating (60%, 15 of 25), with 32% (8 of 25) of trends improving and 8% (2 of 25) of trends deteriorating (Figure 71).

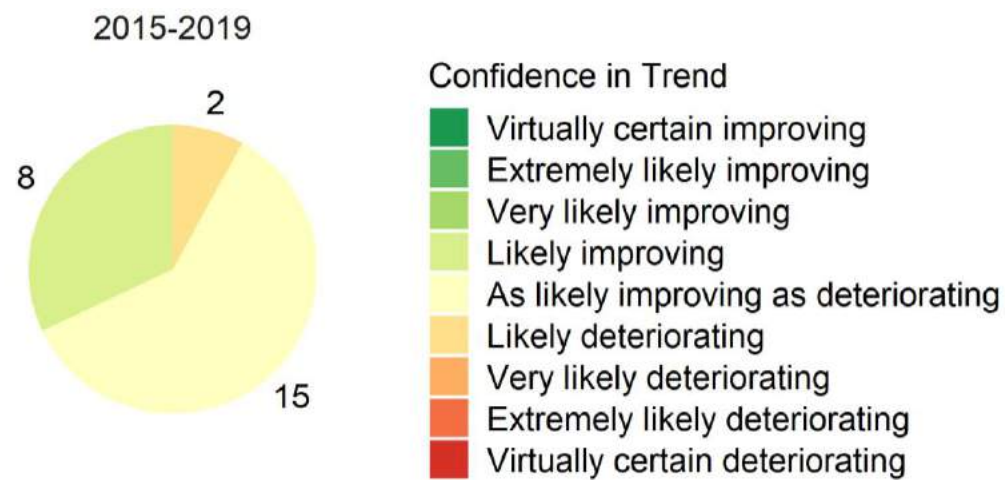

Figure 71: Trends in Waikato River macrophyte channel clogginess, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Six of the seven improving trends in macrophyte channel clogginess over the 2015-2019 time period were located in the Karāpiro to Ngāruawāhia RCU, along with one in the Waipā RCU and one in the Huka to Ōhakuri RCU (Figure 72).

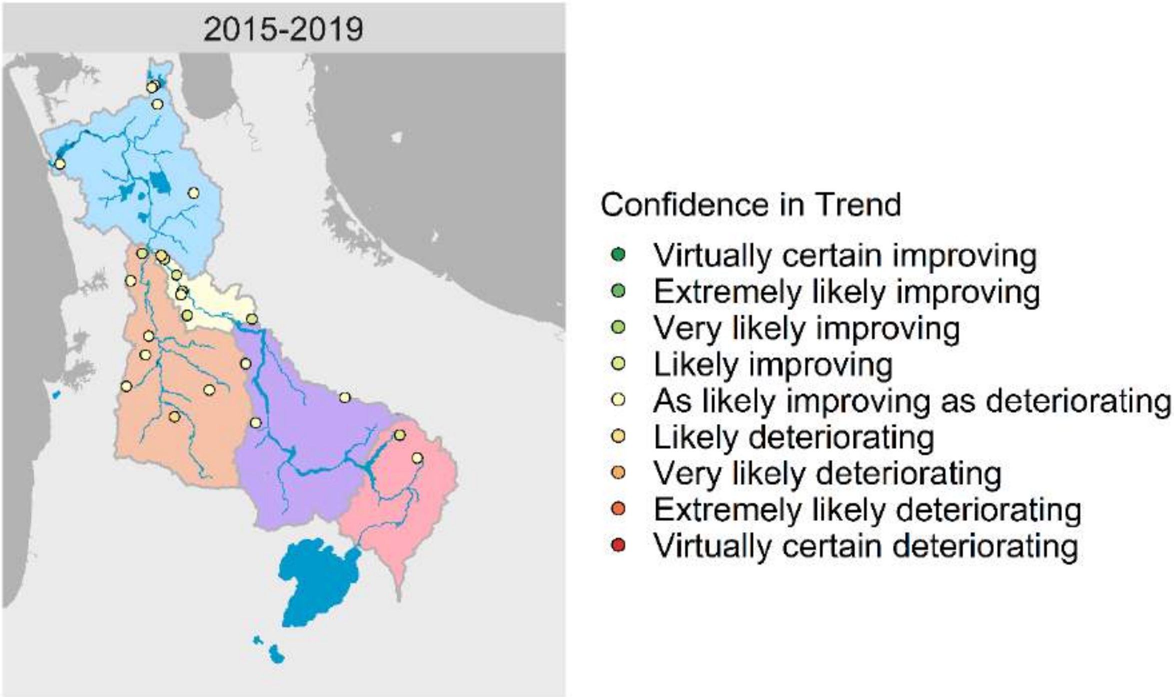

Figure 72: Trends in Waikato River macrophyte channel clogginess, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

A similar pattern of trends in macrophyte channel clogginess occurred over the previous five-year period (2010 to 2014). Most trends were as likely improving as deteriorating (78%, 14 of 18), along with 17% (3 of 18) improving trends and one deteriorating trend (Figure 73).

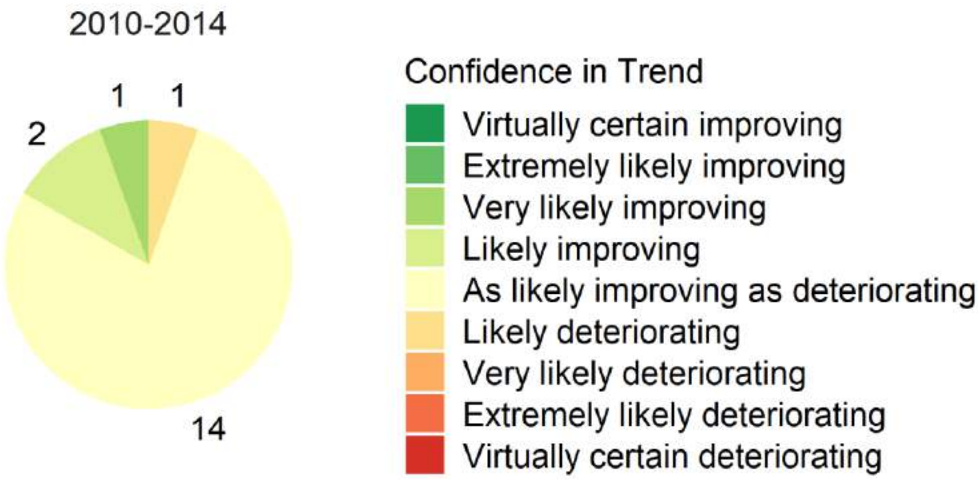

Figure 73: Trends in Waikato River macrophyte channel clogginess, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Trends in macrophyte channel clogginess were predominately as likely improving as deteriorating over the 10-year period from 2010-2019. Seventy percent (14 of 20) trends were as likely improving as deteriorating, 15% (3 of 20) were improving, and 15% (3 of 20) were deteriorating (Figure 74).

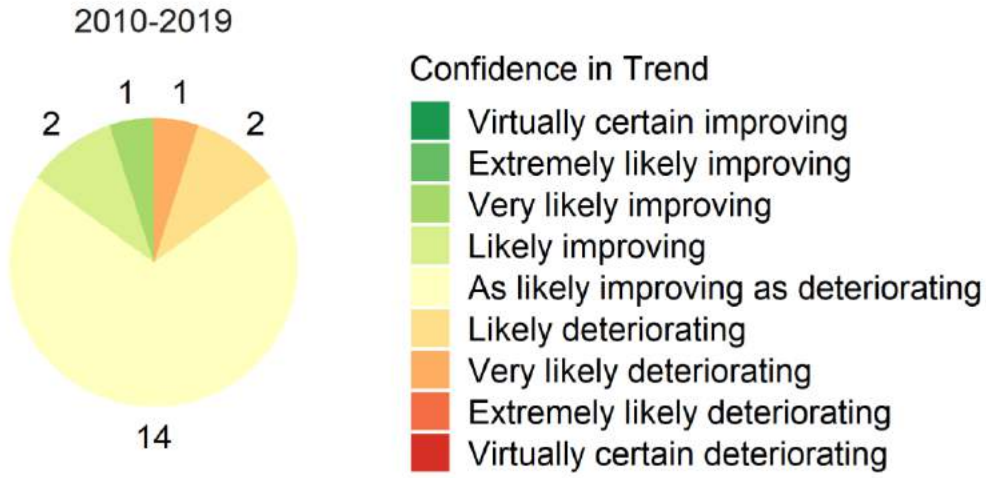

Figure 74: Trends in Waikato River macrophyte channel clogginess, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

What are the trends? – Exotic cover

Trends in percent cover of exotic macrophytes over the 2015-2019 reporting period were largely as likely improving as deteriorating (76%, 19 of 25). Sixteen percent (4 of 25) of trends were improving and 8% (2 of 25) were deteriorating (Figure 75).

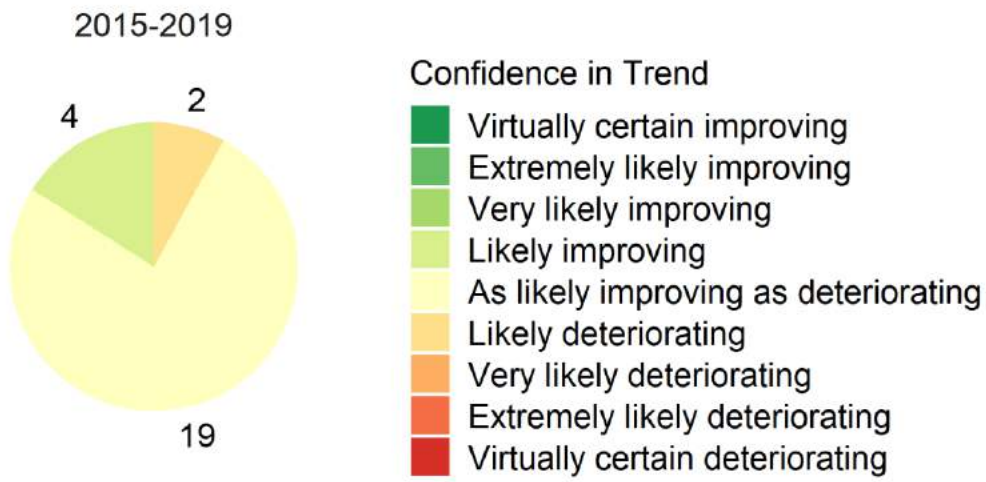

Figure 75: Trends in Waikato River exotic macrophyte cover, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Three improving trends and the two deteriorating trends were located in the Karāpiro to Ngāruawāhia RCU. The fourth improving trend was in the Huka to Ōhakuri RCU. Trends in exotic macrophyte cover in the other RCUs were as likely improving as deteriorating (Figure 76).

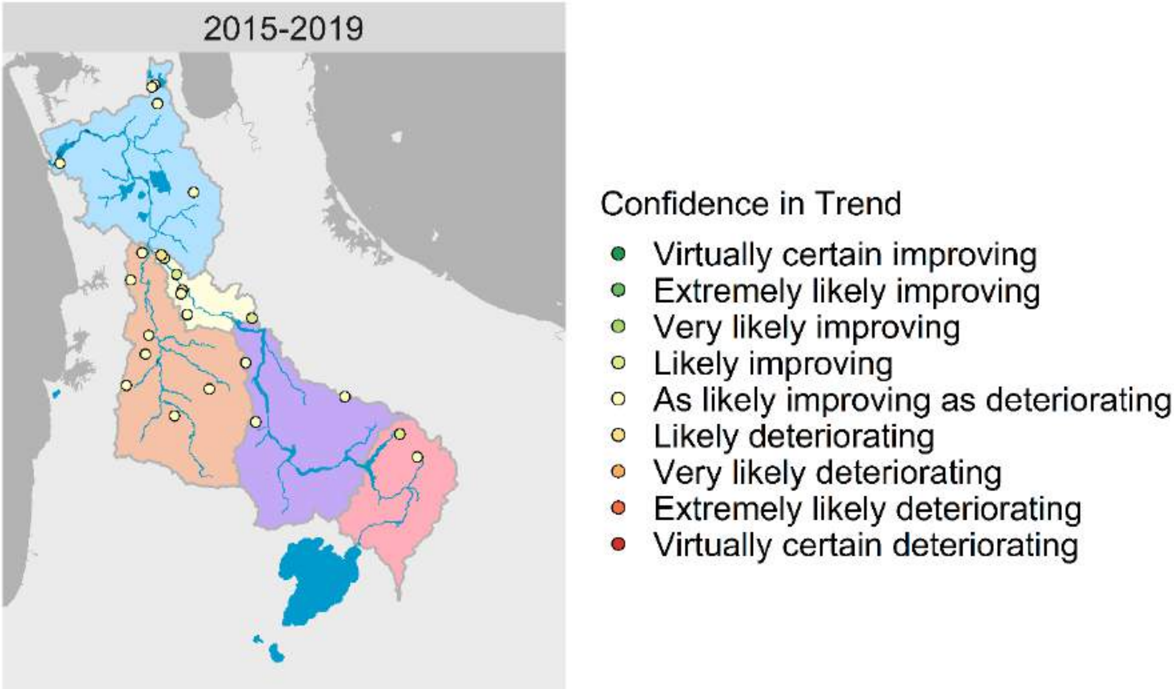

Figure 76: Trends in Waikato River exotic macrophyte cover, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In the preceding five-year period (2010-2014), 89% (16 of 18) of trends in exotic macrophyte cover were as likely improving as deteriorating. There was also one improving and one deteriorating trend (Figure 77).

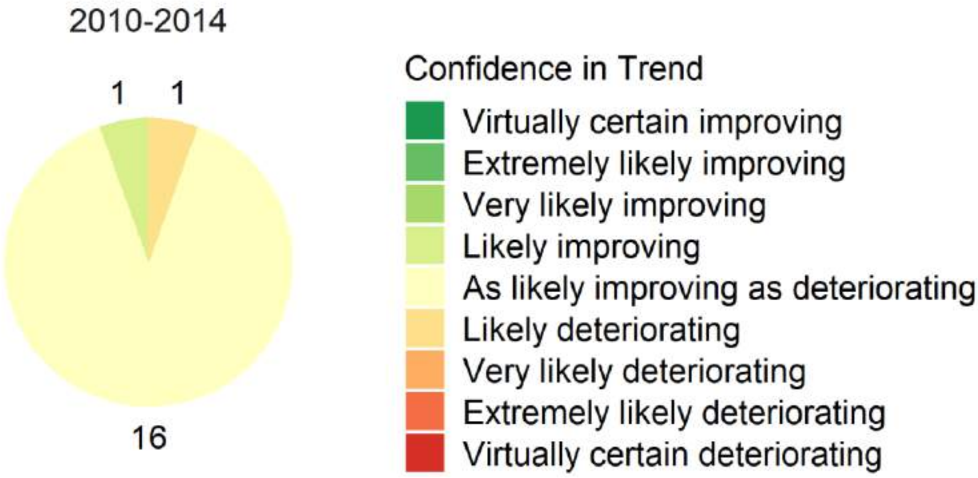

Figure 77: Trends in Waikato River exotic macrophyte cover, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010-2019, there were slightly more deteriorating (25%, 5 of 20) than improving (15%, 3 of 20) trends in exotic macrophyte cover. However, the majority of trends (60%, 12 of 20) remained as likely improving as deteriorating (Figure 78).

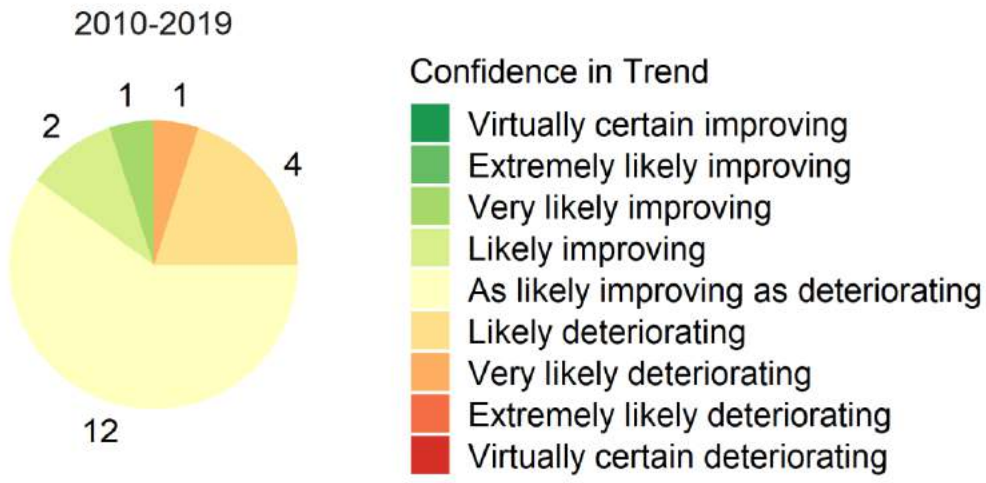

Figure 78: Trends in Waikato River exotic macrophyte cover, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

What are the trends? – Native cover

Trends in native macrophyte cover over the 2015-2019 reporting period were 80% (20 of 25 sites) as likely improving as deteriorating, along with 4% (1 of 25) improving trends and 16% (4 of 25) deteriorating trends (Figure 79).

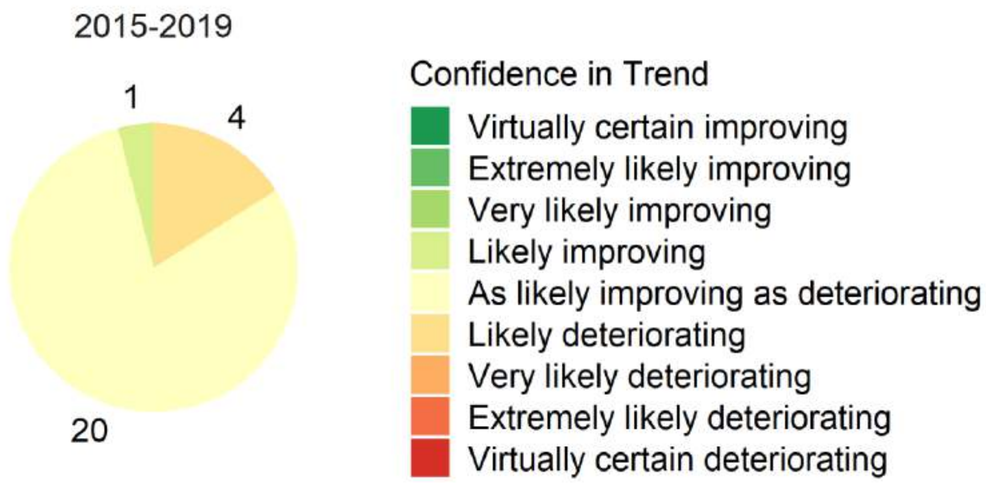

Figure 79: Trends in Waikato River native macrophyte cover, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Three of the four deteriorating trends in native macrophyte cover over the 2015-2019 period were located in the Karāpiro to Ngāruawāhia RCU, along with one in the Waipā RCU. The single improving trend was also located in the Karāpiro to Ngāruawāhia RCU (Figure 80).

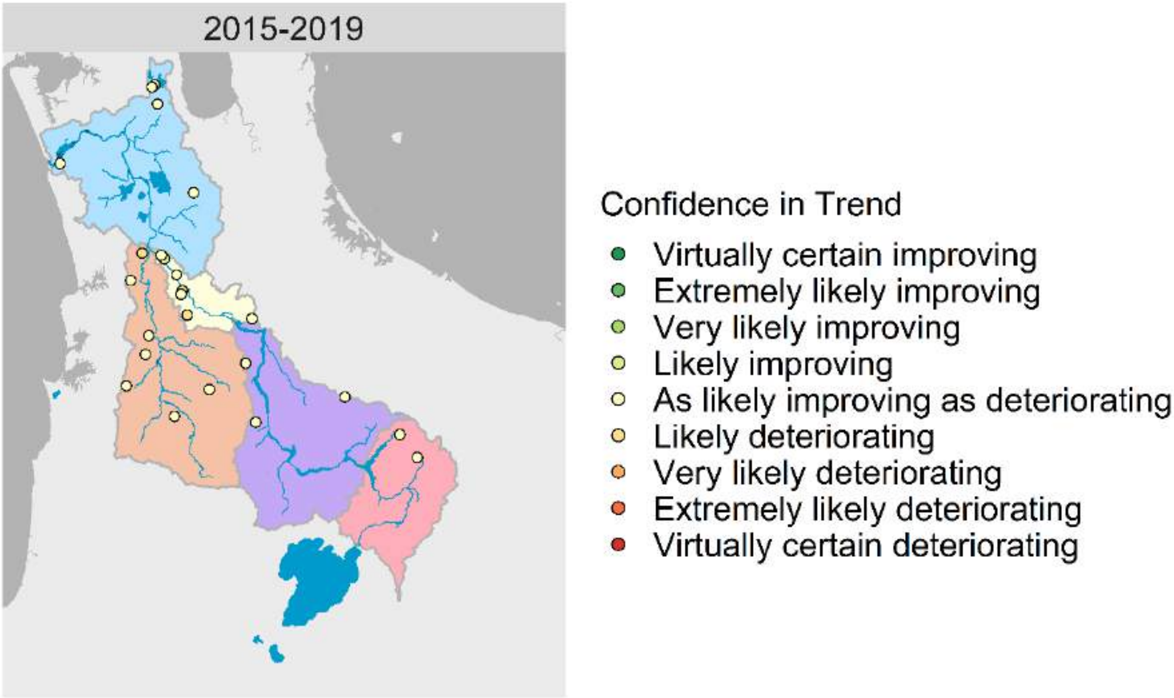

Figure 80: Trends in Waikato River native macrophyte cover, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

In the preceding five years (2010 and 2014), 17% (3 of 18) of trends in native macrophyte cover were improving, 6% (1 of 18) were deteriorating, and 77% (14 of 18) were as likely improving as deteriorating (Figure 81).

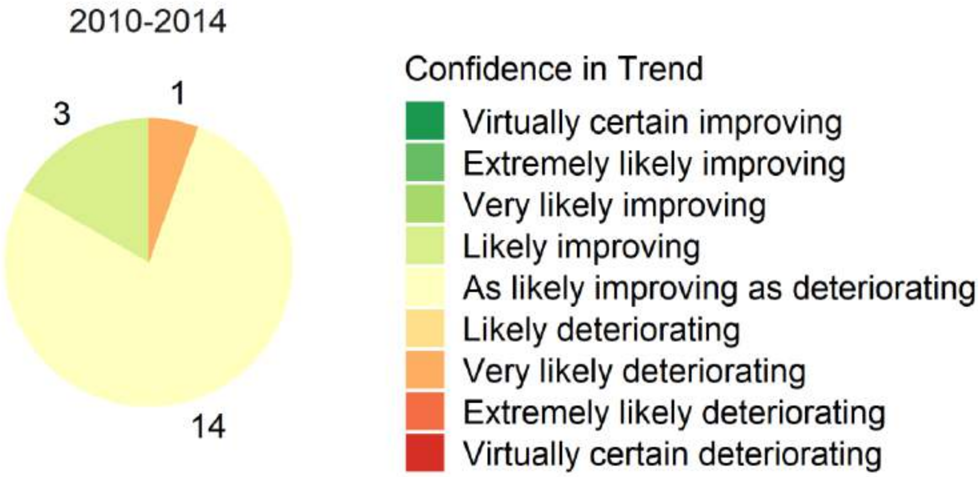

Figure 81: Trends in Waikato River native macrophyte cover, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010 to 2019, 80% (16 of 20) of detectable trends were as likely improving as deteriorating, 15% (3 of 20) were improving and one (5%) was deteriorating (Figure 82).

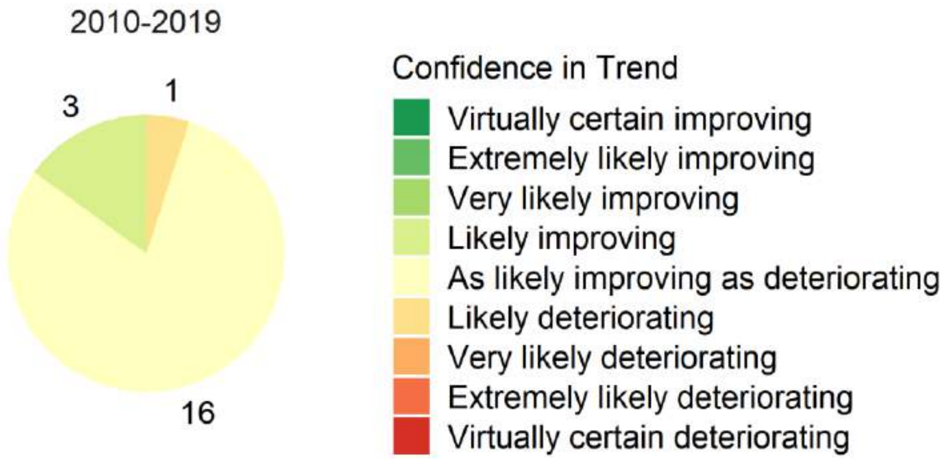

Figure 82: Trends in Waikato River native macrophyte cover, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.1.14 Riparian zone

Why measure it?

The riparian zone is an important area of transition between land and water environments. Undisturbed riparian vegetation and soils can function as buffers, trapping and transforming runoff and contaminants from adjacent land use, and intercepting nutrients transported in subsurface flow (e.g., farming, forestry, urban development). Riparian vegetation can also protect stream banks from erosion and support healthy aquatic ecosystem functioning through provision of channel shade (to keep waters cool), leaf litter and wood (habitat and organic matter for aquatic biota). Wider riparian zones, and those planted with a greater diversity of species and plant types (e.g., grasses, shrubs and trees, ideally native and suited to the area), are likely to provide greatest overall benefit to adjacent waterways through diversification of litter inputs and rooting depths. They can also contribute to the enhancement of terrestrial biodiversity. Three riparian indicators were analysed for trends: stream shade, riparian vegetation protection score and riparian width score.

- **Stream shade** is assessed as the overhead canopy cover provided by riparian vegetation using a densiometer. Highly shaded stream and river channels are more likely to maintain cool water temperatures which benefits fish and aquatic insects, especially during hot and dry summer conditions.
- **Vegetation protection** is an indicator of the amount and type of vegetation protection that is afforded to the stream bank and near-stream portion of the riparian zone, enabling it, primarily, to resist stream bank erosion (Collier and Kelly 2005). Undisturbed, native vegetation on both banks scores most highly (scores 15-20), while grazed grass and/or disturbed weedy banks are scored lowest (0-5).
- **Riparian width** is an indicator of the amount of natural riparian vegetation extending out into the near-stream zone from the stream or river channel, with a wider (>10 m) and less disturbed riparian zone supporting a more robust stream system (Collier and Kelly 2005).

Increases in stream shade, riparian vegetation protection scores, and riparian width scores are considered improving trends.

What are the trends? – Stream shade

Stream shade has only been recorded since 2013. Therefore, sufficient data exist to assess shade for the 2015 to 2019 time period only. The monitored sites cover a range of shade values (from 0 to 100%). Seventy-two percent (18 of 25) of trends were as likely improving as deteriorating, although there were also 16% (4 of 25) improving trends and 12% (3 of 25) deteriorating trends (Figure 83).

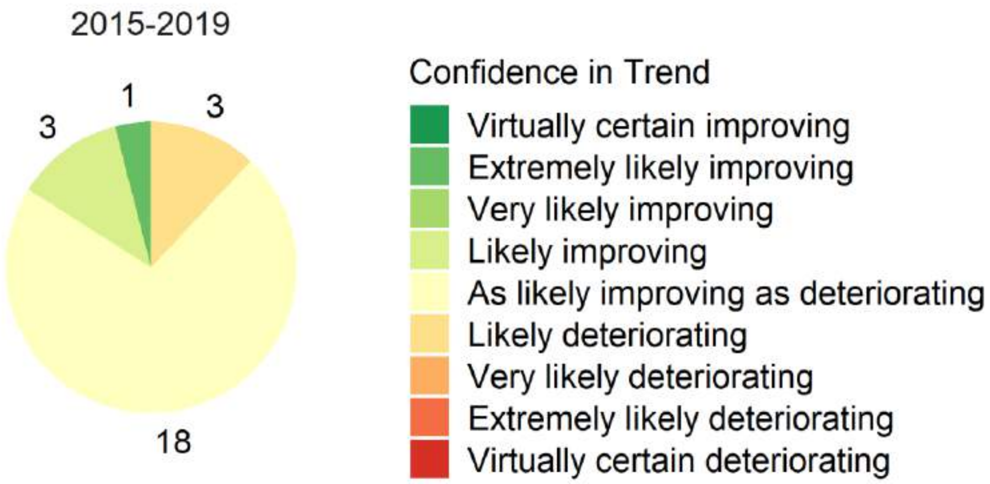

Figure 83: Trends in Waikato River stream shade, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Two of the four improving trends in stream shade over the 2015-2019 period were located in the Karāpiro to Ngāruawāhia RCU. There was also one site with an improving trend in the Waipā RCU and one in the Huka to Ōhakuri RCU. The three deteriorating trends were located (one each) in the Karāpiro to Ngāruawāhia, Waipā, and Ngāruawāhia to Te Pūaha RCUs (Figure 84).

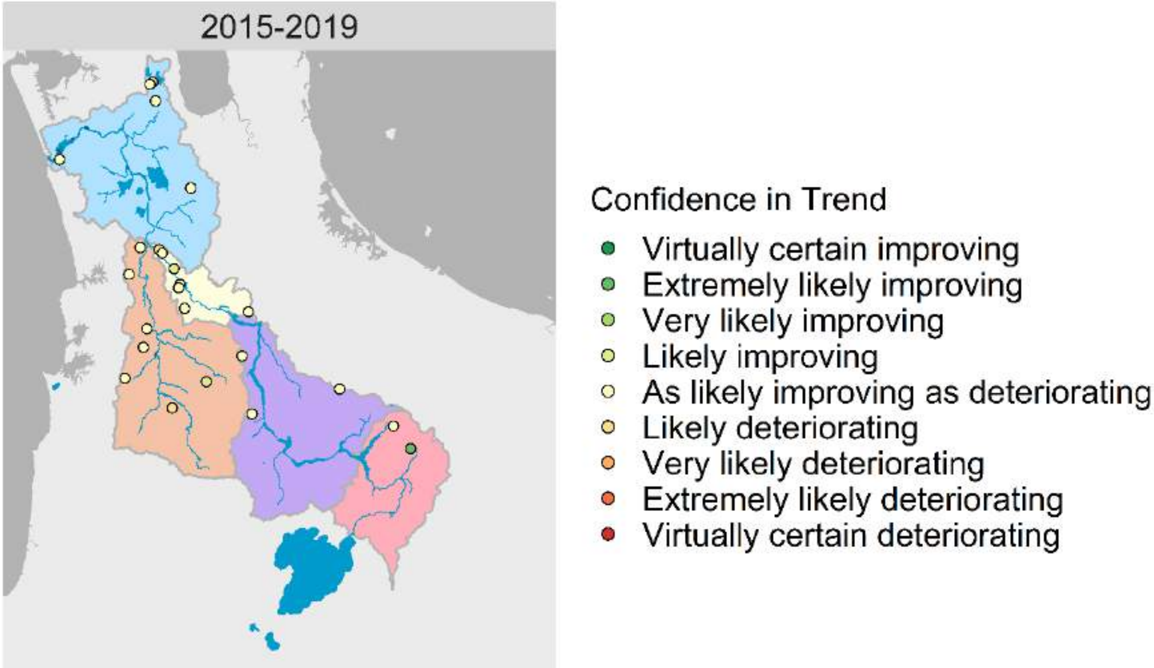

Figure 84: Trends in Waikato River stream shade, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

What are the trends? – Riparian vegetation protection

Trends in riparian vegetation protection scores over the 2015-2019 period were a mixture of 30% (8 of 27) improving, 40% (11 of 27) deteriorating, and 30% (8 of 27) as likely improving as deteriorating (Figure 85).

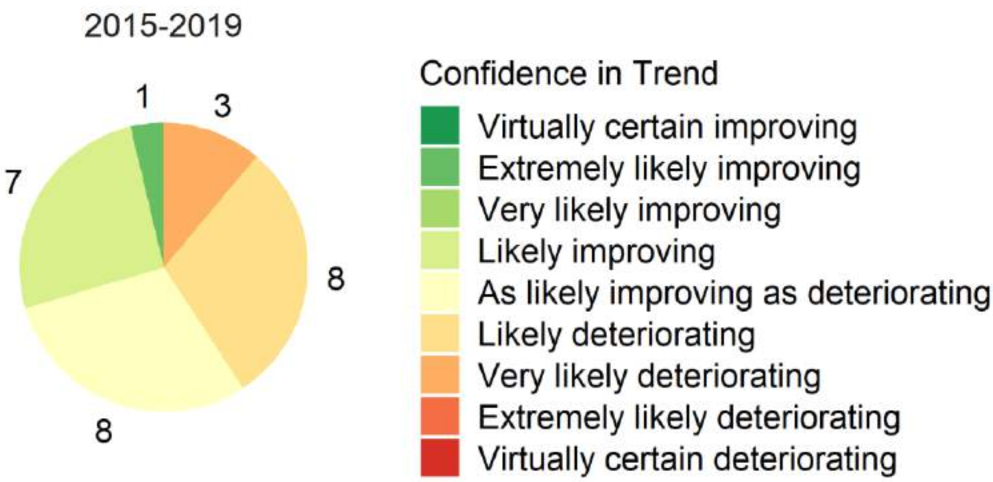

Figure 85: Trends in Waikato River riparian vegetation protection, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

The eight improving trends in riparian vegetation protection scores over the 2015-2019 time period were spread across all RCUS, with one improving trend in the Huka to Ōhakuri RCU, 1 improving trend in the Ōhakuri to Karāpiro RCU, three improving trends in the Karāpiro to Ngāruawāhia RCU, two improving trend in the Waipā RCU, and one improving trend in the Ngāruawāhia to Te Pūaha

RCU. The majority (5 of 12) of deteriorating trends were located in the Waipā RCU, along with one in the Huka to Ōhakuri RCU, two in the Ngāruawāhia to Te Pūaha RCU, two in the Karāpiro to Ngāruawāhia RCU, and one in the Ōhakuri to Karāpiro RCU (Figure 86).

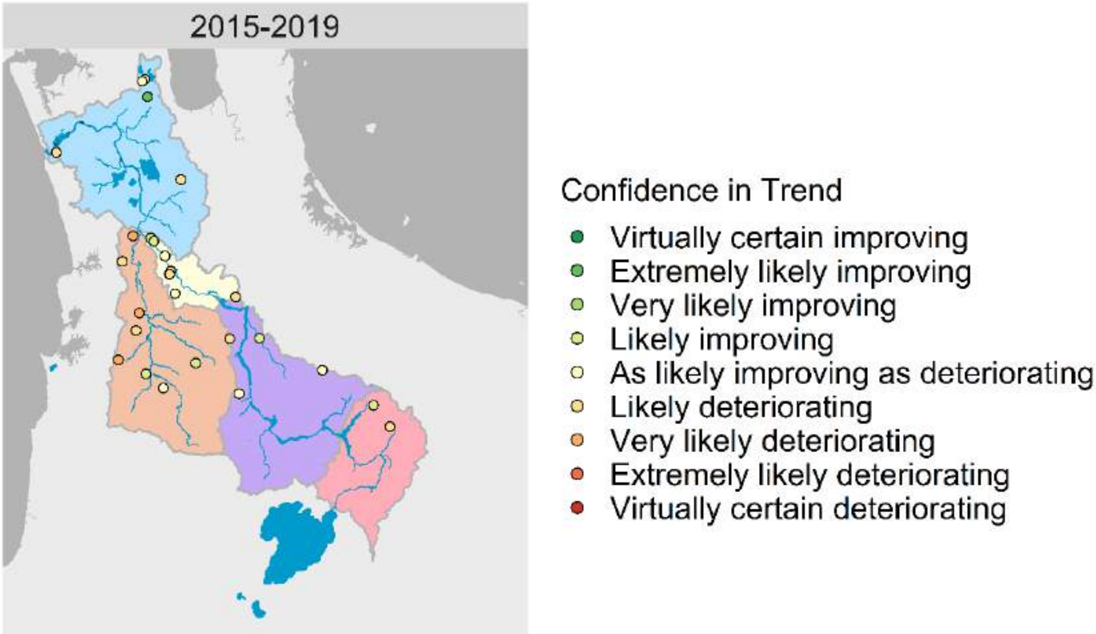

Figure 86: Trends in Waikato River riparian vegetation protection, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

Trends in riparian vegetation protection over the preceding five years, from 2010 to 2014, were also mixed, with 20% (4 of 20) of trends improving, 35% (7 of 20) of trends deteriorating, and 45% (9 of 20) of trends as likely improving as deteriorating (Figure 87).

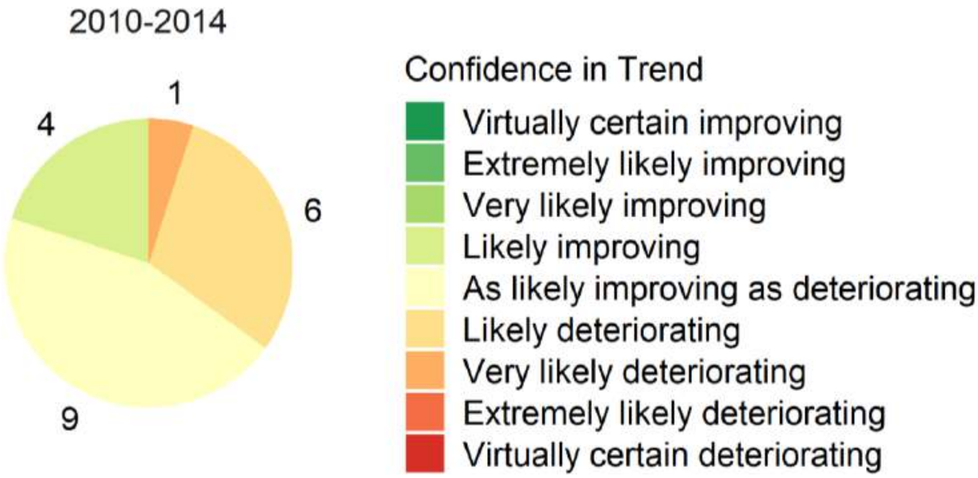

Figure 87: Trends in Waikato River riparian vegetation protection, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Over the 10-year period from 2010-2019, 41% (9 of 22) of trends in riparian protection scores were improving, 27% (6 of 22) were deteriorating, and 22% (7 of 22) were as likely improving as deteriorating (Figure 88).

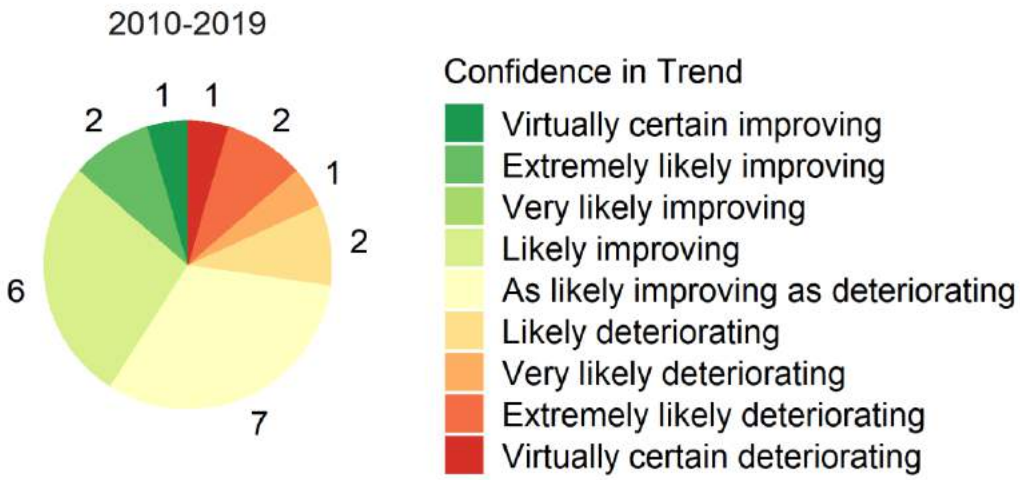

Figure 88: Trends in Waikato River riparian vegetation protection, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

What are the trends? – Riparian width

Riparian width score trends over the 2015-2019 period were 44% (12 of 27) as likely improving as deteriorating, 33% (9 of 27) deteriorating, and 22% (6 of 27) improving (Figure 89).

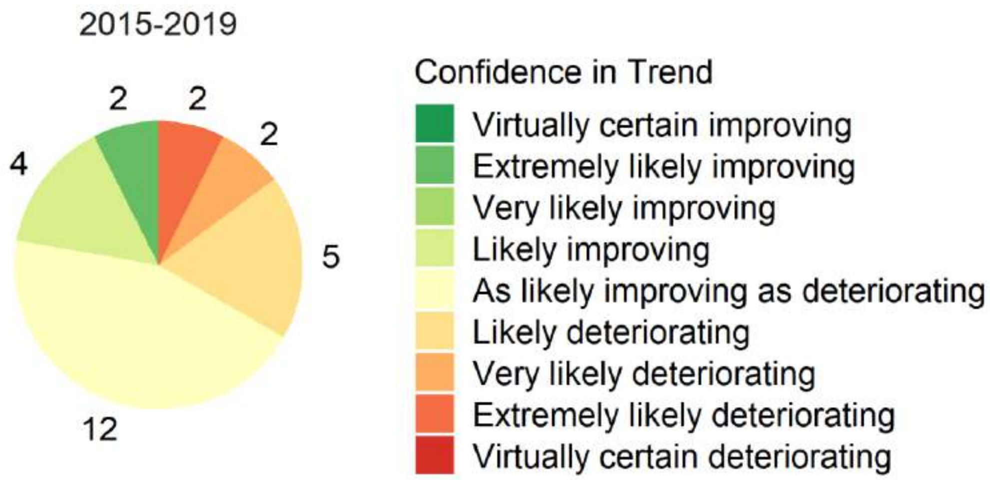

Figure 89: Trends in Waikato River riparian width, 2015-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

Improving trends were primarily located in the Karāpiro to Ngāruawāhia and Ōhakuri to Karāpiro RCUs. Deteriorating trends, on the other hand, were predominately located in the Waipā and Ngāruawāhia to Te Pūaha RCUs (Figure 90).

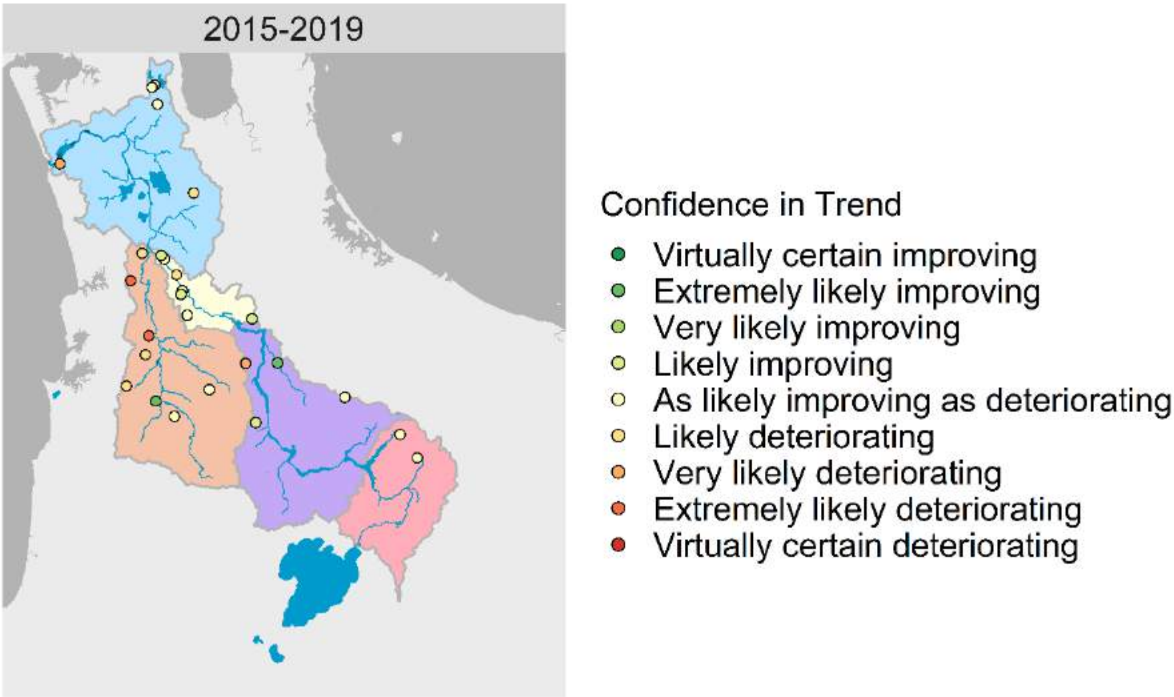

Figure 90: Trends in Waikato River riparian width, 2015-2019. Each dot represents a monitoring site where a trend could be determined. The colour of the dots indicates the trend direction and confidence.

Over the preceding five years (2010-2014), trends in riparian width scores were approximately evenly split between 30% improving (6 of 20 trends), 30% deteriorating (6 of 20 trends), and 40% (8 of 20 trends) as likely improving as deteriorating (Figure 91).

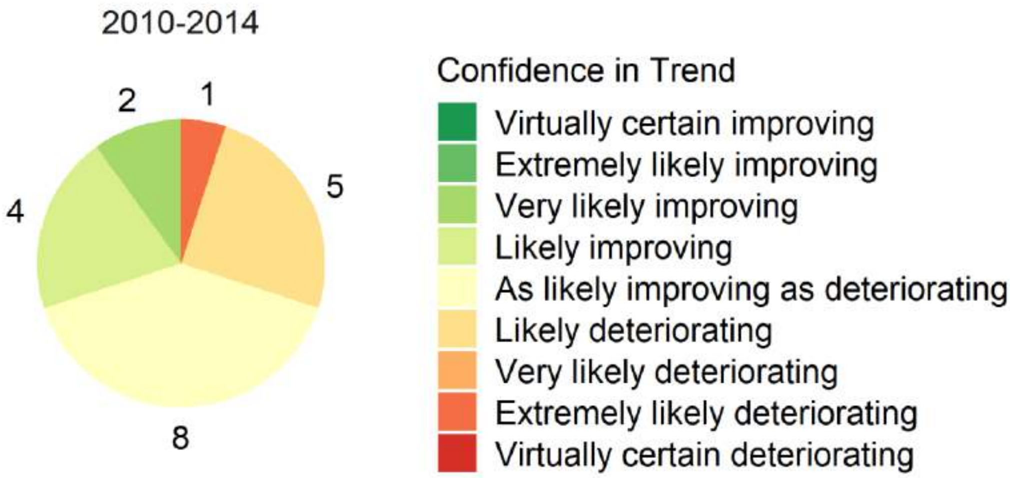

Figure 91: Trends in Waikato River riparian width, 2010-2014. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

The majority of trends in riparian width score over the 10-year period from 2010 to 2019 were deteriorating (55%, 12 of 22), followed by 27% (6 of 22) improving and 18% (4 of 22) as likely improving as deteriorating (Figure 92). This reflects the larger proportions of deteriorating or as likely improving as deteriorating trends in the last five years (2015-2019) compared to the preceding five years (2010-2014).

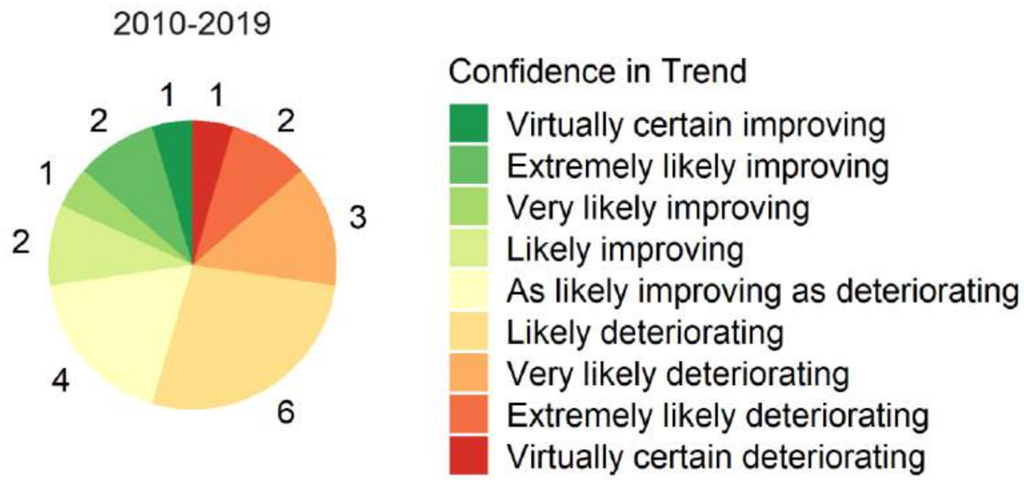

Figure 92: Trends in Waikato River riparian width, 2010-2019. The colour of the segments indicates the confidence that the trend is improving or deteriorating, with the number of sites showing trends in each category noted on the outside.

4.2 Trend results summary by RCU

Trends were also examined for each RCU individually. In general, trends varied between indicators and time periods, and similar patterns across all indicators within an RCU were not observed. However, some spatial variation was observed between RCUs, with trend patterns more similar within RCUs than between up-river, mid-river, and down-river RCUs.

4.2.1 OW - Huka to Ōhakuri

The three OW sites showed deteriorating or as likely improving as deteriorating trends in water clarity, chlorophyll *a*, *E. coli*, total nitrogen and total phosphorus for the 2015-2019 five-year period. The 10-year (2010-2019) time period showed similar deteriorating trends for the above parameters, although there was some improvement with water clarity and total phosphorus (Figure 93). This is in contrast to the preceding five-years (2010-2014) where overall improving trends in water clarity, *E. coli* and total nitrogen were observed (Figure 93). By contrast, dissolved oxygen and arsenic showed deteriorating or as likely improving as deteriorating trends in the 2010-2014 time period but predominately improving or as likely improving as deteriorating trends in the 2015-2019 and 2010 to 2019 time periods (Figure 94). Water temperature was a mixture of improving and indeterminant trends in each time period (Figure 94). Data on macroinvertebrates, macrophytes, periphyton cover and riparian condition were not collected at the OW sites because the mainstem Waikato is too wide and deep for wadeable stream sampling protocols to be undertaken.

4.2.2 OWT - Huka to Ōhakuri tributaries

The eight OWT sites showed largely deteriorating trends in water clarity, *E. coli* and total nitrogen for the 2015-2019 five-year period (Figure 93). Total phosphorus showed a mixture of improving and deteriorating sites for this time period. Between 2010 and 2014 all eight sites showed improving or indeterminant trends in water clarity, *E. coli*, total nitrogen, and total phosphorus (Figure 93), except for one site (Waiotapu Stream at the Campbell Road bridge), which showed a deteriorating trend in total nitrogen. The 10-year trends were largely improving for water clarity and total phosphorus but deteriorating for *E. coli* and total nitrogen (Figure 93). Trends in ammoniacal nitrogen showed 2/8 deteriorating trends from 2015-2019, 6/8 from 2010-2014, and overall, 5/8 deteriorating for the 2010-2019 time period (Figure 94). Dissolved oxygen trends were largely improving in both the 2010-2014 and 2015-2019 time periods, but a mixture of improving and deteriorating over the 10-year time period (Figure 94). Water temperature trends were predominately improving across all three time periods (Figure 94).

Trends in MCI scores were as likely improving as deteriorating in the two OWT ecological monitoring sites over the 2010-2014 time period, a mixture of improving and deteriorating in the 2015-2019 time period, and deteriorating over the ten-year time period from 2010-2019 (Figure 95). QMCI scores were as likely improving as deteriorating in one site and improving in the other in 2010-2014, then improving in one site and deteriorating in the other in the 2015-2019 time period (Figure 95). The 10-year trend was as likely improving as deteriorating in one site and deteriorating in the other. Percent EPT abundance was as likely improving as deteriorating in the two sites in 2010-2014 and as likely improving as deteriorating in the other. One site showed an improving trend in 2015-2019 while the other showed a deteriorating trend. However, the 10-year trends for both sites indicated deterioration. Percent EPT taxa trends went from one as likely improving as deteriorating and one improving in 2010-2014 to both as likely improving as deteriorating in 2015-219 and both deteriorating over the 10-year period (Figure 95).

Native macrophyte cover remained as likely improving as deteriorating in both OWT sites over all three time periods, while one site showed improving trend in the percentage cover by exotic macrophytes and channel clogginess in the 2015-2019 period and over the ten-year period (Figure 96Trend in cover of periphyton thick mats were as likely improving as deteriorating in the two sites over all three periods, except for an deteriorating trend in one site in 2010-2019 (Figure 97). Trends in percentage cover of periphyton long filaments were as likely improving as deteriorating in both sites in the 2010-2014 period but deteriorating in one site in both 2015-2019 and over the ten-year period from 2010-2019. The other site, however, showed an improving trend over the 10-year period (Figure 97). Riparian shade showed an improving trend in one site and an as likely improving as deteriorating trend in the second site over the 2015-2019 period (Figure 98). Riparian vegetation score trends were a mix of as likely improving as deteriorating and deteriorating in 2010-2014, improving and deteriorating in 2015-2019, and a mix of as likely improving as deteriorating and as likely improving as deteriorating over the 10-year period from 2010-2019 (Figure 98). Riparian width scores went from one each improving and as likely improving as deteriorating in 2010-2014 to both as likely improving as deteriorating in 2015-2019, and one improving and one as likely improving as deteriorating over the entire 10-year period (Figure 98).

4.2.3 KW - Ōhakuri to Karāpiro

The two KW sites had improving trends in water clarity in the 2010-2014 and 2010-2019 time periods but deteriorated in one site in 2015-2019 (the data from the other site did not meet selection criteria for trend analysis). Chlorophyll *a* showed a deteriorating trend in one site in 2010-2014 and improving trends at both sites over the 10-year time period (Figure 93). *E. coli* showed one improving trend in 2010-2014 (Figure 93), and deteriorating trends for both sites for the other two time periods (2015-2019 and 2010- 2019). Total nitrogen showed improving trends in both sites in 2010-2014 but deteriorating trends in 2015-2019 and over the 10-year time period (Figure 93). Total phosphorus and dissolved oxygen showed deteriorating trends in both sites over all three time periods (Figure 93 and Figure 94). Arsenic predominately showed improving trends across all time periods, except for one deteriorating trend in 2010-2014. Water temperature was a mixed bag across the time periods

(Figure 94). Data on invertebrates, macrophyte and periphyton cover, and riparian condition were not collected at the KW mainstem sites due to the size of the Waikato River.

4.2.4 KWT - Ōhakuri to Karāpiro Tributaries

The nine KWT sites showed overall improving trends in clarity in 2010-2014, although about half became as likely improving as deteriorating in 2015-2019 (Figure 93). As a result, the 10-year trends were a mix of improving and deteriorating (Figure 93). For E. coli all trends showed deteriorating or as likely improving as deteriorating trends in the 2015-2019 time period, the 10-year period from 2010 to 2019 was similar, excluding one site (Figure 93). Total nitrogen showed improving trends in seven of the nine sites in 2010-2014, but all but one site showed deteriorating trends in total nitrogen in 2015-2019 and 2010-2019 (Figure 93). Total phosphorus was a mix of improving, deteriorating, and as likely improving as deteriorating trends in 2010-2014, mostly improving trends in 2015-2019, and mostly deteriorating trends over the 10-year time period (Figure 93). For ammoniacal nitrogen the overall 10-year trend was deteriorating. The two five-year periods (2010-2014 and 2015-2019) were a mix of improving, deteriorating, and as likely improving as deteriorating (Figure 94). Dissolved oxygen trends in the KWT sites were primarily as likely improving as deteriorating in 2010-2014 and improving in 2015-2019, but overall deteriorating across the ten-year period (Figure 94).

Water temperature trends were primarily improving in 2010-2014, a mix of predominately likely improving and likely deteriorating in 2015-2019, and mostly improving with a few deteriorating over the 10 years from 2010-2019 (Figure 94).

Three of the four ecological monitoring sites in the KWT RCU had macroinvertebrate data which met the selection criteria for trend analysis in the 2010-2014 time period, all four in the 2015-2019 time period, and three in the 2010-2019 time period. At these sites MCI trends were a mix of deteriorating and as likely improving as deteriorating in 2010-2014 and a mix of improving and as likely improving as deteriorating in 2015-2019 and 2010-2019, along with one deteriorating trend in 2010-2019 (Figure 95). QMCI trends were deteriorating in 2010-2014 and improving in 2015-2019. The overall 10-year trends were a mix of improving and deteriorating (Figure 95). The percentage of EPT taxa and abundance both showed deteriorating or as likely improving as deteriorating trends in 2010-2014 and a mix of improving, deteriorating, and as likely improving as deteriorating trends in 2015-2019. The ten-year trends for percentage EPT abundance were a mix of improving and deteriorating trends while percentage EPT taxa showed a mix of deteriorating and as likely improving as deteriorating trends (Figure 95).

Macrophyte cover data meeting selection criteria was available for two of the four KWT sites in the 2010-2014 time period, in three of the four sites in the 2015-2019 time period, and in two of the four sites in the 2010-2019 time period. All macrophyte trends were as likely improving as deteriorating across all time periods (Figure 96). Periphyton long filament cover data meeting selection criteria was available for two of the four sites in 2010-2014, in three of the four sites in 2015-2019, and in two of the four sites over the 2010-2019 time period. The majority of trends were as likely improving as deteriorating, although there was one improving trend in 2015-2019 and one deteriorating trend over 2010-2019 (Figure 97). Periphyton thick mats showed the same pattern as long filaments across all three time periods. Riparian shade was as likely improving as deteriorating in three of the four KWT sites in 2015-2019, the fourth site data did not meet selection criteria. Riparian vegetation protection and riparian width scores were able to be analysed in three of the four KWT sites in the 2010-2014 time period, in all four sites in the 2015-2019 time period, and in three of the four sites in the 2010-2019 time period. Riparian vegetation protection and riparian width scores were deteriorating or as likely improving as deteriorating in 2010-2014 and a mixture of improving and deteriorating trends in 2015-2019 (Figure 98). The overall 10-year trends were deteriorating or as likely improving as deteriorating (Figure 98).

4.2.5 MW - Karāpiro to Ngāruawāhia

The MW sites showed improving trends in water clarity in both 2010-2014 and 2010-2019, with deteriorating trends in 2015-2019 (Figure 93). Improving trends in chlorophyll *a* were observed for all three time periods. *E. coli* showed improving trends in all three sites in 2010-2014, one improving and one deteriorating trend in 2015-2019 (Figure 93). Over the 10-year period, one site showed a deteriorating trend and one site showed an as likely improving as deteriorating trend in *E. coli* (Figure 93). Only one site was able to be analysed for total nitrogen in 2010-2014, which showed an improving trend, whereas both sites analysed in 2015-2019 and over 2010-2019 showed deteriorating trends (Figure 93). One site showed an improving trend in total phosphorus over all three time periods, while the second was as likely improving as deteriorating in 2010-2014 but likely deteriorating over the 10-year period (Figure 93). Trends in ammoniacal nitrogen were deteriorating or as likely improving as deteriorating for all three time periods.

On the converse, trends in arsenic were improving or as likely improving as deteriorating for all three time periods (Figure 94). All sites showed deteriorating trends in dissolved oxygen in 2010-2014, with one improving in 2015-2019 (Figure 94). However, both sites with 10-year trends in dissolved oxygen showed deteriorating trends (Figure 94). Water temperature trends were improving in 2010-2014, deteriorating in 2015-2019, and a mix of improving and deteriorating over the ten-year period (Figure 94). Data on invertebrates, macrophyte and periphyton cover, and riparian condition was not collected at the MW mainstem sites.

4.2.6 MWT - Karāpiro to Ngāruawāhia Tributaries

The six MWT water quality sites showed mostly improving trends in clarity and *E. coli* in 2010-2014 and deteriorating trends in 2015-2019 (Figure 93). Over the 2010-2019 period, clarity trends were a mix of improving and deteriorating, whereas *E. coli* trends were primarily deteriorating (Figure 93). All sites showed improving trends in total nitrogen and total phosphorus in 2010-2014, and primarily deteriorating trends in 2015-2019 (Figure 93). However, over the 10-year period, the majority of total nitrogen trends were improving while total phosphorus trends were a mixture of improving and deteriorating (Figure 93).

The majority of ammoniacal nitrogen trends were improving in 2010-2014, mixed in 2015-2019, and largely improving over the 10-year period (Figure 94). Dissolved oxygen trends were a mix of improving and deteriorating in 2010-2014, largely improving in 2015-2019, and a mix of improving and deteriorating (but mostly deteriorating) over the 10-year period (Figure 94). Water temperature trends were predominately improving in the 2010-2014 period, deteriorating in 2015-2019, and a mix of deteriorating or as likely improving or deteriorating over the 10-year period (Figure 94).

The eight macroinvertebrate and habitat sites in the MWT RCU showed primarily as likely improving as deteriorating trends in MCI in 2010-2014, with only one site showing a deteriorating trend. Two sites showed improving trends and three sites showed deteriorating trends in 2015-2019 (Figure 95). There were also four sites with deteriorating trends in 2010-2019 (Figure 95). QMCI trends were a combination of improving and as likely improving as deteriorating in 2010-2014 and 2015-2019, along with one deteriorating trend in 2015-2019 (Figure 95). However, over the 10-year period, there were three sites with deteriorating trends, three sites with improving trends, and one site with a trend as likely improving as deteriorating (Figure 95). Percent EPT taxa and percent EPT abundance trends showed similar patterns, with a mixture of deteriorating and as likely improving as deteriorating trends in 2010-2014, a few improving trends in 2015-2019, but predominately deteriorating trends over the ten-year period (Figure 95).

Macrophyte and periphyton cover were able to be analysed in five of the eight MWT sites in 2010-2014. Trends in channel clogginess and percent cover of exotic and native species were largely improving over this time period, with a few deteriorating trends present, as well as some as likely improving as deteriorating trends (Figure 96). All eight sites were able to be analysed in 2015-2019 and seven sites were able to be analysed in 2010-2019, with a mixture of improving, deteriorating, and as likely improving as deteriorating trends in each time period. Overall, macrophyte indicators in the MWT RCU showed a mixture of improving and deteriorating trends over the 10-year period (Figure 96). Periphyton, on the other hand, showed more improving trends in the 2015-2019 and 2010-2019 time periods, than in 2010-2014, particularly for percent cover by long filaments (Figure 97). Riparian vegetation protection scores also showed more improving trends in 2015-2019 and 2010-2019, while riparian width scores were a mixture of improving, deteriorating, and as likely improving as deteriorating trends across all three time periods (Figure 98).

4.2.7 Wp – Waipā

The five Wp sites showed improving trends in water clarity in the 2010-2014 period, deteriorating trends in 2015-2019, and overall a mixture of improving and deteriorating trends over the 10-year period from 2010-2019 (Figure 93). *E. coli*, on the other hand, showed deteriorating or as likely improving as deteriorating trends across all three periods, excluding one site in 2015-2019 (Figure 93). Total nitrogen and total phosphorus showed improving trends in 2010-2014, deteriorating trends in 2015-2019, and a mixture of improving and deteriorating trends over the full 10-year period (Figure 93).

Ammoniacal nitrogen showed deteriorating or as likely improving as deteriorating trends across all three periods, excluding one site in 2015-2019. Dissolved oxygen showed a mixture of improving and deteriorating trends across all three time periods, while water temperature trends were primarily deteriorating over all three time periods (Figure 94). Data on invertebrates, macrophyte and periphyton cover, and riparian condition was not collected at the mainsteam Wp sites.

4.2.8 WpT - Waipā Tributaries

The eleven Waipā tributary sites showed largely improving trends in water clarity, *E. coli*, total nitrogen and total phosphorus in the 2010-2014 time period (Figure 93). However, water clarity and *E. coli* trends were primarily deteriorating in the 2015-2019 time period (Figure 93). The 10-year water clarity trends were a mix of improving and deteriorating, while the *E. coli* trends were mostly deteriorating (Figure 93). Total nitrogen and total phosphorus showed a mix of improving and deteriorating trends in this RCU for both the 2015-2019 and 2010-2019 time periods (Figure 93). Ammoniacal nitrogen trends were mostly deteriorating or as likely improving as deteriorating in the 2015-2019 and 2010-2019 time periods. They were the opposite in the 2010-2014 time period with primarily improving or as likely improving as deteriorating trends (Figure 94). Dissolved oxygen trends were approximately half improving and half deteriorating in the two five-year time periods but overall mostly deteriorating over the 10-year time period (Figure 94). Water temperature trends in the WpT RCU were largely deteriorating over all three time periods (Figure 94).

Six of the eight invertebrate and habitat sites in the WpT RCU were able to be analysed for trends in macroinvertebrates in 2010-2014 and 2010-2019, while all eight sites were able to be analysed in 2015-2019. MCI trends in 2010-2014 were mostly as likely improving as deteriorating, along with one improving trend and one deteriorating trend (Figure 95). MCI trends in 2015-2019 were split between improving and as likely improving as deteriorating, with one deteriorating trend (Figure 95). The overall 10-year trends in MCI were a mixture of deteriorating and as likely improving as deteriorating, along with one improving trend (Figure 95). QMCI trends were largely deteriorating in 2010-2014, mostly improving or as likely improving as deteriorating in 2015-2019 and deteriorating overall for the 10-year time period (Figure 95). Percent EPT taxa trends showed a mixture of improving, deteriorating, and as likely improving as deteriorating across all three time periods, while percent EPT abundance trends were mostly deteriorating in 2010-2014 and as likely improving as deteriorating in 2015-2019 (Figure 95). However, the overall ten-year trends were largely deteriorating (Figure 95).

Five of the eight sites were able to be analysed for trends in macrophytes and periphyton in the 2010-2014 period, seven of the eight sites were able to be analysed for trends in the 2015-2019 time period, and five of the eight sites were able to be analysed for trends in the 2010-2019 time period. Macrophyte and periphyton trends in all three time periods were predominately as likely improving as deteriorating, with a few improving trends in the 2015-2019 and 2010-2019 time periods (Figure 96 and Figure 97, respectively). Six of the eight sites were able to be analysed for trends in riparian vegetation protection and width scores in 2010-2014 and 2010-2019, while all eight sites were able to be analysed in 2015-2019. Riparian vegetation protection and width scores were a mix of improving and deteriorating in the two five-year time periods but mostly deteriorating over the entire 10-year period (Figure 98).

4.2.9 LW - Ngāruawāhia to Te Pūaha

Water clarity showed improving trends in three of the four LW sites in 2010-2014, deteriorating trends in two sites in 2015-2019, and improving trends in two sites over the 10-year period (Figure 93). Chlorophyll *a* trends were also mostly improving in all three time periods (Figure 93). *E. coli*, on the other hand, showed improving trends in all four sites in 2010-2014, but deteriorating trends in three sites in 2015-2019 and over the entire 10-year period (Figure 93). Total nitrogen trends showed a similar pattern to *E. coli*, whereas total phosphorus trends were improving in both 2010-2014 and 2010-2019, with one deteriorating trend in 2015-2019 (Figure 93). Trends in ammoniacal nitrogen were all as likely improving as deteriorating for all three time periods and sites, excluding one site which was deteriorating in 2010-2019. There were two sites with deteriorating trends and one site with an improving trend in arsenic in 2010-2014 (Figure 94). All sites in 2015-2019 were as likely improving as deteriorating and all sites in 2010-2019 were improving. Dissolved oxygen trends were a mixture of improving and deteriorating in 2010-2014 and mostly improving in 2015-2019, but deteriorated in all three analysed sites over the 10-year period (Figure 94). Water temperature showed improving or as likely improving as deteriorating for all three time periods (Figure 94). Data on invertebrates, macrophyte and periphyton cover, and riparian condition was not collected at the mainstem LW sites.

4.2.10 LWT - Ngāruawāhia to Te Pūaha Tributaries

The majority of the fourteen LWT sites showed improving trends in clarity, *E. coli*, total nitrogen, and total phosphorus over the first five-year time period from 2010-2014 (Figure 93). Water clarity, *E. coli*, and total phosphorus trends in the second period from 2015-2019 were mostly deteriorating, while total nitrogen trends were a mixture of improving, deteriorating, and as likely improving as deteriorating (Figure 93). Over the 10-year period, water clarity, *E. coli* and total phosphorus trends were also a mixture of improving and deteriorating, while total nitrogen trends were largely deteriorating (Figure 93).

Ammoniacal nitrogen trends were predominately deteriorating in all three time periods (Figure 94). Dissolved oxygen was a mixture of deteriorating and as likely improving as deteriorating, with just two improving trends in the 2010-2014 time period and mostly improving trends in 2015-2019 (Figure 94). However, over the 10-year period most trends were deteriorating (Figure 94). Water temperature trends were a mix of deteriorating and as likely improving as deteriorating in 2010-2014, but mostly deteriorating in both 2015-2019 and over the 10-year period from 2010-2019 (Figure 94).

Four of the five invertebrate and habitat sites in the LWT RCU were able to be analysed for trends in macroinvertebrates, periphyton, macrophytes, and riparian vegetation scores in 2010-2014, all five in 2015-2019, and four of the five in 2010-2019. All four invertebrate metrics (MCI, QMCI, % EPT taxa, % EPT abundance) showed a mixture of deteriorating or as likely improving as deteriorating trends in the two-five-year periods and largely deteriorating trends over the 10-year period, except for two sites with improving trends in MCI in 2010-2019 (Figure 95).

Macrophyte trends were predominately as likely improving as deteriorating in all three time periods (Figure 96). Periphyton trends were also largely as likely improving as deteriorating in all three time periods, although there were two sites with improving trends in thick mat cover over the ten-year period and two sites with improving trends in long filament cover in 2015-2019 and one site with an improving trend in long filament cover over the ten-year period (Figure 97). Riparian vegetation protection and width scores were a mixture of improving, deteriorating, and as likely improving as deteriorating across all three time periods (Figure 98).

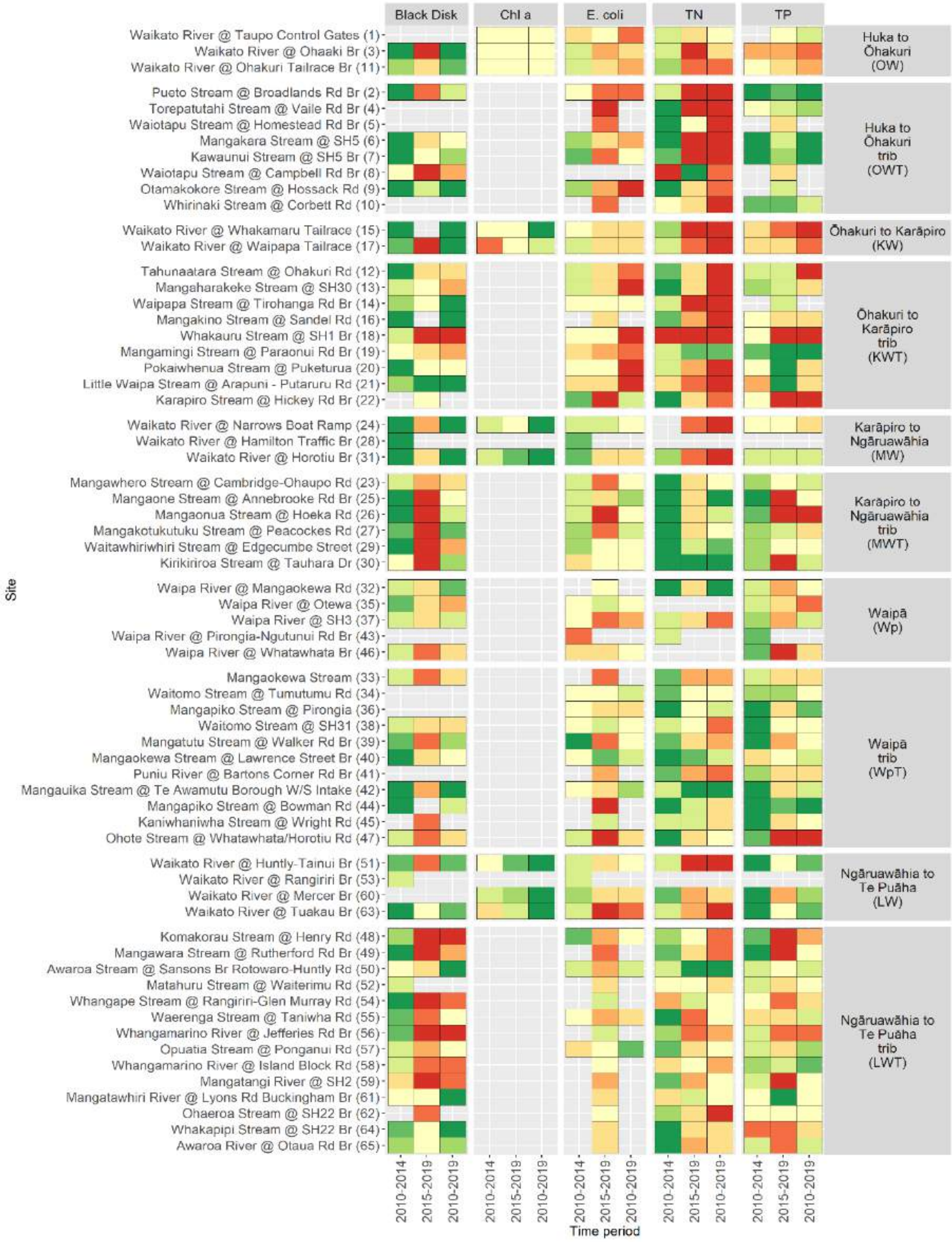

Figure 93: Heatmap plot showing trend confidence and direction for water clarity (Black Disk), Chlorophyll *a* (Chl *a*), *E. coli*, total nitrogen (TN) and total phosphorus (TP) indicators across RCUs. Each cell represents a single site (site names listed down the left-hand y-axis) over a single time period. The colour in each cell represents the confidence in trend direction, with green colours indicating improving trends and red colours indicating deteriorating trends. The darker the colour, the greater the confidence in trend direction. Yellow indicates the trend is as likely improving as deteriorating.

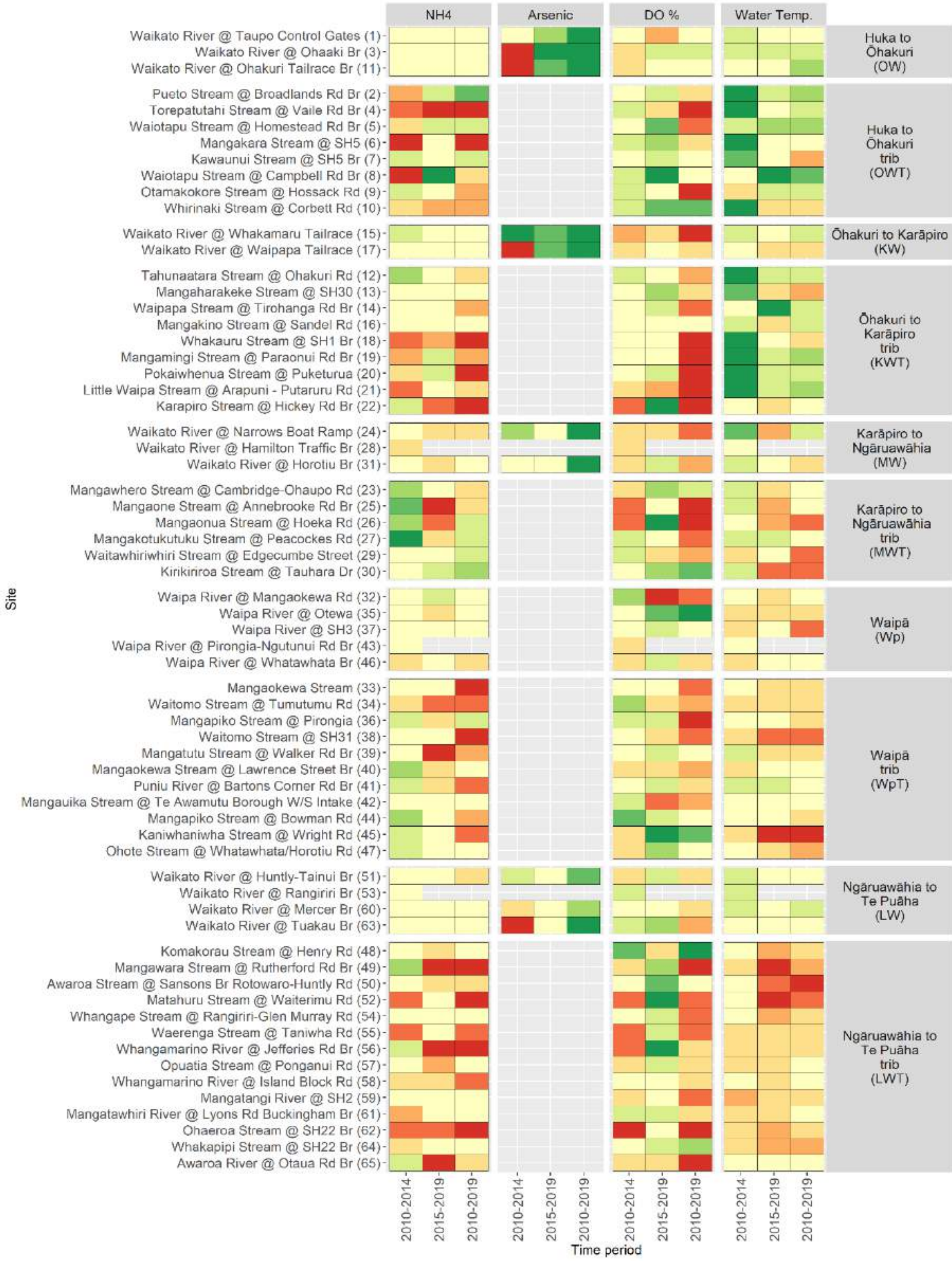

Figure 94: Heatmap plot showing confidence in trend direction for ammoniacal nitrogen (NH_4), arsenic, dissolved oxygen (DO) and water temperature indicators. Each cell represents a single site (site names listed down the left-hand y-axis) over a single time period. The colour in each cell represents the confidence in trend direction, with green colours indicating improving trends and red colours indicating deteriorating trends. The darker the colour, the greater the confidence in trend direction. Yellow indicates the trend is as likely improving as deteriorating.

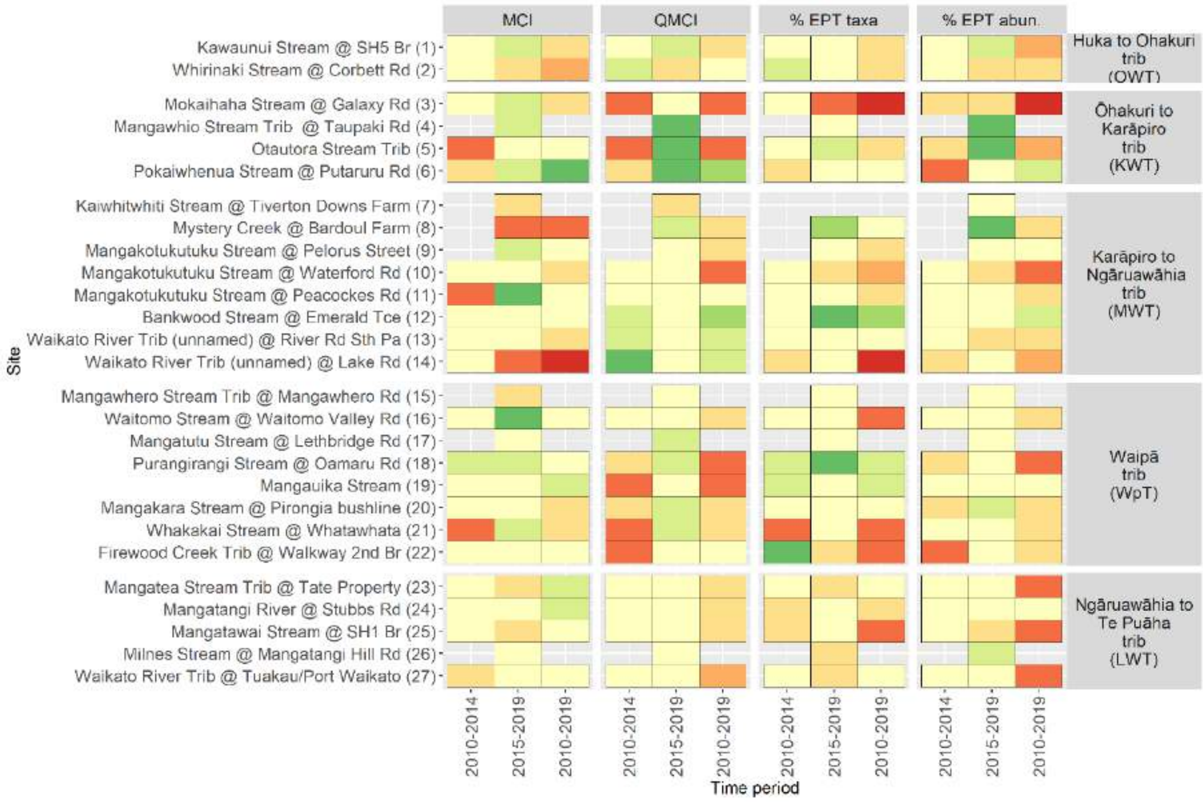

Figure 95: Heatmap plot showing confidence in trend direction for macroinvertebrate indicators. Each cell represents a single site (site names listed down the left-hand y-axis) over a single time period. The colour in each cell represents the confidence in trend direction, with green colours indicating improving trends and red colours indicating deteriorating trends. The darker the colour, the greater the confidence in trend direction. Yellow indicates the trend is as likely improving as deteriorating.

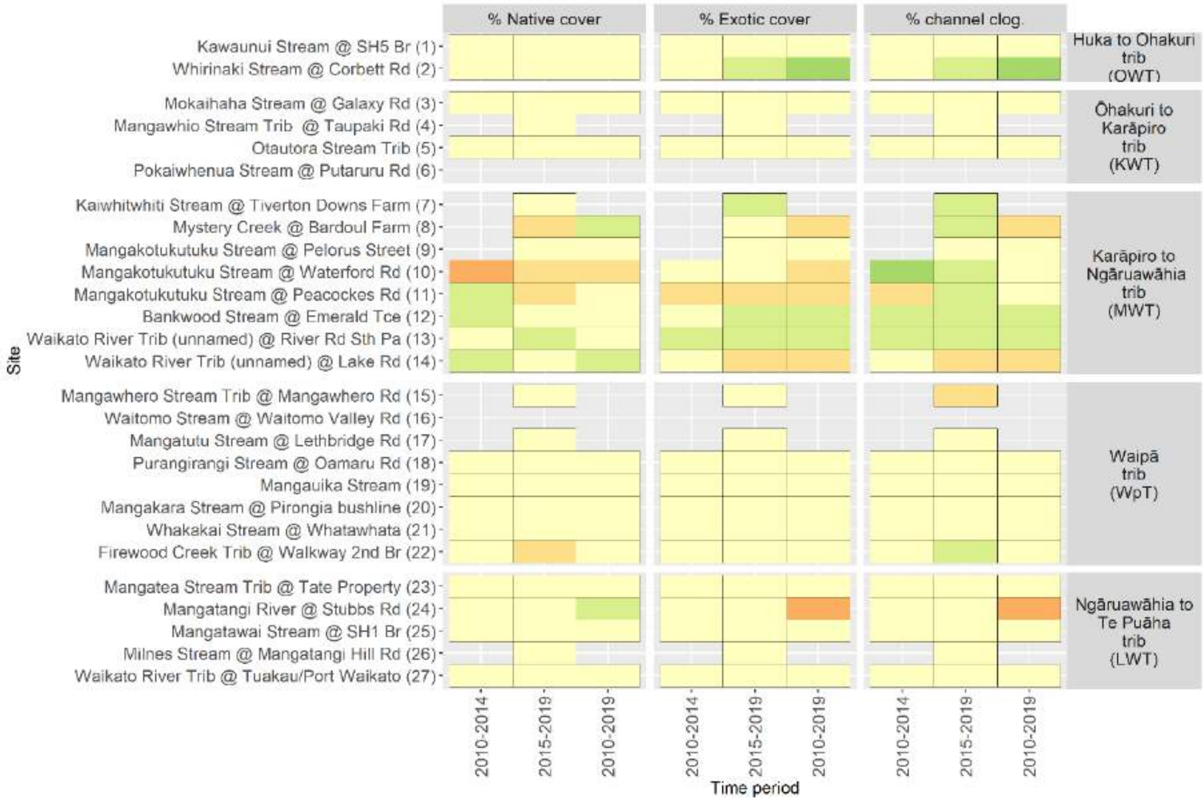

Figure 96: Heatmap plot showing confidence in trend direction for macrophyte indicators. Each cell represents a single site (site names listed down the left-hand y-axis) over a single time period. The colour in each cell represents the confidence in trend direction, with green colours indicating improving trends and red colours indicating deteriorating trends. The darker the colour, the greater the confidence in trend direction. Yellow indicates the trend is as likely improving as deteriorating.

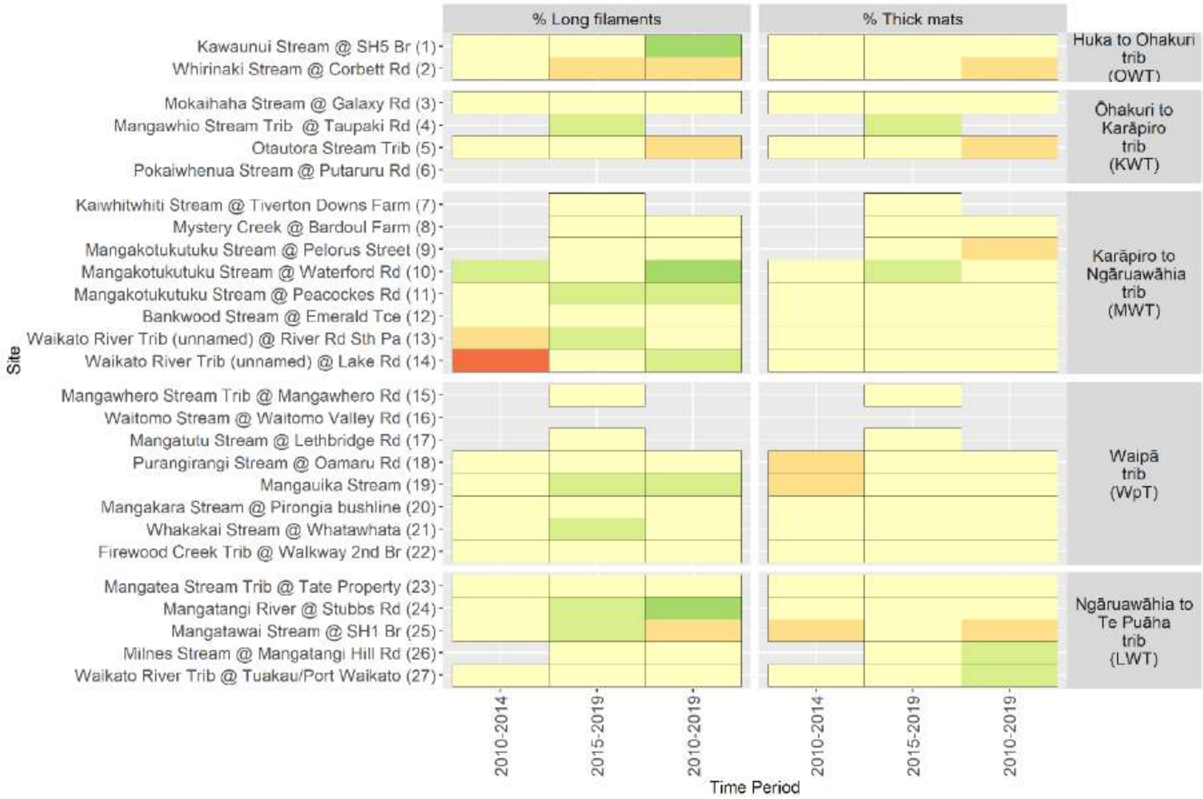

Figure 97: Heatmap plot showing confidence in trend direction for periphyton indicators. Each cell represents a single site (site names listed down the left-hand y-axis) over a single time period. The colour in each cell represents the confidence in trend direction, with green colours indicating improving trends and red colours indicating deteriorating trends. The darker the colour, the greater the confidence in trend direction. Yellow indicates the trend is as likely improving as deteriorating.

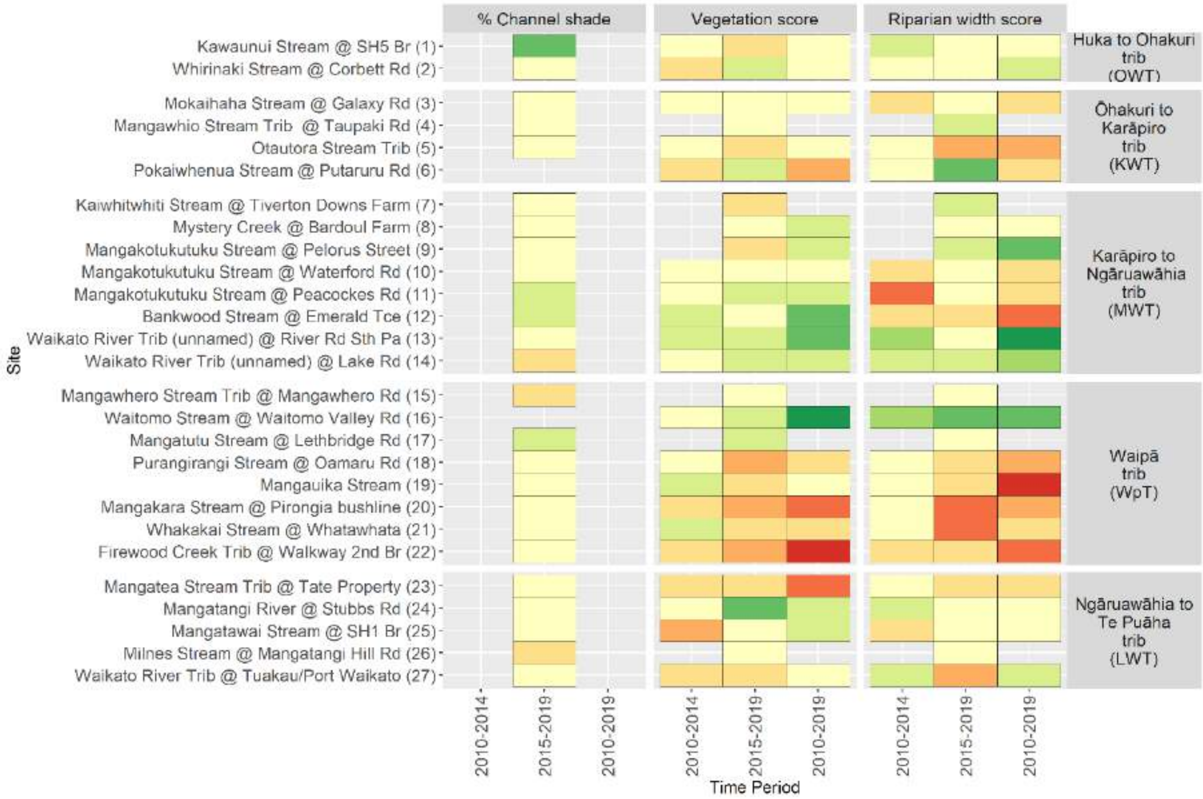

Figure 98: Heatmap plot showing confidence in trend direction for riparian indicators. Each cell represents a single site (site names listed down the left-hand y-axis) over a single time period. The colour in each cell represents the confidence in trend direction, with green colours indicating improving trends and red colours indicating deteriorating trends. The darker the colour, the greater the confidence in trend direction. Yellow indicates the trend is as likely improving as deteriorating.

5 Discussion

Twenty-one riverine-focused indicators were analysed for trends using the latest best-practice methods. The indicators were closely aligned with those used in the 2015 Report Card to populate the water quality, experience and ecological integrity taura. The water quality and experience indicators used generally had larger and more robust datasets for trends analysis than the ecological indicators. Three new indicators of riparian health were also included in this analysis: channel shade, riparian vegetation protection, and riparian vegetation width, these are likely to be included in future report cards.

The 5 and 10-year trend periods were deliberately chosen to align with the WRA's reporting cycles. The 2015 Report Card assessed the state of the health and wellbeing of the Waikato River catchment using data gathered between 2010-2014. The 2015 Report Card did not include an assessment of trends, therefore the 2010-2014 period is also included in this report. State was not reported as part of this analysis because it will be assessed for the 2025 Report Card.

The trend analysis showed a high level of spatial and temporal diversity in improving and deteriorating trends for the 21 indicators where suitable datasets were readily available. During the current WRA five-yearly reporting period (2015-2019) water clarity, *E.coli* and total nitrogen have deteriorated at ≥ 70% of Waikato River sites monitored across all RCUs (Table 5-1). Over the same period, the majority of the ecological indicators have shown as likely improving as deteriorating trends (Table 5-1). Generally, more deteriorating trends were observed at sites in the lower Waikato River catchment for total phosphorus, water temperature and ammoniacal nitrogen.

It is important to note, however, that while five-year trends provide a useful preliminary assessment of recent conditions, short-term trends (up to ten years) are considered to be less robust than longer time series due to the low number of data points used to determine each trend. The observed 5-year trends could have been influenced by either statistical sampling errors due to low sample sizes or natural fluctuations in environmental drivers, such as flow and climate cycles, as well as anthropogenic drivers such as land-use change or ecological restoration. Therefore, the presented five-year trends are indicative only.

Nevertheless, many of the ten-year trends showed similar overall patterns of deteriorating trends. Total nitrogen and *E. coli* in particular showed deteriorating trends in the upper catchment RCUs over the last ten years. It is still possible that these trends were influenced by climate patterns, especially rainfall, over this time period.

The trend analysis shows continuing deterioration in the health of the river and its tributaries, and should such a general picture of deterioration continue then it is probable that the 2025 Report Card will show lower grades for the Experience, Water Quality and Ecological Integrity taura.

Table 5-1: Summary of water quality, ecological and riparian indicators assessed for trends at Waikato River sites over three time periods (2010-2014, 2015-2019). The number of sites used in this assessment varied between indicators and time periods. All percentages rounded to the nearest whole number.

	Indicator	2010-2014 (i.e., comparison to 2015 Report Card period)	2015-2019 (i.e., current WRA five-year reporting period)	2010-2019 (i.e., ten-year period)
WATER QUALITY	Water clarity	89% improving, 9% as likely improving as deteriorating,2% deteriorating (N=53)	4% improving, 18% as likely improving as deteriorating, 78% deteriorating (N=50)	52% improving, 12% as likely improving as deteriorating, 36% deteriorating (N=50)
	E.coli	56% improving, 29% as likely improving as deteriorating, 16% deteriorating (N=45)	11% improving, 18% as likely improving as deteriorating, 70% deteriorating (N=61)	19% improving, 31% as likely improving as deteriorating, 50% deteriorating (N=42)
	Total nitrogen	85% improving, 5% as likely improving as deteriorating, 10% deteriorating (N=61)	18% improving, 12% as likely improving as deteriorating, 70% deteriorating (N=60)	17% improving, 17% as likely improving as deteriorating, 67% deteriorating (N=60)
	Total phosphorus	71% improving, 17% as likely improving as deteriorating, 12% deteriorating (N=58)	29% improving, 16% as likely improving as deteriorating, 55% deteriorating (N=62)	40% improving, 20% as likely improving as deteriorating, 40% deteriorating (N=58)
	Phytoplankton (Chlorophyll *a*)	30% improving, 50% as likely improving as deteriorating, 20% deteriorating (N=10)	40% improving, 60% as likely improving as deteriorating (N=10)	70% improving, 30% as likely improving as deteriorating (N=10)
	Dissolved oxygen	26% improving, 33% as likely improving as deteriorating, 40% deteriorating (N=62)	56% improving, 23% as likely improving as deteriorating, 21% deteriorating (N=62)	13% improving, 16% as likely improving as deteriorating, 71% deteriorating (N=62)
	Water temperature	42% improving, 32% as likely improving as deteriorating, 26% deteriorating (N=65)	19% improving, 31% as likely improving as deteriorating, 50% deteriorating (N=62)	26% improving, 27% as likely improving as deteriorating, 47% deteriorating (N=62)
	Ammoniacal nitrogen	28% improving, 43% as likely improving as deteriorating, 29% deteriorating (N=65)	11% improving, 52% as likely improving as deteriorating, 37% deteriorating (N=62)	13% improving, 35% as likely improving as deteriorating, 52% deteriorating (N=62)
	Arsenic in water	30% improving, 20% as likely improving as deteriorating, 50% deteriorating (N=10)	50% improving, 50% as likely improving as deteriorating (N=10)	100% improving (N=10)

Table 5-2: Continued.

	Indicator	2010-2014 (i.e., comparison to 2015 Report Card period)	2015-2019 (i.e., current WRA five-year reporting period)	2010-2019 (i.e., ten-year period)
ECOLOGICAL	Macroinvertebrate Community Index	5% improving, 70% as likely improving as deteriorating, 25% deteriorating (N=20)	33% improving, 41% as likely improving as deteriorating, 26% deteriorating (N=27)	18% improving, 41% as likely improving as deteriorating, 41% deteriorating (N=22)
	Quantitative Macroinvertebrate Community Index	20% improving, 40% as likely improving as deteriorating, 40% deteriorating (N=20)	33% improving, 59% as likely improving as deteriorating, 8% deteriorating (N=27)	18% improving, 13% as likely improving as deteriorating, 68% deteriorating (N=22)
	% EPT abundance	65% as likely improving as deteriorating, 35% deteriorating (N=20)	22% improving, 59% as likely improving as deteriorating, 19% deteriorating (N=27)	9% improving, 13% as likely improving as deteriorating, 77% deteriorating (N=22)
	% EPT taxa	20% improving, 55% as likely improving as deteriorating, 25% deteriorating (N=20)	15% improving, 63% as likely improving as deteriorating, 22% deteriorating (N=27)	14 % improving, 27% as likely improving as deteriorating, 59% deteriorating (N=22)
	Periphyton long filaments	6% improving, 83% as likely improving as deteriorating, 11% deteriorating (N=18)	28% improving, 68% as likely improving as deteriorating, 4% deteriorating (N=25)	29% improving, 57% as likely improving as deteriorating, 14% deteriorating (N=21)
	Periphyton thick mat cover	83% as likely improving as deteriorating, 27% deteriorating (N=18)	8% improving, 92% as likely improving as deteriorating (N=25)	10% improving, 71% as likely improving as deteriorating, 19% deteriorating (N=21)
	Macrophyte channel clogginess	17% improving, 78% as likely improving as deteriorating, 5% deteriorating (N=18)	32% improving, 60% as likely improving as deteriorating, 8% deteriorating (N=25)	15% improving, 70% as likely improving as deteriorating, 15% deteriorating (N=20)
	% cover exotic macrophytes	5% improving, 80% as likely improving as deteriorating, 5% deteriorating (N=18)	16% improving, 76% as likely improving as deteriorating, 8% deteriorating (N=25)	15% improving, 60% as likely improving as deteriorating, 25% deteriorating (N=20)
	% cover native macrophytes	17% improving, 77% as likely improving as deteriorating, 6% deteriorating (N=18)	4% improving, 80% as likely improving as deteriorating, 16% deteriorating (N=25)	15% improving, 80% as likely improving as deteriorating, 5% deteriorating (N=20)
RIPARIAN	Channel shade	–	16% improving, 72% as likely improving as deteriorating, 12% deteriorating (N=25)	–
	Riparian vegetation protection	20% improving, 45% as likely improving as deteriorating, 35% deteriorating (N=27)	30% improving, 30% as likely improving as deteriorating, 40% deteriorating (N=27)	41% improving, 22% as likely improving as deteriorating, 27% deteriorating (N=27)
	Riparian width	30% improving, 40% as likely improving as deteriorating, 30% deteriorating (N=20)	22% improving, 44% as likely improving as deteriorating, 33% deteriorating (N=27)	27% improving, 18% as likely improving as deteriorating, 55% deteriorating (N=22)
	All 21 indicators	40% improving, 38% as likely improving as deteriorating, 22% deteriorating (N=642)	22% improving, 41% as likely improving as deteriorating, 37% deteriorating (N=751)	25% improving, 30% as likely improving as deteriorating, 45% deteriorating (N=650)

Traditional trend analysis methods have tended to focus on acknowledging a trend in the data only where it is statistically significant (at least 95% probability). The results of trends analysis summarised in this report were derived from current best practice procedures for water quality trend analysis. The methods applied provided:

- A determination of trend direction (improving or deteriorating).
- The confidence in that trend ranging from almost certain (at 99-100% or 0-1% probabilities, respectively) to as likely as not (at 33-67% probabilities).
- A more informative assessment of trend relative to previously used methods, provided adequate data were available.

Our approach highlighted issues related to using the same analytical trend procedures for water quality data and ecological datasets, where significant amounts of tied data values occur. For example, percentage cover datasets for aquatic plants commonly contain many zero values which get treated as ties. However, in this case zero values are valid and meaningful datapoints (i.e., no cover of aquatic places). It was necessary therefore to modify the trend analysis procedure to include these tied values in order to provide a more complete picture of trends for these parameters. Nevertheless, the large number of sites with numerous zero values resulted in many as likely improving as deteriorating trends.

Time series of at least 10-years are typically recommended as more robust assessments compared to shorter term trends (Ballantine 2012). Our analysis has highlighted that trend assessments over short time periods have high uncertainty. Several indicators (i.e., water clarity, *E. coli*, total nitrogen) switched from mostly improving trends in the 2010-2014 period to mostly deteriorating trends in the 2015-2019 period. However, because there are few data in a 5-year period, it is possible that these changes in direction and/or rate between the two periods were due to statistical sampling errors alone (i.e. due to the sparsity of data points, the data set does not accurately represent the true population). This is more often the case for low-rate trends which vary little over time, where a single (or few) high or low values can drive the trend and direction (i.e. clarity and total nitrogen, Figure B-2 and Figure B-6, respectively).

Changes in trend direction and confidence between trend periods can also be due to changes in site locations or methodology. The latter is unlikely in this analysis, as WRC has either maintained methodology over time or provided corrected data for changes in methodology (i.e., total phosphorus). However, the number of sites analysed did vary between trend periods due to sites not meeting the data availability criteria (measurements for 90% of years and 90% of seasons) in a given time period. The most notable example of this in our data was *E. coli*, sixteen more sites were able to be analysed for trends in *E. coli* in 2015-2019 than in 2010-2014. Those sixteen new sites could have made up the majority of the increase in deteriorating *E. coli* trends (18 trends) between the two time periods.

On the other hand, water clarity and total nitrogen also switched from improving to declining trends between the two five-year periods, even though numbers of sites analysed were similar between the two periods (water clarity: 53 in 2010-2014 and 50 in 2015-2019, total nitrogen: 61 in 2010-2014 and 60 in 2015-2019).

If these switches in trend direction were not due to sampling errors, as discussed above, they could be due to the influence of variation in natural environmental drivers which could influence the delivery of contaminants to waterways, or biogeochemical processing of these contaminants, and are not accounted for in the trend analysis. Key drivers include flow, which in turn is influenced by climate. Rainfall and temperature are subject to short-term fluctuations and specific events (floods and droughts), as well as long-term cycles. For example, Snelder et al. (submitted) found that cyclic phases in the El Nino Southern Oscillation climate pattern (ENSO) which occur every two to seven years correlated with variation in water quality trends at both site and national scales. Several significant climatic events occurred during the time periods analyses, including a drought in 2013-2015 and tropical storms in 2017 and 2018. The effects of natural fluctuations on several drivers may therefore mask (or dominate) the effects on trends of more gradual changes arising from land use change, other anthropogenic stressors or management actions such as riparian restoration.

Furthermore, Snelder et al. (submitted) also found that the direction of national-scale water quality varied according to the length of record selected, and by the particular period selected, from the same overall data set. They found that time windows separated by only one or two years frequently switched between greater than 95% confidence that the majority of trends were increasing to greater than 95% confidence that the majority of trends were decreasing. However, changes in trend direction were less frequent for the 15-year time windows, suggesting that longer trend windows are preferable. Therefore, we recommend that five-year trends should be interpreted with caution. Ten-year trends are more robust, but care should still be taken with regards to ascribing observed changes in trend direction to either natural environmental drivers or anthropogenic activities in the catchment.

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This report was reviewed by various parties who have interests in the gathering, analyses and the interpretation of the datasets used in this project. The scope and outcome sought by this project was determined by the WRA. The indicators and spatial framework (RCUs) used to identify the datasets required was determined by the 2015 Report Card. The availability of datasets suitable for trends analysis then determined which indicators could be included, which varied across the RCUs. We appreciate the guidance provide by Caroline Fraser and Ton Snelder regarding the application of the trend assessment methodology which is considered current best practice.

The results of this project have been reviewed by WRC (Haydon Jones, Mike Scarsbrook, Michael Pingram, Eloise Ryan, Thomas Wilding) and WRA (Bob Penter and Michelle Hodges). We also thank NIWA reviewers, Scott Larned and Neale Hudson, for their suggested improvements to this report. This report has responded to as much of the feedback as possible from all of the reviewers involved and has addressed the commonly agreed needs for strengthening the analyses and narratives presented in this report.

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8 Glossary of Abbreviations and Terms

BPJ	Best professional judgement
DO	Dissolved oxygen
EPT	Ephemeroptera, Plecoptera and Trichoptera (i.e., invertebrate taxa)
KW	Karāpiro to Ōhakuri (i.e., a Waikato River RCU used to present the results of the trends analysis spatially)
KWT	Karāpiro to Ōhakuri Tributaries (i.e., a Waikato River RCU used to present the results of the trends analysis spatially)
LWP	Land Water People
MCI	Macroinvertebrate Community Index
NH_4	Ammonia
OW	Ōhakuri to Huka (i.e., a Waikato River RCU used to present the results of the trends analysis spatially)
OWT	Ōhakuri to Huka Tributaries (i.e., a Waikato River RCU used to present the results of the trends analysis spatially)
IPCC	Intergovernmental Panel on Climate Change
QMCI	Quantitative Macroinvertebrate Community Index
RCU	Waikato River Report Card Unit
SSE	Sen Slope Estimator
TDA	Trend direction assessment
TN	Total nitrogen
TP	Total phosphorus
WRA	Waikato River Authority
WRC	Waikato Regional Council
WRISS	Waikato River Independent Scoping Study
WRRT	Waikato Raupatu River Trust

Appendix A Site Locations

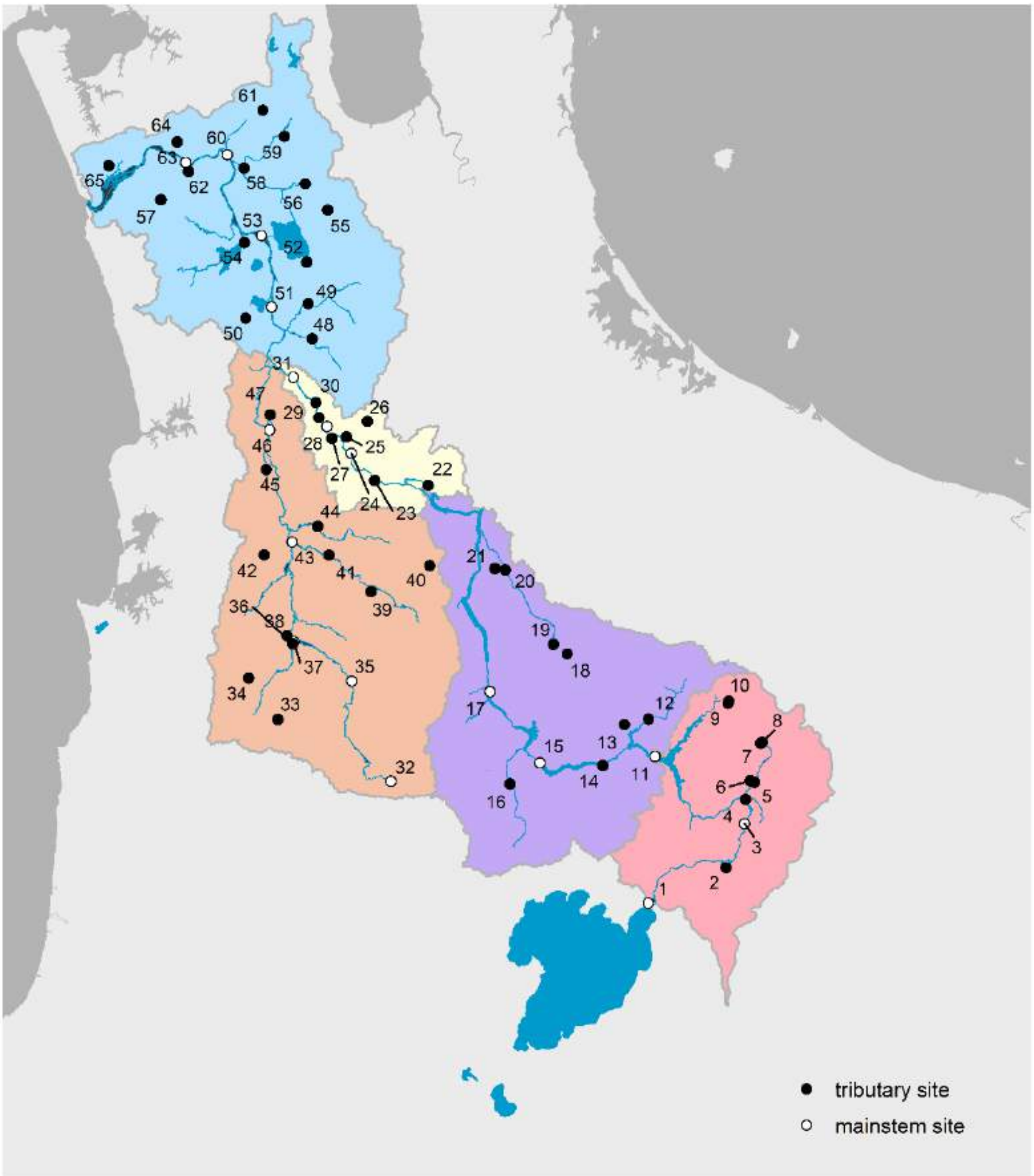

Figure A-1: Water quality monitoring site locations.

Table A-1: Water quality monitoring site locations.

RCU	Site number	WRC number	Site name	Easting (NZMG)	Northing (NZMG)
OW	1	1131_127	Waikato River Taupo Control Gates	2777133	6275733
OWT	2	802_1	Pueto Stream Broadlands Rd Bridge	2793822	6282490
OW	3	1131_105	Waikato River Ohaaki Bridge	2798071	6291450
OWT	4	1057_6	Torepatutahi Stream Vaile Rd Bridge	2798500	6296500
OWT	5	1186_4	Waiotapu Stream Homestead Rd Bridge	2800466	6300003
OWT	6	380_2	Mangakara Stream (Reporoa) SH5	2799600	6300332
OWT	7	240_5	Kawaunui Stream SH5 Bridge	2802077	6308022
OWT	8	1186_2	Waiotapu Stream Campbell Rd Bridge	2802444	6308250
OWT	9	683_4	Otamakokore Stream Hossack Rd	2795500	6316600
OWT	10	1323_1	Whirinaki Stream Corbett Rd	2795641	6317052
OW	11	1131_107	Waikato River Ohakuri Tailrace Bridge	2779596	6306083
KWT	12	934_1	Tahunaatara Stream Ohakuri Rd	2778493	6313934
KWT	13	359_1	Mangaharakeke Stream (Atiamuri) SH30 (Off Jct SH1)	2773329	6312942
KWT	14	1202_7	Waipāpa Stream (Mokai) Tirohanga Rd Br	2768476	6304619
KW	15	1131_147	Waikato River Whakamaru Tailrace	2755134	6305593
KWT	16	388_1	Mangakino Stream (Whakamaru) Sandel Rd	2748675	6301404
KW	17	1131_143	Waikato River Waipāpa Tailrace	2745012	6320697
KWT	18	1287_7	Whakauru Stream U/S SH1 Br	2761664	6328033
KWT	19	407_1	Mangamingi Stream (Tokoroa) Paraonui Rd Br	2758808	6330101
KWT	20	786_2	Pokaiwhenua Stream Puketurua	2749051	6345843

Table A-1: Continued.

RCU	Site number	WRC number	Site name	Easting (NZMG)	Northing (NZMG)
KWT	21	335_1	Little Waipā Stream Arapuni - Putaruru Rd	2746800	6346200
KWT	22	230_5	Karāpiro Stream Hickey Rd Bridge - Cambridge	2733100	6363900
MWT	23	488_1	Mangawhero Stream (Cambridge) Cambridge-Ohaupo Rd	2721672	6365211
MW	24	1131_328	Waikato River Narrows Boat Ramp	2716821	6371002
MWT	25	417_7	Mangaone Stream (Waikato) Annebrooke Rd Br	2715900	6374400
MWT	26	421_10	Mangaonua Stream Hoeka Rd	2720486	6377539
MWT	27	398_1	Mangakotukutuku Stream (Rukuhia) Peacockes Rd	2712745	6374200
MW	28	HM3	Waikato River Hamilton Traffic bridge	2711768	6376678
MWT	29	1236_2	Waitawhiriwhiri Stream Edgecumbe Street	2710149	6378545
MWT	30	253_4	Kirikiriroa Stream Tauhara Dr	2709500	6381700
MW	31	1131_69	Waikato River Horotiu Br	2704815	6387066
Wp	32	1191_5	Waipā River Mangaokewa Rd	2723471	6302695
WpT	33	414_6	Mangaokewa Stream	2699776	6316160
WpT	34	1253_7	Waitomo Stream Tumutumu Rd	2693800	6324900
Wp	35	HM1	Waipā River Otewa	2715669	6323737
WpT	36	443_3	Mangapiko Stream (Pirongia/Te Awamutu)	2703300	6331800
Wp	37	1191_12	Waipā River SH3 Otorohanga	2703600	6332200
WpT	38	1253_5	Waitomo Stream SH31 Otorohanga	2702133	6333502
WpT	39	476_7	Mangatutu Stream (Waikeria) Walker Rd Br	2720300	6342200

Table A-1: Continued.

RCU	Site number	WRC number	Site name	Easting (NZMG)	Northing (NZMG)
WpT	40	411_9	Mangaokewa Stream Lawrence Street Br	2732928	6347201
WpT	41	818_2	Puniu River Bartons Corner Rd Br	2711500	6350000
WpT	42	477_10	Mangauika Stream Te Awamutu Borough W/S Intake	2697702	6350376
Wp	43	1191_10	Waipā River Pirongia-Ngutunui Rd Br	2703700	6352900
WpT	44	438_3	Mangapiko Stream (Pirongia/Te Awamutu) Bowman Rd	2709300	6356000
WpT	45	222_16	Kaniwhaniwha Stream Wright Rd	2698533	6368031
Wp	46	HM2	Waipā River Whatawhata Bridge	2699495	6376246
WpT	47	624_5	Ohote Stream Whatawhata/Horotiu Rd	2699743	6379440
LWT	48	258_4	Komakorau Stream Henry Rd	2709073	6394989
LWT	49	481_7	Mangawara Stream Rutherford Rd Br	2708400	6402300
LWT	50	39_11	Awaroa Stream (Rotowaro) Sansons Br @ Rotowaro-Huntly Rd	2694900	6399600
LW	51	1131_77	Waikato River Huntly-Tainui Br	2700546	6401768
LWT	52	516_5	Matahuru Stream Waiterimu Road Below Confluence	2708300	6410900
LW	53	HM4	Waikato River Rangiriri Bridge	2698736	6416666
LWT	54	1302_1	Whangape Stream Rangiriri-Glen Murray Rd	2695013	6415331
LWT	55	1098_1	Waerenga Stream Taniwha Rd	2713074	6421620
LWT	56	1293_9	Whangamarino River Jefferies Rd Br	2708394	6427183
LWT	57	665_5	Opuatia Stream Ponganui Rd	2677249	6424619
LWT	58	1293_7	Whangamarino River Island Block Rd	2695305	6430748

Table A-1: Continued.

RCU	Site number	WRC number	Site name	Easting (NZMG)	Northing (NZMG)
LWT	59	453_6	Mangatangi River SH2 Maramarua	2704126	6437110
LW	60	1131_91	Waikato River Mercer Br	2691787	6433612
LWT	61	459_6	Mangatawhiri River Lyons Rd At Buckingham Br	2699651	6442637
LWT	62	612_9	Ohaeroa Stream SH22 Br	2683349	6430335
LW	63	1131_133	Waikato River Tuakau Br	2682750	6432184
LWT	64	1282_8	Whakapipi Stream SH22 Br	2681052	6436497
LWT	65	41_9	Awaroa River (Waiuku) Otaua Rd Br opp Moseley Rd	2666200	6431900

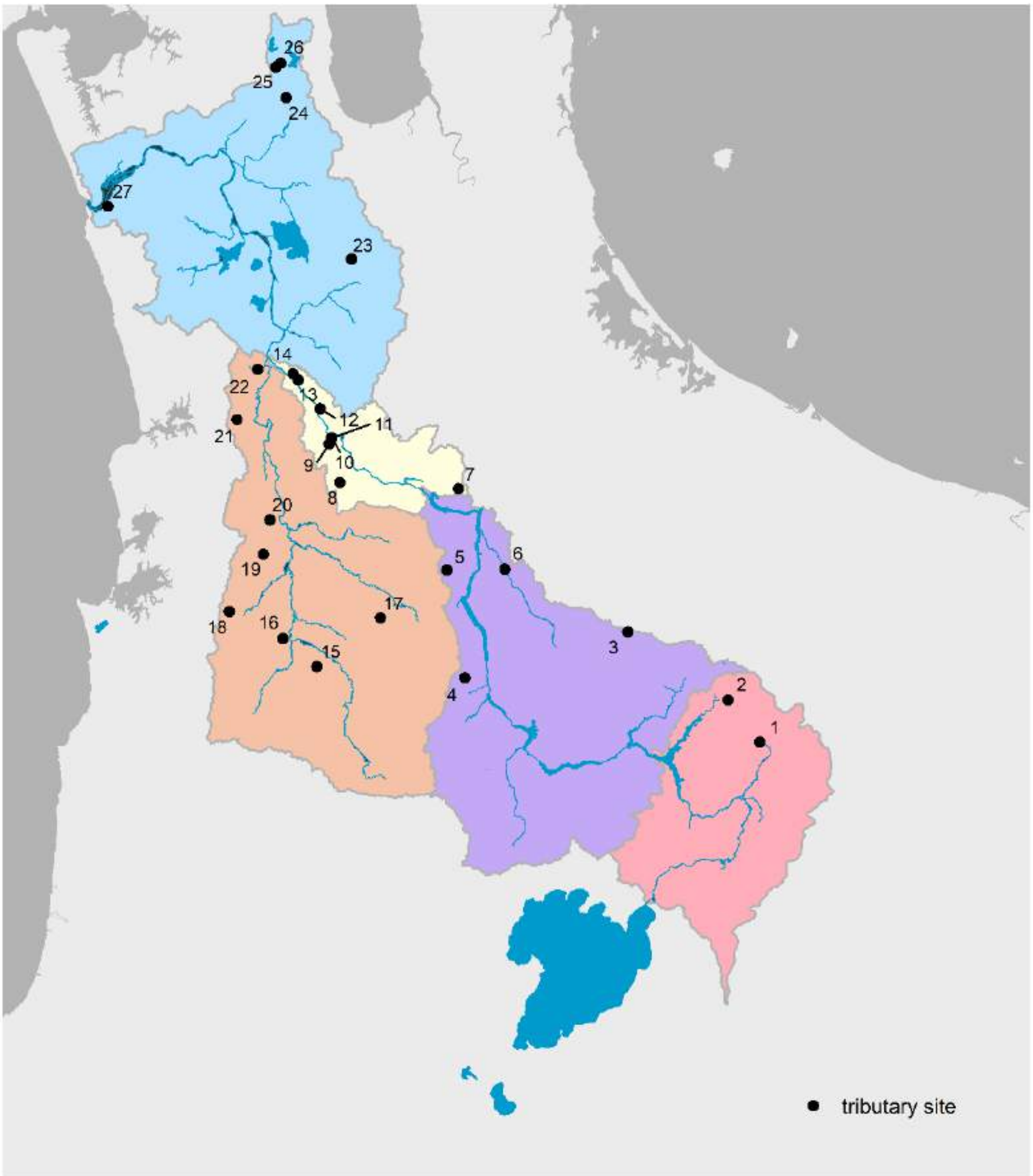

Figure A-2: Invertebrate and habitat (periphyton, macrophytes, riparian) monitoring site locations.

Table A-2: Invertebrate and habitat (periphyton, macrophytes, riparian) monitoring site locations.

RCU	Site number	WRC number	Site name	Easting (NZMG)	Northing (NZMG)
OWT	1	240_5	Kawaunui Stream @ SH5 Br	2802100	6308100
OWT	2	1323_1	Whirinaki Stream Corbett Rd	2795641	6317052
KWT	3	555_2	Mokaihaha Stream @ Galaxy Road Upstream of Road	2774869	6331990
KWT	4	495_1	Mangawhio Stream Trib Taupaki Rd	2739851	6323541
KWT	5	1888_4	Otautora Stream Trib	2736641	6346040
KWT	6	786_2	Pokaiwhenua Stream Arapuni - Putaruru Rd	2749051	6345843
MWT	7	220_1	Kaiwhitwhiti Stream Tiverton Downs Farm	2739623	6362859
MWT	8	571_10	Mystery Creek Bardoul Farm, 123 Kaipaki Rd	2714294	6364917
MWT	9	398_6	Mangakotukutuku Stream (Rukuhia) Pelorus Street	2712200	6372900
MWT	10	398_13	Mangakotukutuku Stream (Rukuhia) Waterford Road	2712751	6374066
MWT	11	398_1	Mangakotukutuku Stream (Rukuhia) Peacockes Rd	2712746	6374201
MWT	12	47_2	Bankwood Stream Emerald Tce	2710500	6380300
MWT	13	1132_70	Waikato River Trib@Unnamed Trib At River Rd Sth Pa	2705939	6386431
MWT	14	1132_69	Waikato River Trib@Unnamed Trib At Lake Road	2704813	6387770
WpT	15	493_1	Mangawhero Stream Trib (Otorohanga) Mangawhero Rd	2708413	6326725
WpT	16	1253_8	Waitomo Stream Waitomo Valley Rd	2701300	6332700
WpT	17	476_1	Mangatutu Stream (Waikeria) Lethbridge Rd	2722200	6336500
WpT	18	1966_1	Purangirangi Stream Oamaru Road	2690007	6338665
WpT	19	477_14	Mangauika Stream	2697600	6350400

Table A-2: Continued.

RCU	Site number	WRC number	Site name	Easting (NZMG)	Northing (NZMG)
WpT	20	379_1	Mangakara Stream (Pirongia) Bushline	2699203	6357477
WpT	21	1968_1	Whakakai Stream Whatawhata Research Station	2692600	6378500
WpT	22	125_15	Firewood Creek Trib Off Walkway 2nd Bridge On DO	2697316	6388818
LWT	23	1961_1	Mangatea Stream Trib (Tate Property)	2718019	6411182
LWT	24	453_8	Mangatangi River @ Stubbs Rd	2704800	6445100
LWT	25	458_1	Mangatawai Stream @ Off SH1 U/S Bridge	2702754	6451519
LWT	26	3104_1	Milnes Stream @ Mangatangi Hill Rd, Hunua	2703836	6452324
LWT	27	1132_67	Waikato River Trib Tuakau/Port Waikato	2665837	6423399

Appendix B Technical Appendices by Indicator

Water Clarity (Black Disk)

Water clarity data was collected across all ten RCUs. Fifty-three out of the 65 sites were able to be analysed for trends in the 2010-2014 time period, and 50 out of the 65 sites were able to be analysed for both the 2015-2019 and 2010-2019 time periods (Table B-1). There were no strong differences in water clarity trend direction and confidence between RCUs in any of the three periods. In general, the majority of trends across all RCUs were primarily improving in 2010-2014 and deteriorating in 2015-2019 (Table B-2, Figure B-1). As a result, the ten-year trends were a mixture of improving (26 trends), deteriorating (18 trends), and as likely improving as deteriorating (6 trends) (Table B-2, Figure B-1). All RCUs except the mainstem Waikato River RCUs also had at least one or more sites with a deteriorating ten-year trend.

Black disk medians were similar across all three time periods, indicating that measured values did not change between time periods. Correspondingly, the trend rates were small, with largest slopes and greatest variability in slopes in the 2010-2014 time period (Figure B-2).

Table B-1: Data filtering statistics for water clarity (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	**Total possible trends**	**Sites eliminated**	**Number analysed**	**Total possible trends**	**Sites eliminated**	**Number analysed**	**Total possible trends**	**Sites eliminated**	**Number analysed**
OW	3	1	2	3	1	2	3	1	2
OWT	8	3	5	8	3	5	8	3	5
KW	2	0	2	2	1	1	2	0	2
KWT	9	1	8	9	1	8	9	1	8
MW	3	0	3	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	1	4	5	1	4	5	1	4
WpT	11	4	7	11	4	7	11	4	7
LW	4	1	3	4	2	2	4	2	2
LWT	14	1	13	14	1	13	14	2	12
Total	**65**	**12**	**53**	**65**	**15**	**50**	**65**	**15**	**50**

Table B-2: The number of analysed trends in water clarity in each confidence category per time period. See Table 3 for more information about IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	21	1	13
Extremely likely improving	8	0	5
Very likely improving	5	0	4
Likely improving	13	1	4
As likely improving as deteriorating	5	9	6
As likely improving as deteriorating * (manually assigned)	0	0	0
Likely deteriorating	1	11	6
Very likely deteriorating	0	4	6
Extremely likely deteriorating	0	10	3
Virtually certain deteriorating	0	14	3
Total number of analysed trends	**53**	**50**	**50**

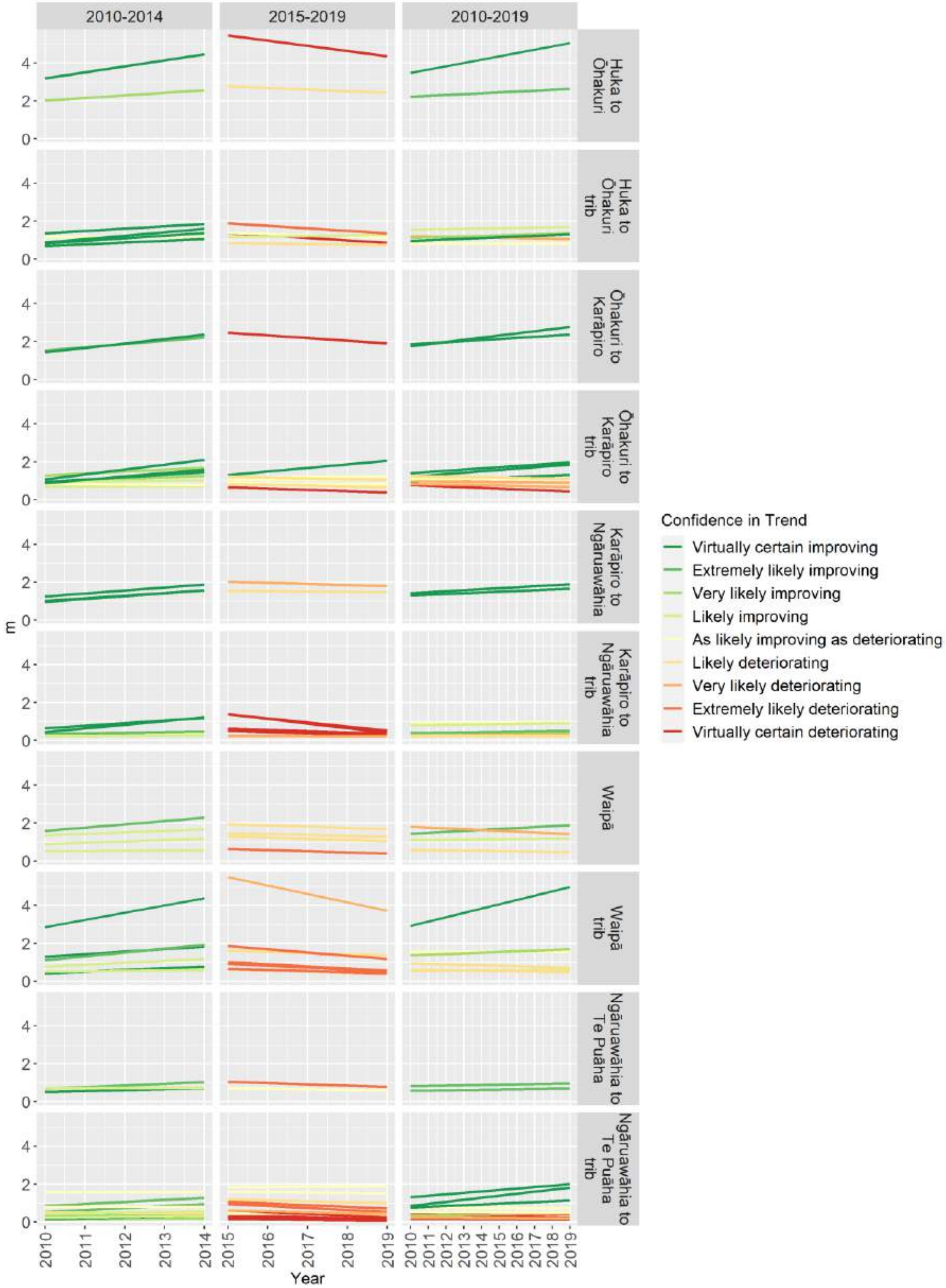

Figure B-1: Trends in water clarity in Waikato River RCUs over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

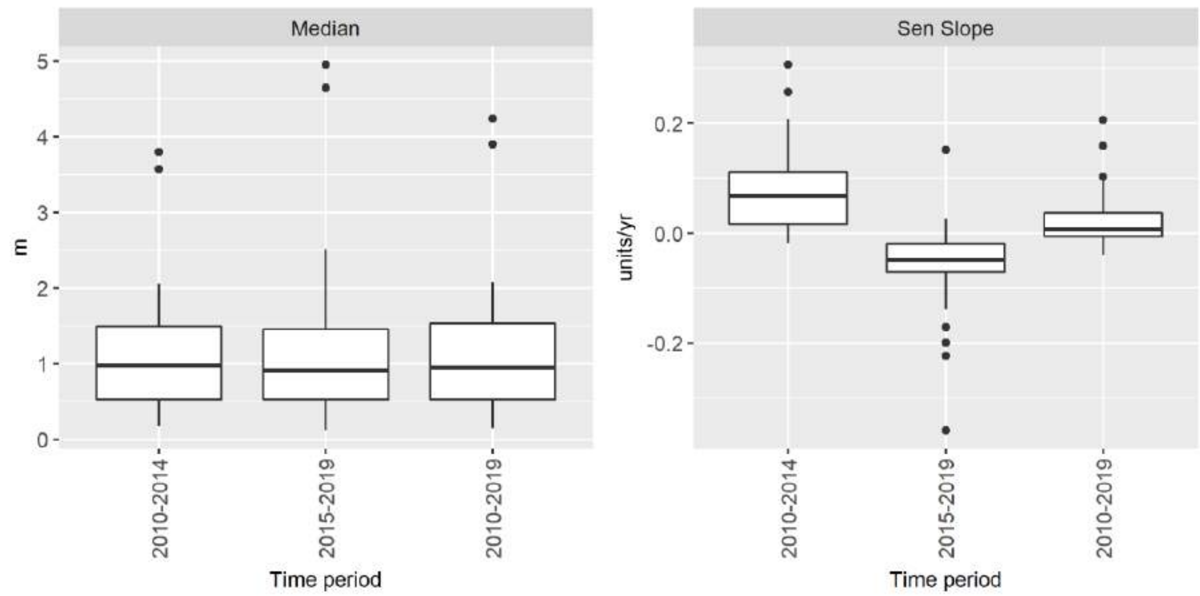

Figure B-2: Summary of medians and trend rates for water clarity. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period**.** The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

E.coli

E. coli data was collected across all ten RCUs. Forty-five out of 65 sites were able to be analysed for trends in the 2010-2014 time period, 61 out of 65 sites were able to be analysed for the 2015-2019 time period, and 42 sites were able to be analysed for the 2010-2019 time period (Table B-3). The majority of trends in 2010-2014 were improving (25 trends), followed by as likely improving as deteriorating (13 trends) (Table B-4) except for in the Waipā (Wp) RCU, which had more deteriorating trends. In the 2015-2019 time period the majority of trends across all RCUs were deteriorating (43 trends) followed by as likely improving as deteriorating (11 trends). Over the ten-year period from 2010-2019 trends were a mixture of deteriorating (21 trends) or as likely improving as deteriorating (13 trends). The majority of deteriorating trends over the ten-year period were in the upper river RCUs (OW, OWT, KW, KWT), while the mid- and lower-river RCUs had more improving trends (Figure B-3).

Median *E. coli* was similar across all three time periods and trend rates were largest and most variable in the 2015-2019 time period (Figure B-4).

Table B-3: Data filtering statistics for *E.coli* (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
OWT	8	4	4	8	1	7	8	4	4
KW	2	0	2	2	0	2	2	0	2
KWT	9	1	8	9	0	9	9	1	8
MW	3	0	3	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	1	4	5	1	4	5	2	3
WpT	11	4	7	11	0	11	11	4	7
LW	4	0	4	4	1	3	4	1	3
LWT	14	10	4	14	0	14	14	10	4
Total	**65**	**20**	**45**	**65**	**4**	**61**	**65**	**23**	**42**

Table B-4: The number of analysed trends in *E.coli* in each confidence category per time period. See Table 3 for more information about IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	1	0	0
Extremely likely improving	5	1	1
Very likely improving	5	0	2
Likely improving	14	6	5
As likely improving as deteriorating	13	11	13
As likely improving as deteriorating * (manually assigned)	0	0	0
Likely deteriorating	6	19	8
Very likely deteriorating	0	8	3
Extremely likely deteriorating	1	10	5
Virtually certain deteriorating	0	6	5
Total number of analysed trends	**45**	**61**	**42**

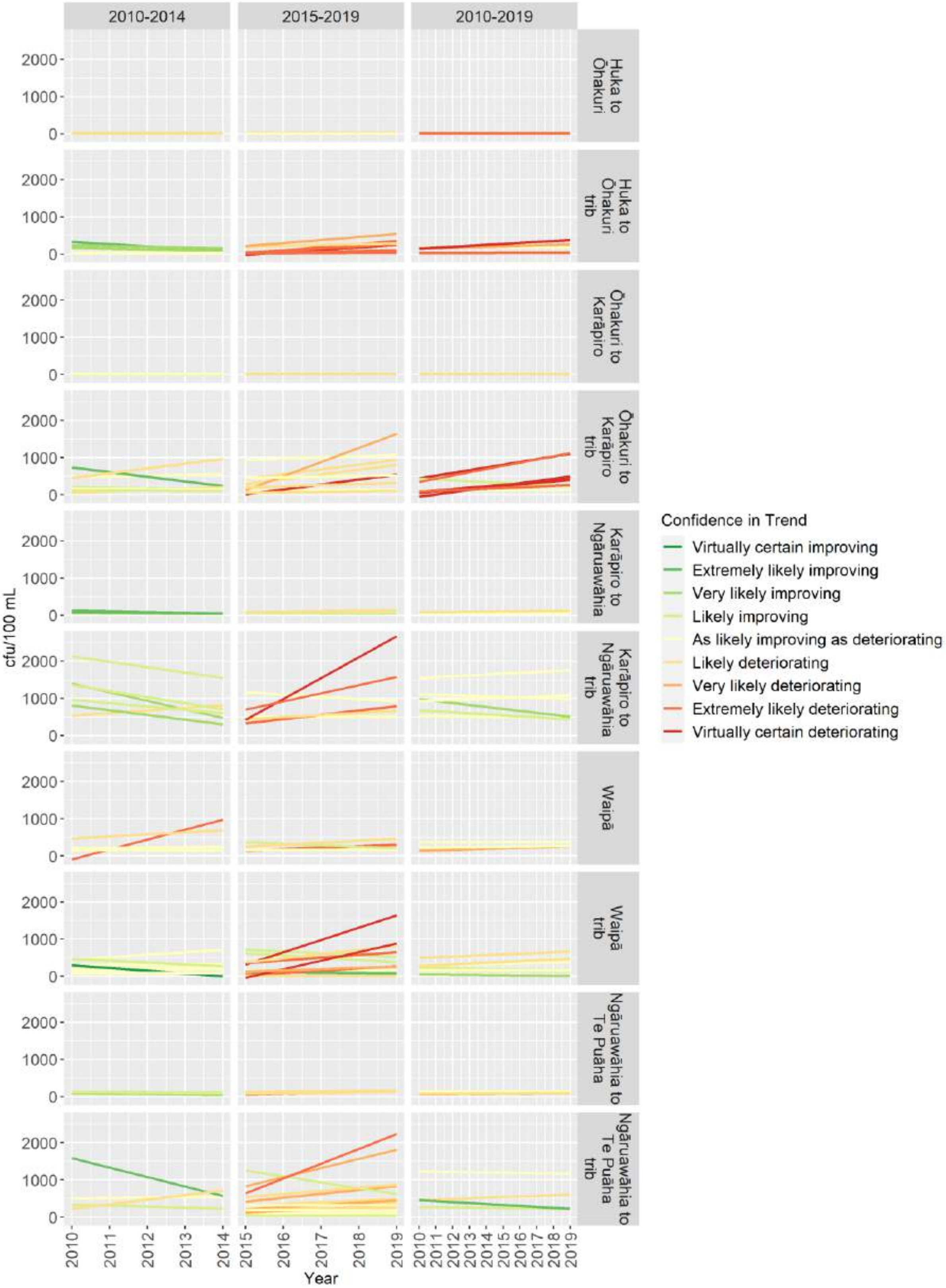

Figure B-3: Trends in *E. coli* in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

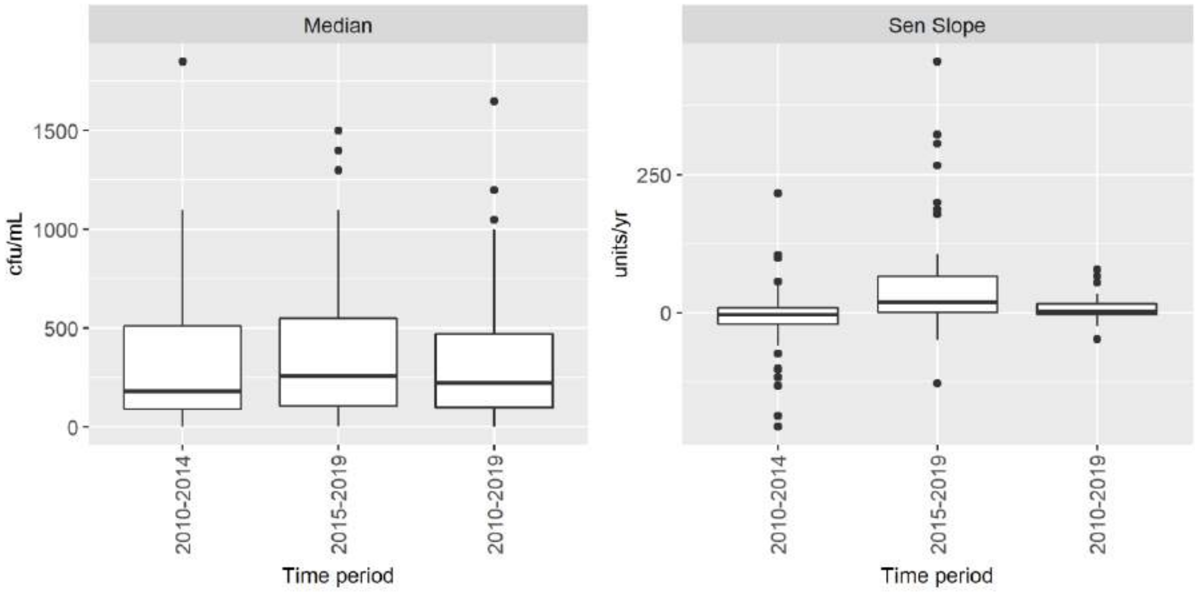

Figure B-4: Summary of medians and trend rates for *E. coli*. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period**.** The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Total Nitrogen (TN)

Total nitrogen data was collected across all ten RCUs. Sixty-one of the 65 sites were able to be analysed for trends in TN in the 2010-2014 time period, and 60 of the 65 sites were able to be analysed for trends in both the 2015-2019 and 2010-2019 time period (Table B-5). Trends varied between time periods, with predominately improving trends in 2010-2014 (52 trends), predominately deteriorating trends in 2015-2019 (42 trends), and 2010-2019 (40 trends) (Table B-6). Trends also varied between RCUs within time periods. In particular, the upper-river RCUs had more deteriorating trends over the ten-year time period, whereas the mid-river RCU (MWT) had more improving trends, and the Waipā (Wp) and lower-river RCU (LWT) had a mixture of improving and deteriorating trends (Figure B-5).

TN medians were similar across all three time periods and trend rates were most variable in the 2010-2014 time period and least variable in the 2019-2019 time period (Figure B-6). Overall, trend rates were small across all three time periods (Figure B-6).

Table B-5: Data filtering statistics for total nitrogen (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
OWT	8	0	8	8	0	8	8	0	8
KW	2	0	2	2	0	2	2	0	2
KWT	9	0	9	9	0	9	9	0	9
MW	3	1	2	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	2	3	5	3	2	5	3	2
WpT	11	0	11	11	0	11	11	0	11
LW	4	1	3	4	1	3	4	1	3
LWT	14	0	14	14	0	14	14	0	14
Total	**65**	**4**	**61**	**65**	**5**	**60**	**65**	**5**	**60**

Table B-6: The number of analysed trends in total nitrogen in each confidence category per time period. See Table 3 for more information about IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	20	4	5
Extremely likely improving	11	2	2
Very likely improving	6	0	0
Likely improving	15	5	3
As likely improving as deteriorating	2	7	10
As likely improving as deteriorating * (manually assigned)	1	0	0
Likely deteriorating	3	18	7
Very likely deteriorating	1	8	4
Extremely likely deteriorating	0	7	9
Virtually certain deteriorating	2	9	20
Total number of analysed trends	**61**	**60**	**60**

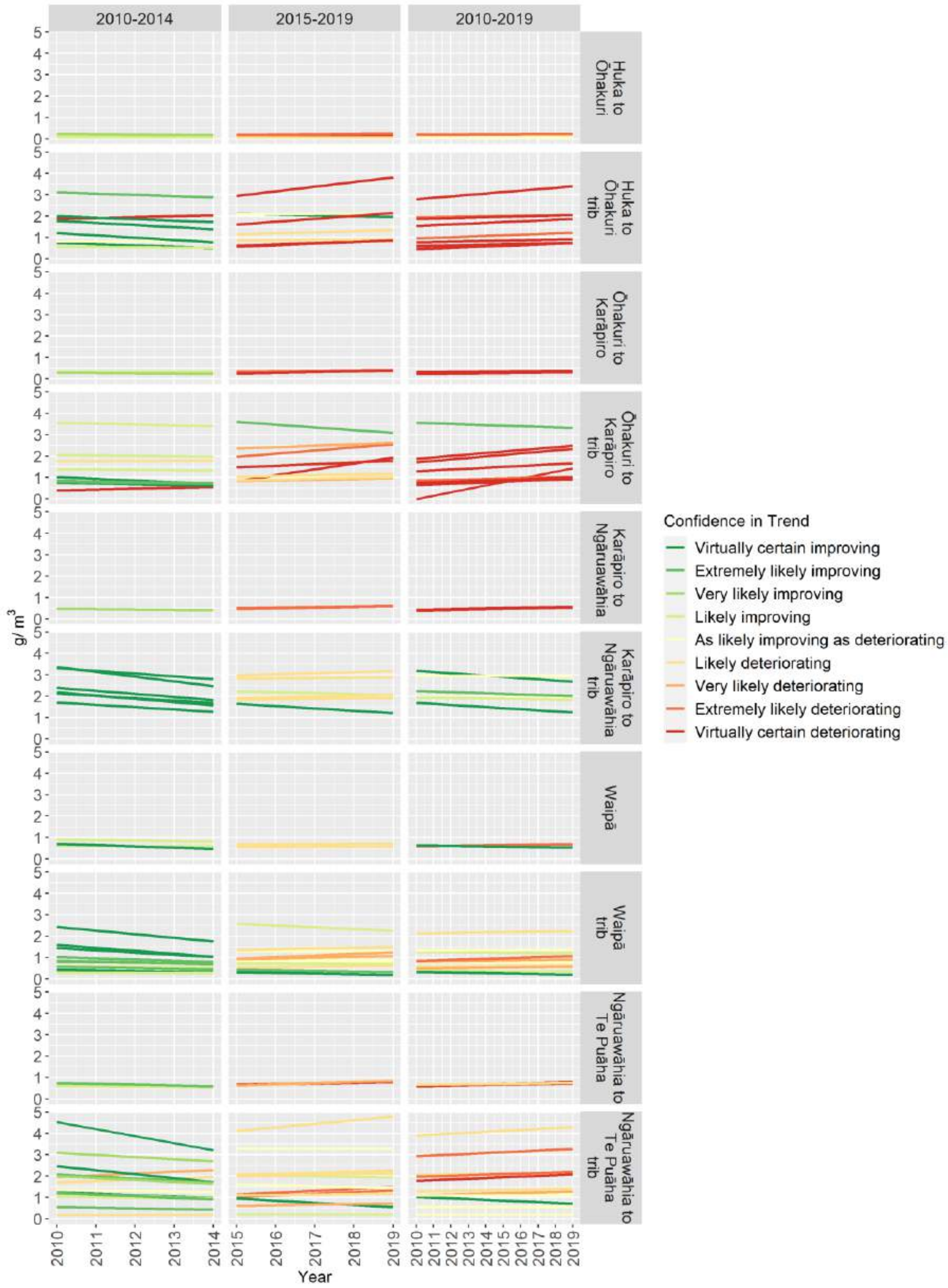

Figure B-5: Trends in total nitrogen in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

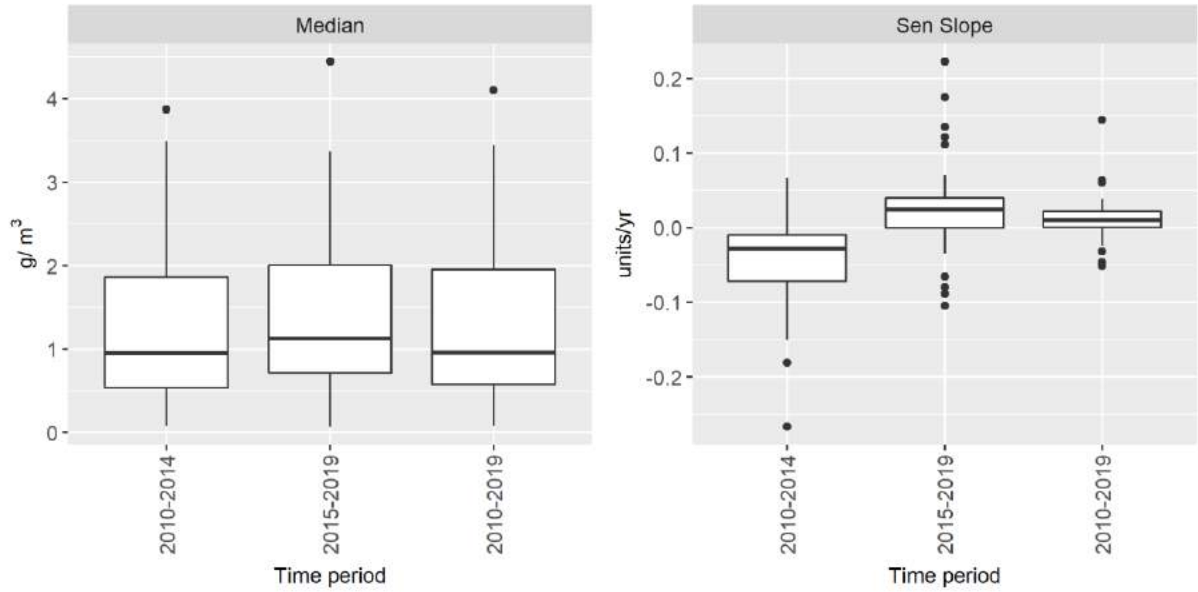

Figure B-6: Summary of medians and trend rates for total nitrogen. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period**.** The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Total Phosphorus (TP)

Total phosphorus data was gathered across all ten RCUs. Fifty-eight out of the 65 sites were able to be analysed for trends in the 2010-2014 time period, 62 sites were able to be analysed in the 2015-2019 time period, and 58 sites were able to be analysed in the 2010-2019 time period (Table B-7). Trends were a mixture of improving, deteriorating, and as likely improving as deteriorating across all three time periods. In general, there were more improving trends (41 trends) than deteriorating trends (7 trends) in the 2010-2014 period and more deteriorating trends (34 trends) than improving trends (18 trends) in the 2015-2019 time period (Table B-7). The majority of deteriorating trends in 2015-2019 were in mid- and lower-river RCU tributary sites (MWT, WpT, LWT) (Figure B-7). Over the ten-year period trends were a mixture of improving (23 trends), deteriorating (23 trends), and as likely improving as deteriorating (12 trends) across all RCUs (Figure B-7).

TP medians and trend rates were similar across all three time periods although trend rates were more variable in the 2010-2014 time period than in 2015-2019 or 2010-2019 (Figure B-8).

Table B-7: Data filtering statistics for total phosphorus (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	1	2	3	0	3	3	0	3
OWT	8	3	5	8	0	8	8	3	5
KW	2	0	2	2	0	2	2	0	2
KWT	9	1	8	9	0	9	9	1	8
MW	3	1	2	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	0	5	5	1	4	5	1	4
WpT	11	0	11	11	0	11	11	0	11
LW	4	1	3	4	1	3	4	1	3
LWT	14	0	14	14	0	14	14	0	14
Total	**65**	**7**	**58**	**65**	**3**	**62**	**65**	**7**	**58**

Table B-8: The number of analysed trends in total phosphorus in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	14	4	5
Extremely likely improving	7	3	4
Very likely improving	9	2	3
Likely improving	11	9	11
As likely improving as deteriorating	10	9	12
As likely improving as deteriorating * (manually assigned)	0	1	0
Likely deteriorating	4	14	11
Very likely deteriorating	2	5	2
Extremely likely deteriorating	1	5	4
Virtually certain deteriorating	0	10	6
Total number of analysed trends	**58**	**62**	**58**

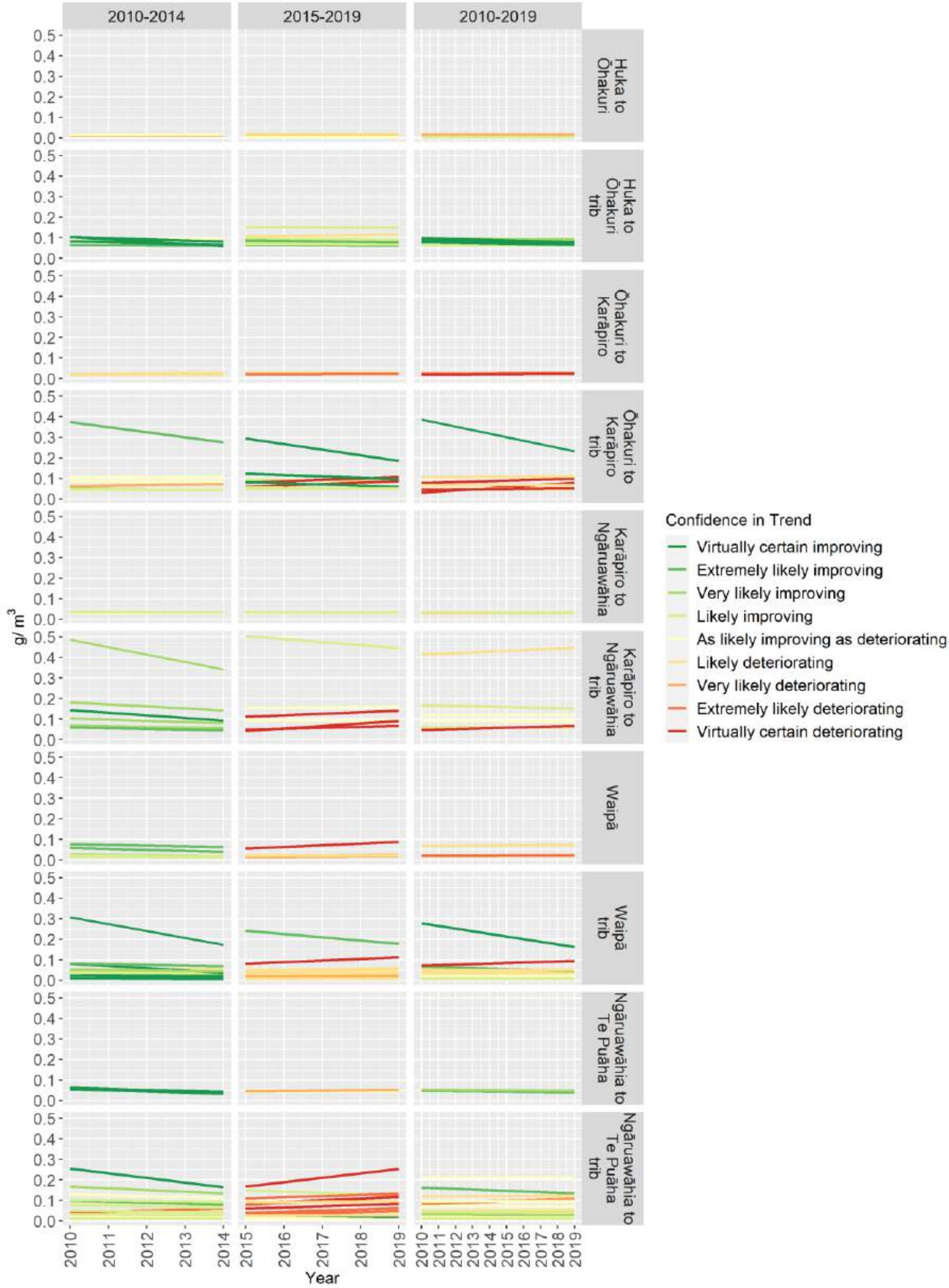

Figure B-7: Trends in total phosphorus in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

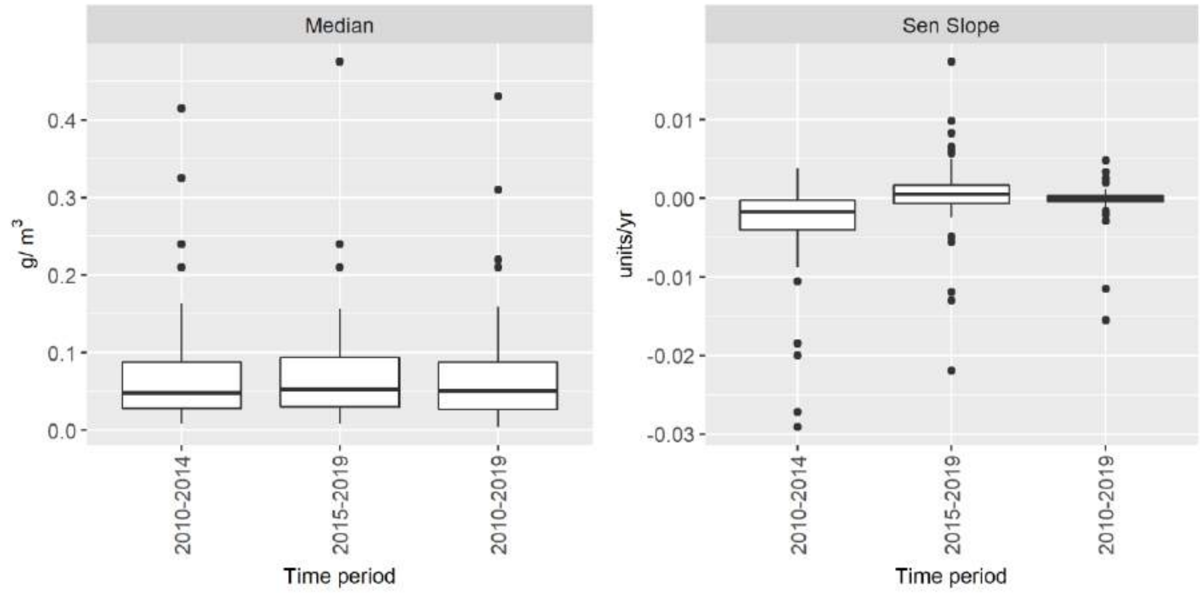

Figure B-8: Summary of medians and trend rates for total phosphorus. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period**.** The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Phytoplankton (Chlorophyll *a*)

The concentration of phytoplankton (Chlorophyll *a*) was only measured in the 10 mainstem Waikato River sites. All ten sites were able to be analysed for temporal trends in each time period (Table B-9). Trends were similar in the KW, MW, and LW RCUs within each time period, with more improving trends in 2015-2019 than in 2010-2014 (Table B-10). The OW trends remained as likely improving as deteriorating across all three time periods (Figure B-9). The overall ten-year trends were primarily improving (7 trends), with 3 as likely improving as deteriorating trends (Figure B-9).

Median Chlorophyll *a* was lower in the 2015-2019 time period than in the other two time periods (Figure B-10). Trend rates were also larger in the 2015-2019 time period and more variable in both the 2010-2014 and 2015-2019 time periods than in the 2019-2019 time period (Figure B-10).

Table B-9: Data filtering statistics for Chlorophyll a (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
KW	2	0	2	2	0	2	2	0	2
MW	2	0	2	2	0	2	2	0	2
LW	3	0	3	3	0	3	3	0	3
Total	**10**	**0**	**10**	**10**	**0**	**10**	**10**	**0**	**10**

Table B-10: The number of analysed trends in Chlorophyll *a* in each confidence category per time period. See Table 3 for more information about IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	6
Extremely likely improving	0	2	0
Very likely improving	0	1	0
Likely improving	3	1	1
As likely improving as deteriorating	2	0	0
As likely improving as deteriorating * (manually assigned)	3	6	3
Likely deteriorating	1	0	0
Very likely deteriorating	0	0	0
Extremely likely deteriorating	1	0	0
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**10**	**10**	**10**

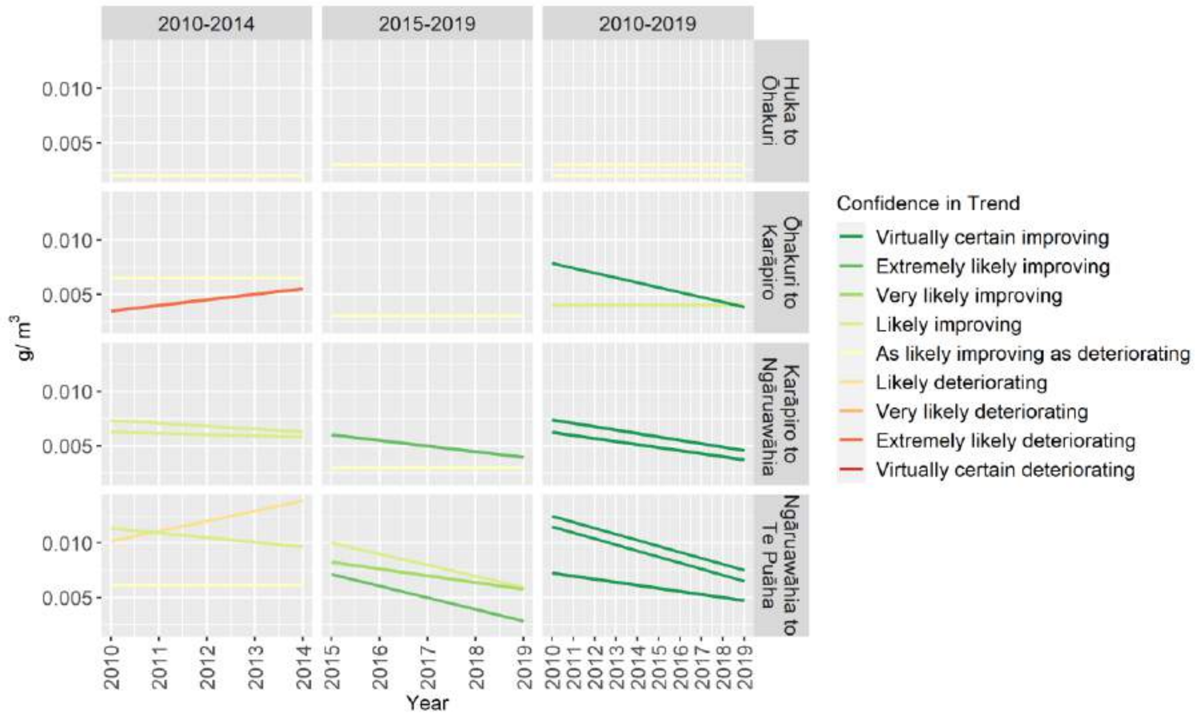

Figure B-9: Trends in Chlorophyll *a* in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating. The scale reflects the trend around 16 in RCU LW during 2010-2014 time period.

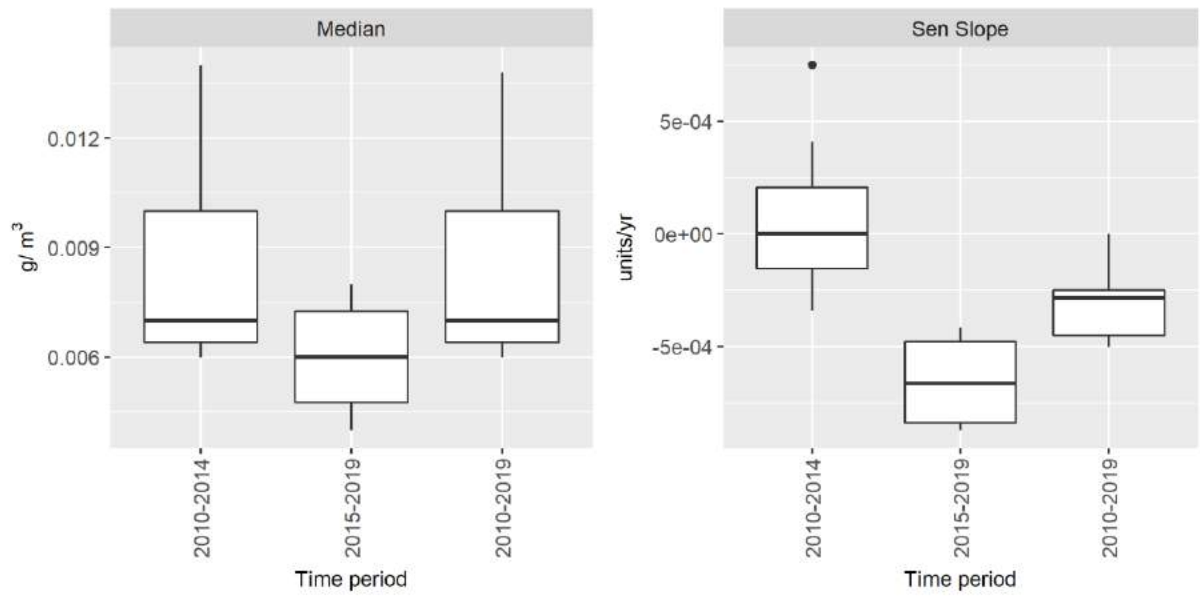

Figure B-10: Summary of medians and trend rates for Chlorophyll *a*. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period**.** The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Dissolved Oxygen (DO)

Dissolved oxygen data was gathered for all ten RCUs. All 65 sites were able to be analysed for trends in dissolved oxygen in the 2010-2014 period, and 62 trends were able to be analysed in both the 2015-2019 and 2010-2019 time periods (Table B-11). Trends varied between RCUs and between time periods, the OWT, WpT, and LWT RCUS had more improving trends in 2010-2014 and over the ten-year period than the other RCUS (Figure B-11). In general, there were more deteriorating trends (26 trends) and as likely improving as deteriorating (22 trends) than improving trends (17 trends) in 2010-2014 and more improving trends (35 trends) than as likely improving as deteriorating (14 trends) or deteriorating trends (13 trends) in 2015-2019 (Table B-12). Over the ten-year period there more deteriorating trends (44 trends) than improving trends (8 trends) and as likely improving as deteriorating trends (10 trends) (Table B-12).

Median dissolved oxygen and trend rates were similar across all three time periods (Figure B-12).

Table B-11: Data filtering statistics for dissolved oxygen (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
OWT	8	0	8	8	0	8	8	0	8
KW	2	0	2	2	0	2	2	0	2
KWT	9	0	9	9	0	9	9	0	9
MW	3	0	3	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	0	5	5	1	4	5	1	4
WpT	11	0	11	11	0	11	11	0	11
LW	4	0	4	4	1	3	4	1	3
LWT	14	0	14	14	0	14	14	0	14
Total	**65**	**0**	**65**	**65**	**3**	**62**	**65**	**3**	**62**

Table B-12: The number of analysed trends in dissolved oxygen in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	**2010-2014**	**2015-2019**	**2010-2019**
Virtually certain improving	0	6	2
Extremely likely improving	2	4	3
Very likely improving	2	7	1
Likely improving	13	18	2
As likely improving as deteriorating	22	14	10
As likely improving as deteriorating * (manually assigned)	0	0	0
Likely deteriorating	18	9	12
Very likely deteriorating	1	2	7
Extremely likely deteriorating	6	1	11
Virtually certain deteriorating	1	1	14
Total number of analysed trends	**65**	**62**	**62**

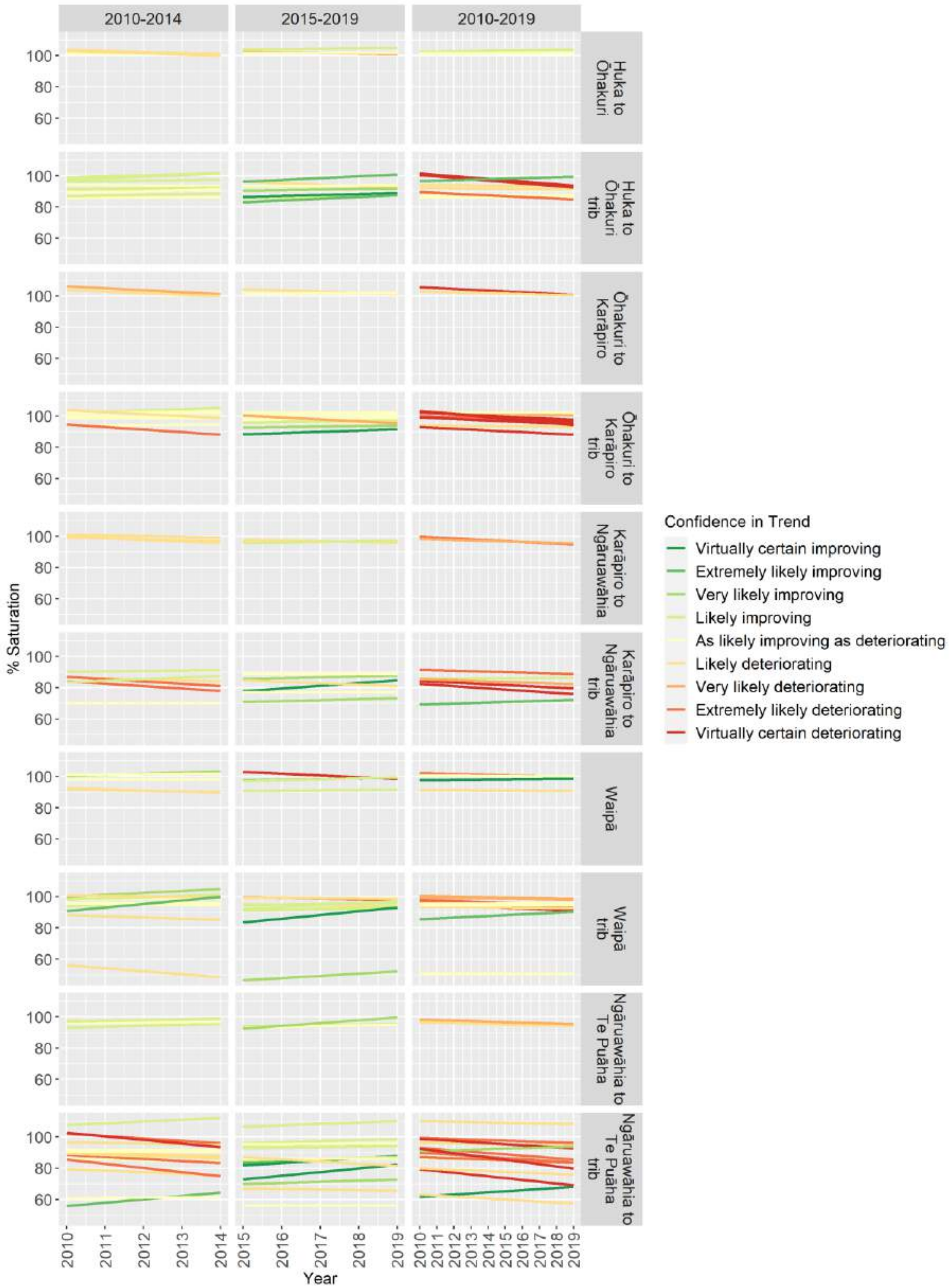

Figure B-11: Trends in dissolved oxygen percent saturation in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

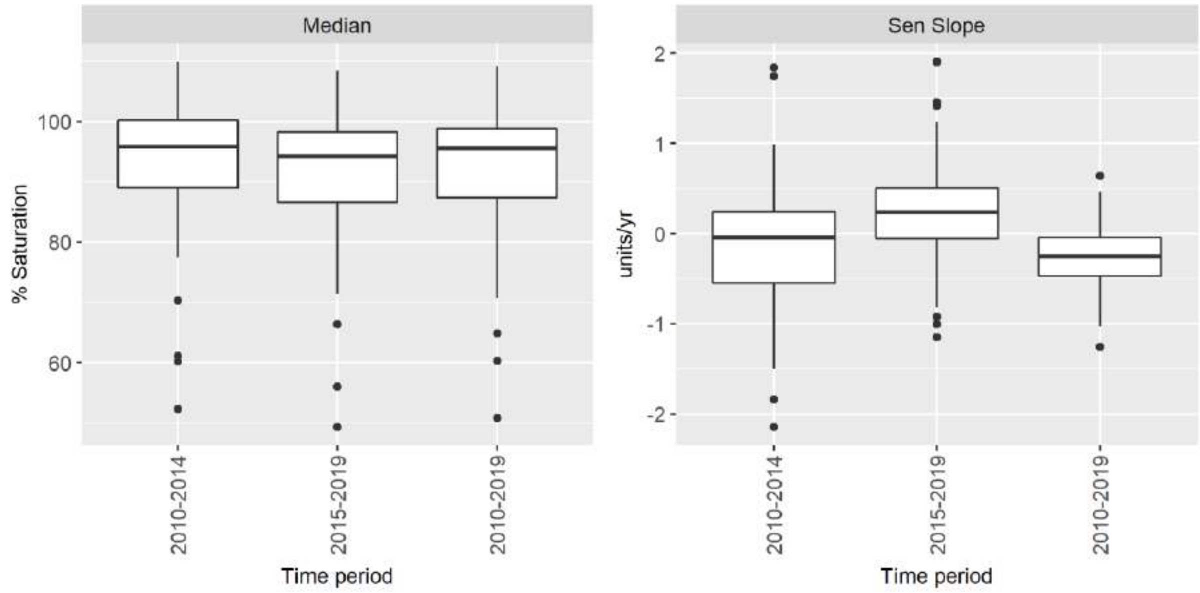

Figure B-12: Summary of medians and trend rates for dissolved oxygen. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Water Temperature

Water temperature was gathered for all ten RCUs. All 65 sites were able to be analysed for trends in water temperature in the 2010-2014 period, and 62 trends were able to be analysed in both the 2015-2019 and 2010-2019 time periods (Table B-13). Trends were a mixture of improving (27 trends), as likely improving as deteriorating (21 trends), and deteriorating (17 trends) in the 2010-2014 time period, with more improving trends in the upper-river tributary sites (OWT and KWT RCUs) than the mid- and lower-river RCU sites. Trends in 2015-2019 were mostly deteriorating in the lower-river and Waipā tributary sites (MWT, WpT, LWT RCUs) but improving in the upper-river tributary sites (OWT, KWT RCUs) (Table B-14). Trends over the ten-year period were similar to those in 2015-2019, with more deteriorating (29 trends) than improving trends (17 trends) and as many as likely improving as deteriorating trends as improving trends (17 trends) (Table B-14). The improving trends were mostly located in the upper-river RCUs (OW, OWT, KW, KWT) and the deteriorating trends in the lower-river RCUs (MW, MWT, WpT, LW, LWT) (Figure B-13).

Median water temperatures were similar across all three time periods (Figure B-14). Water temperature trend rates were small across all three time periods, although larger and more variable in the 2010-2014 time period and smallest and least-variable in the 2010-2019 time period (Figure B-14).

Table B-13: Data filtering statistics for water temperature (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT) Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
OWT	8	0	8	8	0	8	8	0	8
KW	2	0	2	2	0	2	2	0	2
KWT	9	0	9	9	0	9	9	0	9
MW	3	0	3	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	0	5	5	1	4	5	1	4
WpT	11	0	11	11	0	11	11	0	11
LW	4	0	4	4	1	3	4	1	3
LWT	14	0	14	14	0	14	14	0	14
Total	65	0	**65**	65	3	**62**	65	3	**62**

Table B-14: The number of analysed trends in water temperature in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	9	2	0
Extremely likely improving	3	0	1
Very likely improving	0	1	5
Likely improving	15	9	10
As likely improving as deteriorating	20	19	17
As likely improving as deteriorating * (manually assigned)	1	0	0
Likely deteriorating	16	18	16
Very likely deteriorating	1	7	5
Extremely likely deteriorating	0	3	6
Virtually certain deteriorating	0	3	2
Total number of analysed trends	**65**	**62**	**62**

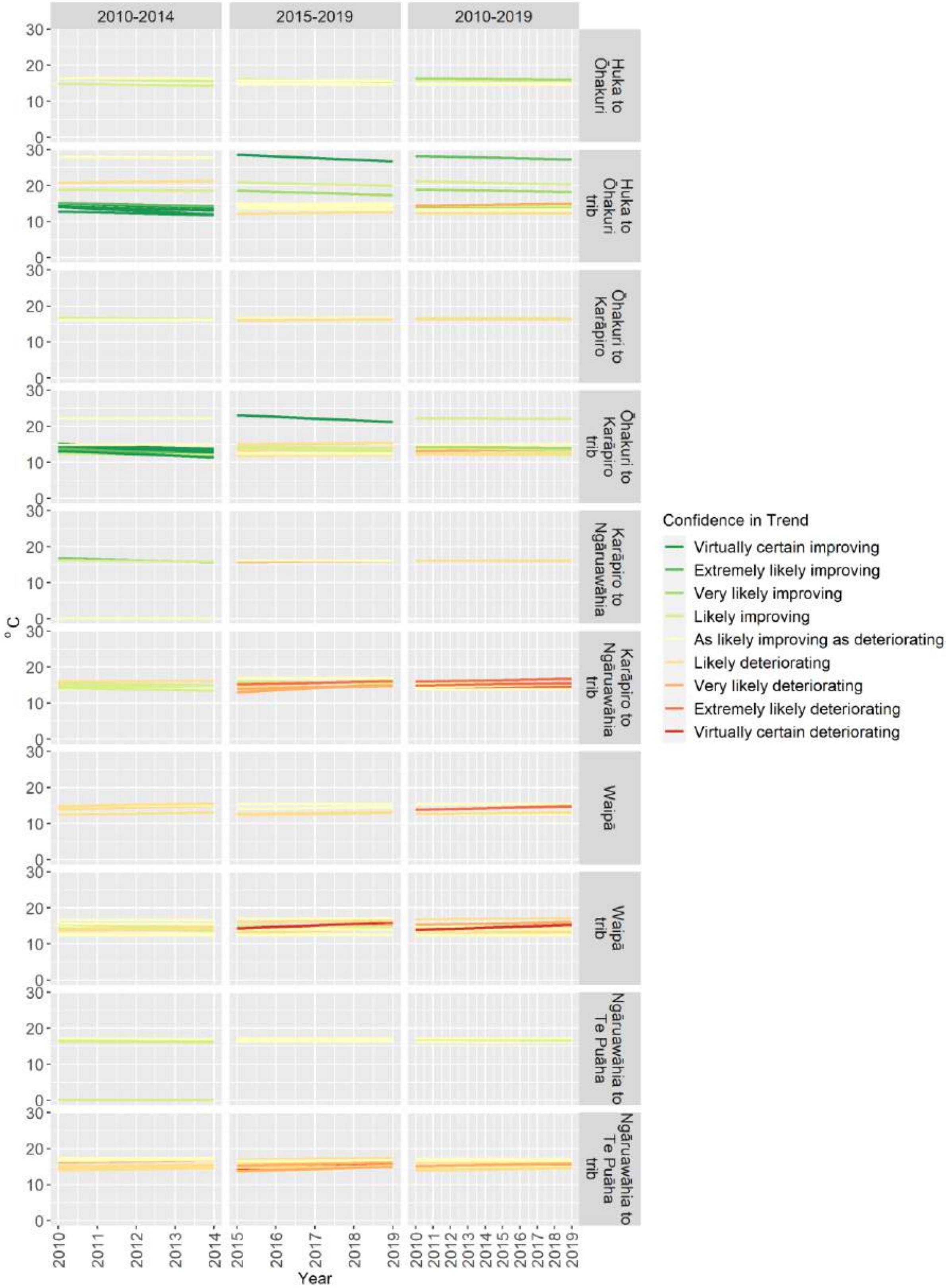

Figure B-13: Trends in water temperature in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

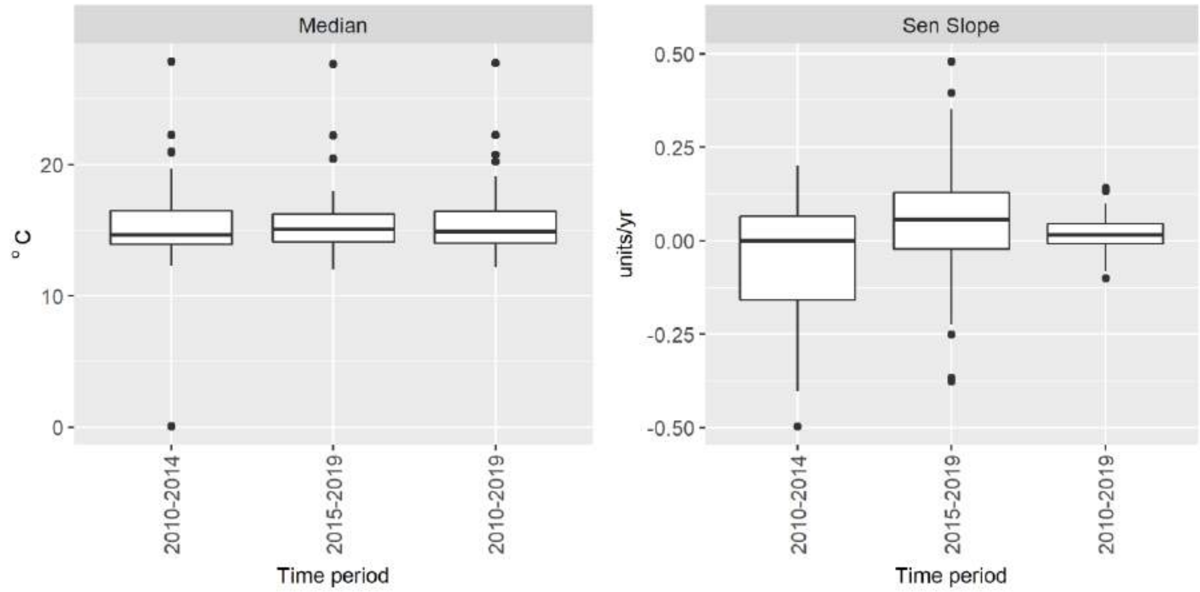

Figure B-14: Summary of medians and trend rates for water temperature. Box-and-whisker plots show the distributions of site medians and trend rates (Sen Slopes) within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Ammoniacal Nitrogen

Ammoniacal nitrogen was sampled across all ten RCUs. All 65 sites were able to be analysed for trends in water temperature in the 2010-2014 period (Table B-15). For the 2015-2019 time period, 20 sites had measurements consistently below detection limits, and trends were manually assigned "as likely improving as deteriorating" (see Section 3.3). Including those 20 sites, 62 trends were able to be analysed for trends in ammoniacal nitrogen in the 2015-2019 time period (Table B-15). For the 2010-2019 time period, a total of 62 sites were able to be analysed, including 15 manually assigned trends (Table B-15). Trends varied between RCUs and time periods, with more improving trends (18 trends), particularly in the lower-river tributary sites (MWT, WpT, LWT RCUs) in 2010-2014, but predominately deteriorating trends (23 trends) or as likely improving as deteriorating (32 trends) trends in 2015-2019 across all RCUs (Table B-16, Figure B-15). Over the ten-year period trends were mostly deteriorating (33 trends), except in the MWT RCU which had improving trends in several sites (Table B-16, Figure B-15).

Median ammoniacal nitrogen was similarly low across all three time periods (Figure B-16). Trend rates were also consistently very small across all three time periods (Figure B-16).

Table B-15: Data filtering statistics for ammoniacal nitrogen (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
OWT	8	0	8	8	0	8	8	0	8
KW	2	0	2	2	0	2	2	0	2
KWT	9	0	9	9	0	9	9	0	9
MW	3	0	3	3	1	2	3	1	2
MWT	6	0	6	6	0	6	6	0	6
Wp	5	0	5	5	1	4	5	1	4
WpT	11	0	11	11	0	11	11	0	11
LW	4	0	4	4	1	3	4	1	3
LWT	14	0	14	14	0	14	14	0	14
Total	**65**	**0**	**65**	**65**	**3**	**62**	**65**	**3**	**62**

Table B-16: The number of analysed trends in ammoniacal nitrogen in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	1	1	0
Extremely likely improving	1	0	1
Very likely improving	6	0	1
Likely improving	10	6	6
As likely improving as deteriorating	12	12	7
As likely improving as deteriorating * (manually assigned)	0	20	15
Likely deteriorating	8	10	10
Very likely deteriorating	3	3	6
Extremely likely deteriorating	6	4	5
Virtually certain deteriorating	2	6	11
Total number of analysed trends	**65**	**62**	**62**

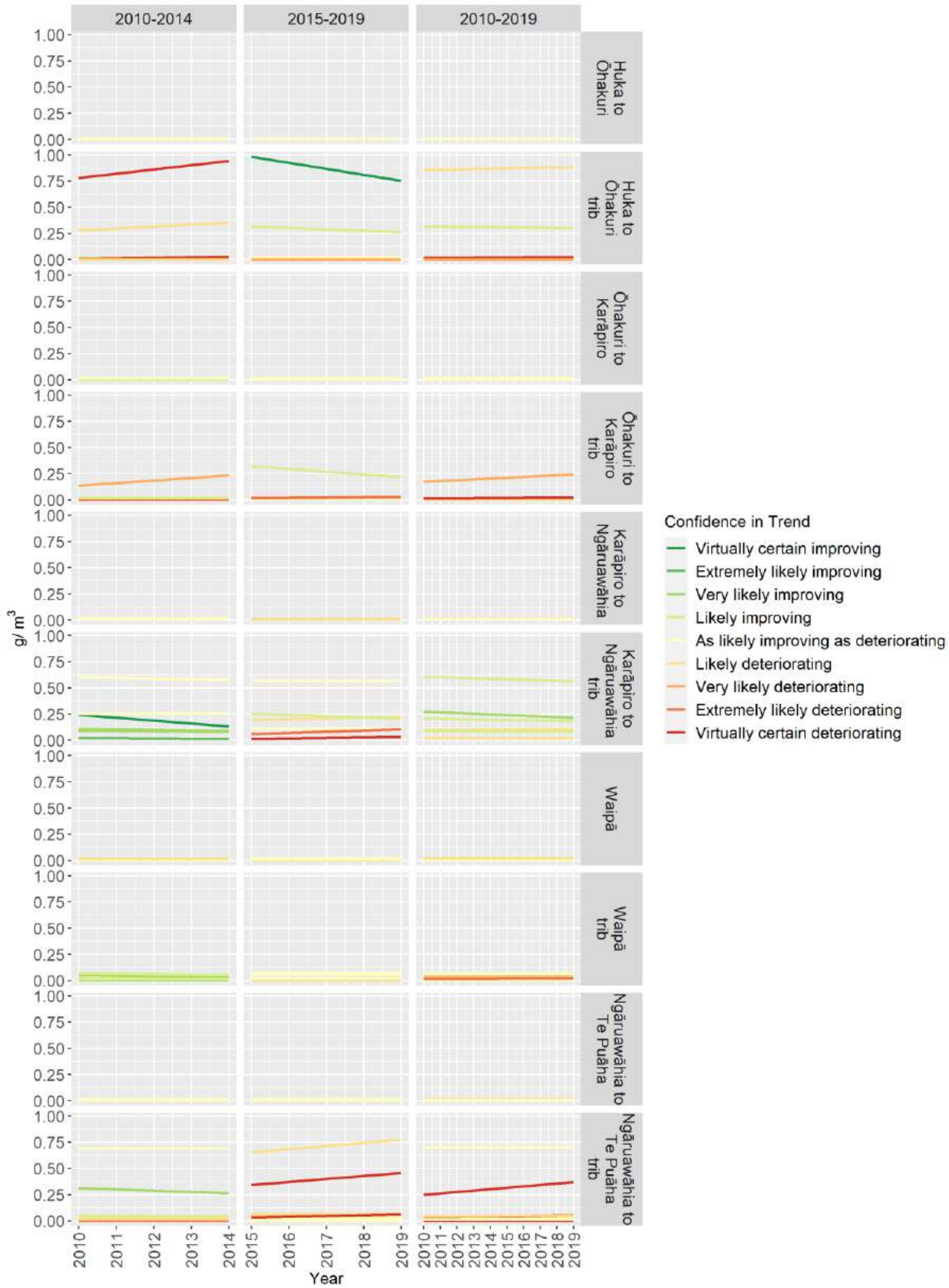

Figure B-15: Trends in ammoniacal nitrogen in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

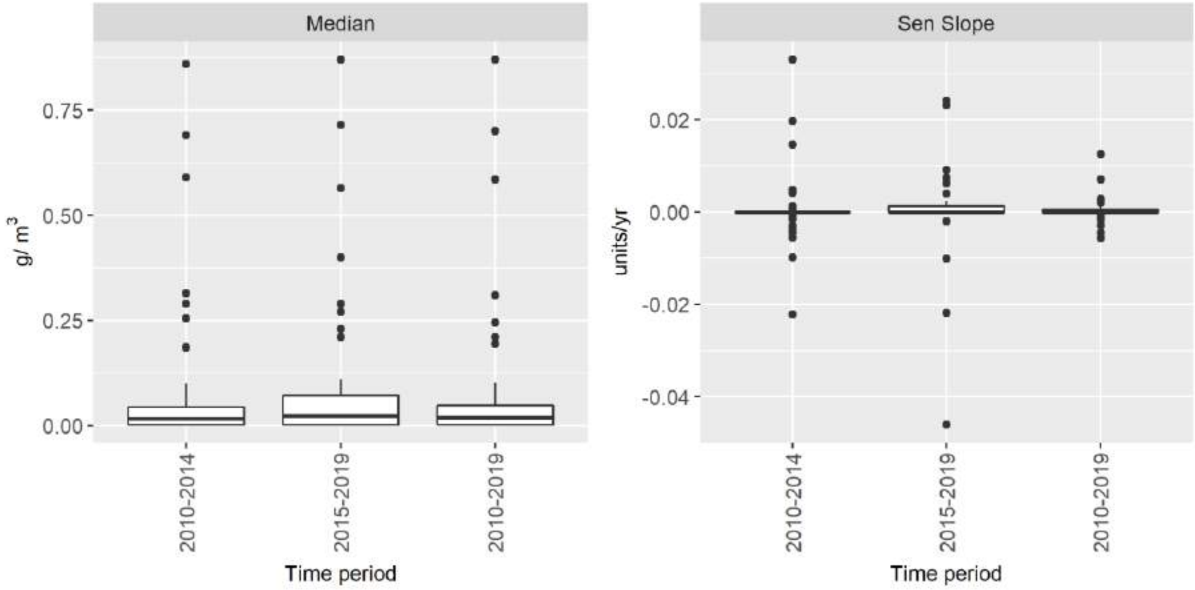

Figure B-16: Summary of medians and trend rates for ammoniacal nitrogen. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Arsenic (As)

Arsenic was only measured consistently[6] in the 10 mainstem Waikato River sites. All ten sites were able to be analysed for temporal trends in each time period (Table B-17). Trends in arsenic were a mixture of deteriorating (5 trends), as likely improving as deteriorating (2 trends), and improving (3 trends) across all four mainstem RCUs in 2010-2014) (Table B-18). In 2015-2019 trends were evenly split between improving (5 trends) and as likely improving as deteriorating (5 trends) (Table B-18). The improving trends in this period were located in the upper-river RCUs (OW, KW) and the as likely improving as deteriorating trends were located in the lower-river RCUs (MW, LW) (Figure B-17). Over the ten-year period all ten trends were improving (Figure B-17).

Median arsenic was much more variable in 2010-2014 (and therefore also over the ten year-period from 2010-2019) than in 2015-2019 (Figure B-18). Trend rates were small in both five-year periods but slightly larger and more variable over the ten-year period (Figure B-18).

[6] Arsenic was measured in some regional river sites for 1-2 years but the available data record was insufficient for trend analysis.

Table B-17: Data filtering statistics for arsenic (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OW	3	0	3	3	0	3	3	0	3
KW	2	0	2	2	0	2	2	0	2
MW	2	2	2	2	2	2	2	2	2
LW	3	0	3	3	0	3	3	0	3
Total	**10**	**0**	**10**	**10**	**0**	**10**	**10**	**0**	**10**

Table B-18: The number of analysed trends in arsenic in each confidence category for the 2010-2014 time period. See Table 3 for explanations of IPCC likelihood categories. Arsenic monitoring ceased after 2014.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	1	1	8
Extremely likely improving	0	3	1
Very likely improving	1	1	1
Likely improving	1	0	0
As likely improving as deteriorating	1	4	0
As likely improving as deteriorating * (manually assigned)	1	1	0
Likely deteriorating	1	0	0
Very likely deteriorating	0	0	0
Extremely likely deteriorating	0	0	0
Virtually certain deteriorating	4	0	0
Total number of analysed trends	**10**	10	10

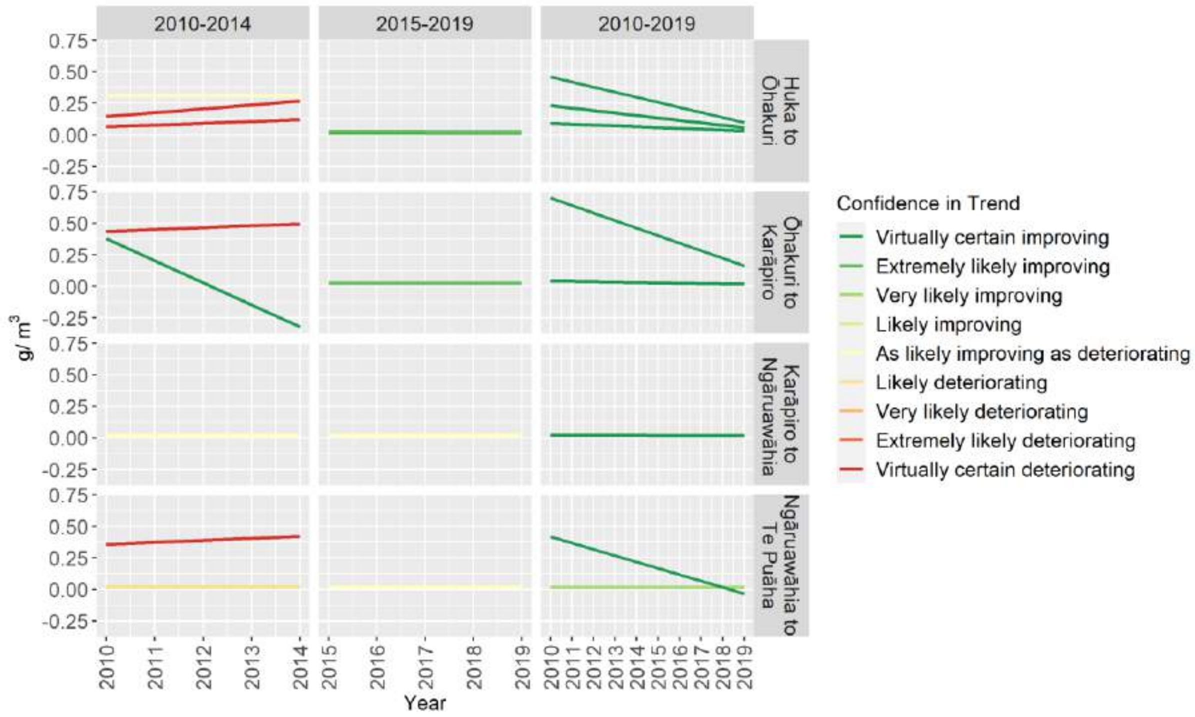

Figure B-17: Trends in arsenic in RCU sites for the 2010-2014 time period. The colour of the line indicates the confidence that the trend is improving or deteriorating.

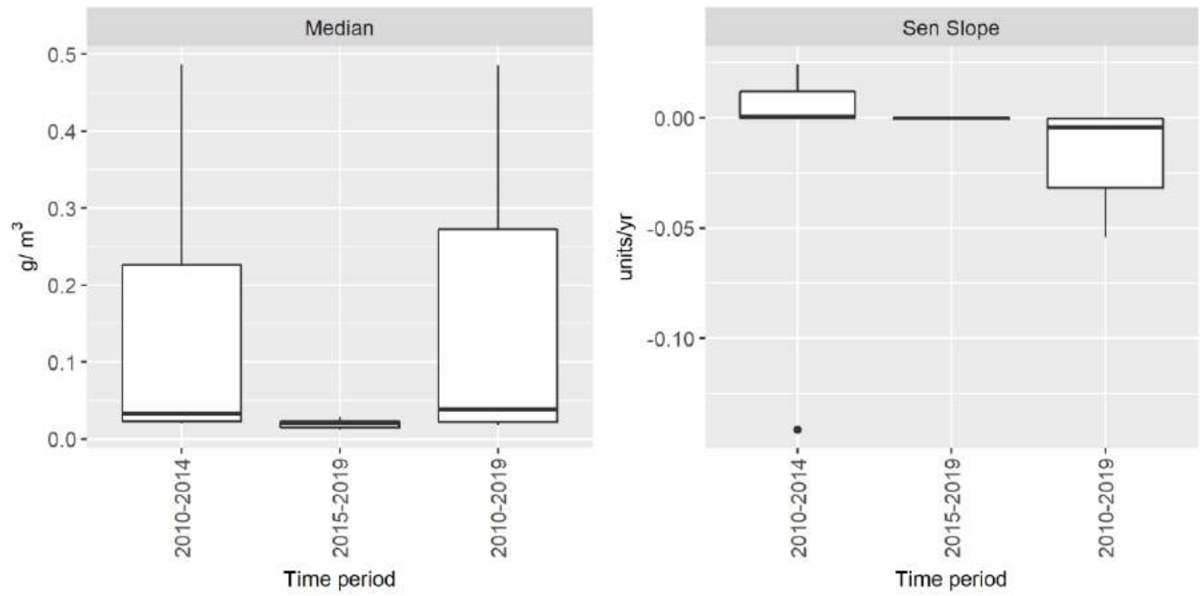

Figure B-18: Summary of medians and trend rates for arsenic (As). Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Macroinvertebrates

Macroinvertebrates were sampled annually at 27 sites across the tributary RCUs. Macroinvertebrates were not sampled in any of the mainstem river sites. For each macroinvertebrate metric, 20 out the 27 sites were able to be analysed for trends in the 2010-2014 time period, all 27 sites were able to be analysed for trends in the 2015-2019 time period, and 22 sites were able to be analysed for trends in the 2010-2019 time period (Table B-19, Table B-21, Table B-23, Table B-25).

Macroinvertebrate Community Index (MCI)

In the 2010-2014 time period, the majority of trends in MCI scores were as likely improving as deteriorating (14 trends) across all RCUs, along with 1 improving trend in the WpT RCU and 5 deteriorating trends spread across the KWT, MWT, WpT, and LWT RCUs. There were more improving trends (9 trends) in 2015-2019, although the majority of trends remained as likely improving as deteriorating (11 trends) (Table B-20). Trends over the ten-year period were a mixture of improving (4 trends), as likely improving as deteriorating (9 trends) and deteriorating (9 trends), spread across all RCUs (Table B-20, Figure B-19).

Median MCI scores were similar across all three time periods (Figure B-20). Trend rates were small and also similar across time periods, although more variable during the two five-year periods than in the ten-year period (Figure B-20).

Table B-19: Data filtering statistics for macroinvertebrate community index (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	**Total possible trends**	**Sites eliminated**	**Number analysed**	**Total possible trends**	**Sites eliminated**	**Number analysed**	**Total possible trends**	**Sites eliminated**	**Number analysed**
OWT	2	0	2	2	0	2	2	0	2
KWT	4	1	3	4	0	4	4	1	3
MWT	8	3	5	8	0	8	8	1	7
WpT	8	2	6	8	0	8	8	2	6
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**7**	**20**	**27**	**27**	**27**	**27**	**5**	**22**

Table B-20: The number of analysed trends in MCI scores in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

Confidence in trend	Time period		
	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	0	2	1
Very likely improving	0	0	0
Likely improving	1	7	3
As likely improving as deteriorating	14	11	9
Likely deteriorating	2	5	6
Very likely deteriorating	0	0	1
Extremely likely deteriorating	3	2	1
Virtually certain deteriorating	0	0	1
Total number of analysed trends	**20**	**27**	**22**

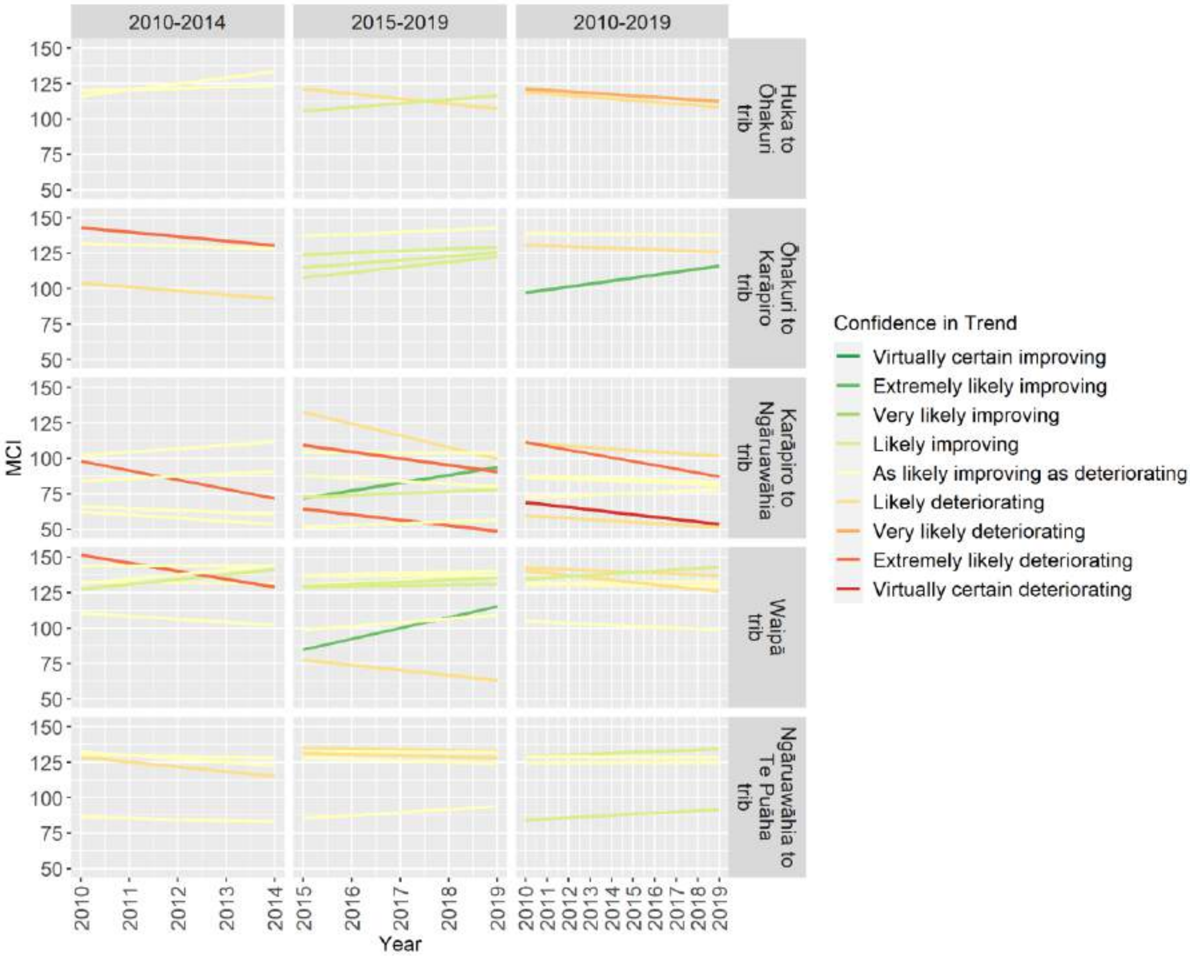

Figure B-19: Trends in MCI scores in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

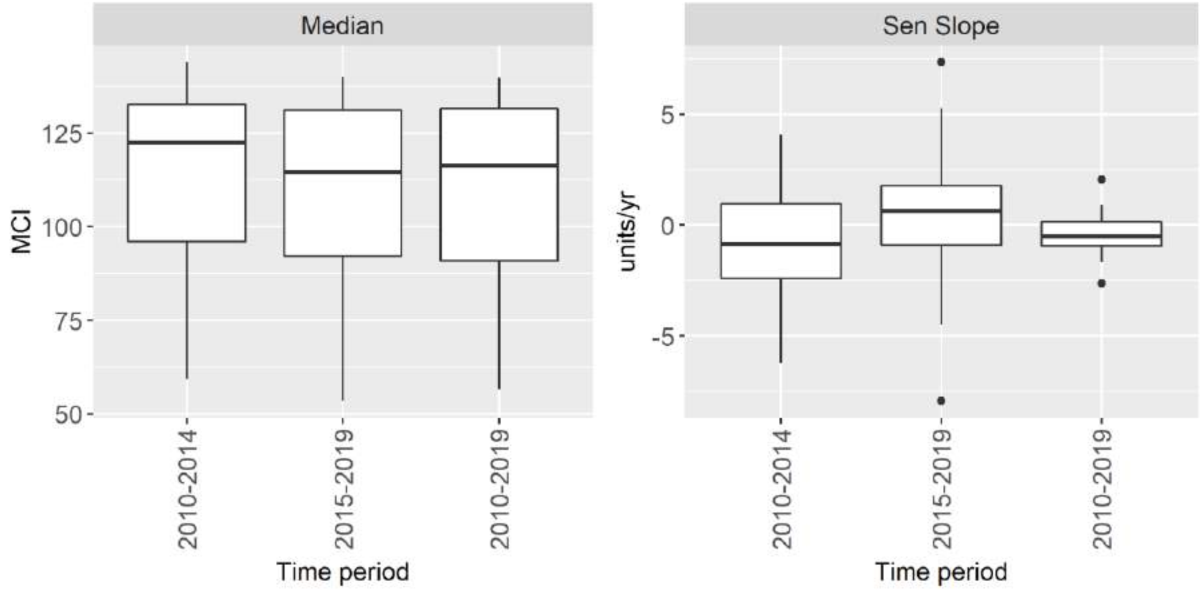

Figure B-20: Summary of medians and trend rates for MCI scores. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Quantitative Macroinvertebrate Community Index (QMCI)

Trends in QMCI scores were predominately deteriorating (8 trends) or as likely improving as deteriorating (8 trends) across all RCUs in the 2010-2014 time period (Table B-22, Figure B-21). In the 2015-2019 time period, trends were primarily improving (9 trends) or as likely improving as deteriorating (16 trends), with only 2 deteriorating trends (Table B-22, Figure B-21). However, trends remained mostly deteriorating (15 trends) over the ten-year period (Figure B-21).

Median QMCI scores were similar across all three time periods, although slightly higher in 2010-2014 than in 2015-2019 or 2010-2019 (Figure B-22). Trend rates were also larger and more variable in the 2010-2014 time period (Figure B-22).

Table B-21: Data filtering statistics for QMCI scores (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	1	3	4	0	4	4	1	3
MWT	8	3	5	8	0	8	8	1	7
WpT	8	2	6	8	0	8	8	2	6
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**7**	**20**	**27**	**27**	**27**	**27**	**5**	**22**

Table B-22: The number of analysed trends in QMCI scores in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	1	3	0
Very likely improving	0	0	2
Likely improving	3	6	2
As likely improving as deteriorating	8	16	3
Likely deteriorating	3	2	9
Very likely deteriorating	0	0	1
Extremely likely deteriorating	5	0	5
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**20**	**27**	**22**

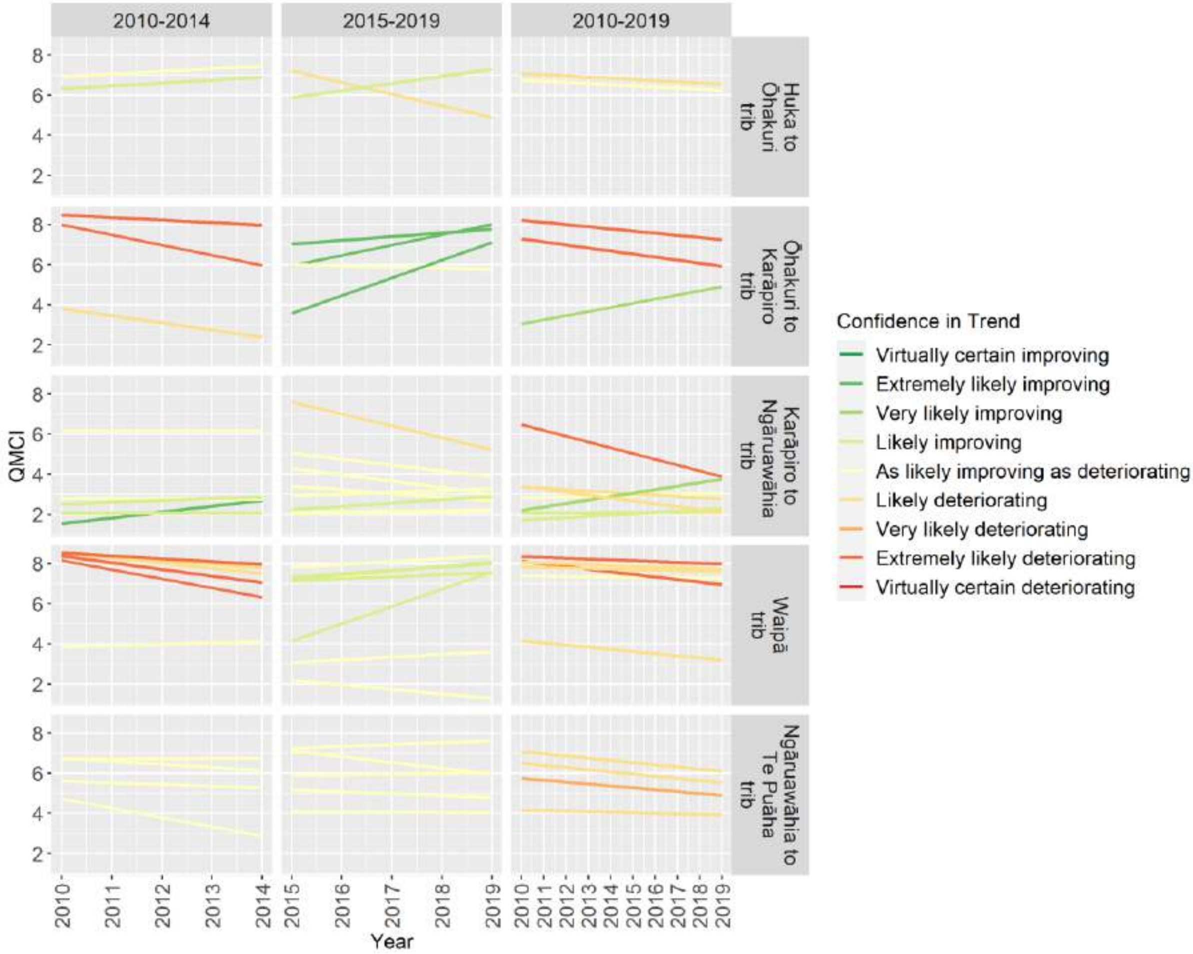

Figure B-21: Trends in QMCI scores in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

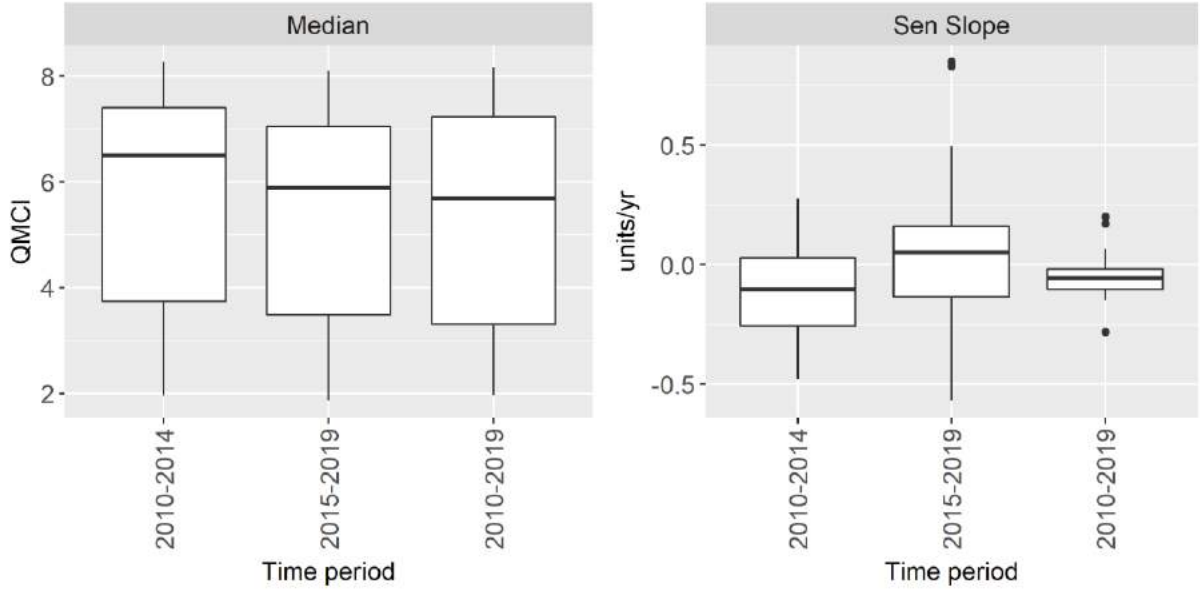

Figure B-22: Summary of medians and trend rates for QMCI scores. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Percent EPT Abundance

Trends in percent EPT abundance were primarily as likely improving as deteriorating (13 trends) followed by deteriorating (7 trends) across all RCUs in the 2010-2014 time period (Table B-24, Figure B-23). In the 2015-2019 time period, there were 6 improving trends spread across the KWT, MWT, and WpT RCUs, as well as 16 as likely improving as deteriorating trends and 5 deteriorating trends (Table B-24, Figure B-23). Over the ten-year period, the majority of trends were deteriorating (17 trends) across all RCUs with 2 improving trends and 3 as likely improving as deteriorating trends (Table B-24, Figure B-23).

Percent EPT abundance medians were highly variable across all three time periods (Figure B-24). Median trend rates, however, were small across all three time periods, although slightly more variable in 2015-2019 (Figure B-24).

Table B-23: Data filtering statistics for percent EPT abundance (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	1	3	4	0	4	4	1	3
MWT	8	3	5	8	0	8	8	1	7
WpT	8	2	6	8	0	8	8	2	6
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**7**	**20**	**27**	**27**	**27**	**27**	**5**	**22**

Table B-24: The number of analysed trends in %EPT abundance in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	0	3	0
Very likely improving	0	3	0
Likely improving	0	0	2
As likely improving as deteriorating	13	16	3
Likely deteriorating	5	5	8
Very likely deteriorating	0	0	3
Extremely likely deteriorating	2	0	5
Virtually certain deteriorating	0	0	1
Total number of analysed trends	**20**	**27**	**22**

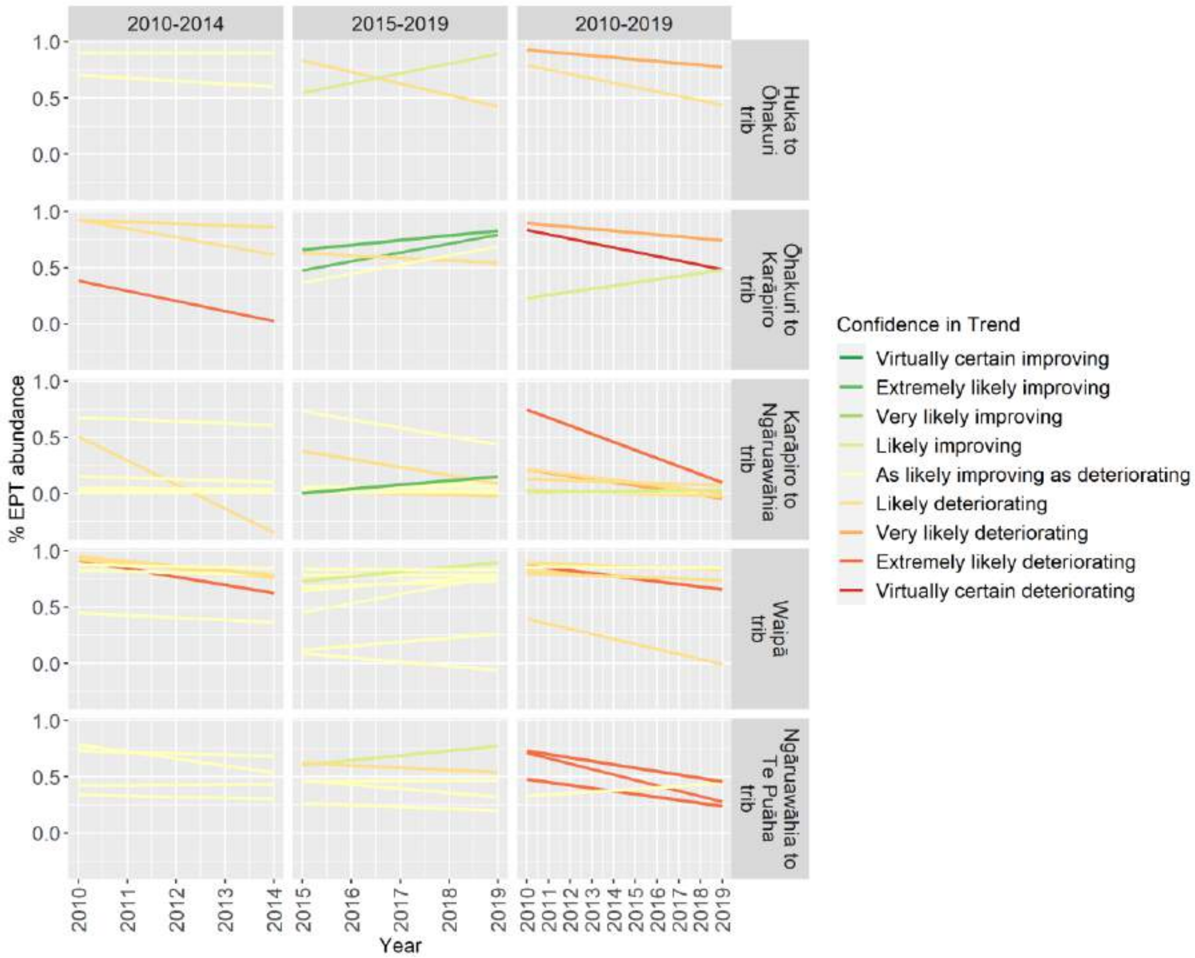

Figure B-23: Trends in % EPT abundance in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

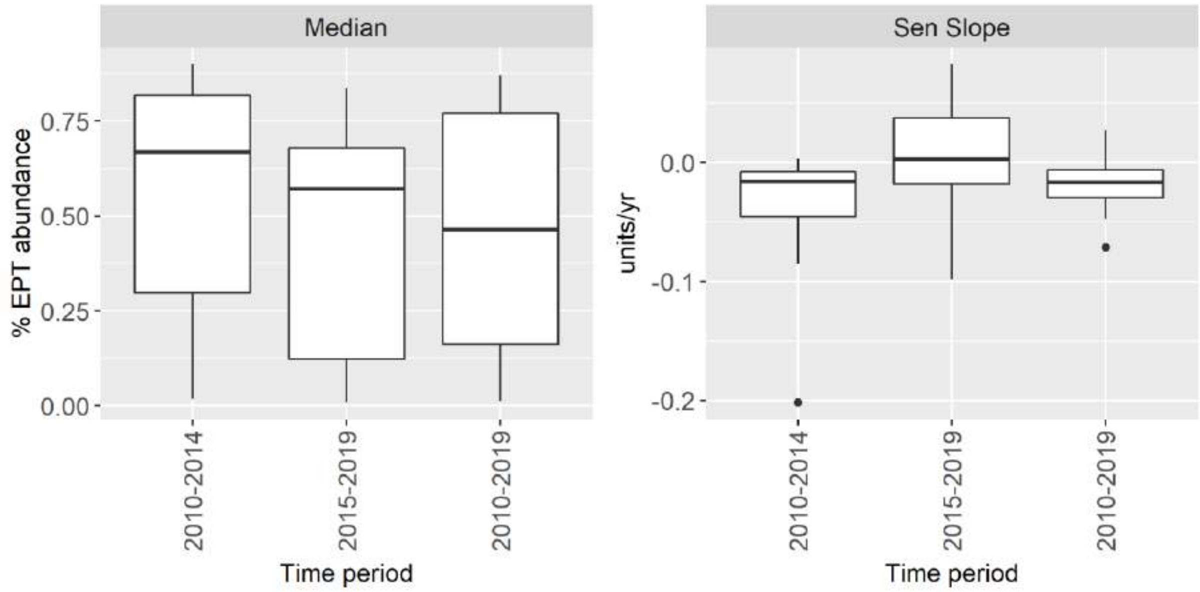

Figure B-24: Summary of medians and trend rates for % EPT abundance. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Percent EPT Taxa

Trends in percent EPT taxa were primarily as likely improving as deteriorating in both the 2010-2014 and 2015-2019 periods (11 trends and 16 trends, respectively) (Table B-26, Figure B-25). However, there were also 4 improving trends and 5 deteriorating trends in 2010-2014 and 4 improving trends and 7 deteriorating trends in 2015-2019. Over the ten-year period, however, the majority of trends were deteriorating (13 trends) across all RCUs (Table B-26, Figure B-25).

Percent EPT taxa medians were similar and moderately variable across all three time periods (Figure B-26). Median trend rates were small, although trend rates were more variable in 2010-2014 and least variable over the ten-year period from 2010-2019 (Figure B-26).

Table B-25: Data filtering statistics for percent EPT taxa (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	1	3	4	0	4	4	1	3
MWT	8	3	5	8	0	8	8	1	7
WpT	8	2	6	8	0	8	8	2	6
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**7**	**20**	**27**	**27**	**27**	**27**	**5**	**22**

Table B-26: The number of analysed trends in %EPT taxa in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	1	2	0
Very likely improving	0	1	1
Likely improving	3	1	2
As likely improving as deteriorating	11	16	6
As likely improving as deteriorating * (manually assigned)	0	1	0
Likely deteriorating	4	5	6
Very likely deteriorating	0	0	1
Extremely likely deteriorating	1	1	4
Virtually certain deteriorating	0	0	2
Total number of analysed trends	**20**	**27**	**22**

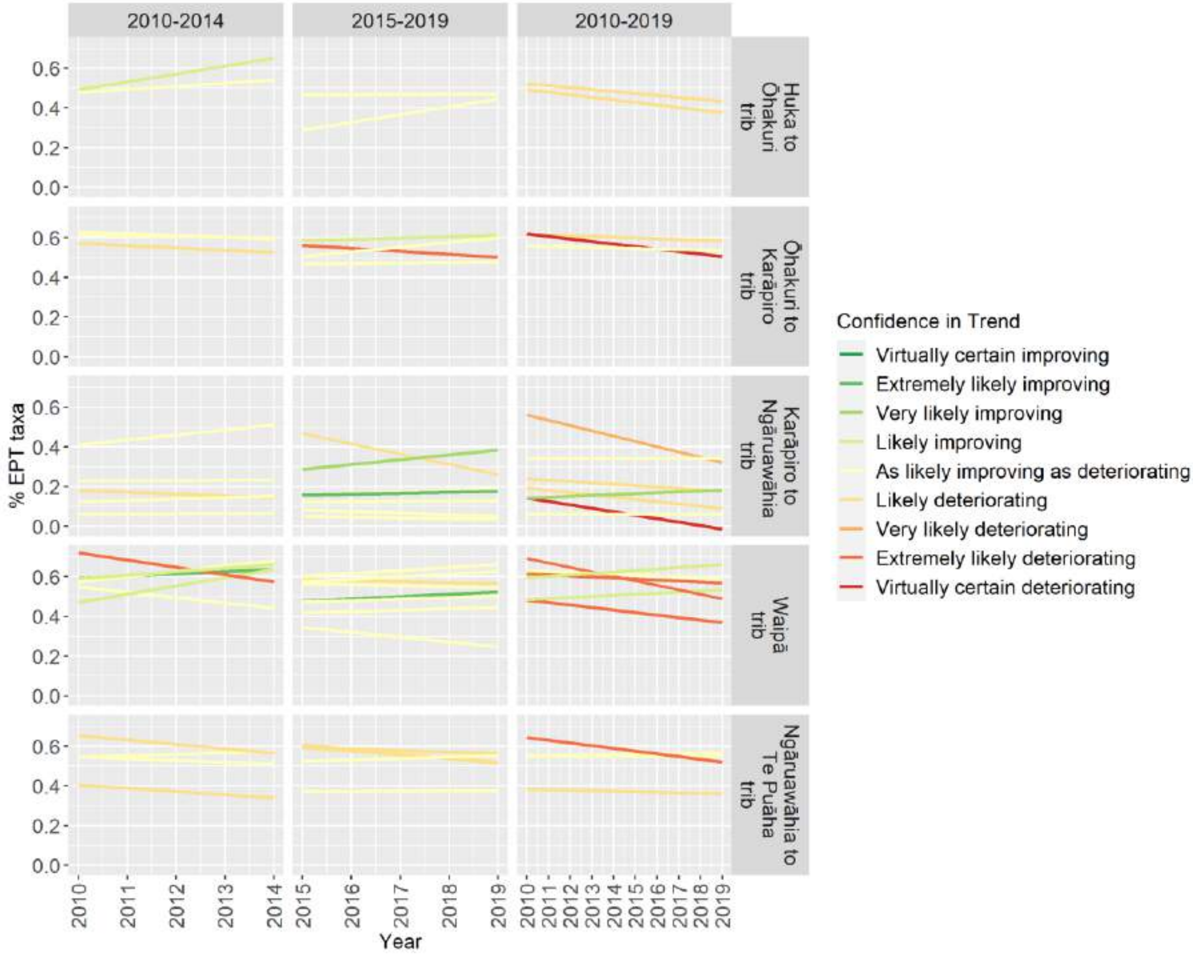

Figure B-25: Trends in % EPT taxa in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

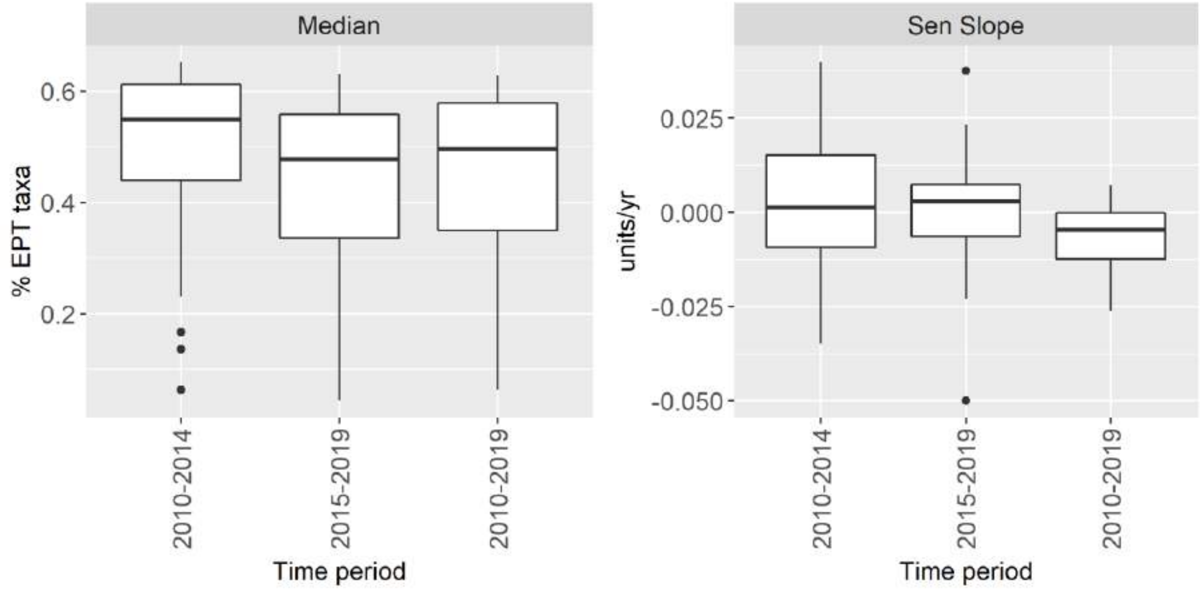

Figure B-26: Summary of medians and trend rates for % EPT taxa. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Periphyton

For both measures of periphyton cover, trends were able to be analysed for 18 of the 27 sites for the 2010-2014 time period, for 25 of the 27 sites for the 2015-2019 time period, and for 21 of the 27 sites in the 2010-2019 time period (Table B-27, Table B-29).

Cover of Long Filaments

The majority of trends in coverage of long filaments of periphyton were as likely improving as deteriorating in each RCU across all three time periods (Table B-28). This is because many sites had zero cover every year, therefore the trend is a flat line at zero. However, there were more improving trends in 2015-2019 (7 trends) than in 2010-2014 (1 trend) and more improving (6 trends) than deteriorating (3 trends) trends over the ten-year time period (Table B-28, Figure B-27).

Median percent cover by long filaments of periphyton were very low (close to zero) in all three time periods and did not show much variation (Figure B-28). Trend rates were also consistently very small (Figure B-28).

Table B-27: Data filtering statistics for periphyton long filaments (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	2	2	4	1	3	4	2	2
MWT	8	3	5	8	0	8	8	1	7
WpT	8	3	5	8	1	7	8	3	5
LWT	5	1	4	5	0	5	5	0	5
Total	**27**	**9**	**18**	**27**	**2**	**25**	**27**	**6**	**21**

Table B-28: The number of analysed trends in periphyton long filaments in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	0	0	0
Very likely improving	0	0	3
Likely improving	1	7	3
As likely improving as deteriorating	15	17	12
Likely deteriorating	1	1	3
Very likely deteriorating	0	0	0
Extremely likely deteriorating	1	0	0
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**18**	**25**	**21**

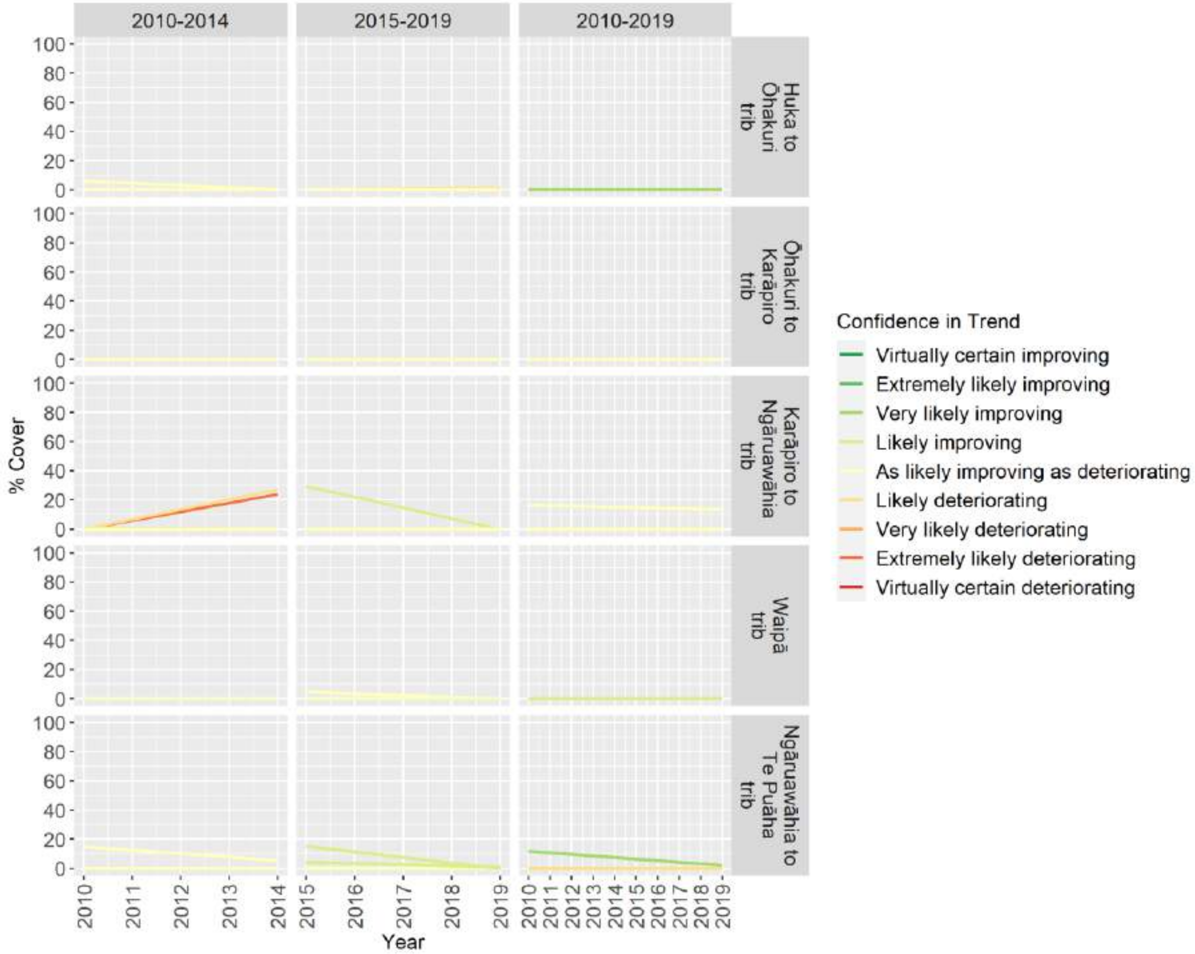

Figure B-27: Trends in periphyton long filaments in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

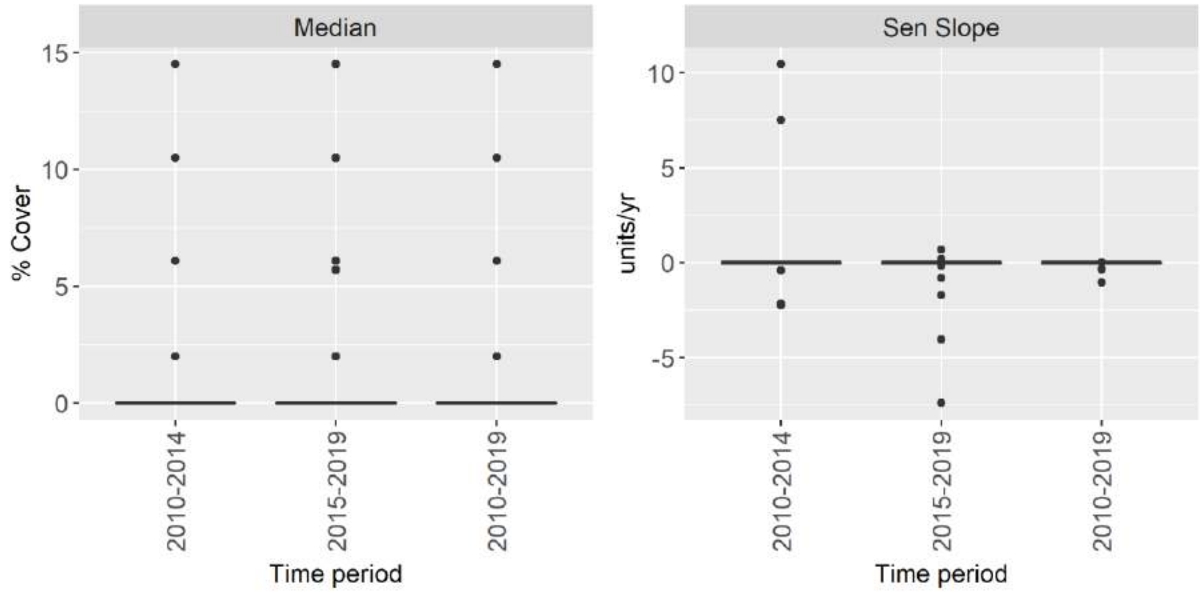

Figure B-28: Summary of medians and trend rates for periphyton long filaments. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Cover of Thick Mats

The majority of trends in cover of thick mats of periphyton were as likely improving as deteriorating across all RCUs and time periods (Table B-30) due to the large number of sites with zero cover in each year. There were also 3 deteriorating trends in 2010-2014, 2 improving trends in 2015-2019, and 2 improving and 4 deteriorating trends over the ten-year period (Table B-30, Figure-29).

Median percent cover by thick mats of periphyton was close to zero in all three time periods and did not show much variation (Figure B-30). Median trend rates were also consistently very small Figure B-30).

Table B-29: Data filtering statistics for periphyton thick mats (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	2	2	4	1	3	4	2	2
MWT	8	3	5	8	0	8	8	1	7
WpT	8	3	5	8	1	7	8	3	5
LWT	5	1	4	5	0	5	5	0	5
Total	**27**	**9**	**18**	**27**	**2**	**25**	**27**	**6**	**20**

Table B-30: The number of analysed trends in periphyton thick mats in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	0	0	0
Very likely improving	0	0	0
Likely improving	0	2	2
As likely improving as deteriorating	15	23	15
Likely deteriorating	3	0	4
Very likely deteriorating	0	0	0
Extremely likely deteriorating	0	0	0
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**18**	**25**	**21**

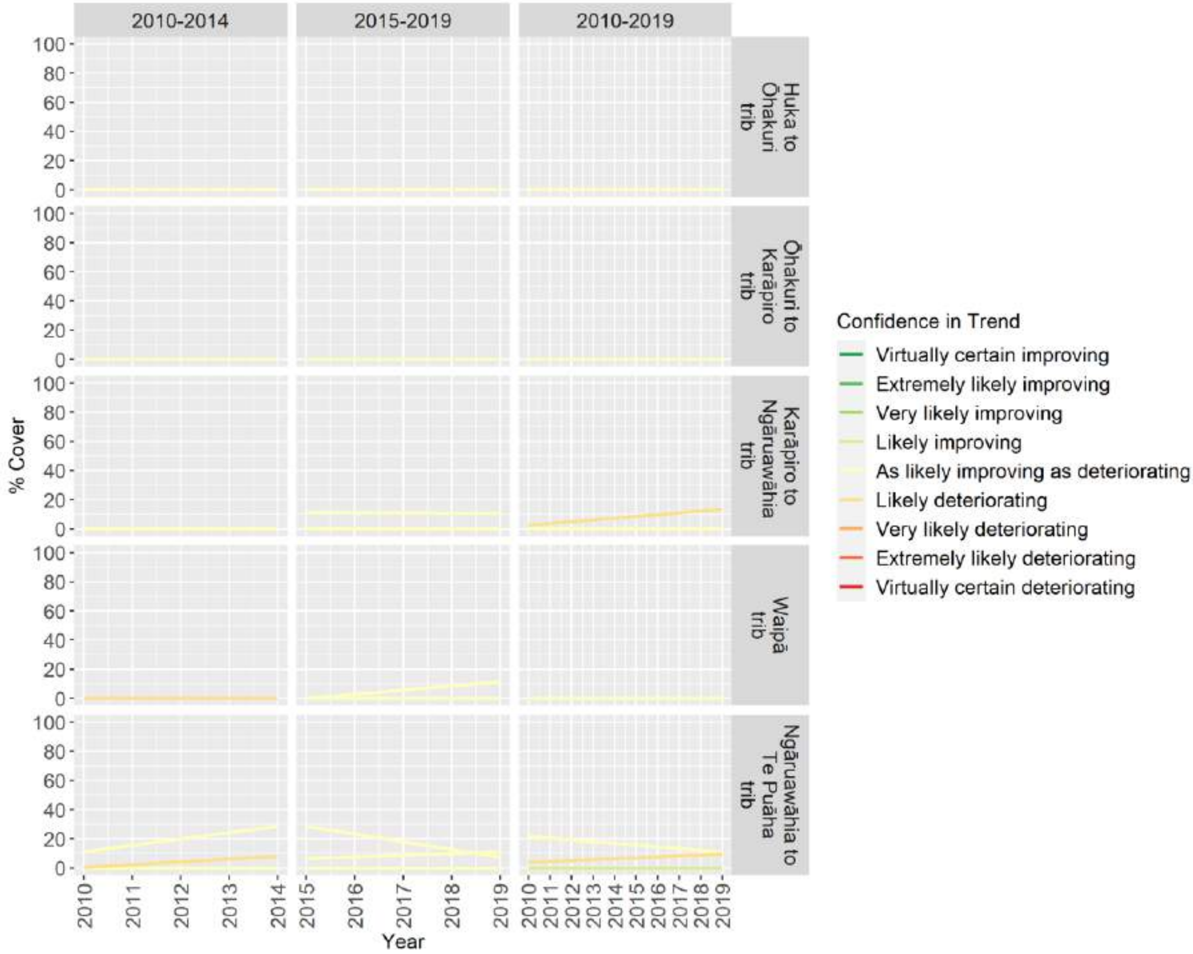

Figure B-29: Trends in periphyton thick mats in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

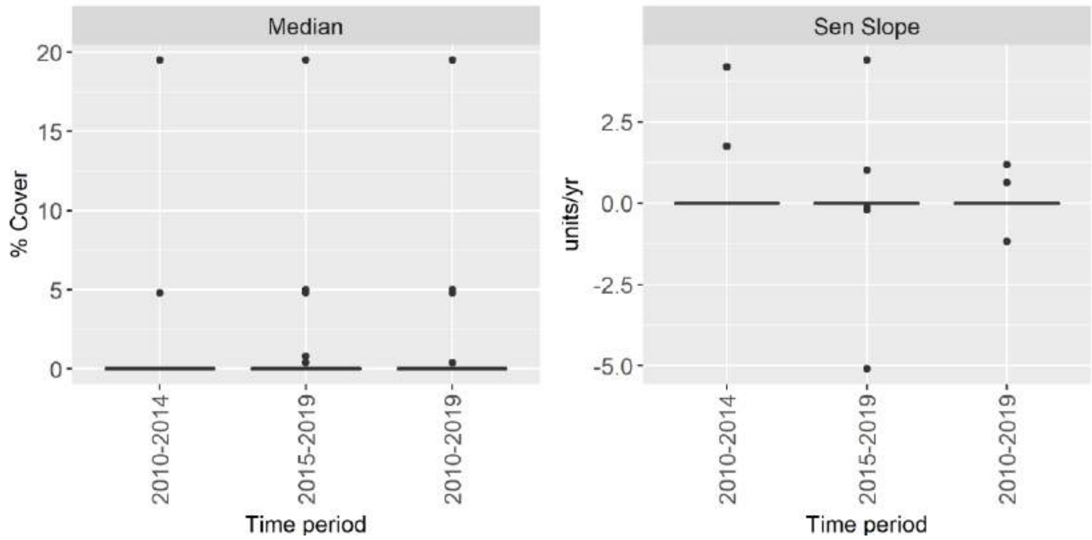

Figure B-30: Summary of medians and trend rates for periphyton thick mats. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Macrophytes

For all three measures of macrophyte cover, trends were able to be analysed for 18 of the 27 sites for the 2010-2014 time period, in 25 of the 27 sites for the 2015-2019 time period, and 20 of the 27 sites in the 2010-2019 time period (Table B-33, Table B-35).

Channel Clogged by Macrophytes

The majority of trends in macrophyte channel clogginess were as likely improving as deteriorating across all RCUs and time periods (Table B-32), again due to the prevalence of zeros in the dataset. However, the MWT RCU had 3 improving trends in 2010-2014 and 6 improving trends in in 2015-2019 (Table B-32, Figure B-31). Over the ten-year period there were 3 improving trends, 2 in the MWT RCU and one in the OWT RCU and three deteriorating trends, 2 in the MWT RCU and one in the LWT RCU (Figure B-31).

Median channel clogginess by macrophytes was close to zero in all three time periods, although there were more larger medians in 2015-2019 than 2010-2014 (Figure B-32). Median trend rates were also very small in all three time periods, but slightly larger and more variable in 2015-2019 (Figure B-32).

Table B-31: Data filtering statistics for macrophytes – channel clogginess (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	2	2	4	1	3	4	2	2
MWT	8	3	5	8	0	8	8	1	7
WpT	8	3	5	8	1	7	8	3	5
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**9**	**18**	**27**	**2**	**25**	**27**	**7**	**20**

Table B-32: The number of analysed trends in macrophyte channel clogginess in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	**2010-2014**	**2015-2019**	**2010-2019**
Virtually certain improving	0	0	0
Extremely likely improving	0	0	0
Very likely improving	1	0	1
Likely improving	2	8	2
As likely improving as deteriorating	14	15	14
Likely deteriorating	1	2	2
Very likely deteriorating	0	0	1
Extremely likely deteriorating	0	0	0
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**18**	**25**	**20**

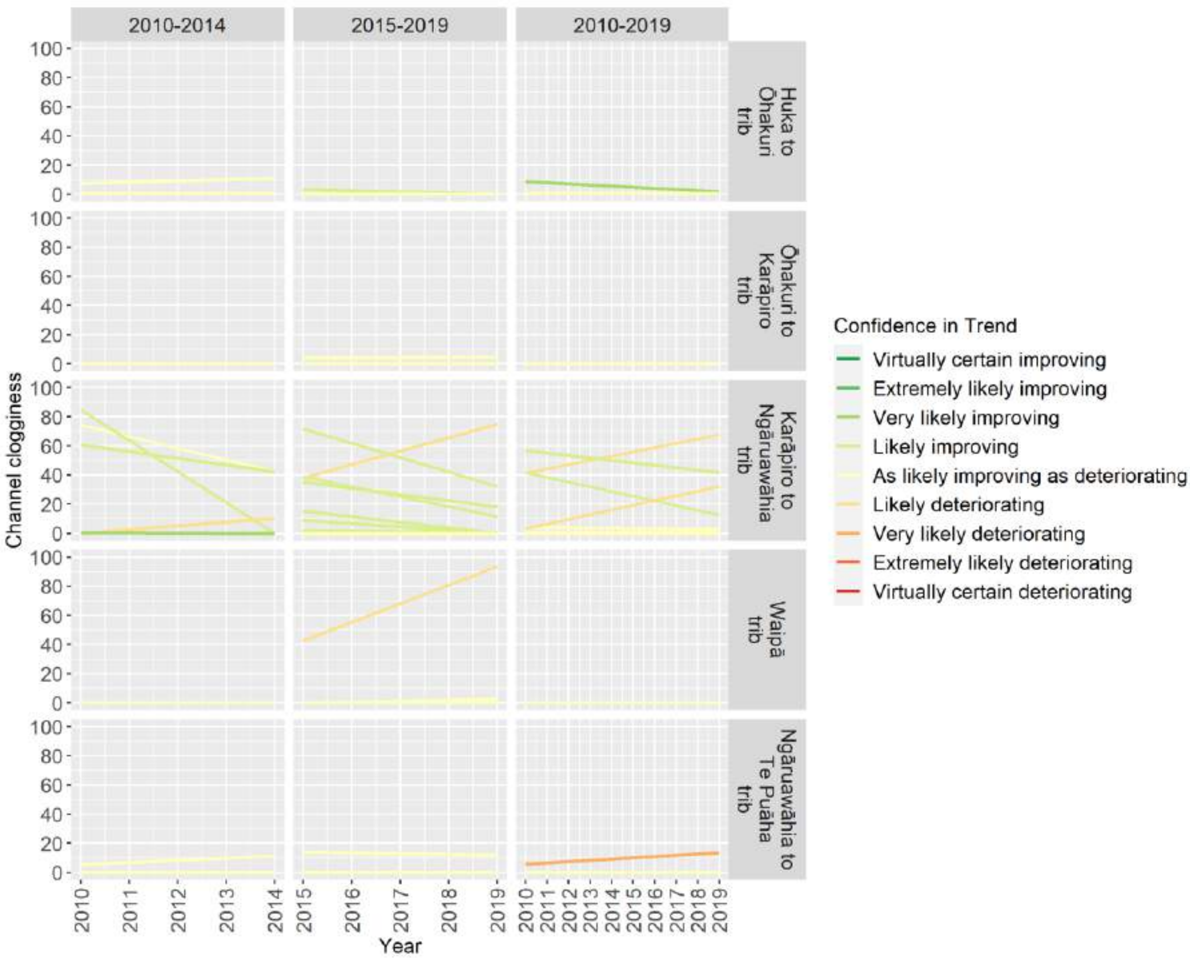

Figure B-31: Trends in macrophyte channel clogginess in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

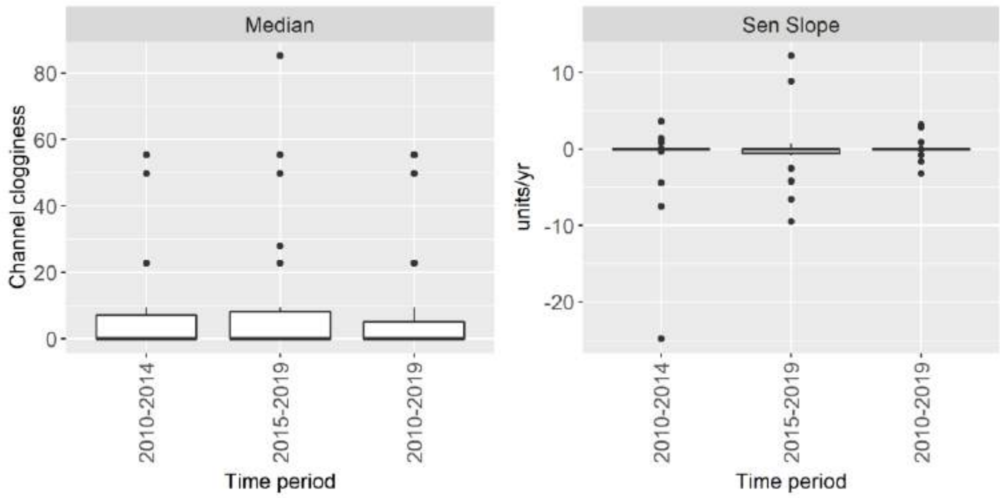

Figure B-32: Summary of medians and trend rates for macrophytes channel clogginess. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Exotic Cover

Trends in percent cover of exotic macrophytes were mostly as likely improving as deteriorating (Table B-34) due to the large number of sites with zero cover. There were more improving trends in the OWT and MWT RCUs than in the other RCUs in both the 2015-2019 and 2010-2019 time periods (Figure B-33). There were slightly more deteriorating trends (5 trends) over the ten-year period than in either the 2015-2019 (2 trends) or 2010-2014 (1 trend) time periods (Table B-34, Figure B-33).

Median percent cover of exotic macrophytes was similarly variable across all three time periods and trend rates were consistently small (Figure B-34).

Table B-33: Data filtering statistics for macrophytes – % exotic cover (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	2	2	4	1	3	4	2	2
MWT	8	3	5	8	0	8	8	1	7
WpT	8	3	5	8	1	7	8	3	5
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**9**	**18**	**27**	**2**	**25**	**27**	**7**	**20**

Table B-34: The number of analysed trends in percent exotic macrophyte cover in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

Confidence in trend	Time period		
	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	0	0	0
Very likely improving	0	0	1
Likely improving	1	4	2
As likely improving as deteriorating	16	19	12
Likely deteriorating	1	2	4
Very likely deteriorating	0	0	1
Extremely likely deteriorating	0	0	0
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**18**	**25**	**20**

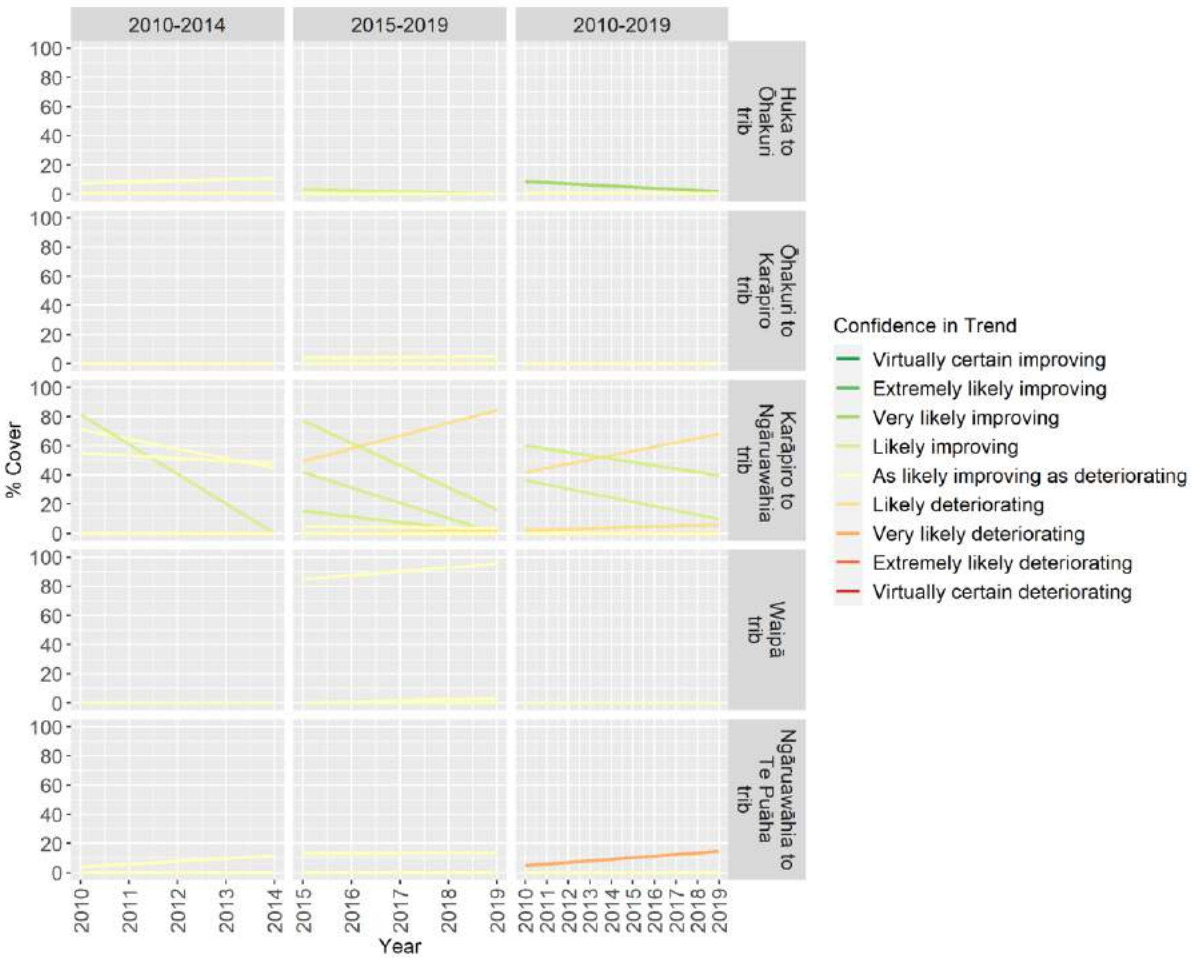

Figure B-33: Trends in percent exotic macrophyte cover in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

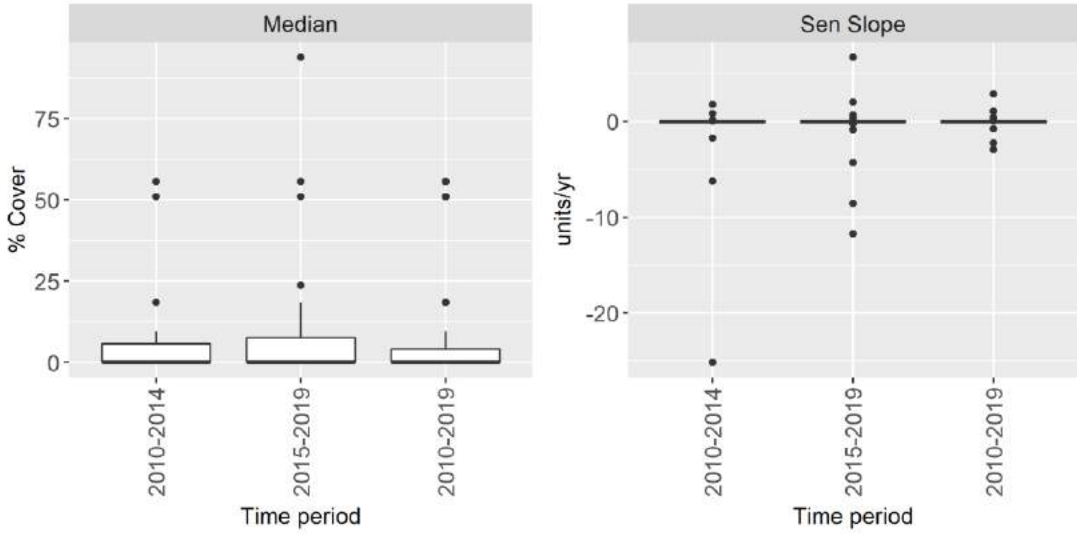

Figure B-34: Summary of medians and trend rates for exotic macrophytes cover. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Native Cover

Trends in percent cover of native macrophytes were also predominately as likely improving as deteriorating (Table B-36, Figure B-35) due to repeated zero measurements over time in many sites. There were more improving trends (3 trends) and less deteriorating trends (1 trend) in the 2010-2014 time period than in the 2015-2019 time period (1 improving trend and 4 deteriorating trends) (Table B-36). Over the ten-year period there were 3 improving trends and 1 deteriorating trend (in addition to 16 as likely improving as deteriorating trends) (Table B-36).

Median percent cover of native macrophytes and median rates for native cover macrophyte trends were small and close to zero across all three time periods (Figure B-36).

Table B-35: Data filtering statistics for macrophytes – percentage native cover (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	2	2	4	1	3	4	2	2
MWT	8	3	5	8	0	8	8	1	7
WpT	8	3	5	8	1	7	8	3	5
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**9**	**18**	**27**	**2**	**25**	**27**	**7**	**20**

Table B-36: The number of analysed trends in percent native macrophyte cover in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	0
Extremely likely improving	0	0	0
Very likely improving	0	0	0
Likely improving	3	1	3
As likely improving as deteriorating	14	20	16
Likely deteriorating	0	4	1
Very likely deteriorating	1	0	0
Extremely likely deteriorating	0	0	0
Virtually certain deteriorating	0	0	0
Total number of analysed trends	**18**	**25**	**20**

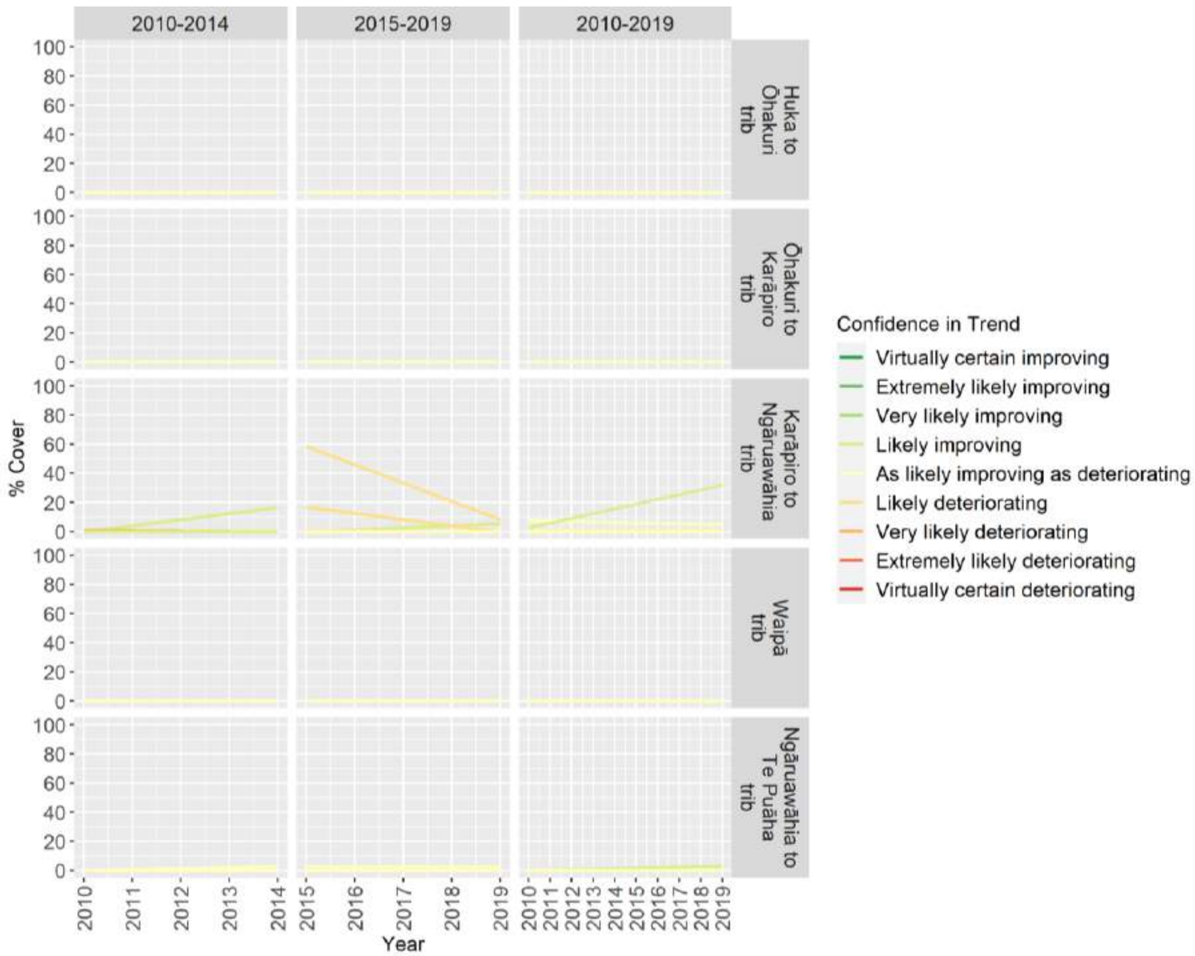

Figure B-35: Trends in percent native macrophyte cover in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

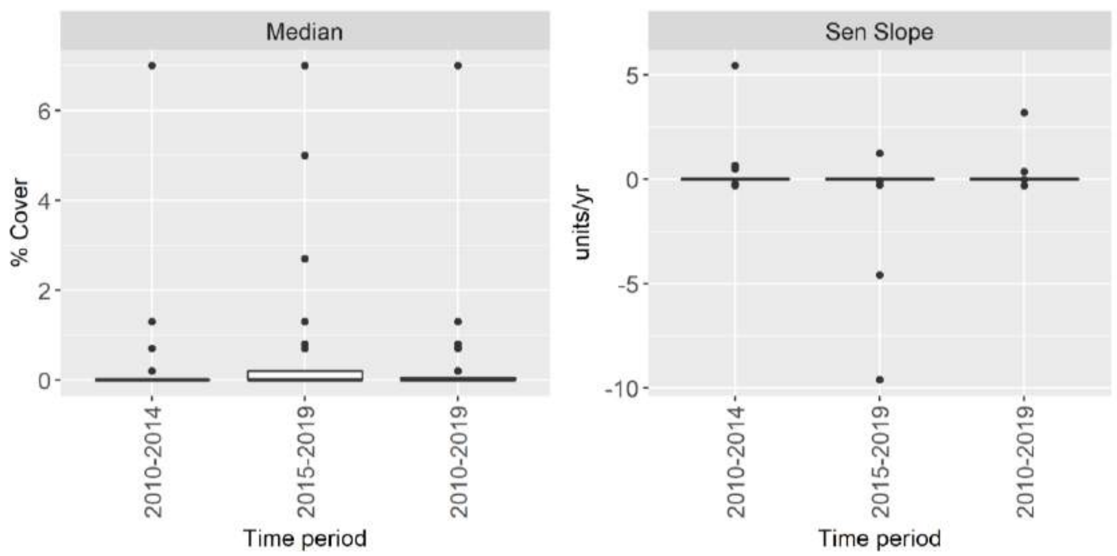

Figure B-36: Summary of medians and trend rates for native macrophytes cover. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Stream Shade

Channel shading was only measured in the 2015-2019 time period. 25 of the 27 sites were able to be analysed for trends for that time period (Table B-37, Table B-38). The majority of trends were as likely improving as deteriorating due to only small changes in channel shade being observed over the 5 years (Figure B-37). However, there were 4 improving trends, one in the OWT RCU, 2 in the MWT RCU, and one in the WpT RCU (Table B-38, Figure B-37). There were also 3 deteriorating trends, one each in the MWT, WpT, and LWT RCUs (Table B-38, Figure B-37).

Median riparian shade was highly variable in 2015-2019 and trend rates were small (Figure B-38).

Table B-37: Data filtering statistics for riparian metric – percent channel shade (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	0	2	0	2	2	0	0
KWT	4	0	0	4	1	3	4	0	0
MWT	8	0	0	8	0	8	8	0	0
WpT	8	0	0	8	1	7	8	0	0
LWT	5	0	0	5	0	5	5	0	0
Total	**27**	**27**	**0**	**27**	**2**	**25**	**27**	**0**	**0**

Table B-38: The number of analysed trends in percent channel shading in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving		0	
Extremely likely improving		1	
Very likely improving		0	
Likely improving		3	
As likely improving as deteriorating		18	
Likely deteriorating		3	
Very likely deteriorating		0	
Extremely likely deteriorating		0	
Virtually certain deteriorating		0	
Total number of analysed trends	0	25	0

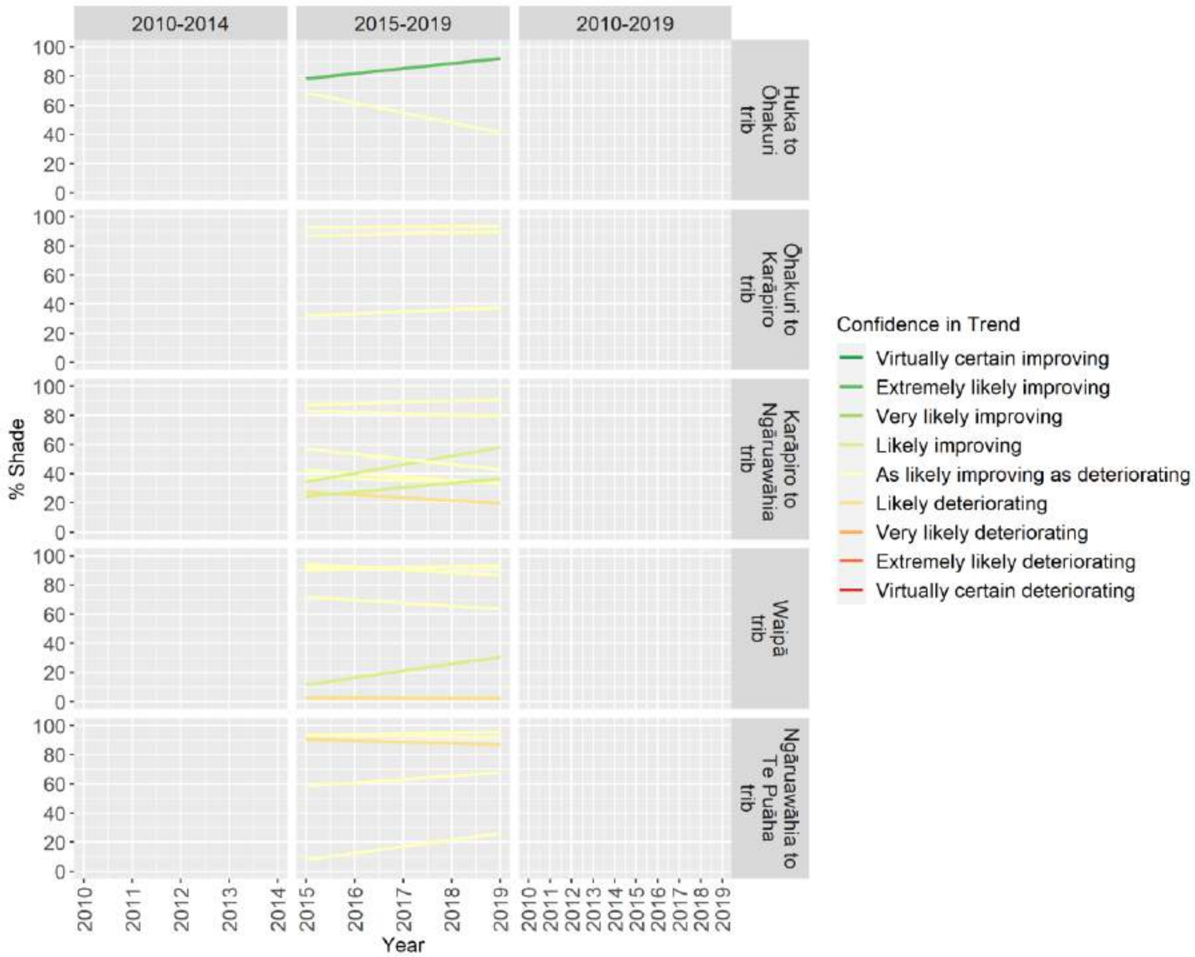

Figure B-37: Trends in percent channel shading in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

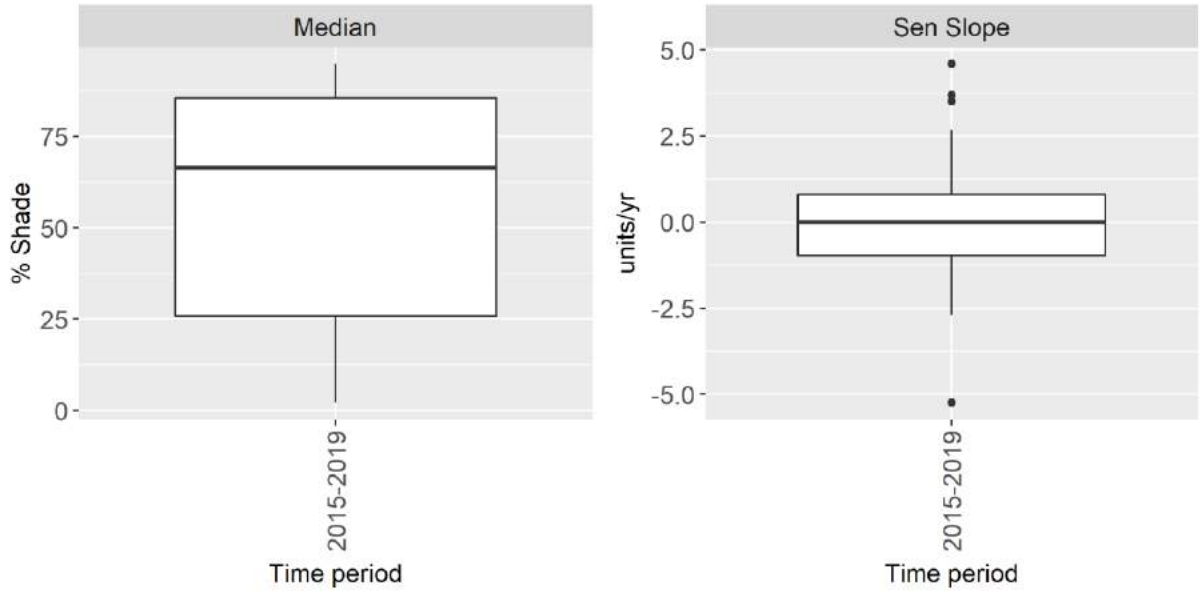

Figure B-38: Summary of medians and trend rates for channel shading. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Riparian Vegetation Protection

Vegetation protection scores were able to be analysed for 20 of the 27 sites in the 2010-2014 time period, for all 27 sites for the 2015-2019 time period, and for 22 sites for the 2010-2019 time period (Table B-39). Trends were a mixture of improving, deteriorating, and as likely improving as deteriorating across all three time periods (Table B-39, Figure B-39). The majority of improving trends were in the MWT, WpT, and LWT RCUs in each time period. Overall, there were more improving trends in the 2015-2019 (8 trends) and 2010-2019 (9 trends) time periods than in the 2010-2014 time period (4 trends) (Table B-39).

Median riparian vegetation protection scores were similarly variable across all three time periods while median trend rates were larger and more variable in 2015-2019 (Figure B-40).

Table B-39: Data filtering statistics for riparian metric – vegetation protection score (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	1	3	4	0	4	4	1	3
MWT	8	3	5	8	0	8	8	1	7
WpT	8	2	6	8	0	8	8	2	6
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**7**	**20**	**27**	**0**	**27**	**27**	**5**	**22**

Table B-40: The number of analysed trends in riparian vegetation protection scores in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

	Time period		
Confidence in trend	2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	1
Extremely likely improving	0	1	2
Very likely improving	0	0	0
Likely improving	4	7	6
As likely improving as deteriorating	9	8	7
Likely deteriorating	6	8	2
Very likely deteriorating	1	3	1
Extremely likely deteriorating	0	0	2
Virtually certain deteriorating	0	0	1
Total number of analysed trends	**20**	**27**	**22**

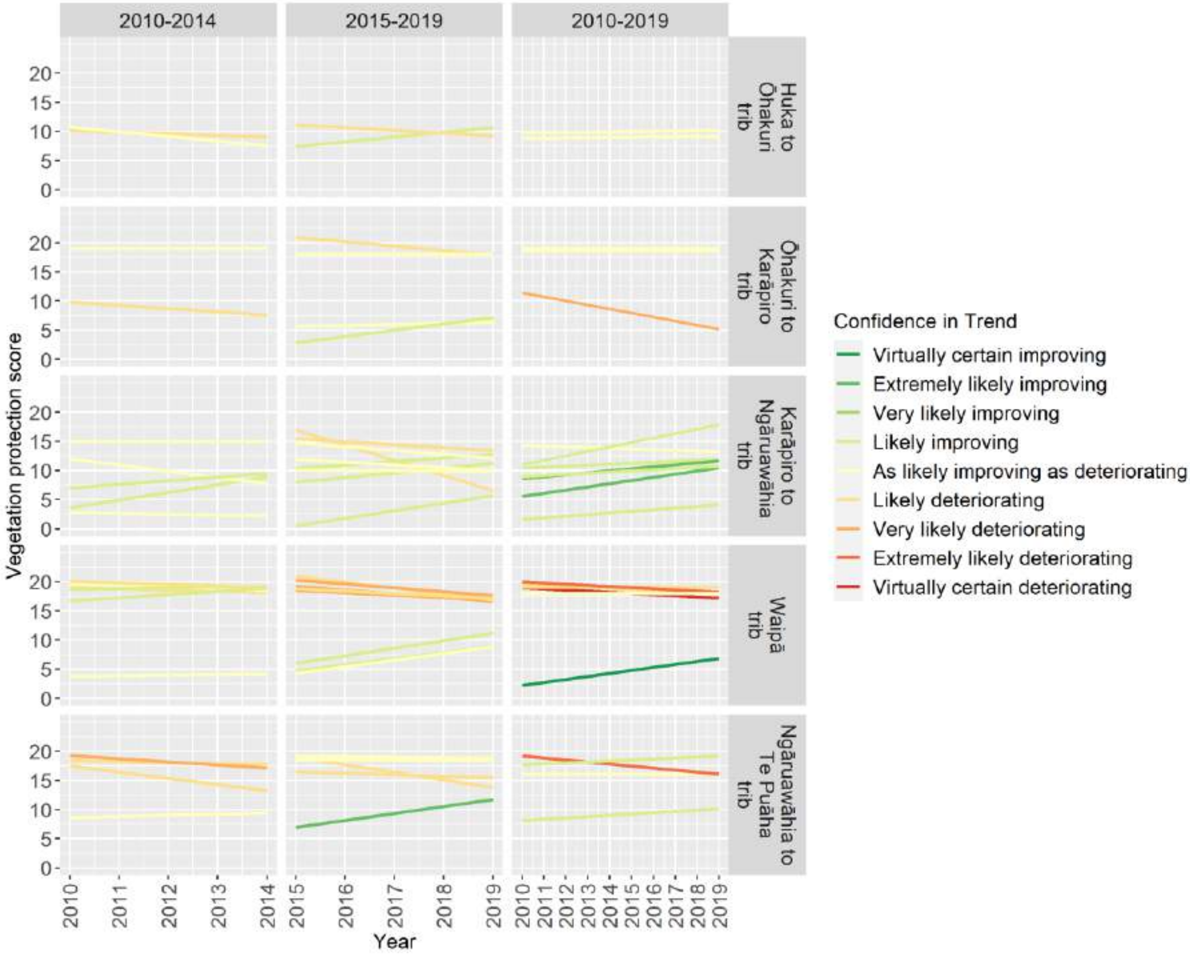

Figure B-39: Trends in riparian vegetation protection scores in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

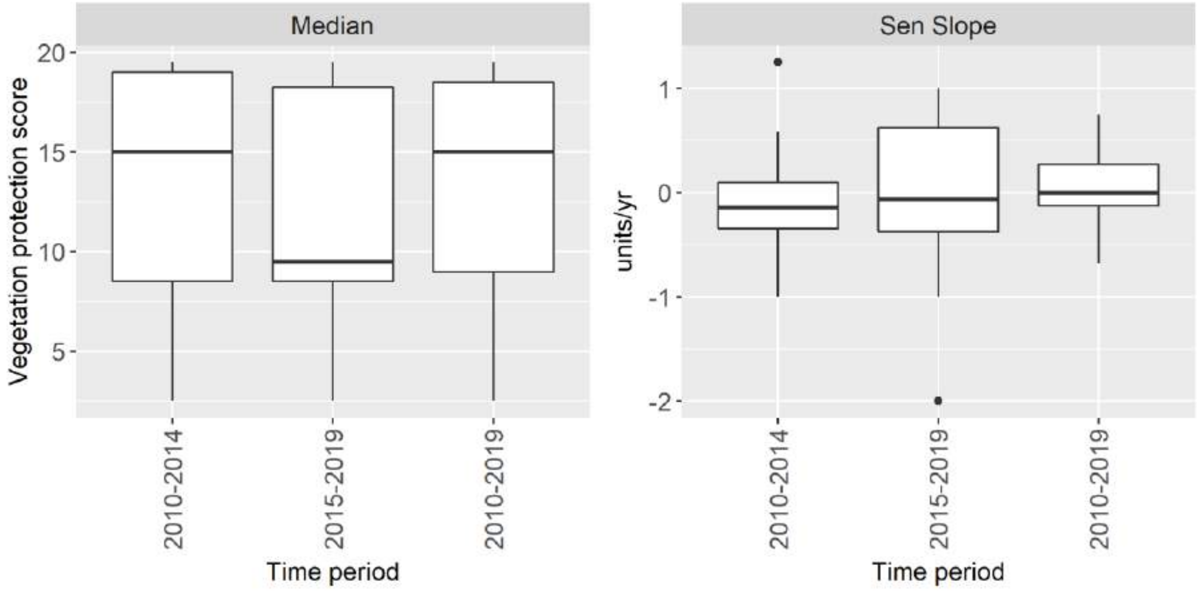

Figure B-40: Summary of medians and trend rates for riparian vegetation protection scores. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Riparian Width

Vegetation width scores were able to be analysed for 20 of the 27 sites in the 2010-2014 time period, for all 27 sites for the 2015-2019 time period, and for 22 sites for the 2010-2019 time period. Trends were a mixture of improving, deteriorating, and as likely improving as deteriorating across all RCUs and time periods (Table B-42), although the MWT, WpT, and LWT RCUs had more improving trends than other RCUS (Figure B-41).

Median riparian width scores and trend rates were similarly variable in all three time periods (Figure B-42).

Table B-41: Data filtering statistics for riparian metric – width score (displayed per RCU). Where Huka to Ōhakuri = Mainstem (OW), Tributaries (OWT), Ōhakuri to Karāpiro = Mainstem (KW), Tributaries (KWT), Waipā = Mainstem (Wp), Tributaries (WpT), Mid Waikato (Karāpiro to Ngāruawāhia) = Mainstem (MW), Tributaries (MWT), and Lower Waikato (Ngāruawāhia to Te Pūaha) = Mainstem (LW), Tributaries (LWT).

	2010-2014			2015-2019			2010-2019		
Report Card Unit	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed	Total possible trends	Sites eliminated	Number analysed
OWT	2	0	2	2	0	2	2	0	2
KWT	4	1	3	4	0	4	4	1	3
MWT	8	3	5	8	0	8	8	1	7
WpT	8	2	6	8	0	8	8	2	6
LWT	5	1	4	5	0	5	5	1	4
Total	**27**	**7**	**20**	**27**	**0**	**27**	**27**	**5**	**22**

Table B-42: The number of analysed trends in riparian width scores in each confidence category per time period. See Table 3 for explanations of IPCC likelihood categories.

Confidence in trend	Time period 2010-2014	2015-2019	2010-2019
Virtually certain improving	0	0	1
Extremely likely improving	0	2	2
Very likely improving	2	0	1
Likely improving	4	4	2
As likely improving as deteriorating	8	12	4
Likely deteriorating	5	5	6
Very likely deteriorating	0	2	3
Extremely likely deteriorating	1	2	2
Virtually certain deteriorating	0	0	1
Total number of analysed trends	**20**	**27**	**22**

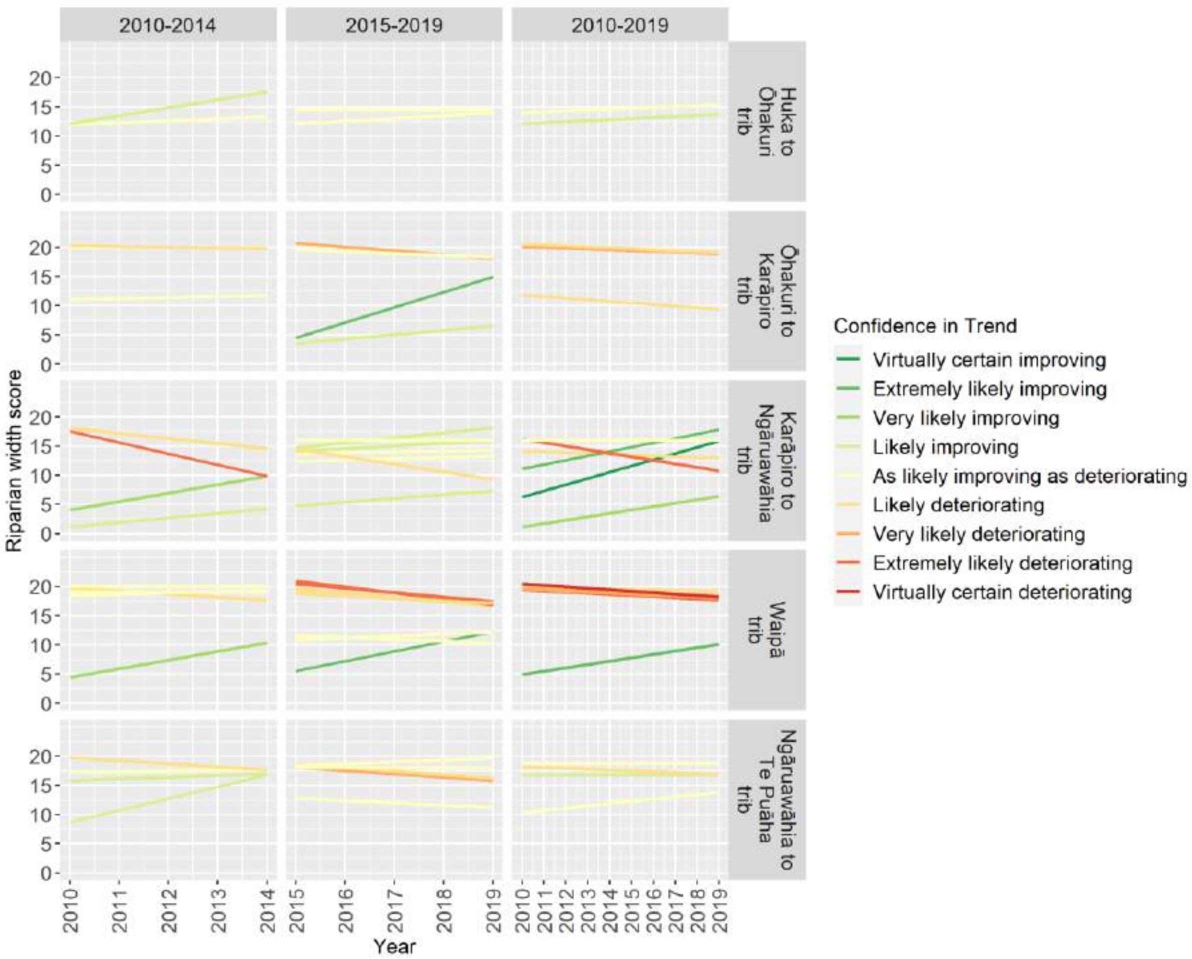

Figure B-41: Trends in riparian width scores in RCU sites over three time periods, 2010-2014, 2015-2019, and 2010-2019. The colour of the line indicates the confidence that the trend is improving or deteriorating.

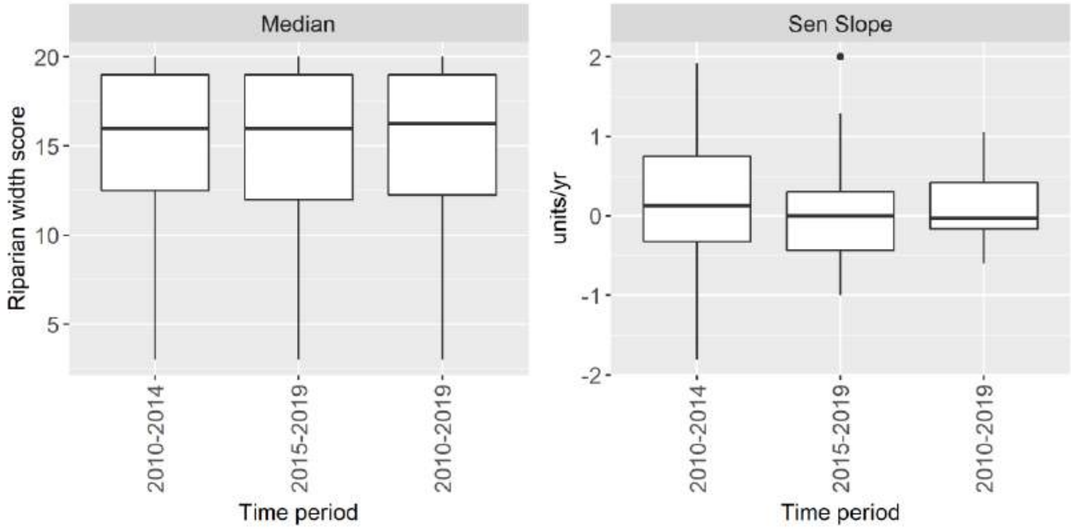

Figure B-42: Summary of medians and trend rates for riparian width. Box-and-whisker plots show the distributions of site medians and trend rates within each time period. The black horizontal line in each box indicates the median, the box indicates the inter-quartile range, the whiskers indicate the 25th and 75th percentiles, and the points indicate outliers.

Appendix C List of all Figures and Tables

Tables

Figures