Christchurch City Surface Water Quality Annual Report 2021

Prepared to meet the Requirements of CRC214226

Christchurch City Council

June 2022

Christchurch City Council

Internal Document Review

	Name	Title
Prepared By	Dr Belinda Margetts	Principal Waterways Ecologist Quality and Compliance Three Waters
	Dr Salina Poudyal	Environmental Compliance Officer Quality and Compliance Three Waters
Reviewed By	Clive Appleton	Healthy Waterways Programme Lead Quality and Compliance Three Waters
Approved By	Veronica Zefferino	Team Leader Quality and Compliance Quality and Compliance Three Waters

Executive Summary

- The Christchurch City Council (Council) monitors the water quality of representative waterbodies within Christchurch and Banks Peninsula, as part of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC214226).
- Monthly water samples were collected from 51 sites in Banks Peninsula (Stream Reserve Drain, Balguerie Stream, and Aylmers Stream), Ōtākaro-Avon River, Ōpāwaho-Heathcote River, Huritini-Halswell River, Pūharakekenui-Styx River, Ōtūkaikino River, Linwood Canal, and coastal water (Ihutai – Avon-Heathcote Estuary, Lyttelton Port, Cass Bay, and Akaroa Harbour) catchments. Eleven sites in the Pūharakekenui-Styx River catchment were monitored by the Styx Living Laboratory Trust. Three wet weather monitoring events were also monitored in the Huritini-Halswell River catchment.
- Over 33,500 tests were conducted during 2019-2021 for the Council monthly monitoring, with 20,813 of these allowing the assessment of each waterway site against relevant guideline levels.
- The priority parameters to address include bacteria (as indicated by *Escherichia coli*), dissolved copper, phosphorus (Dissolved Reactive Phosphorus), and dissolved zinc. The coastal sites generally had issues with dissolved copper and enterococci contamination.
- Based on the WQI, the Ōtūkaikino River catchment recorded 'very good' water quality, the Ōtākaro-Avon River and the Pūharakekenui-Styx River recorded 'good' water quality, and the Ōpāwaho-Heathcote River and Huritini-Halswell River recorded 'poor' water quality. The Banks Peninsula waterways recorded 'poor' (Stream Reserve Drain) and 'fair' (Balguerie and Aylmers Streams) water quality. The Ōtūkaikino River recorded the best water quality out of all the catchments. The best site for water quality was Ōtūkaikino at Groynes, followed by Wilsons Stream and Styx at Gardiners Road. The catchment with the worst water quality was the Ōpāwaho-Heathcote River. The worst site was Curletts at Motorway, followed by Heathcote at Tunnel Rd, and Heathcote at Warren Cres.
- Water quality at the sites has mostly remained steady over time since monitoring began in the early (mostly in the mid-2000s).
- Wet weather monitoring concentrations were generally similar to that recorded for the monthly monitoring; however, sediment levels were lower during monthly monitoring and nitrogen levels were higher.
- Thirty-one of the 51 sites triggered further investigations under the CSNDC, due to not meeting the ATLs for Total Suspended Solids, copper, or zinc. These sites are prioritised to four: Curletts at Motorway and Heathcote at Ferrymead Bridge in the Ōpāwaho-Heathcote River catchment, Addington Brook in the Ōtākaro-Avon River catchment, and Nottingham at Candys Rd in the Huritini-Halswell River catchment. These are the same sites prioritised for investigation last year and therefore Condition 59 investigations are already under way.
- A number of recommendations are provided in the report. In particular:
    - Curletts Stream, Nottingham Stream, Haytons Stream, Addington Brook, and the lower Ōpāwaho-Heathcote River are prioritised for contaminant source control and treatment.
    - An investigation into increasing levels of *E. coli* in the Ōtūkaikino River is implemented.
    - Construction of the Council stormwater wetlands in Belfast (Ōtūkaikino River catchment) is prioritised.
    - Erosion and sediment control measures continue to be implemented as a priority, and further investigations in particular are carried out to determine how to mitigate discharges of loess sediment into the Ōpāwaho-Heathcote River (principally Cashmere Stream).
    - Investigations on sources of faecal and phosphorus contamination are carried out.
    - The Action Plan for the Council Community Outcome for Healthy Water Bodies is continued to be developed.
- If the report recommendations are implemented (at a bare minimum), surface water quality improvements are anticipated. However, changes may only occur over long time scales, due to the size of the issues and the lag time in observing reductions in contaminants within the environment.

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1. Introduction

The Christchurch City Council (Council) is required to monitor the water quality of representative waterbodies within Christchurch and Banks Peninsula, as part of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC214226). In accordance with the CSNDC Environmental Monitoring Programme (EMP), monitoring was undertaken monthly at waterway and coastal sites. This report summarises the results for the monthly monitoring for the 2021 calendar year and analyses trends over time since monitoring has been undertaken. The report also analyses wet weather monitoring at three sites in the Huritini-Halswell River catchment in 2021. The results of community monitoring in the Pūharakekenui-Styx River catchment in 2021 by the Styx Living Laboratory Trust (SLLT) are also presented in this report.

2. Methods

2.1. Monitoring Sites

Water samples were collected from 47 sites from waterways within the catchments of Banks Peninsula (Stream Reserve Drain/Zephyr Stream, Balguerie Stream, and Aylmers Stream), Ōtākaro-Avon River, Ōpāwaho-Heathcote River, Huritini-Halswell River, Pūharakekenui-Styx River, Ōtūkaikino River, and Linwood Canal (Table 1; Figure 1). Samples were also taken from four coastal sites: Ihutai – Avon-Heathcote Estuary, Lyttelton Port, Cass Bay, and Akaroa Harbour (Table 1; Figure 1). An additional 13 sites in the Pūharakekenui-Styx River catchment were also monitored by the SLLT (Table 1).

Seven of the waterway sites[1] and all four coastal sites were specifically chosen because they are in proximity to stormwater outfalls. However, it should be noted that there are hundreds of outfalls throughout the Christchurch City catchments and therefore many of the other sites are also located near stormwater discharge pipes.

2.2. Sampling and Testing Methods

Council has monitored most sites monthly since approximately 2007 (Table i, Appendix A). These samples were collected predominantly via grab sampling, with field testing of temperature and oxygen using a hand-held meter (YSI Pro ODO meter). There were eight sites that were in strongly tidal areas[2] (defined by having median 2020 salinity values of ≥2.5%), where sampling was undertaken at low tide (± 1 hour), with sampling within catchments starting at the most downstream site. The exception to this was the Ihutai – Avon-Heathcote Estuary site, which was sampled at high tide.

In 2021, COVID19 impacts and other logistical issues (e.g., locked gates and construction) meant that a number of sites were unable to be sampled. These included Pūharakekenui-Styx River and Ōtūkaikino River catchments during January, Balguerie Stream in February, Ihutai – Avon-Heathcote Estuary, Linwood Canal, Styx at Harbour Rd, Styx at Marshland Rd, and Ōtākaro-Avon River catchment during April, Curletts at Motorway, Ōtūkaikino at Scout Camp in July, and French Bay, Lyttelton Port and Styx at Richard Bridge in August.

[1] Avon at Carlton Mill, Avon at Avondale Rd, Heathcote at Catherine St, Heathcote at Mackenzie Ave, Haytons Stm, Curletts at Motorway, and Balguerie Stream

[2] Avon at Bridge St, Heathcote at Ferrymead Bridge, Heathcote at Tunnel Rd, Linwood Canal, Ihutai - Avon-Heathcote Estuary, Lyttelton Port, Cass Bay, and Akaroa Harbour

Wet weather samples from three sites in the Huritini-Halswell River catchment were collected on the 4th of October 2021, 28th of November 2021, and 16th of December 2021. Wet weather samples were collected using Nalgene bottles (a sampling bottle used to collect a one litre grab sample of first flush stormwater runoff). The exception to this was the first event, as the water did not rise sufficiently to collect a sample. Grab sampling using the Nalgene bottles was carried out instead. Sampling for all events was carried out to achieve as far as possible the following criteria:

- Minimum of a three-day dry period prior to sampling;
- Minimum of 3 mm total rainfall depth; and
- Catching of the "First Flush" (15-25mm), by sampling within 1 – 2 hours of the desired rainfall depth being achieved.

Monthly and wet weather samples were analysed at the Council International Accreditation New Zealand (IANZ) laboratory for the parameters outlined in Table i in Appendix B. The exception to this was field measurements of temperature and oxygen using a hand-held meter (YSI Pro ODO or DSS meter) at the time of sampling. For the wet weather sampling using Nalgene bottles, these temperature and oxygen readings should be viewed with caution, as they are taken outside of the wet weather event when the Nalgene bottles are being retrieved.

The methods used to analyse each parameter, including laboratory Limits of Detection (LOD), are presented in Table i in Appendix C. Some of these methods have changed over time, as more advanced equipment has become available, and timeframes for changes are detailed in this table.

For the second wet weather event, a number of parameters were not analysed, due to an error at the lab. These included pH, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD_5), and *Escherichia coli*. Because of this, a third wet weather event was sampled, when only two are required by the CSNDC EMP.

SLLT volunteers have analysed water in the field for pH (Eutech pH pocket testers 30), conductivity (Eutech Cybernetics TDScan 3), water clarity (clarity tube) and water temperature (glass spirit thermometer) since 2004. Water clarity results should be viewed with caution, as the clarity tube is only 1m long, so it is not possible to record a clarity greater than this.

SLLT samples were aimed to be taken every third Saturday of the month, but as this was based on volunteer availability, the number of samples taken annually at each site ranged from 6 – 11. Of note:

- There was no data available for 2016;
- 2015 and 2017 had a small number of recordings; and
- pH readings changed from using test strips to a handheld meter in February 2010; therefore, pH data prior to this time have been excluded from this report.

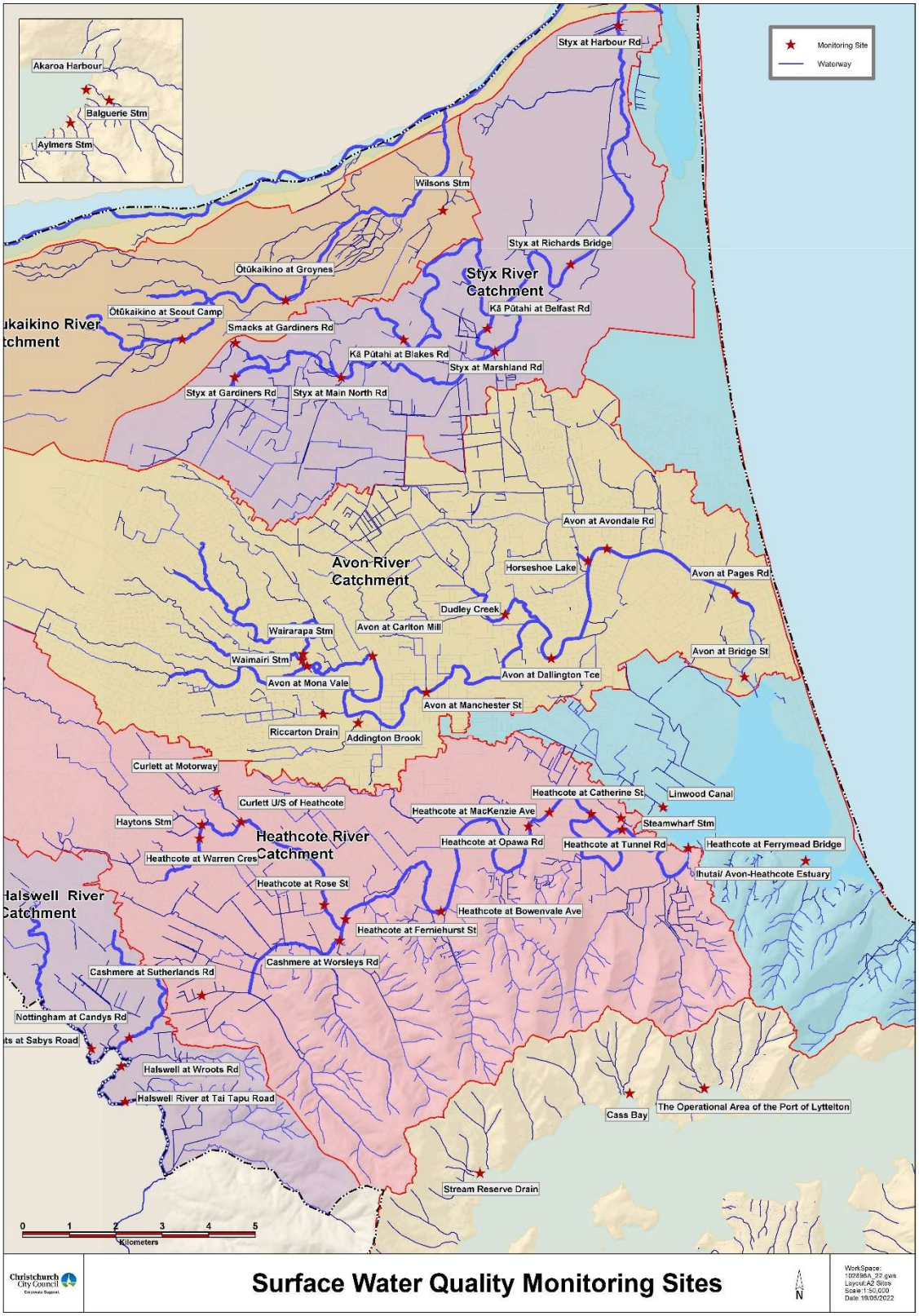

Figure 1. Location of Christchurch City Council surface water quality monitoring sites

Table 1. Christchurch City Council and Styx Living Laboratory Trust (SLLT) surface water quality monitoring sites, and associated waterway classifications under the Comprehensive Stormwater Network Discharge Consent Environmental Monitoring Programme to allow comparison to guideline levels.

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
Ōtākaro-Avon	AVON01	Avon River at Pages/Seaview Bridge[3]	1577484	5182589	Spring-fed – plains – urban
	AVON02	Avon River at Bridge Street[3]	1577691	5180813	Spring-fed – plains – urban
	AVON03	Avon River at Dallington Terrace/Gayhurst Road[3]	1573560	5181210	Spring-fed – plains – urban
	AVON04	Avon River at Manchester Street	1570890	5180481	Spring-fed – plains – urban
	AVON05	Wairarapa Stream	1568250	5181303	Spring-fed – plains – urban
	AVON06	Waimairi Stream	1568233	5181172	Spring-fed – plains – urban
	AVON07	Avon River at Mona Vale	1568334	5181046	Spring-fed – plains – urban
	AVON08	Riccarton Main Drain	1568683	5180019	Spring-fed – plains – urban
	AVON09	Addington Brook	1569427	5179826	Spring-fed – plains – urban
	AVON10	Dudley Creek	1572574	5182150	Spring-fed – plains – urban
	AVON11	Horseshoe Lake Discharge[3]	1574342	5183294	Spring-fed – plains – urban
	AVON12	Avon River at Carlton Mill Corner[4]	1569737	5181259	Spring-fed – plains – urban
	AVON13	Avon River at Avondale Road[3,4]	1574752	5183557	Spring-fed – plains – urban
Ōpāwaho-Heathcote	HEATH01	Heathcote River at Ferrymead Bridge[3]	1576491	5177150	Spring-fed – plains – urban
	HEATH02	Heathcote River at Tunnel Road[3]	1575074	5177543	Spring-fed – plains – urban
	HEATH03	Heathcote River at Opawa Road/Clarendon Terrace[3]	1573071	5177615	Spring-fed – plains – urban
	HEATH04	Heathcote River at Bowenvale Avenue	1571198	5175780	Spring-fed – plains – urban
	HEATH05	Cashmere Stream at Worsleys Road	1569030	5175155	Banks Peninsula
	HEATH06	Heathcote River at Rose Street	1568701	5175918	Spring-fed – plains – urban

[3] Tidally influenced site
[4] These sites are specifically located in proximity to stormwater outfalls

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
	HEATH07	Heathcote River at Ferniehurst Street	1569157	5175612	Spring-fed – plains – urban
	HEATH09	Haytons Stream at Retention Basin[5]	1566020	5177596	Spring-fed – plains – urban
	HEATH10	Curlett Road Stream Upstream of Heathcote River Confluence	1566928	5177711	Spring-fed – plains – urban
	HEATH11	Heathcote River at Catherine Street[3,4]	1574413	5177883	Spring-fed – plains – urban
	HEATH12	Heathcote River at Mackenzie Avenue Footbridge[3,4]	1573520	5177917	Spring-fed – plains – urban
	HEATH14	Curlett Road Stream at Southern Motorway[4]	1566405	5178358	Spring-fed – plains – urban
	HEATH16	Cashmere Stream at Sutherlands Road	1566086	5173988	Banks Peninsula
	HEATH17	Steamwharf Stream upstream of Dyers Road[3]	1575049	5177794	Spring-fed – plains – urban
	HEATH31	Heathcote River at Warren Crescent	1566034	5177359	Spring-fed – plains – urban
Pūharakekenui-Styx	STYX01	Smacks Creek at Gardiners Road near Styx Mill Road	1566804	5187956	Spring-fed – plains
	STYX02	Styx River at Gardiners Road	1566790	5187226	Spring-fed – plains
	STYX03	Styx River at Main North Road	1569066	5187219	Spring-fed – plains
	STYX04	Kā Pūtahi[6] Creek at Blakes Road	1570401	5188030	Spring-fed – plains
	STYX05	Kā Pūtahi[6] Creek at Belfast Road	1572194	5188267	Spring-fed – plains
	STYX06	Styx River at Marshland Road Bridge	1572358	5187778	Spring-fed – plains
	STYX07	Styx River at Richards Bridge	1573975	5189640	Spring-fed – plains
	STYX08	Styx River at Harbour Road Bridge[3]	1574998	5194749	Spring-fed – plains
	SLLT01	Smacks Creek at Wilkinsons Road	1567089	5068802	Spring-fed – plains
	SLLT02	Styx River at Willowbank	1567218	5187641	Spring-fed – plains
	SLLT03	Styx River at Styx Mill Conservation Reserve	567918	5187613	Spring-fed – plains
	SLLT04	Styx Drain at Redbrook Road	1568628	5069246	Spring-fed – plains

[5] This monitoring site was moved from the old outlet location to the new outlet location in May 2020.
[6] While officially shown on maps as Kaputone Creek, CCC has recently endorsed the use of the original Māori name for the area, Kā Pūtahi Creek.

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
	SLLT05	Rhodes Drain at Hawkins Rd	1571548	5187060	Spring-fed – plains
	SLLT06	Horner's Drain at Hawkins Rd	1571569	5187095	Spring-fed – plains
	SLLT07	Styx River at Radcliffe Road	1571720	5187413	Spring-fed – plains
	SLLT08	Kā Pūtahi Creek at Blakes Road	1570925	5068237	Spring-fed – plains
	SLLT09	Kā Pūtahi Creek at Ouruhia Domain	1571771	5190129	Spring-fed – plains
	SLLT10	Kā Pūtahi Creek at Everglades Golf Course	1571798	5189270	Spring-fed – plains
	SLLT11	Styx River at Brooklands	1575110	5193308	Spring-fed – plains
Huritini-Halswell	HALS03	Nottingham Stream at Candys Road	1564532	5173080	Spring-fed – plains
	HALS04	Halswell River at Akaroa Highway (Tai Tapu Road)	1564446	5171721	Spring-fed – plains
	HALS05	Knights Stream at Sabys Road	1563723	5172852	Spring-fed – plains
	HALS07	Halswell River at Wroots/Halswell Roads	1564359	5172477	Spring-fed - plains
Ōtūkaikino	OTUKAI01	Ōtūkaikino River at Groynes Inlet	1567878	5188869	Spring-fed – plains
	OTUKAI02	Wilsons Drain at Main North Road	1571241	5190793	Spring-fed – plains
	OTUKAI03	Ōtūkaikino Creek at Omaka Scout Camp	1565664	5188038	Spring-fed – plains
Linwood Canal	OUT01	Linwood Canal/City Outfall Drain[3]	1575952	5178026	Spring-fed – plains – urban
Stream Reserve Drain/Zephyr Stream	BP01	Stream Reserve Drain Above Outfall to Governors Bay	1572035	5170197	Banks Peninsula
Purau Bay Drain Number 1	BP02	Purau Bay Drain Number 1 Above Purau Avenue	1579234	5169180	Banks Peninsula
Balguerie Stream	BP03	Balguerie Stream Downstream of Settlers Hill (road)	1597748	5149578	Banks Peninsula
Aylmers Stream	BP04	Aylmers Stream Downstream of Rue Jolie, next to Bruce Terrace	1596920	5149096	Banks Peninsula
Ihutai - Avon-Heathcote Estuary	CW01	Estuary of the Heathcote and Avon Rivers – Ihutai at the Eastern Tip by Beachville Road[4]	1579001	5176882	Coastal Contact Recreation Water

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
The Operational Area of the Port of Lyttelton	CW02	Lyttelton Port at the Small Wharf Opposite Voelas Road[7]	1576834	5172004	Coastal Aquatic Ecology Water
Cass Bay	CW03	Eastern Side of Cass Bay off the Cass Bay Walkway[4]	1575236	5171897	Coastal Contact Recreation Water
Akaroa Harbour	CW04	Akaroa Harbour at the Termination of Rue Balguerie[4]	1597257	5149806	Coastal Shellfish Gathering Water

[7] Site in location of stormwater outfall from an urban and industrial (i.e. port) catchment

2.3. Data Analysis

2.3.1. Summary Statistics and Graphs

Boxplots (for monthly data) were produced using the program RStudio (Version 4.1.3) for the most pertinent parameters (typically those with guideline levels). To allow graphing of monthly samples, concentrations less than the LOD were converted to half the detection limit. In some samples, monthly *E. coli* concentrations exceeded the maximum laboratory limit for counting (24,000 MPN/100ml) and these were graphed as 24,000, although concentrations may have been much higher than this. There were four such *E. coli* cases for this report: two during 2019 and two during 2021.

The dark lines in the boxes of the boxplots represent the medians, and the bottom and top lines of the boxes represent the 25th and 75th percentiles (the interquartile range), respectively. The T-bars that extend from the boxes approximate the location of 90% of the data (i.e., the 5th and 95th percentiles). The exception to this is for faecal coliforms where the T-bars represent the approximate location of 80% of the data (i.e., the 10th and 90th percentiles). This adjustment was necessary as faecal coliform guidelines refer to the 90th percentile. These percentiles were calculated using Hazen methodology (Ministry for the Environment, 2003). Circles represent outliers. In some cases, boxplots do not show all components, such as the percentiles, due to a lack of variation in the data, with some showing only the medians. This usually occurred where a large proportion of the data were below the laboratory limit of detection.

Graphs were created based on three years of rolling monitoring data. Additional graphs with data from the monitoring year (2021) alone were created for TSS, copper, lead and zinc. This was to allow an assessment for the CSNDC as to whether the Receiving Environment Objectives and Attribute Target Levels (these are consistent with the guideline levels) for these parameters are being met, or whether further investigations are triggered (in accordance with Condition 59).

2.3.1. Guideline Levels

The results of the monitoring were compared to guideline levels where these were available as outlined in Table i in Appendix B. This table also provides information on which parameters were assessed against percentiles (95th or 90th) versus medians, as required by the individual guidelines. Background on the environmental concern surrounding each parameter is also provided in this table. Comparisons to guideline levels for the wet weather monitoring must be viewed with caution, as these are based on individual samples, not datasets (i.e, not medians or percentiles).

Dissolved lead and zinc guidelines for waterway sites were modified to account for water hardness (Warne et al., 2018). Hardness modified values were calculated for the three Banks Peninsula waterway sites this monitoring year (Stream Reserve Drain, Balguerie Stream, and Aylmers Stream) in accordance with Condition 52(a) of the CSNDC (Appendix D). Metals, TSS, and turbidity for strongly tidal waterway sites (Avon at Bridge St, Heathcote at Ferrymead Bridge, Heathcote at Tunnel Rd, and Linwood Canal) were compared to the coastal water guidelines, rather than waterway guidelines, as this was considered more appropriate. Although turbidity is now measured using Formazin Nephelometric Units (FNU) and not Nephelometric Turbidity Units (NTU), the NTU waterway and coastal guideline values are still used for direct comparison against this FNU data (Michele Stevenson, Environment Canterbury, personal communication, May 2020).

2.3.2. Water Quality Index

A Water Quality Index (WQI) was developed for the Council monthly monitoring sites, based on a Canadian WQI (CCME; Canadian Council of Ministers for the Environment, 2001). This index uses three factors to assess water quality: scope (the percentage of parameters not meeting the guideline on at least one occasion); frequency (the percentage of samples that did not meet the guideline); and amplitude (the amount by which the guideline was not met). The WQI ranges from 0 – 100, with 100 representing high water quality. The user can choose which parameters to include and what guideline levels are appropriate to their system.

The parameters used in this Council WQI were copper, zinc, pH, TSS, Dissolved Oxygen (DO), temperature, BOD_5, total ammonia, nitrate, Dissolved Reactive Phosphorus (DRP), and *E. coli*. Dissolved Inorganic Nitrogen (DIN) could not be used in the WQI, as ammonia forms part of this parameter, and ammonia is already included in the index, so this may have potentially biased the results.

WQI scores could not be calculated at the coastal sites as total ammonia, nitrate, and DRP are not collected. No TSS guideline exists for coastal sites, therefore WQI scores could also not be generated for the strongly tidal waterway sites (Avon at Bridge St, Heathcote at Tunnel Rd, Heathcote at Ferrymead Rd and Linwood Canal).

WQI scores were used to categorise the Council sites as being 'very poor' (0 – 39.99), 'poor' (40 – 69.99), 'fair' (70 – 79.99), 'good' (80 – 89.99), or 'very good' (90 – 100). The categories were selected based on local knowledge of water quality compared to other waterways nationally. These categorise Christchurch City waterways as expected. The WQI index was calculated for every year from 2016 (inclusive), to allow comparisons over time.

2.3.3. Temporal Trends

Temporal trends analysis was carried out on the monthly data, SLLT data, and both the site and catchment wide WQI, to determine whether water quality is declining, improving, or staying the same over time. Analyses on the monthly and SLLT data were undertaken on all data collected since monitoring began at each site (Appendix A, Table i). Trends in WQI were calculated from data collated from 2016-2021.

Trends analysis was conducted using Time Trends Version 7.0, build 1 (NIWA, 2014). The Seasonal Kendall trend test was used to test the significance, magnitude and direction of the trends, providing an average annual percentage change. Data were treated as independent (i.e., all values were used instead of medians), as it was considered that site data were independent of each other (i.e., the concentrations at one site were not influenced by the concentrations at another site). A change was considered meaningful when there was a statistically significant ($p \leq 0.05$) positive or negative result of greater than 1% (NIWA, 2020). Trend lines on graphs were fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method.

Time Trends accommodates for variable LODs and the option for using censored concentrations (records below the LOD) in Sen slope calculation was selected. For some of the parameters, a large proportion of data was below the LOD (e.g., dissolved copper, lead, and BOD_5), or missing (e.g., SLLT data in some years), affecting the accuracy of the Time Trends analyses. Due to this, the direction of change for BOD_5 could be calculated at most sites, but not the magnitude (i.e. %).

This software requires three years of data to robustly analyse trends. Therefore the following parameters were unable to be analysed: all parameters at 11 Council sites where monitoring was instigated in 2020, turbidity at five Council sites where this was instigated in 2020, salinity at seven

Council sites where this was instigated in 2020, and enterococci at one site where this was instigated in 2020 (Appendix A, Table i).

Concentrations of parameters may vary depending on flow rates at the time of sampling, due to variations in the level of dilution. Therefore, flow-adjusted data can be used in the Time Trends software to account for this potentially confounding factor. However, a flow recorder is only directly present at one of the sites (Heathcote at Ferniehurst St). It is considered that extrapolation of this flow data to other locations, as well as the use of other flow gauges in Christchurch not directly at the monitoring sites, may bias the results through differences in stream habitat and additional discharge inputs. This may lead to inaccurate trend conclusions. Given the long period of monitoring, it is considered that variations in flow rates between sampling events will not strongly influence the trends analysis, as most events will have been conducted during base flow conditions. To ensure accurate comparisons between sites, the flow data for Heathcote River at Ferniehurst St was not used even for this site.

3. Results

3.1. Rainfall

- Rainfall in Christchurch City and Banks Peninsula during the monitoring year was assessed based on daily rainfall collected at the Christchurch Botanic Gardens and Akaroa, respectively, by the Council since the early 1960's.
- Over the last seven years Christchurch City rainfall has been variable, including dry years (2015, 2016, 2020), wet years (2017 and 2018), and intermediate years (2019, 2021) (Figure 2(a)).
- Near normal rainfall was recorded in Christchurch for the year overall. March was the driest month, with just 19 mm recorded (41% of the March normal). July was also notably dry, with just 39% of the normal rainfall recorded in the city. May and December were particularly wet months, with 165 mm (286% of the May normal) and 130 mm (277% of the December normal) recorded, respectively.
- The Akaroa region recorded over 25 dry days during March 2021 (a dry day is a day with less than 1 mm of rainfall recorded). Contrary to this, the region recorded 98 mm of rain on 30 May, which was Akaroa's 3rd –highest 1 day rainfall for May on record (Figure 2b).
- For the Council monthly data within the City, the Ihutai – Avon-Heathcote Estuary site recorded the greatest number of sampling days affected by rain (58%) during 2021, followed by Linwood Canal (55%), Ōtākaro-Avon River catchment (51%), Ōtūkaikino River catchment (32%), Ōpāwaho-Heathcote River catchment (31%), Huritini-Halswell River catchment (27%), and Pūharakekenui-Styx River catchment (28%).
- For the Council monthly data on Banks Peninsula, the French Bay and Cass Bay sites recorded the greatest number of sampling days affected by rain (58%), followed by Lyttelton Port (55%) and Stream Reserve Drain (44%).
- These results are based on observations of the water quality samplers as to whether it had rained within the 24 hours prior to sampling. This means that it is a subjective assessment only and these results should be viewed with caution.

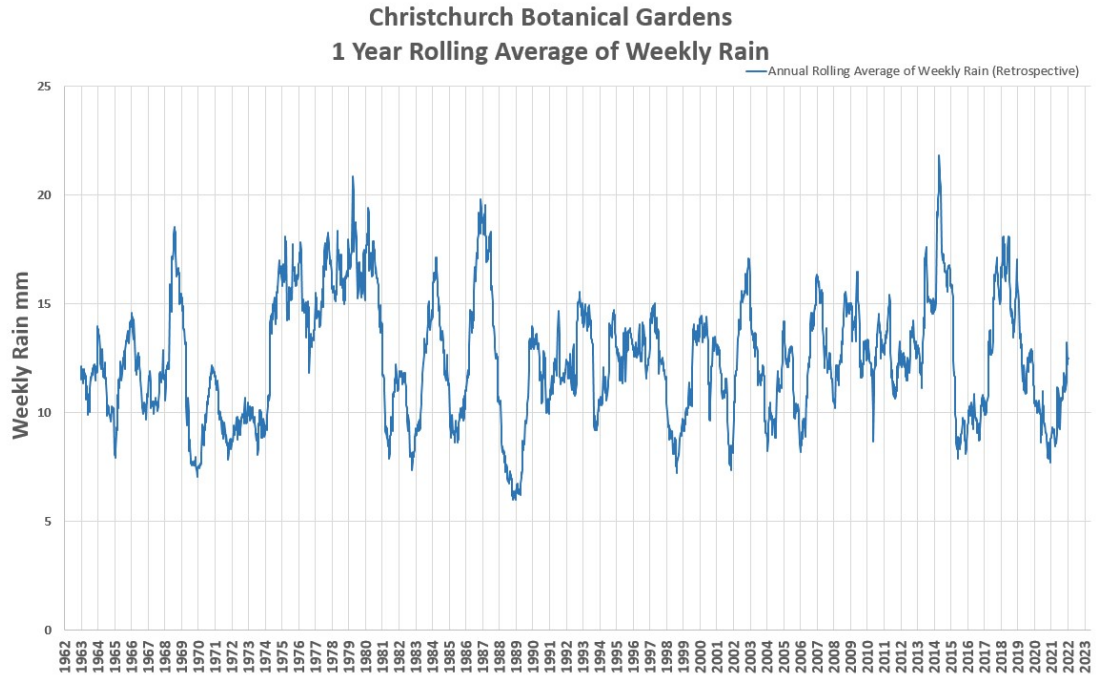

Figure 2(a). Annual rolling average of weekly rainfall at the Botanic Gardens in Hagley Park, Christchurch.

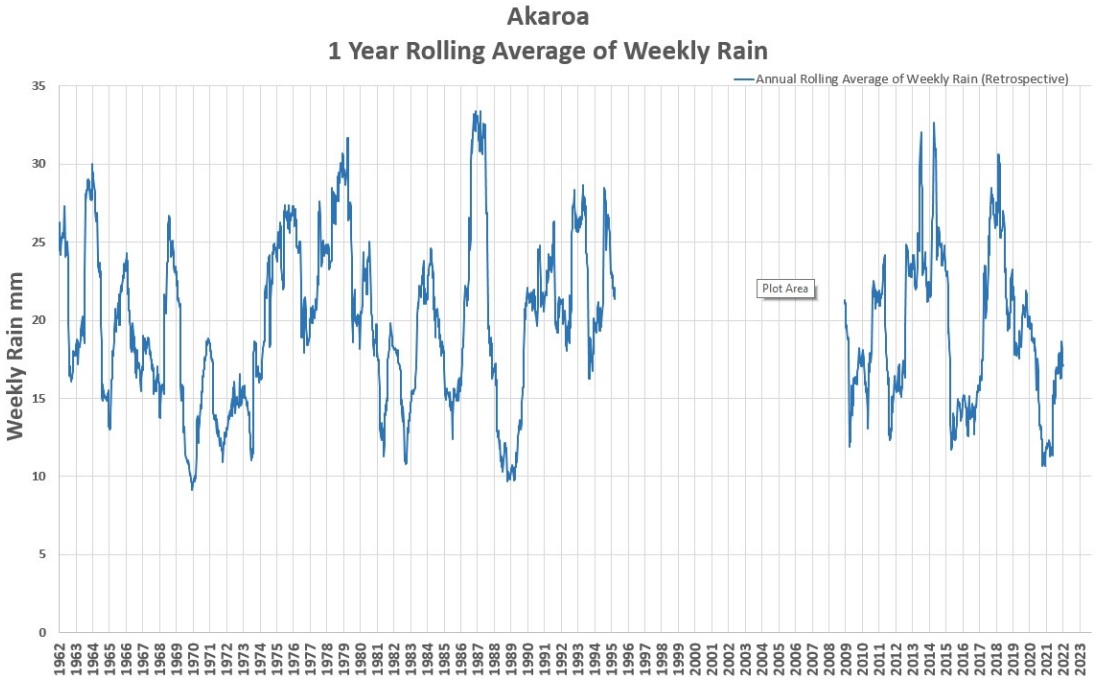

Figure 2(b). Annual rolling average of weekly rainfall in Akaroa. From approximately 1992 to 2008 no data was collected.

3.2. Water Quality Parameters

3.2.1. Summary

- Over 33,500 tests were conducted during 2019-2021 for the Council monthly monitoring, with 20,813 of these allowing the assessment of each waterway site against relevant guideline levels (Table 2).
- 51 sites (100%) did not meet the guideline for at least one parameter (Table 2).
- Parameters that exceeded guidelines at the most sites were *E. coli* (43 of 47 sites), dissolved copper (32 of 51 sites), DRP (28 of 47 sites), and dissolved zinc (22 of 51 sites) (Table 2).
- Most parameters did not show a statistical change in concentration since monitoring began, with 339 (59%) parameter-site combinations recording no significant upwards or downwards trends in concentrations (Appendix F, Tables i–iv). However, 172 (30%) parameter-site combinations recorded a significant improvement in water quality, 63 (11%) parameter-site combinations recorded a significant decline in water quality, and 3 (1%) parameter-site combinations recorded a change in pH that is not necessarily a decline or improvement in water quality. This is similar to that recorded last year.

- The largest increases in parameter concentrations were:
  - 25% for *E. coli* at Ōtūkaikino at Scout Camp (Figure 3; Table iv in Appendix F), due to a step increase in levels since mid-2018, with higher baseline levels overall since that time. This is likely due to faeces contamination from waterfowl and stock. This increase was accompanied by a 10% increase in DIN, which is often also associated with faeces.
  - 16% for zinc at Curletts at Motorway, due to a steady increase over the duration of monitoring since 2014 (Figure 4; Table ii in Appendix F). This is likely due to increasing urban inputs in the catchment, such as from tyres and roofing materials, which shed zinc. A 10% and 8% increase for copper and TSS was also recorded at this site, respectively.
  - 16% for turbidity at Wilsons Stm, due to a steady increase over time (Figure 5; Table iv in Appendix F). A 14% increase for *E.coli* and 13% increase for TSS at Wilsons Stm was also recorded. This suggests a similar source of sediment and stock inputs into the catchment.
- The largest decreases in parameter concentrations were:
  - 24% for DIN at Curlett at Motorway, due to lower concentrations since 2016 (Figure 6; Table ii in Appendix F). This is likely due to a decrease in nitrogen sources from industrial sites within the catchment.
  - 16% for turbidity at Ōtūkaikino at Groynes, due to lower concentrations since 2013 (Figure 7; Table iv in Appendix F). This may be a reflection of the planting undertaken over the years within the catchment filtering sediment loads, as well as less stock accessing the waterways due to fencing.
  - 16% in DRP at the Cashmere at Sutherlands site, due to lower concentrations since 2013 (Figure 8; Table ii in Appendix F). This is likely due to the gradual urbanisation for this traditionally agricultural catchment (i.e., reducing runoff and erosion).
  - 15% for DRP at the Heathcote at Ferrymead site, due to a steady decline since monitoring began (Figure 9; Table ii in Appendix F). Most of the other catchment sites also recorded a decrease in DRP concentrations, along with DIN. This suggests less inputs across the catchment from related sources such as sediment, fertilisers and faecal input, but this would need further investigation to confirm.
- Decreasing trends for DRP, BOD_5, total ammonia, and DIN were recorded at most sites within the Ōtākaro-Avon River, Ōpāwaho-Heathcote River, Huritini-Halswell River, and Pūharakekenui-Styx River catchments (Appendix F).

3.2.2. Dissolved Copper

- Approximately half of the sites in the Ōtākaro-Avon River and Huritini-Halswell River catchments met their respective guidelines (based on 95th percentiles; Appendix E, Figure i (a) – (b)). In the Ōpāwaho-Heathcote River catchment, Heathcote at Warren Cres was the only site to meet the guideline. All sites in the Pūharakekenui-Styx River catchment met the guideline. In the Ōtūkaikino River catchment, Wilsons Stream met the guideline, but Ōtūkaikino at Scout Camp and Ōtūkaikino at Groynes did not. The three Banks Peninsula waterway sites all exceeded their respective guidelines.
- Copper concentrations were generally higher in the Ōtākaro-Avon River, Ōpāwaho-Heathcote River, and coastal catchments, compared to the other catchments.
- The two Curlett Stream sites, Haytons Stream, Addington Brook, Dudley Creek, and Lyttelton Port recorded higher concentrations than the other waterway sites. On occasion, high concentrations were recorded at Ōtūkaikino at Scout Camp, Cass Bay, and Akaroa Harbour. The Banks Peninsula waterways recorded relatively high concentrations, similar to the most urban sites in Christchurch City.
- The three highest concentrations recorded were all from 2020. The highest (0.036 mg/L – Nottingham at Candys Rd) and third highest (0.027 mg/L – Curletts at Motorway) records were associated with rain, while the second highest record (0.035 mg/L – Styx at Richards Bridge) was not.
- Concentrations have not generally changed since monitoring began, with the exception of a 10% increase at Curletts at Motorway and a 13% reduction at Curletts U/S of Heathcote (Appendix F, Tables i–iv).

3.2.3. Dissolved Lead

- All 95th percentiles for each site complied with the respective guidelines (Appendix E, Figure ii (a) – (b)).
- The three highest concentrations were from Dudley creek (0.021 mg/L), Heathcote at MacKenzie Ave (0.0096 mg/L), and jointly Heathcote at Catherine St and Nottingham at Candys Rd (0.0059 mg/L). Only the Heathcote at Catherine St sample was not associated with rain.
- Addington Brook typically had higher concentrations as compared to all other waterway sites. Heathcote at Ferrymead Bridge and Heathcote at Tunnel Road also recorded very high levels on occasion.
- Concentrations at the Banks Peninsula waterways were similar to the lower concentrations recorded in the Christchurch City waterways.
- Concentrations at the coastal sites were also generally comparable to most waterway sites, except for the Ihutai – Avon-Heathcote Estuary site, which had typically higher concentrations.
- Concentrations did not significantly change over time, except at the Dudley Creek (12% reduction), and Curletts U/S of Heathcote sites (13% reduction) (Appendix F, Tables i–iv).

3.2.4. Dissolved Zinc

- 95th percentiles for most sites in the Ōtākaro-Avon River catchment met the guideline level, with the exception of Avon at Mona Vale, Riccarton Main Drain, Addington Brook and Dudley Creek (Appendix E, Figure iii (a) – (b)). In the Ōpāwaho-Heathcote River catchment, approximately half the sites met their respective guideline levels – all mainstem sites met the guidelines except for Rose St, Mackenzie Ave, and Ferrymead Bridge. Zinc concentrations were low for Pūharakekenui-Styx River catchment and Ōtūkaikino sites as compared to other sites, and all met the guideline levels. Aylmers Stream was the only Banks Peninsula waterway site to meet the guideline level.

- The three highest concentrations of 0.77 mg/L (2019), 0.64 mg/L (2020), and 0.64 mg/L (2020) were from the Curletts at Motorway site and only the highest record was not associated with rain. Additionally, the Ihutai – Avon-Heathcote Estuary site recorded 0.64 mg/L and this sample was not associated with rain.
- Concentrations at the Bank Peninsula waterways were similar to the lower concentrations recorded in the Christchurch City waterways.
- Similar to last year, concentrations at the coastal sites were generally comparable to waterway sites. Levels at Ihutai – Avon Heathcote Estuary were much higher compared to the other coastal sites.
- Addington Brook, Curletts at Motorway, Haytons Stream, and Curletts at U/S of Heathcote typically had relatively higher concentrations than the rest of the sites. Kā Pūtahi at Blakes Rd and Nottingham at Candys Rd were also notable for their respective catchments, despite not being as elevated as some of the other sites.
- Concentrations generally remained stable since sampling was instigated (Appendix F, Tables i–iv). However, ten sites recorded a decrease, the largest being Ōtūkaikino at Groynes (13%). Four sites recorded an increase, the largest being Curletts at Motorway (16%).

3.2.5. pH

- Medians of all Council and SLLT waterway sites complied with the guideline levels (Appendix E, Figure iv (a) – (c)).
- The three highest values were from 2019 and 2020 at Haytons Stream (9.6, 9.5 and 9.5) and Curletts at Motorway (9.1), with none of these values recorded in association with rain. The lowest recorded pH of 6.5 was at Curletts U/S Heathcote and the Haytons Stream (both in 2021).
- Coastal sites recorded generally higher pH than waterway sites.
- No substantial changes in pH levels were recorded since monitoring began (Appendix F, Tables i–v).

3.2.6. Conductivity

- No relevant NZ guidelines currently exist for conductivity.
- Coastal and tidal waterway sites had much higher variability compared to non-tidal waterway sites, due to saline influence (Appendix E, Figure v (a) – (c)).
- The majority of the sites in the Ōpāwaho-Heathcote River Catchment showed more variability and higher levels compared to other catchments.
- Conductivity generally did not change over time at the sites by any large degree (Appendix F, Tables i–v). The largest change was at Styx Drain (a SLLT site), where an 11% increase was recorded. A residential subdivision has been recently constructed adjacent to this monitoring site and this change is likely due to the presence of dissolved metals in the associated stormwater discharge. Although partial treatment is provided by a stormwater facility on-site, full treatment will not occur until the large stormwater treatment facility in Belfast is constructed in the coming years.

3.2.7. Salinity

- No relevant NZ guidelines currently exist for salinity.
- Linwood Canal, Avon at Pages Rd, Heathcote at Tunnel Rd, Steamwharf Stream, and Styx at Harbour Rd all recorded samples below the LOD of 2.0% (Appendix E, Figure vi).
- The coastal sites of Cass Bay, Akaroa Harbour, Lyttelton Port, and Avon – Heathcote Estuary recorded much higher salinity than the tidal waterway sites.
- Insufficient data was available to carry-out trends over time, as the sites have only been monitored for two years.

3.2.8. Total Suspended Solids

- Medians of all waterway sites complied with the guideline level (Appendix E, Figure vii (a) – (b)).
- The two highest TSS concentrations were recorded at Cass Bay (580 mg/L in December 2021) which was associated with rain and Heathcote at Opawa Rd (310 mg/L in November 2019; associated with a time of river dredging and not rain). The third highest record was at the Halswell at Wroots Rd site (300 mg/L in May 2020) and this sample was associated with rain.
- The coastal sites generally recorded concentrations similar to the waterway sites. The Cass Bay site had notably higher TSS than the other coastal and waterway sites.
- Concentrations were particularly high at Cashmere at Worsley Rd, Halwell at Wroots Rd, and Halswell at Tai Tapu Rd. High levels were recorded on occasion at many of the Ōpāwaho-Heathcote catchment sites, Avon at Carlton Mill, and Stream Reserve Drain. Tidal sites typically had higher TSS concentrations than non-tidal sites, likely due to resuspension of the naturally softer substrate at these locations during tide changes.
- TSS concentrations generally did not change over time (Appendix F, Tables i–iv). Wilsons Stm recorded the largest change, with a 13% increase recorded.

3.2.9. Turbidity

- The medians were below the guidelines for the majority of sites, although over half of the Ōpāwaho-Heathcote catchment sites exceeded the guidelines. The lower tidal sites had higher turbidity than non-tidal sites (Appendix E, Figure viii (a) – (b)).
- The three highest turbidity readings were recorded from Cass Bay (296 FNU in December 2021), Heathcote at Bowenvale Road (174 FNU in December 2021), and Cashmere at Worsleys Rd (139 FNU in December 2021). All of these recordings were associated with rain.
- The Ōpāwaho-Heathcote River catchment and Huritini-Halswell River mainstem recorded higher turbidity concentrations compared to the other sites.
- The majority of sites did not record a change in turbidity over time (Appendix F, Tables i–iv). The most substantial decrease over time (16%) was at the Ōtūkaikino at Groynes site and the most substantial increase (16%) was at the Wilsons Stm site.

3.2.10. Water Clarity (SLLT sites only)

- No site complied with the guideline (Appendix E, Figure ix). However, it should be noted that a clarity tube is only 1m in length, so it is not possible to ever comply with this guideline value.
- The three best values were from the Smacks at Wilkinsons Road (100 cm) in 2020, Styx Drain at Redbrook Road (100 cm) in 2019 and Kā Pūtahi at Blakes Rd (99 cm) in 2020.
- The three poorest values were all recorded at Horners Drain at Hawkins Rd (32 cm in 2019, 35 cm in 2019, and 35 cm in 2020).
- Water clarity was similar across sites, and between the mainstem and tributaries.
- No substantial changes were recorded over time (Appendix F, Table v).

3.2.11. Dissolved Oxygen

- Medians of the following sites did not meet the guideline: Horseshoe Lake, Addington Brook, Heathcote at Warren Cres, both Curletts sites, both Cashmere Stream sites, Styx at Gardiners Rd, Smacks at Gardiners Rd, and Linwood Canal (Appendix E, Figure x (a) – (b)).
- The three lowest readings were from the Haytons Stream (8.1% in 2020) and the Curletts U/S of Heathcote (8.4% in 2020 and 9.4% in 2020) sites. The third lowest record was associated with rain.
- DO concentrations were generally higher at the coastal sites than the waterway sites.

- Dissolved oxygen concentrations were lower in the Ōpāwaho-Heathcote catchment, particularly at the upstream tributary sites.
- No substantial changes in oxygen were recorded at the sites over time (Appendix F, Tables i–iv).

3.2.12. Water Temperature

- Medians of all Council and SLLT sites complied with their respective guidelines, and temperature overall was similar across all waterway and coastal sites (Appendix E, Figure xi (a) – (c)).
- The three highest readings from the waterway sites were from Linwood Canal (24.5°C in 2021 and 22.8 °C in 2019) and Avon at Bridge Street (22.4 °C in 2021).
- Temperature generally did not change over time by any large degree (Appendix F, Tables i–v).

3.2.13. Biological Oxygen Demand

- Medians of all waterway sites complied with the guideline (Appendix E, Figure xii (a) – (b)).
- The highest concentrations recorded at the waterway sites were from Heathcote at Warren Cres (11 mg/L in 2021 and 6.9 mg/L in 2021), followed by 7.6 mg/L at Heathcote at Ferniehurst St in 2021. None of these events were associated with rain.
- Concentrations were typically higher in the tributary sites compared to the mainstems.
- Most sites recorded decreases over time, with the largest being at Linwood Canal (8%) (Appendix F, Tables i–iv).

3.2.14. Total Ammonia

- The 95th percentiles of all waterways sites complied with their respective guidelines (Appendix E, Figure xiii (a) – (b)).
- The three highest concentrations were from the Riccarton Main Drain (1.7 mg/L in 2020), and jointly Curletts at Motorway and Heathcote at Catherine St (1.1 mg/L respectively in 2020). None of these events were associated with rain.
- Ammonia was generally higher and more variable in the tributaries compared to mainstems. Haytons Stream, Curletts at Motorway, and Linwood Canal recorded high levels compared to the other sites.
- Many sites recorded a decrease in ammonia over time, with the largest reduction at Heathcote at Ferrymead Bridge (13%) (Appendix F, Tables i–iv). Wilsons Stream recorded the only increase (6%).

3.2.15. Nitrate and Dissolved Inorganic Nitrogen

- The majority of all the sites complied with the two nitrate guidelines (Appendix D, Figure xiv (a) – (b)). The exceptions to this being Heathcote at Warren Cres, Curletts U/S of Heathcote, the two Cashmere Stream sites, Knights at Sabys Rd, Halswell at Wroots Rd, and Halswell at Tai Tapu Rd.
- The medians of most sites in each catchment complied with their respective DIN guideline, although approximately half of the sites in the Ōpāwaho-Heathcote River Catchment did not, as well as most sites in the Huritini-Halswell River catchment not complying (Appendix E, Figure xv (a) – (b)).
- Heathcote at Warren Cres, Knights at Sabys Rd, Halswell at Wroots Rd, and Halswell at Tai Tapu Rd recorded much higher concentrations of nitrogen than the other sites, with the three highest

exceedances of nitrate and DIN all from the Heathcote at Warren Cres site (Nitrate and DIN: 5.6 mg/L, 5.4 mg/L, and 5.3 mg/L). Only one record was associated with rain (5.4 mg/L).

- Both parameters typically decreased downstream in the mainstems, and were higher in the Ōtākaro-Avon, Ōpāwaho-Heathcote, and Huritini-Halswell River catchments.
- Many sites recorded minor decreases in DIN concentrations over time (Appendix F, Tables i–iv). Large decreases were recorded at Curletts at Motorway (24%) and Haytons Stream (11%). Four sites recorded increases in concentrations, the most notable being Ōtūkaikino at Scout Camp (10%).

3.2.16. Dissolved Reactive Phosphorus

- The medians of many of the sites complied with their respective guidelines, although there were many sites in the Ōtākaro-Avon River catchment, Ōpāwaho-Heathcote River catchment, Huritini-Halswell River catchment, and the Banks Peninsula Streams that did not (Appendix E, Figure xvi (a) – (b)).
- The three highest concentrations were from Haytons Stream (0.73 mg/L in 2020), Curletts at Motorway (0.45 mg/L in 2021), and Haytons Stream (0.44 mg/L in 2020). None of the samples were associated with rain.
- The majority of sites recorded a decrease in DRP concentrations (Appendix F, Tables i–iv). The largest decreases were from Cashmere at Sutherlands Rd (16%) and Heathcote at Ferrymead Bridge (15%). There were no sites where concentrations increased over time.

3.2.17. *E. coli*, Enterococci, and Faecal Coliforms

- Haytons Stream, Curletts U/S of Heathcote, Cashmere at Sutherland Rd, and Ōtūkaikino at Groynes were the only sites that complied with the 95th percentile *E. coli* guideline level (Appendix E, Figure xvii (a) – (b)).
- Of the eight sites where enterococci was sampled, only Ihutai – Avon Heathcote Estuary complied with the 95th percentiles guideline (Appendix E, Figure xviii).
- The Akaroa Harbour site is the only site monitored for faecal coliforms. The site complied with the median guideline, but not the 90th percentile guideline (Appendix E, Figure xviii). The highest faecal coliform concentration (67 MPN/100 ml) was recorded in June 2021.
- The highest *E. coli* concentration (>24,000 MPN/100ml) was recorded on multiple occasions each at the Dudley Creek (2020), Riccarton Main Drain (2019 and 2020), Linwood Canal (2020), and Nottingham at Candys Rd sites (2019 and 2021). The next highest record of 20,000 MPN/100ml was recorded at the Addington Brook (2020), Nottingham at Candys Rd (2020), Halswell at Tai Tapu Rd (2021) and Heathcote at Ferrymead Bridge (2021). The third highest concentration of 17,000 MPN/100ml was recorded at Steamwharf Stream. Some of these records were associated with rain, but not all. No wastewater overflows were recorded during these events.
- The highest enterococci concentrations were recorded from Steamwharf Stream (>24,000 MPN/100ml), Heathcote at Tunnel Rd (24,000 MPN/100ml), and Heathcote at Ferrymead Bridge (24,000 MPN/100ml). All of these results were associated with rain. The highest faecal coliform record was 67 MPN/100ml at Akaroa Harbour and was associated with the rain. No wastewater overflows were recorded during these events.
- *E. coli* levels generally did not change at the sites over time (Appendix F, Tables i–iv). The largest changes were recorded at Ōtūkaikino at Scout Camp (25% increase) and Wilsons Stm (14% increase).
- Changes over time in enterococci were able to be calculated at three sites: Avon at Bridge St (6% reduction), Heathcote at Ferrymead Bridge (11% reduction), and Linwood canal (13% reduction).
- Insufficient data was available to measure trends in faecal coliforms.

Table 2. Number of waterway and coastal sites monitored for each parameter (where guideline levels are available), the number of samples analysed, and the number of samples and sites (based on medians/95th percentiles, depending on the parameter) not meeting the guideline levels, during the monitoring period of January 2019 to December 2021.

Parameter	Guideline	Number of Sites Monitored	Number of Samples Analysed	Number of Sites Not Meeting Guideline
Escherichia coli	95%th percentile ≤550/100ml	47	1,567	43
Dissolved copper	Varies depending on catchment, from 95th percentile ≤0.001 mg/L to ≤0.0018 mg/L	51	1,626	32
Dissolved Reactive Phosphorus	Varies depending on catchment, from median ≤0.016 mg/L to ≤0.025 mg/L	47	1,547	28
Dissolved zinc	Varies depending on catchment, from 95th percentile ≤0.00634 mg/L to ≤0.0396 mg/L	51	1,624	22
Dissolved Inorganic Nitrogen	Varies depending on catchment, from median ≤0.09 mg/L to ≤1.5 mg/L	47	1,547	14
Turbidity	Varies depending on catchment, from median ≤5.6 NTU to ≤10 NTU	51	1,498	13
Dissolved oxygen	Varies depending on catchment, from median ≥70% to ≥90%	51	1,625	10
Enterococci	Varies depending on catchment, from 95th percentile ≤500 MPN/100ml to ≤200 MPN/100ml	8	247	7
Nitrate	Varies depending on catchment, from median ≤1.0 mg/L to ≤2.4 mg/L and/or 95%ile ≤1.5 mg/L to ≤3.5 mg/L	47	1,545	7
Faecal coliforms	Median ≤14MPN/100ml and/or 90th percentile ≤43 MPN/100 ml	1	18	1
Total ammonia	Varies depending on catchment, from 95th percentile ≤0.32 mg/L to ≤1.99 mg/L	47	1,548	0
pH	Varies depending on catchment, from median 6.5 to 8.5, to 7.0 to 8.5	51	1,626	0
Total Suspended Solids	Median ≤25 mg/L for waterway sites only	43	1,625	0
Biochemical Oxygen Demand	Median ≤2 mg/L	51	1,545	0
Water temperature	Varies depending on catchment, from median ≤20°C to ≤25°C	51	1,625	0
Dissolved lead	Varies depending on catchment, from 95th percentile ≤0.00427 mg/L to ≤0.02388 mg/L	51	1,626	0
Total	-	51	22,439	51 of 51 (for at least one parameter)

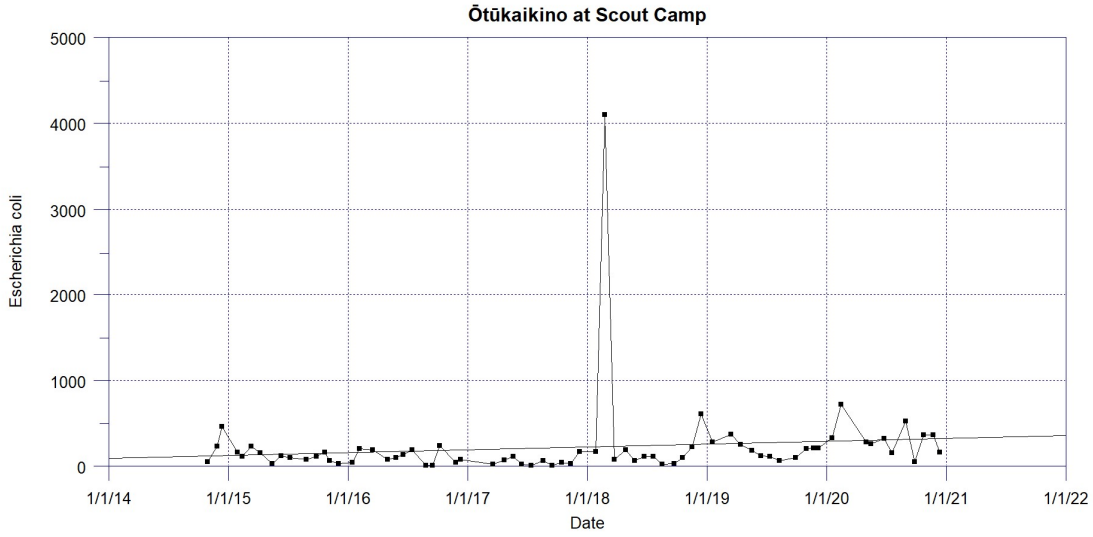

Figure 3. *Escherichia coli* at the Ōtūkaikino at Scout Camp site for the monitoring period October 2014 to December 2021. Squares indicate individual sampling events. An increasing trend of 25% was recorded over the sampling period.

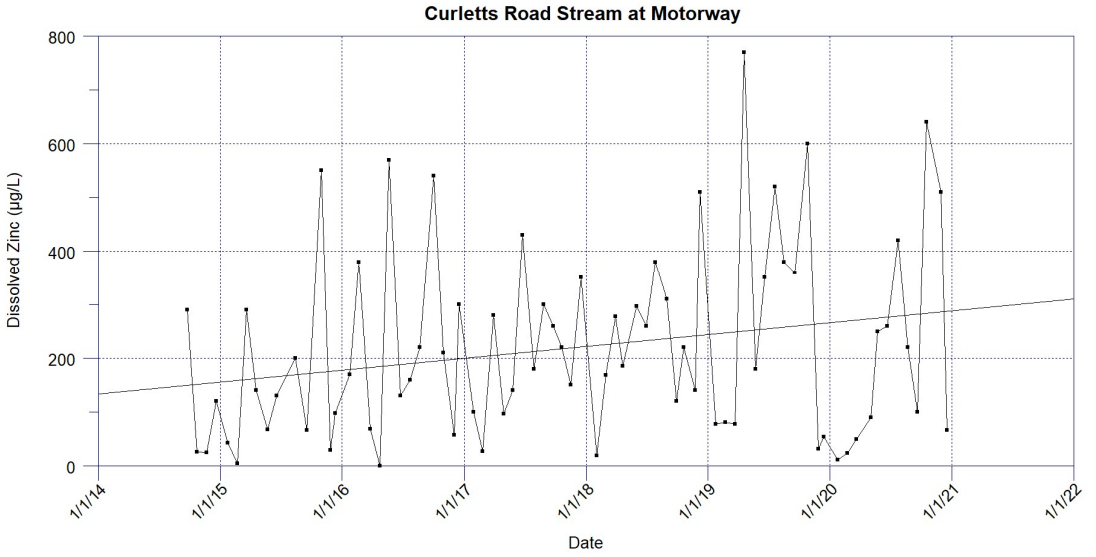

Figure 4. Dissolved Zinc concentrations at the Curletts Road Stream at Motorway site for the monitoring period September 2014 to December 2021. Squares indicate individual sampling events. An increasing trend of 16% was recorded over the sampling period.

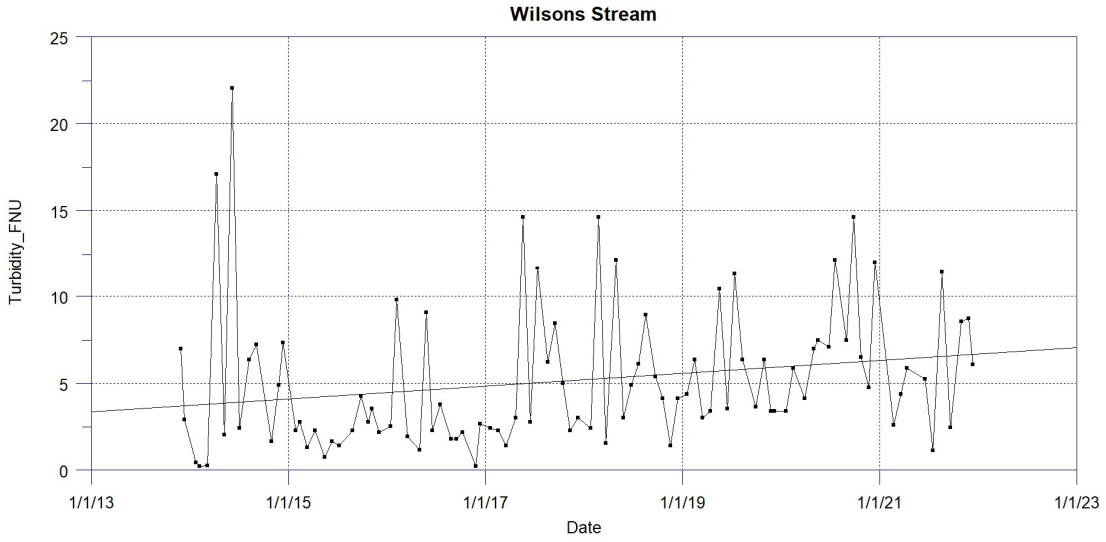

Figure 5. Turbidity concentrations at the Wilsons Stream for the monitoring period October 2013 to December 2021. Squares indicate individual sampling events. An increasing trend of 16% was recorded over the sampling period.

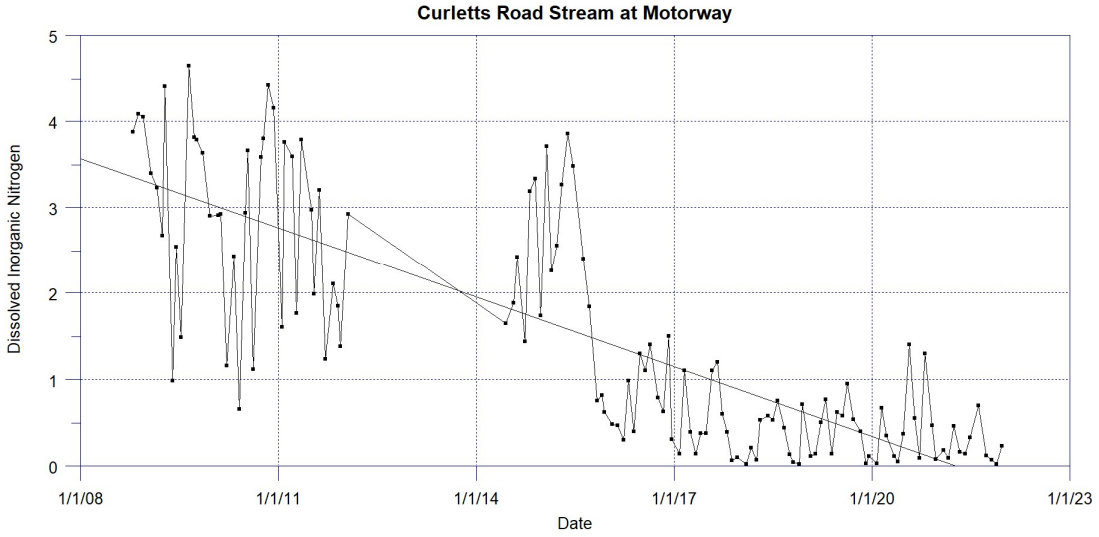

Figure 6. DIN concentrations at the Curletts Road Stream at Motorway for the monitoring period January 2008 to December 2021. Squares indicate individual sampling events. A decreasing trend of 24% was recorded over the sampling period.

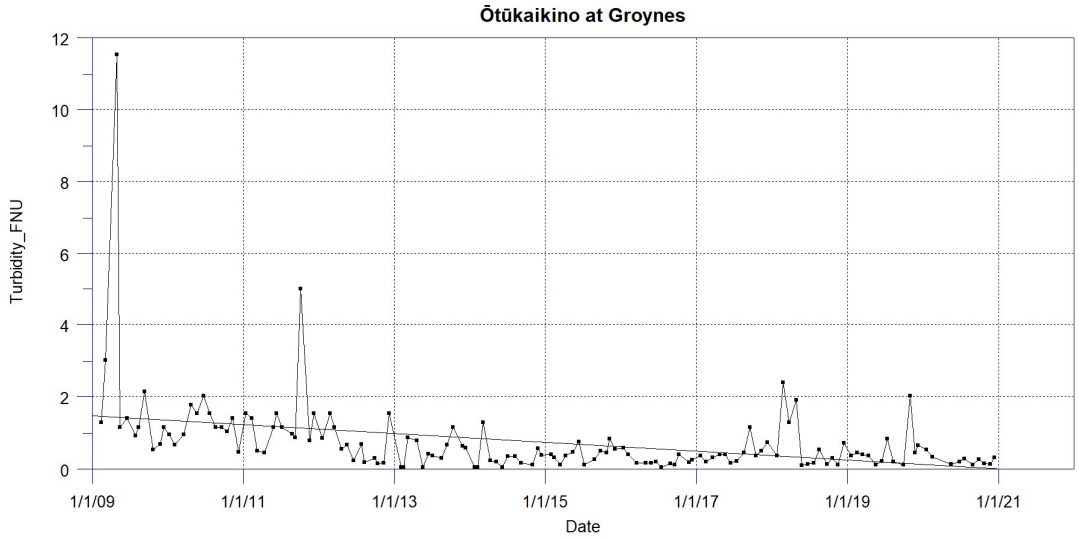

Figure 7. Turbidity concentrations at the Ōtūkaikino River at Groynes for the monitoring period January 2009 to December 2021. Squares indicate individual sampling events. A decreasing trend of 16% was recorded over the sampling period.

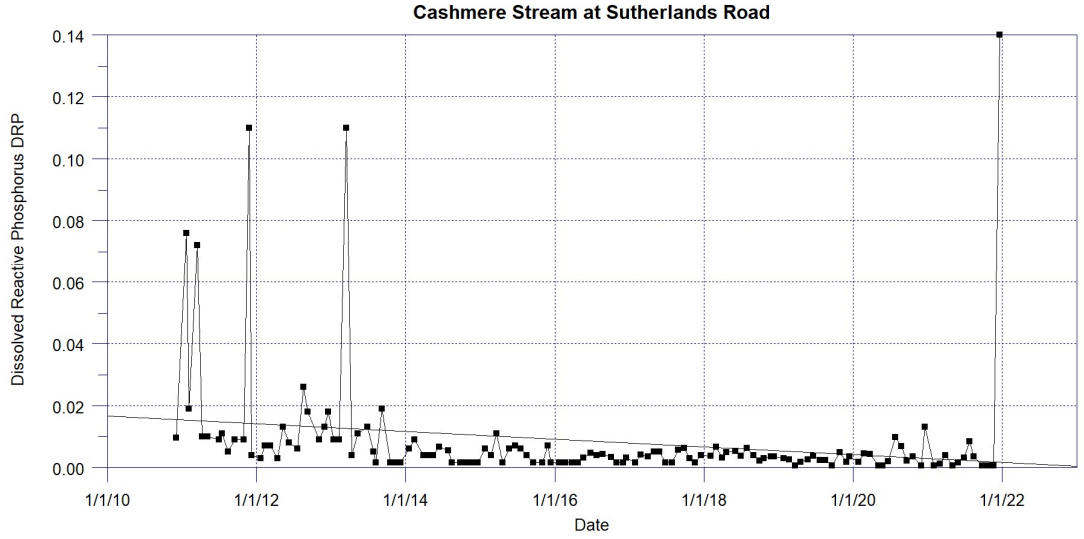

Figure 8. DRP concentrations at the Cashmere at Sutherland for the monitoring period December 2010 to December 2021. Squares indicate individual sampling events. A decreasing trend of 16% was recorded over the sampling period.

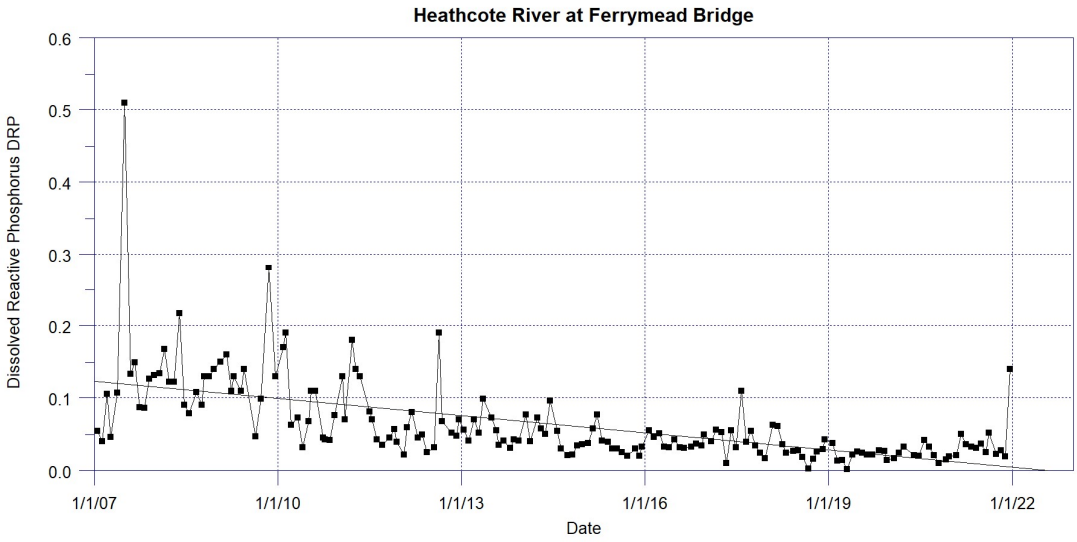

Figure 9. DRP concentrations at the Heathcote at Ferrymead Bridge for the monitoring period January 2007 to December 2021. Squares indicate individual sampling events. A decreasing trend of 15% was recorded over the sampling period.

3.3. Water Quality Index

- 45% (21 sites), 21% (10 sites), 21% (10 sites), and 6% (3 site) of sites recorded 'poor', 'fair', 'good', and 'very good' WQI categories, respectively (Table 3).
- Based on the median WQI for each catchment, the Ōpāwaho-Heathcote River and Huritini-Halswell River recorded 'poor' water quality, the Ōtākaro-Avon River and the Pūharakekenui-Styx River recorded 'good' water quality, and the Ōtūkaikino River recorded 'very good' water quality (Figure 11). The Banks Peninsula waterway sites recorded 'poor' (Stream Reserve Drain) and 'fair' (Balguerie and Aylmers Streams) water quality (Table 3).
- The Ōtūkaikino River recorded the best water quality out of all the catchments and Ōpāwaho-Heathcote River recorded the worst water quality (Table 4).
- The best site for water quality was Ōtūkaikino at Groynes, followed by Wilsons Stream and Styx at Gardiners Road (Table 4). Of note, the Ōtūkaikino at Groynes was the only site to record a perfect score of 100.
- The worst site for water quality was Curletts at Motorway, followed by Heathcote at Tunnel Rd and Heathcote at Warren Cres (Table 4).
- Time Trends analysis showed no catchment significantly improved or declined in WQI over the analysed period (2016–2021). The medians of most catchments varied from 'poor' through to 'good' depending on the year (Figure 11).
- Only Haytons Stream recorded a significant change in WQI in 2021, with a 9% improvement (Table 3).

Table 3. Water Quality Index (WQI) scores and categories for 2021, and direction of significant temporal trends (2016–2021) at each Christchurch City Council surface water quality monitoring site.

Catchment	Site	WQI Score	WQI Category	WQI Temporal Trends
Ōpāwaho-Heathcote	Curletts at Motorway	51.7	Poor	
Ōpāwaho-Heathcote	Heathcote at Tunnel Rd	54.3	Poor	
Ōpāwaho-Heathcote	Heathcote at Warren Cres	54.3	Poor	
Ōpāwaho-Heathcote	Cashmere at Worsleys Rd	54.3	Poor	
Ōpāwaho-Heathcote	Curletts U/S of Heathcote	55.5	Poor	
Ōpāwaho-Heathcote	Heathcote at Ferrymead Bridge	57.1	Poor	
Ōpāwaho-Heathcote	Haytons Stream	57.7	Poor	↑9%
Ōpāwaho-Heathcote	Heathcote at MacKenzie Ave	58.6	Poor	
Ōpāwaho-Heathcote	Heathcote at Catherine St	58.7	Poor	
Stream Reserve Drain	Stream Reserve Drain	59.0	Poor	
Ōtākaro-Avon	Dudley Creek	60.4	Poor	
Ōpāwaho-Heathcote	Cashmere at Sutherlands Rd	60.5	Poor	
Huritini-Halswell	Halswell at Tai Tapu Rd	62.5	Poor	
Ōpāwaho-Heathcote	Heathcote at Rose St	63.2	Poor	
Huritini-Halswell	Halswell at Wroots Rd	63.4	Poor	
Ōpāwaho-Heathcote	Heathcote at Opawa Rd	64.0	Poor	
Ōpāwaho-Heathcote	Heathcote at Ferniehurst St	65.2	Poor	
Ōtākaro-Avon	Avon at Bridge St	66.8	Poor	
Ōpāwaho-Heathcote	Steamwharf Stream	67.1	Poor	
Ōtākaro-Avon	Addington Brook	69.5	Poor	
Ōpāwaho-Heathcote	Heathcote at Bowenvale Ave	69.7	Poor	
Linwood Canal	Linwood Canal	71.99	Fair	
Huritini-Halswell	Nottingham at Candys Rd	72.3	Fair	
Ōtākaro-Avon	Avon at Avondale Rd	72.3	Fair	
Balguerie Stream	Balguerie Stream	76.1	Fair	
Aylmers Stream	Aylmers Stream	76.2	Fair	
Ōtākaro-Avon	Avon at Pages Rd	76.7	Fair	
Pūharakekenui-Styx	Styx at Harbour Rd	76.9	Fair	
Huritini-Halswell	Knights at Sabys Rd	77.0	Fair	
Ōtākaro-Avon	Horseshoe Lake	77.6	Fair	
Pūharakekenui-Styx	Kā Pūtahi at Belfast Rd	79.3	Fair	
Pūharakekenui-Styx	Smacks at Gardiners Rd	82.5	Good	
Ōtākaro-Avon	Avon at Manchester St	82.6	Good	
Ōtākaro-Avon	Avon at Dallington Tce	82.7	Good	
Pūharakekenui-Styx	Styx at Marshland Rd	82.7	Good	
Pūharakekenui-Styx	Kā Pūtahi at Blakes Rd	83.0	Good	
Ōtākaro-Avon	Riccarton Main Drain	83.7	Good	
Pūharakekenui-Styx	Styx at Richards Bridge	88.1	Good	
Ōtākaro-Avon	Avon at Mona Vale	88.5	Good	
Ōtākaro-Avon	Avon at Carlton Mill	88.7	Good	

Catchment	Site	WQI Score	WQI Category	WQI Temporal Trends
Pūharakekenui-Styx	Styx at Main North Rd	88.8	Good	
Ōtākaro-Avon	Waimairi Stm	88.8	Good	
Ōtūkaikino	Otukaikino at Scout Camp	89.3	Good	
Ōtākaro-Avon	Wairarapa Stm	89.3	Good	
Pūharakekenui-Styx	Styx at Gardiners Rd	92.5	Very Good	
Ōtūkaikino	Wilsons Stm	94.0	Very Good	
Ōtūkaikino	Otukaikino at Groynes	100.0	Very Good	

Table 4. Best and worst catchments and sites for the monitoring period January to December 2021, based on the Water Quality Index (WQI).

Placing	Best Sites		Worst Sites	
	Catchment Scale	Site Scale	Catchment Scale	Site Scale
	Ōtūkaikino River (median WQI = 94)	Ōtūkaikino at Groynes (WQI = 100)	Ōpāwaho-Heathcote River (median WQI =59)	Curletts at Motorway (WQI = 52)
	Pūharakekenui-Styx River (median WQI = 83)	Wilsons Stream (WQI = 94)	Huritini – Halswell River (median WQI = 68)	Heathcote at Tunnel Road (WQI = 54)
	Ōtākaro-Avon River (median WQI = 83)	Styx at Gardiners Rd (WQI = 93)	Bank Peninsula (median WQI = 76.1)	Heathcote at Warren Cres (WQI = 54)

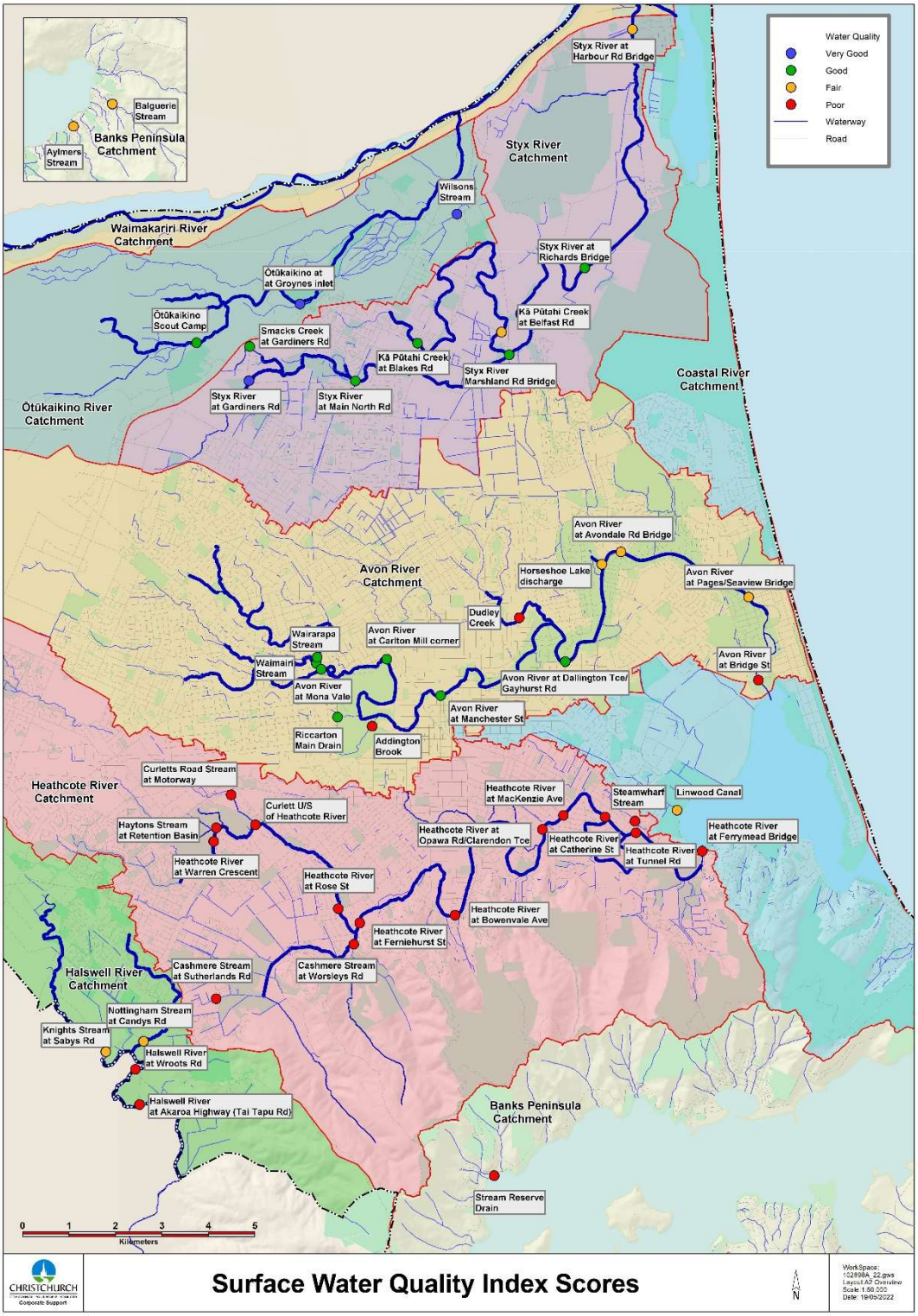

Figure 10. Water Quality Index (WQI) categories for 2021 at the Christchurch City Council surface water quality monitoring sites.

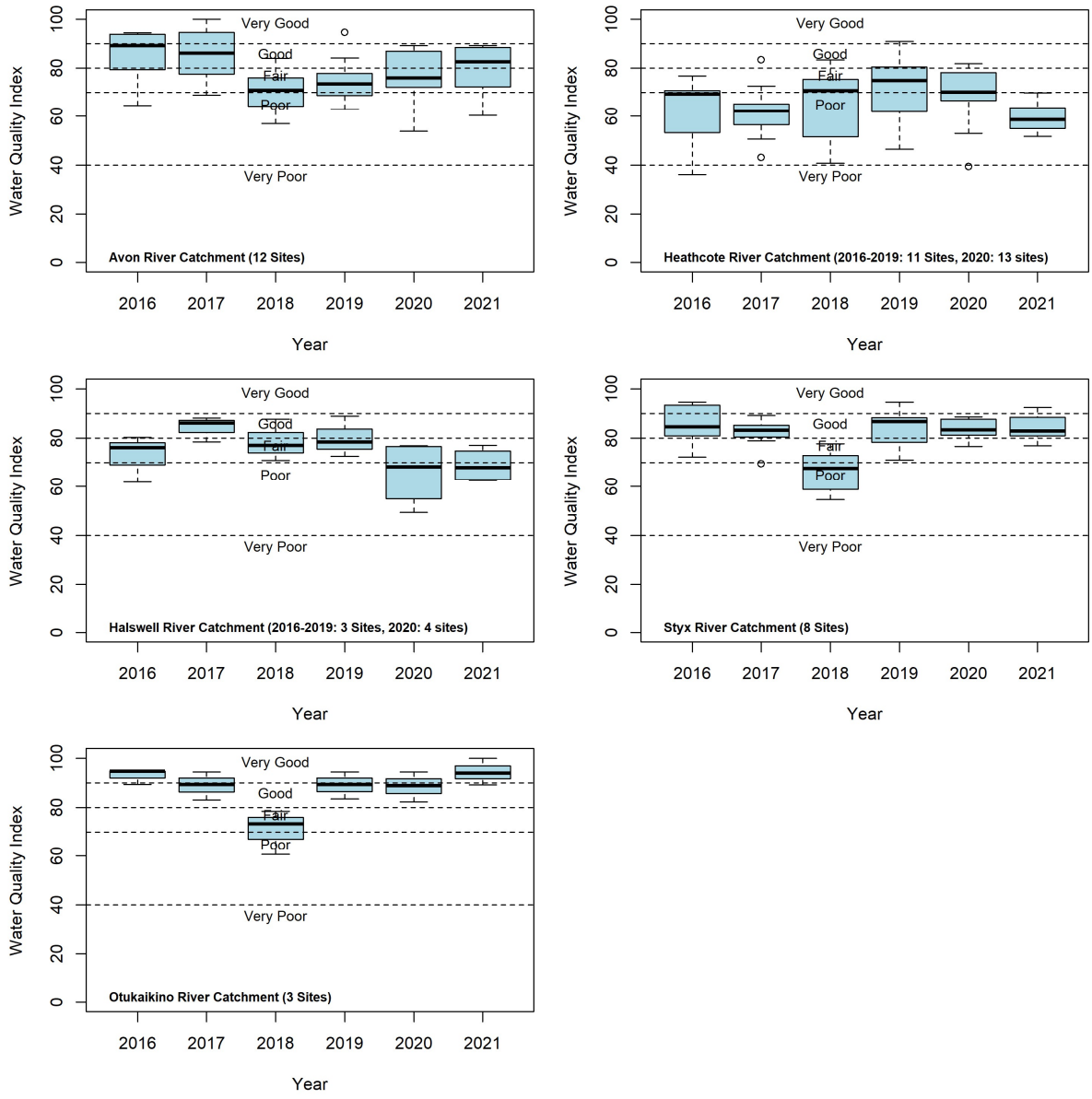

Figure 11. Boxplots of Water Quality Index for each catchment for the 2016 to 2021 monitoring years

3.4. Assessment against Attribute Target Levels

- A requirement for this report under the CSNDC EMP is to assess the Council monthly data against the consent Objectives and Attribute Target Levels (ATLs) for TSS, copper, lead, and zinc, as specified in Schedules 7 (Waterways) and 8 (Coastal Waters) of the consent conditions. If these ATLs are not met, water quality investigations are triggered to determine whether the water quality is due to stormwater inputs.
- These ATLs require that (a) the guidelines used in this report are met, and (b) no increasing trends in concentrations are recorded. This assessment is for results from the monitoring year, not the three-year dataset as used elsewhere in this report.
- 31 of the 51 sites monitored in 2021 did not meet the CSNDC ATLs (Table 5; Appendix G). This is one more site than that recorded last year.
- The sites that are prioritised for investigation are those where a guideline was not met and an increasing trend was recorded. These four sites are the same as those prioritised last year: Curletts at Motorway (prioritised due to copper and zinc), Heathcote at Ferrymead Bridge (prioritised due to zinc), Addington Brook (prioritised due to zinc), and Nottingham at Candys Road (prioritised due to zinc). This work will be carried out in conjunction with work already being conducted under the 2020 Condition 59 investigations and the CSNDC Targeted Wet Weather Monitoring Project (Schedule 3k).

Table 5. Assessment of Christchurch City Council surface water quality monitoring sites against the Comprehensive Stormwater Network Discharge Consent (CSNDC) Attribute Target Levels (ATLs) for Total Suspended Solids (TSS), dissolved copper and dissolved zinc, for the monitoring year January – December 2021. Lead is not shown as all sites met the ATLs. A tick represents a trigger under the CSNDC for further investigations into parameter concentrations, due to levels either not meeting the guidelines or levels statistically increasing over time. The Lyttelton Port site is not included in this table as it is excluded from meeting ATLs under Schedule 8 of the CSNDC. G = guideline level not met; C = statistically significant increase recorded; N/A = parameter not measured; blank cell = investigation not triggered (i.e., ATLs are met).

Site	Dissolved copper	Dissolved zinc	TSS (median)	Investigation Prioritised?	Comments
Curlett at Motorway	✓G,C	✓G,C	✓C	Yes	2021 Condition 59 investigation site; Targeted Wet Weather Monitoring Project
Heathcote at Ferrymead Bridge	✓G	✓G,C		Yes	2021 Condition 59 investigation site
Addington Brook	✓G	✓G,C		Yes	2021 Condition 59 investigation site
Nottingham at Candys Rd	✓G	✓G,C		Yes	2021 Condition 59 investigation site
Cashmere at Sutherlands Rd	✓G	✓G			Recent residential subdivisions built in catchment
Curlett U/S of Heathcote	✓G	✓G			Targeted Wet Weather Monitoring Project
Halswell at Tai Tapu Rd	✓G		✓ G		
Haytons Stream	✓G	✓G	✓C		Targeted Wet Weather Monitoring Project
Halswell at Wroots Rd	✓G	✓G			
Heathcote at Tunnel Rd	✓G	✓G			
Heathcote at Rose St	✓G	✓G			
Ihutai – Avon-Heathcote Estuary	✓G				

Site	Dissolved copper	Dissolved zinc	TSS (median)	Investigation Prioritised?	Comments
Cashmere at Worsleys Rd	✓G	✓G			
Aylmers Stream	✓G				
Balguerie Stream	✓G	✓G			
Stream Reserve Drain	✓G	✓G			
Riccarton Main Drain		✓G			
Dudley Creek	✓G	✓G			
Linwood Canal	✓G	✓G			
Heathcote at Ferniehurst St	✓G				
Heathcote at Bowenvale Ave	✓G				
Heathcote at MacKenzie Ave	✓G	✓G			
Cass Bay	✓G				
Akaroa Harbour		✓G			
Wilsons Stream			✓C		
Avon at Pages Rd	✓G				
Avon at Bridge St	✓G	✓G			
Steamwharf Stream	✓G				
Heathcote at Warren Cres	✓G				
Cashmere at Worsleys Rd	✓G				
Heathcote at Catherine St	✓G				

3.5. Catchment Summary

A collation of the WQI results and contaminants of concern for each catchment are provided in Table 6. Of particular note:

- Dissolved metals, sediment (turbidity/TSS), nitrogen (nitrate/DIN), phosphorus, and *E. coli* are of concern in most waterway catchments.
- Copper and enterococci are the contaminant of concern in coastal areas.
- Water quality at the Banks Peninsula waterways is no better than waterways in the City and is particularly poor at Stream Reserve Drain in Governors Bay.

Table 6. Catchment summary of surface water quality and contaminants of concern, based on data presented in this 2021 monitoring report. WQI = Water Quality Index; N/A = Not Applicable (due to the WQI not being calculated, or only one site being monitored so a catchment summary is not relevant); * = catchment level assessment; DIN = Dissolved Inorganic Nitrogen, DRP = Dissolved Reactive Phosphorus; TSS = Total Suspended Solids; Biochemical Oxygen Demand = BOD_5, DO = Dissolved Oxygen.

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2021)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
Ōtākaro-Avon River	Good (Median WQI = 83)*	Wairarapa Stm Waimairi Stm Avon at Carlton Mill Avon at Mona Vale Riccarton Main Drain	Dudley Creek Avon at Bridge St Addington Brook	No significant trend*	Copper, zinc, turbidity, DIN, DRP, *E. coli*	Wairarapa Stm (*E. coli*) Waimairi Stm (DIN, *E. coli*) Avon at Mona Vale (copper, zinc, DIN, *E. coli*) Avon at Carlton Mill (*E. coli*) Riccarton Main Drain (copper, zinc, DIN, *E. coli*) Addington Brook (copper, zinc, turbidity, DO, DRP, *E. coli*) Avon at Manchester St (copper, *E. coli*) Dudley Creek (copper, zinc, DRP, *E. coli*) Avon at Dallington Tce (copper, DRP, *E. coli*) Horseshoe Lake (turbidity, DO, DRP, *E. coli*) Avon at Avondale Rd (zinc, DRP, *E. coli*) Avon at Pages Rd (DRP, *E. coli*) Avon at Bridge Street (copper, zinc, turbidity, DRP, *E. coli*, enterococci)
Ōpāwaho-Heathcote River	Poor (Median WQI = 59)*	Heathcote at Bowenvale Ave Steamwharf Stream Heathcote at Opawa Rd	Curletts at Motorway Heathcote at Tunnel Rd Cashmere at Worsleys Rd Heathcote at Warren Cres	No significant trend*	Copper, zinc, turbidity, DIN, DRP, *E. coli*	Heathcote at Warren Cres (DO, nitrate, DIN, *E. coli*) Haytons Stream (copper, zinc, turbidity, DRP) Curletts at Motorway (copper, zinc, turbidity, DO, DRP, *E. coli*) Curletts U/S of Heathcote (copper – with a 13% decrease, zinc- with a 11% decrease, turbidity, DO, nitrate, DRP) Heathcote at Rose St (copper, zinc, DIN, DRP, *E. coli*) Cashmere at Sutherlands Rd (copper, zinc, DO, nitrate, DIN)

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2021)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
						Cashmere at Worsleys Rd (copper, zinc, turbidity, nitrate, DIN, *E. coli*) Heathcote at Ferniehurst St (copper, turbidity, DIN, *E. coli*) Heathcote at Bowenvale Ave (copper, DIN, DRP, *E. coli*) Heathcote at Opawa Rd (copper, DIN, DRP, *E. coli*) Heathcote at MacKenzie Ave (copper, zinc, DIN, DRP, *E. coli*) Heathcote at Catherine St (copper, turbidity, DRP, *E. coli*) Heathcote at Tunnel Rd (copper, turbidity, DRP, *E. coli*, enterococci) Steamwharf Stream (copper, DRP, *E. coli*) Heathcote at Ferrymead Bridge (copper, zinc, turbidity, DRP - with a 15% decrease, *E. coli*, enterococci – with a 11% decrease)
Huritini-Halswell River	Poor (Median WQI = 68)*	Knights at Sabys Rd Nottingham at Candys Rd Halswell at Tai Tapu Rd	Halswell at Wroots Rd Halswell at Tai Tapu Rd	No significant trend*	Nitrate, DIN, DRP, *E. coli*	Knights at Sabys Rd (nitrate, DIN, *E. coli*) Nottingham at Candys Rd (copper, zinc, DRP, *E. coli*) Halswell at Wroots Rd (copper, zinc, turbidity, nitrate, DIN, DRP, *E. coli*) Halswell at Tai Tapu Rd (turbidity, nitrate, DIN, *E. coli*)
Pūharakekenui-Styx River	Good (Median WQI = 83)*	Styx at Gardiners Rd Styx at Main North Rd Styx at Richards Bridge	Styx at Harbour Rd Kā Pūtahi at Belfast Rd Styx at Marshland Rd	No significant trend*	DRP, *E. coli*	Styx at Gardiners Rd (DO, *E. coli*) Smacks at Gardiners Rd (DO, *E. coli*) Styx at Main North Rd (*E. coli*) Kā Pūtahi at Blakes Rd (DRP, *E. coli*) Kā Pūtahi at Belfast Rd (DRP, *E. coli*) Styx at Marshland Rd (DRP, *E. coli*) Styx at Richards Bridge (DRP, *E. coli*) Styx at Harbour Rd (DRP, *E. coli*)

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2021)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
Ōtūkaikino River	Good (Median WQI = 94)*	Ōtūkaikino at Groynes Wilsons Stream	Ōtūkaikino at Scout Camp	No significant trend*	Copper, *E. coli*	Ōtūkaikino at Scout Camp (copper, DIN – with a 10% increase, *E. coli* – with a 25% increase Ōtūkaikino at Groynes (copper) Wilsons Stream (DIN, *E. coli*)
Linwood Canal	N/A	N/A	N/A	No significant trend	N/A	Copper, zinc, turbidity, DO, DRP, *E. coli*, enterococci
Stream Reserve Drain	Poor (WQI = 60)	N/A	N/A	N/A	N/A	Copper, zinc, DIN, DRP, *E.coli*
Balguerie Stream	Fair (WQI = 76)	N/A	N/A	N/A	N/A	Copper, zinc, DIN, DRP, *E. coli*
Aylmers Stream	Fair (WQI = 74)	N/A	N/A	N/A	N/A	Copper, DIN, DRP, *E. coli*
Coastal	N/A	N/A	N/A	N/A	Copper, enterococci	Ihutai – Avon-Heathcote Estuary (copper, zinc) Lyttelton Port (copper, enterococci) Cass Bay (copper, enterococci) Akaroa Harbour (Faecal coliforms, enterococci)

3.6. Wet Weather Monitoring

3.6.1. Rainfall

- The total amount of rainfall for the first, second, and third wet weather events were 20 mm, 8.4 mm, and 14.6 mm, respectively.
- Sampling for the first, second, and third event occurred at 12.8 mm, 8.4 mm, and 13 mm total rainfall depth, respectively, which was all before the First Flush (15-25 mm). Only the first sampling event on 4th October met the criteria of three antecedent dry days prior to sampling. All three events met the criteria of a minimum of 5 mm total rainfall depth prior to sampling. Given the criteria for sampling was not fully met, it is likely that the results of the monitoring underestimates stormwater contaminant levels.
- Sampling of the first and third event occurred during the tail end of the storm. Sampling for the second event occurred after the rain event had ended.

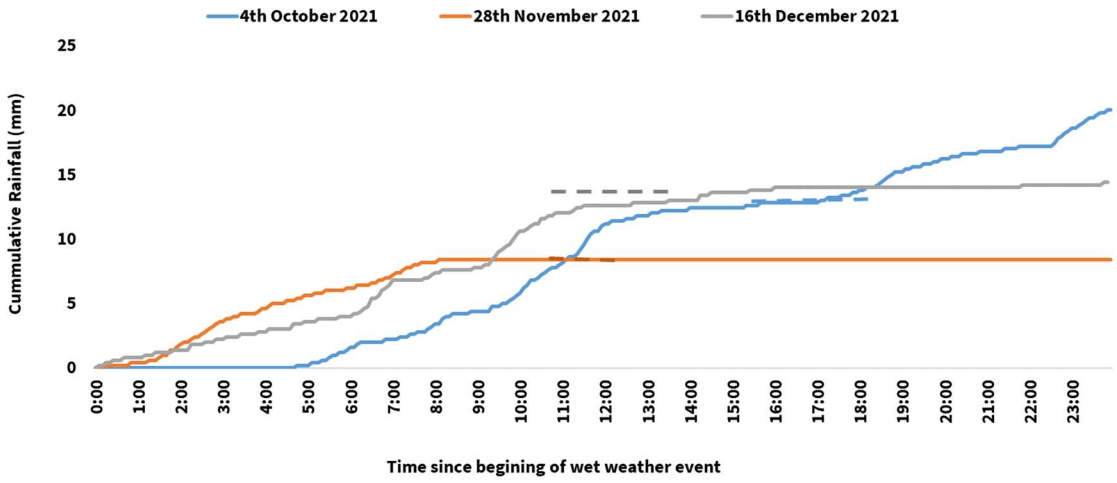

Figure 12. Rainfall during the wet weather events of 4/10/2021 (blue line), 28/11/2021 (orange line), and 16/12/2021 (grey line), with approximate sampling times indicated by dotted lines.

3.6.1. Water Quality Parameters

- The third event for the most part differed from the other two events, notably typically recording higher concentrations of dissolved metals, BOD_5, DRP, and *E.coli*, but lower TSS, turbidity, nitrate, and DIN (Figure 13 - Figure 16).
- Although the third event was sampled before the theoretical First Flush, the results indicate that sampling did occur during a time of higher stormwater contaminants compared to the other two events. The third event had a similar total rainfall depth at the time of sampling as the first event (13mm versus 12.8 mm, respectively); however, sampling occurred sooner after the event had started for the third event. This may have played a part in the higher stormwater contaminant levels. In contrast, lower sediment and nitrogen levels in the third event may reflect dilution of nitrogen rich baseflow water, due to storm flows.

- TSS and turbidity were much higher for the first event. This event was sampled longer after when the event had started compared to the other two occasions, so this may have given more time for sediment to reach the sites.
- The guidelines were not met for:
    - Dissolved copper at Nottingham at Candy Road (third event) and Halswell at Tai Tapu Rd (third event).
    - Dissolved zinc at Nottingham at Candy Road (three events).
    - TSS at Nottingham at Candy Road (event one), and Halswell at Tai Tapu Road (first and third events). Particularly high concentrations were recorded at Nottingham Stream (first event: 750 mg/L) and Halswell at Tai Tapu Road (third event: 120mg/L).
    - Turbidity at Nottingham at Candy Road (all events), Knights at Sabys Road (event three), and Halswell at Tai Tapu Road (all events). Concentrations were particularly high at Nottingham Stream (first and second event: 170FNU and 270 FNU, respectively).
    - Dissolved oxygen at Halswell at Tai Tapu Road (third event).
    - BOD_5 at Nottingham at Candys Road (first event) and Halswell at Tai Tapu Road (third event).
    - Nitrate median guideline at Knights at Sabys Road (first and second events) and Halswell at Tai Tapu Road (first event).
    - DIN at Knights at Sabys Road and Halswell at Tai Tapu Road (all events).
    - DRP at all the three sites during all events, with the exception of the first and second event at Knights at Sabys Road.
    - *E. coli* at all sites during both events, with the exception of the first event at Knights at Sabys Road. No *E. coli* samples were associated with a recorded wastewater overflow event.
- Concentrations were compared to the monthly monitoring results in this report (which also included rain events). Of note:
    - Dissolved metals, DRP and *E. coli* were variable, but generally similar to the monthly monitoring.
    - TSS and turbidity concentrations were lower during the monthly monitoring. For example, turbidity at Candys Rd during the wet weather monitoring was 27 times higher than the highest value recorded during monthly monitoring.
    - Nitrate and DIN were generally higher during the monthly monitoring.

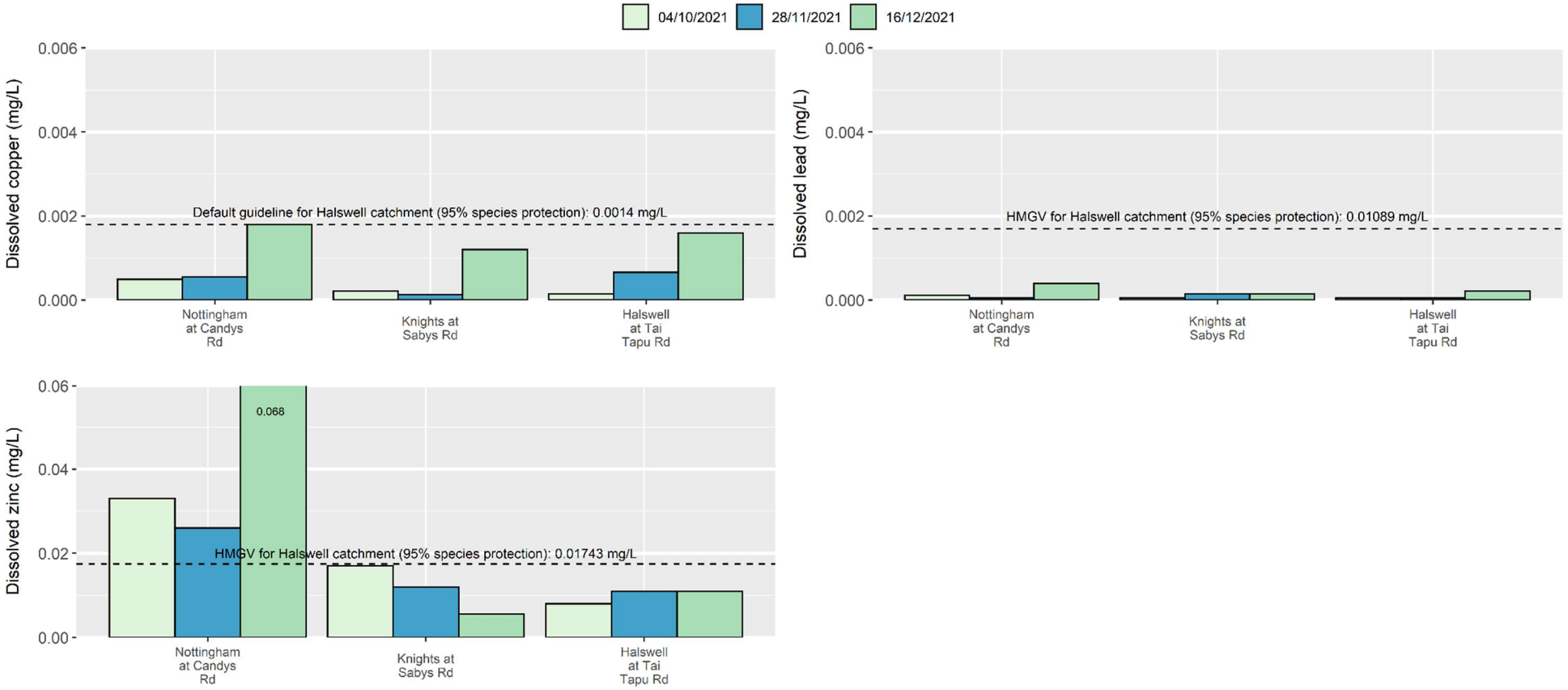

Figure 13. Dissolved copper (top left), lead (top right), and zinc (bottom left) concentrations in water samples taken from the Huritini – Halswell River catchment during three wet weather events in 2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent either the 95% default (copper) or hardness modified (lead, zinc) guideline values (HMGV) as per ANZG (2022).

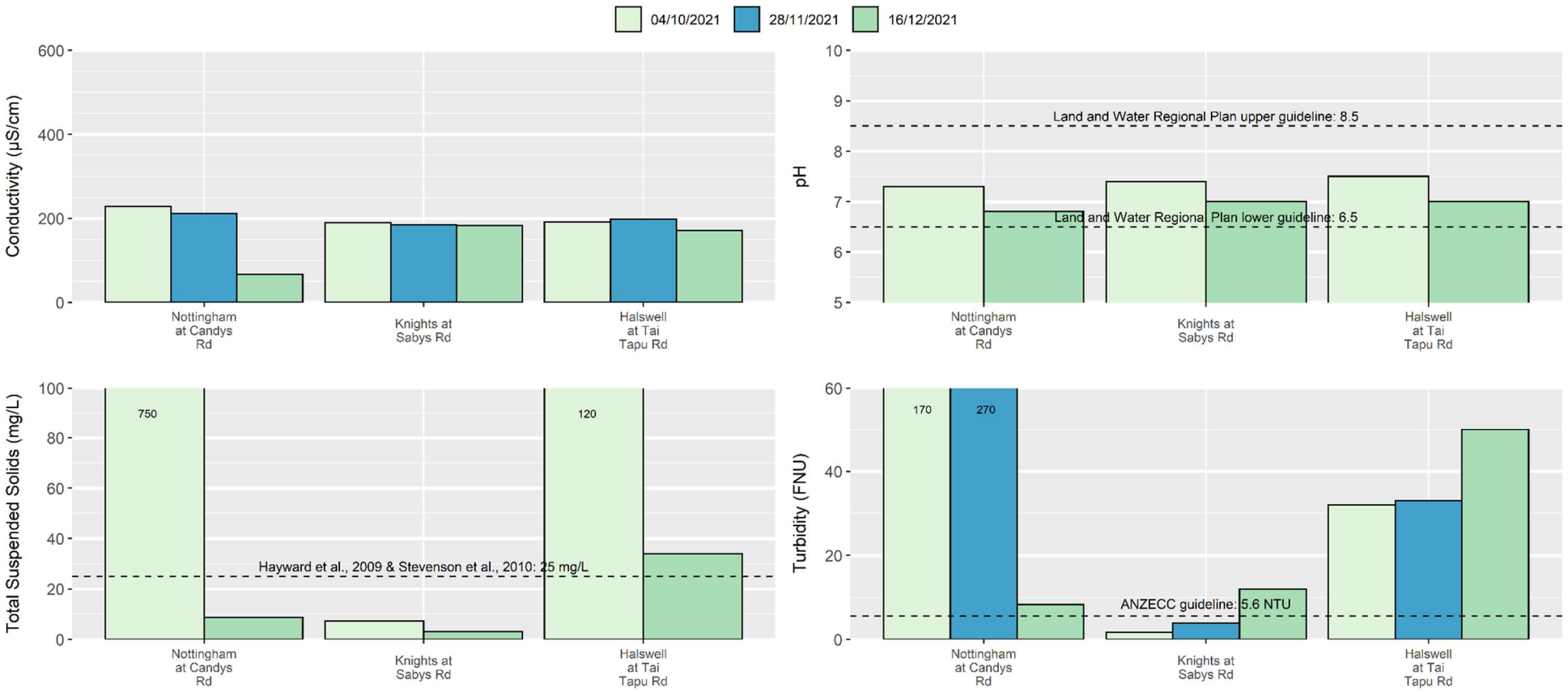

Figure 14. Conductivity (top left), pH(top right), Total Suspended Solids (TSS; bottom left) and turbidity (bottom right) concentrations in water samples taken from the Huritini – Halswell River catchment during three wet weather events in 2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (pH: Land and Water Regional Plan guidelines); TSS: Hayward et al. (2009) & Stevenson et al. (2010); Turbidity: ANZECC (2000)). pH and TSS were not sampled during the 28/11/2021 event.

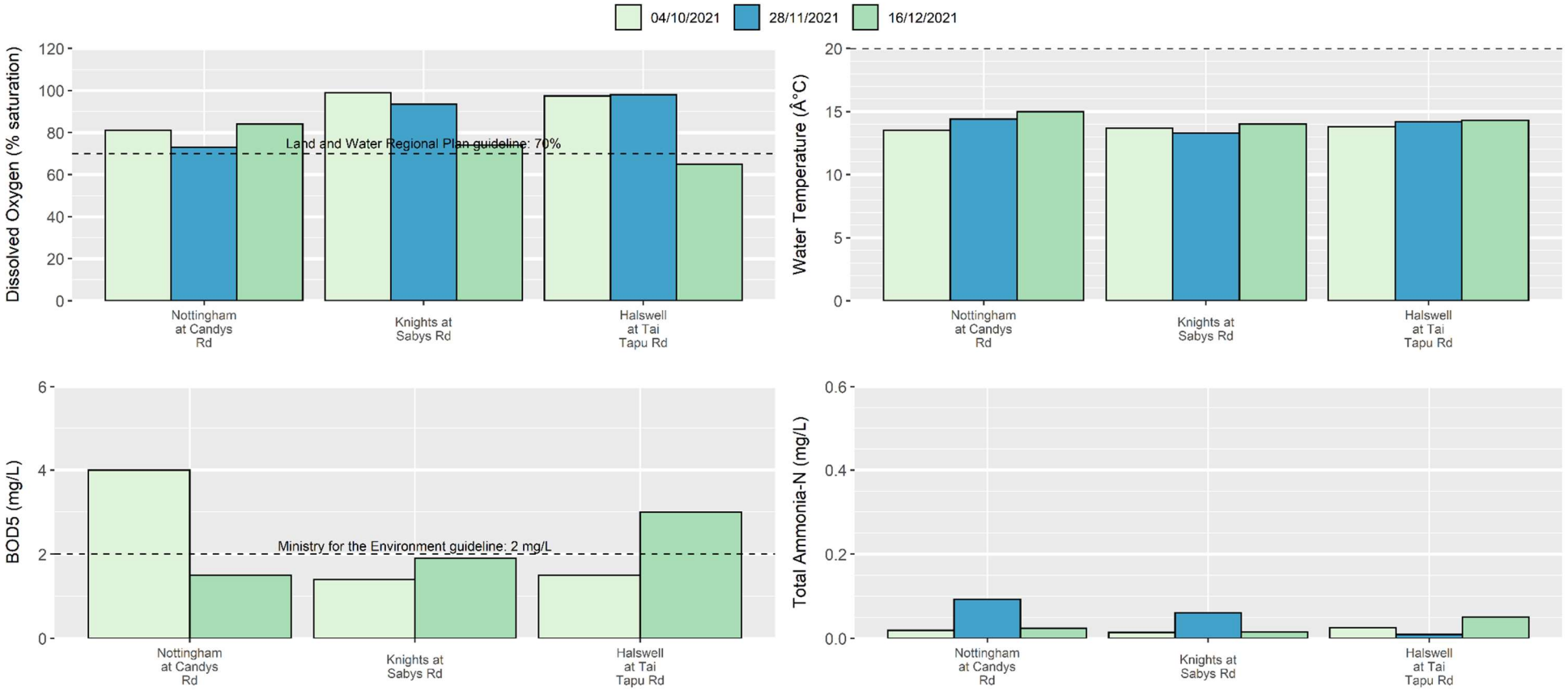

Figure 15. Dissolved oxygen (DO; top left), water temperature (top right), BOD_5 (bottom left) and total ammonia-N (bottom right) concentrations in water samples taken from the Huritini – Halswell River catchment during three wet weather events in 2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (DO and water temperature: Environment Canterbury, 2019; BOD_5: Ministry for the Environment, 1992). The guideline value for total ammonia-N, adjusted in accordance with median 2021 pH (7; Environment Canterbury, 2019), is not visible as it is off the scale (1.61 mg/L). BOD_5 was not sampled during the 28/11/21 event.

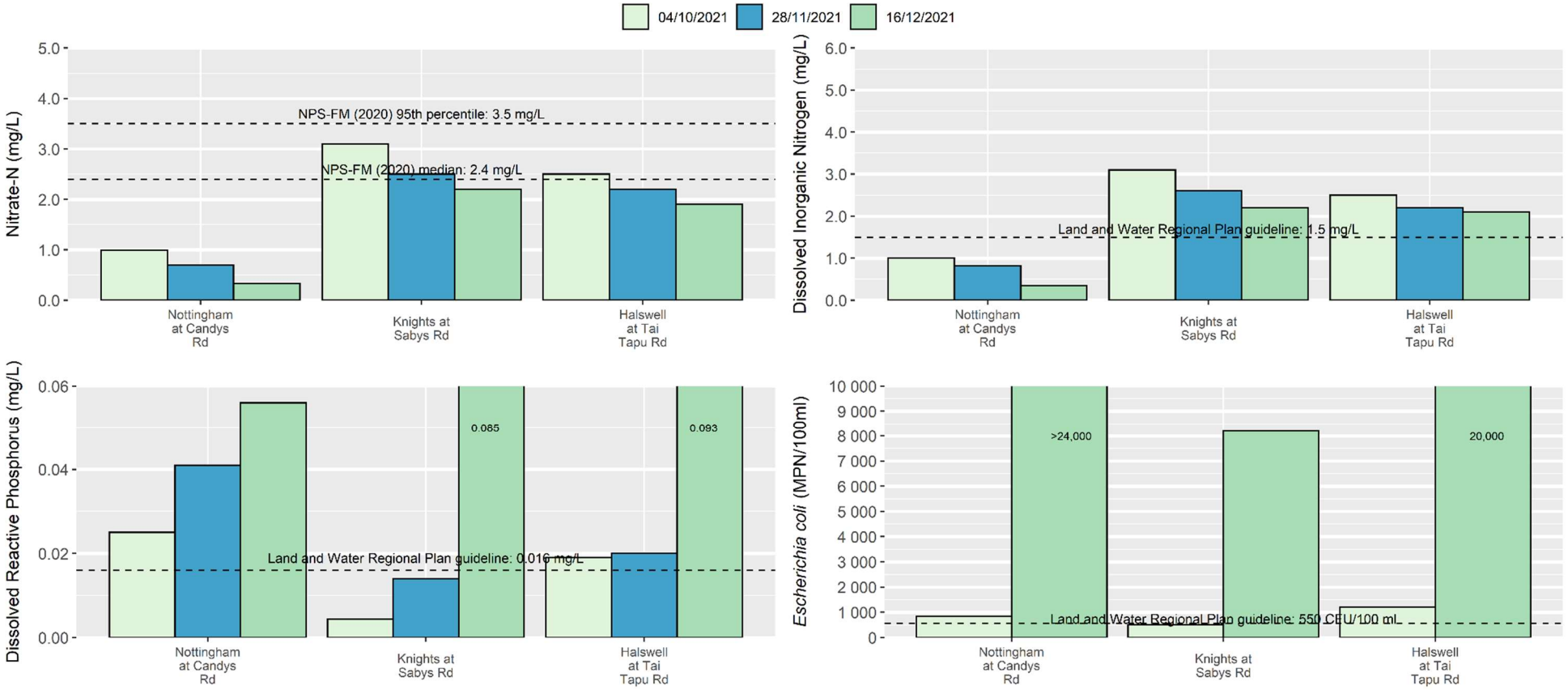

Figure 16. Nitrate-N (top left), Dissolved Inorganic Nitrogen (DIN; top right), Dissolved Reactive Phosphorus (DRP; bottom left), and *E. coli* (bottom right) concentrations in water samples taken from the Huritini – Halswell River catchment during three wet weather events in 2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (Nitrate-N: Cashmere Stream (Environment Canterbury, 2019), remaining sites (NPS-FM); DIN, DRP, and *E. coli*: Environment Canterbury, 2019). *Escherichia coli* was not sampled during the 28/11/21 event.

4. Discussion

4.1. Priority Contaminants for Stormwater Management

There were several parameters that were recorded at concentrations unlikely to cause adverse effects, including dissolved lead, water temperature, BOD_5, TSS, pH, nitrate, and total ammonia. Parameters exceeded at the most sites were *E. coli* (43 sites), dissolved copper (32 sites), DRP (28 sites), and dissolved zinc (22 sites). The concentrations of parameters at the sites have mostly remained steady over time (59% of parameter-site combinations), but some improvements in water quality were recorded this year (30% of parameter-site combinations) and some declines (11% of parameter-site combinations). This is supported by generally no change in WQI over time at the catchment or the site-level. It is heartening to see that decreasing trends for DRP, BOD_5, total ammonia, and DIN were recorded across most catchments. This is likely due to less contaminant inputs across the catchment, such as sediment, fertilisers and groundwater contaminated with nitrogen due to rural land use (Munro, 2015).

Based on these results, the priority parameters to address for improved stormwater management across all catchments include bacteria (as indicated by *E. coli*), dissolved copper, phosphorus, and dissolved zinc. Bacteria is present in waterways predominantly due to direct input of waterfowl faeces during both dry and wet weather (Moriarty & Gilpin, 2015), and wastewater discharges on occasion during wet weather (Moriarty & Gilpin, 2015), but can also be entrained in stormwater due to bird and dog faeces being present on surfaces. Dissolved copper and zinc are likely to be present in the waterways mostly due to stormwater, through such sources as roofing, tyres, and industrial practices. Some metals may also be present due to illicit dry weather industrial discharges. Phosphorus can enter streams through direct sediment inputs, but is also present in stormwater discharges (e.g., due to fertilisers and sediment runoff).

4.2. Priority Catchments and Sites for Stormwater Management

Based on the WQI, the Ōtūkaikino River catchment recorded 'very good' water quality, the Ōtākaro-Avon River and the Pūharakekenui-Styx River recorded 'good' water quality, and the Ōpāwaho-Heathcote River and Huritini-Halswell River recorded 'poor' water quality. The Banks Peninsula waterway sites recorded 'poor' (Stream Reserve Drain) and 'fair' (Balguerie and Aylmers Streams) water quality. The Ōtūkaikino River recorded the best overall water quality out of all the catchments. The best site for water quality was Ōtūkaikino at Groynes, followed by Wilsons Stream and Styx at Gardiners Road. The catchment recording the worst water quality was the Ōpāwaho-Heathcote River. The worst site for water quality was Curletts at Motorway, followed by Heathcote at Tunnel Rd, and Heathcote at Warren Cres. All these results are generally similar to that recorded in previous years. However, the Warren Cres site was a new site in 2020 and was not in the top three worst sites for water quality last year. This site recorded a WQI of 54 this year ('poor') compared to 80 ('fair') last year. This drop in WQI was due to an increase in the percentage of parameters not meeting the relevant guidelines, including BOD_5, dissolved oxygen, nitrate, and DRP. There were several contaminants of concern at these three worst sites (Curletts at Motorway: copper, zinc, turbidity, DO, DRP, and *E. coli*; Heathcote at Tunnel Rd: copper, TSS, turbidity, DRP, *E. coli*, enterococci; Heathcote at Warren Cres: DO, nitrate, DIN, *E. coli*).

The only significant trend in WQI at a site or catchment scale, was a 9% increase at the Haytons Stream site. The improvement in WQI was due to more parameters and samples meeting the relevant

guidelines. The main parameters driving the improvement were dissolved copper, dissolved zinc, and BOD_5.

The seven waterway sites located in proximity to main stormwater outfalls generally did not appear to record differing results compared to the other waterway sites. For example, Curletts Stream was the only one of these sites to be in the top five worst sites for water quality based on the WQI, and only four of these stormwater outfall sites were within the top ten worst sites for water quality. This could be due to (a) many of the other sites being located in waterways saturated with stormwater outfalls/discharges, (b) the monthly monitoring not often being carried out during the early stages of a wet weather event (when the 'first flush' of contaminants typically occurs), and/or (c) stormwater not having any noticeable effects in these locations.

Thirty-one of the 51 sites triggered further investigations under the CSNDC, due to not meeting the ATLs for TSS, copper, lead, and zinc. These sites are prioritised to four: Curletts at Motorway and Heathcote at Ferrymead Bridge in the Ōpāwaho-Heathcote River catchment, Addington Brook in the Ōtākaro-Avon River catchment, and Nottingham at Candys Rd in the Huritini-Halswell River catchment. These are the same sites prioritised for investigation last year and therefore Condition 59 investigations are already under way, as well as monitoring under the CSNDC TWWMP.

5. Recommendations

- The following four sites are prioritised for water quality investigations to determine contaminant sources, due to not meeting CSNDC ATLs during this and last year's monitoring: Curletts at Motorway, Heathcote at Ferrymead Bridge, Addington Brook, and Nottingham at Candys Rd in the Huritini-Halswell River catchment. These investigations should ideally be incorporated into the TWWMP.
- Curletts Stream, Nottingham Stream, Haytons Stream, Addington Brook, and the lower Ōpāwaho-Heathcote River are prioritised for contaminant source control and stormwater treatment:
    - Council and Environment Canterbury (ECan) should continue working with landowners to reduce contaminants entering stormwater systems or waterways directly. Industrial site audits are proving a good avenue for targeting key contaminant sources and increasing education around stormwater.
    - The recommendations within the ECan catchment management plan for Addington Brook and the Haytons Stream Action Plan should be undertaken.
    - Stormwater treatment by the large Council facilities proposed for Addington Brook, Riccarton Main Drain, and Nottingham Stream should be prioritised.
    - Dry weather discharge investigations are carried out to identify if there are contaminants entering the stormwater systems outside of stormwater events and to pinpoint industries for pollution prevention.
- An investigation is collaboratively carried out by Council, ECan, and the Water and Wildlife Habitat Trust to examine the increasing levels of *E. coli* in the Ōtūkaikino River and ways to mitigate this.
- Construction of the Council stormwater wetlands in Belfast (Ōtūkaikino River catchment) is prioritised, due to the increases recorded for turbidity, ammonia, and *E. coli* in Wilsons Stream, and conductivity in Styx Drain.
- Although phosphorus levels appear to be decreasing across most sites, an investigation should be carried out to determine sources (e.g., fertilisers and faecal input) and how concentrations can be reduced, due to this contaminant being one of the parameters of concern in the waterways.

- Erosion and sediment control measures continue to be implemented as a priority. In particular, further investigations are carried out to determine how to mitigate discharges of loess sediment into the Ōpāwaho-Heathcote River (principally Cashmere Stream). This work should incorporate Council's Port Hills sediment and erosion control project.
- Investigations are carried out to identify how best to reduce faecal contamination within the waterways, particularly with the public interest in swimmable rivers and that waterfowl control within the city may be unpopular with some people.
- A whole-of-community approach to addressing stormwater contaminants is cemented through the Community Waterway Partnership[8].
- Council and ECan continue to work together with the community, landowners and industry within the City and Banks Peninsula to improve catchment management practices through such measures as:
    - Source control (e.g., redirection of stormwater to trade waste). For example, Council currently work with ECan to audit business in key catchments, helping reduce the amount of contaminants entering the stormwater system.
    - Installation of more effective stormwater treatment devices. For example, Council are constructing a number of stormwater basins for the purpose of flood mitigation and stormwater treatment.
    - Community education. For example, ECan's Stormwater Superhero programme and other stormwater initiatives, and the Community Waterways Partnership.
    - Implementation of new regional and national policies for improving water quality.
- The Action Plan for the Council Community Outcome for Healthy Water Bodies continues to be developed. This Plan considers what we want to achieve for our waterways (this may vary between different people) and what is required to achieve this. For example, an improvement in stormwater quality may not result in an increase in biodiversity, due to other habitat limitations.

6. Conclusions

The results of this year's monitoring are largely consistent with those recorded in previous years[9]. This indicates that many waterways of Christchurch and Banks Peninsula are historically and currently subjected to contamination from stormwater, wastewater and other inputs (e.g. agriculture, waterfowl faeces and industrial discharges). These parameters may be having short-term and long-term adverse effects on biota (i.e., nitrogen, copper, zinc, sediment, dissolved oxygen (lack of), and BOD_5), may encourage the proliferation of aquatic plants and/or algae (i.e., nitrogen and phosphorus), may indicate human health risks from contact recreation (i.e., bacteria), and may affect water clarity/aesthetics (sediment). Overall, water quality at the monitoring sites is not improving or declining over time.

The results of this report support the Urban Stream Syndrome (Walsh *et al*., 2005). Lower water quality is recorded internationally in urban (particularly industrial) areas (i.e., Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments) and generally better water quality is recorded in rural areas (i.e., Pūharakekenui-Styx River and Ōtūkaikino River catchments).

The priority contaminants to address for improved stormwater management across all catchments include bacteria, dissolved copper, phosphorus, and dissolved zinc. The waterways requiring particular water quality management are Curletts Road Stream, Nottingham Stream, Haytons Stream, Addington Brook, and the lower Ōpāwaho-Heathcote River.

[8] https://ccc.govt.nz/environment/water/waterways/community-waterways-partnership
[9] Monitoring reports since 2012 can be viewed online at https://www.ccc.govt.nz/environment/water/waterways/waterway-monitoring

The results of this monitoring trigger further investigations under the CSNDC. It is recommended that the following four sites are prioritised for water quality investigations: Curletts at Motorway, Heathcote at Ferrymead Bridge, Addington Brook, and Nottingham at Candys Rd.

If the recommendations in this report are implemented (at a bare minimum), surface water quality improvements are anticipated across the City. However, these changes may only occur over long time scales, due to the size of the issues and the lag time in observing reductions in contaminants within the environment.

7. Acknowledgements

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Appendix A

Table i. Summary of the date of first monthly sampling at the 51 water quality monitoring sites. Dissolved metals were monitored from 2011, unless otherwise specified.

Catchment	Site Description	Monitoring Instigated
Ōtākaro-Avon	Wairarapa Stream	January 2007[10]
	Waimairi Stream	January 2007[10]
	Avon River at Mona Vale	January 2007[10]
	Avon River at Carlton Mill Corner	October 2008[11,12]
	Riccarton Main Drain	October 2008
	Addington Brook	October 2008
	Avon River at Manchester Street	July 2008[13]
	Dudley Creek	October 2008
	Avon River at Dallington Terrace/Gayhurst Road[8]	January 2007
	Horseshoe Lake Discharge	October 2008
	Avon River at Avondale Road	October 2008[11,12,]
	Avon River at Pages/Seaview Bridge	January 2007
	Avon River at Bridge Street	January 2007[10]
Ōpāwaho-Heathcote	Heathcote River at Warren Crescent	January 2020
	Haytons Stream at Retention Basin	May 2020
	Curlett Road Stream Upstream of Heathcote River	October 2008
	Curlett Road Stream at Motorway	October 2008[11,12]
	Heathcote River at Rose Street	June 2008[14]
	Cashmere Stream at Sutherlands Road	December 2010
	Cashmere Stream at Worsleys Road	January 2007
	Heathcote River at Ferniehurst Street	July 2008[15,16]
	Heathcote River at Bowenvale Avenue	January 2007
	Heathcote River at Opawa Road/Clarendon Terrace	January 2007
	Heathcote River at Mackenzie Avenue	October 2008[11,12]
	Heathcote River at Catherine Street	October 2008[11,12]
	Heathcote River at Tunnel Road	January 2007[17]
	Steamwharf Stream	January 2020[18]
	Heathcote River at Ferrymead Bridge	January 2007
Pūharakekenui-Styx	Smacks Creek at Gardiners Road	January 2007[19]
	Styx River at Gardiners Road	January 2007[20]
	Styx River at Main North Road	January 2007[20]
	Kā Pūtahi at Blakes Road	January 2007[20]
	Kā Pūtahi at Belfast Road	January 2007[20]
	Styx River at Marshland Road Bridge	January 2007[20]
	Styx River at Richards Bridge	October 2008
	Styx River at Harbour Road Bridge	January 2008
Huritini-Halswell	Knights Stream at Sabys Road	May 2012
	Nottingham Stream at Candys Road	October 2008
	Halswell River at Wroots Road	January 2020
	Halswell River at Akaroa Highway	October 2008
Ōtūkaikino	Ōtūkaikino Creek at Omaka Scout Camp	October 2014
	Ōtūkaikino River at Groynes Inlet	October 2008
	Wilsons Drain at Main North Road	November 2013

[10] Dissolved oxygen monitored from June 2007
[11] Dissolved metals monitored from September 2014
[12] Turbidity monitored since January 2020
[13] Dissolved oxygen monitored from October 2008
[14] Dissolved oxygen, BOD_5, conductivity, nitrate, pH, TSS and water temperature monitored from August 2008. Total ammonia, *E. coli*, nitrogen parameters (excluding nitrate) and DRP monitored from October 2008
[15] BOD_5 and TSS monitored from October 2008
[16] Dissolved oxygen, total ammonia, conductivity, E. coli, nitrogen parameters, pH, DRP and water temperature monitored from October 2008
[17] Enterococci monitored from January 2020
[18] Salinity monitored from July 2020
[19] Dissolved oxygen monitored from March 2007

Catchment	Site Description	Monitoring Instigated
Linwood	Linwood Canal	January 2007[10]
Stream Reserve Drain/Zephyr Stream	Stream Reserve Drain Above Outfall to Governors Bay	May 2020
Balguerie Stream	Balguerie Stream Downstream of Settlers Hill (road)	May 2020
Aylmers Stream	Aylmers Stream Downstream of Rue Jolie, Next to Bruce Terrace	May 2020
Ihutai/ Avon-Heathcote Estuary	Estuary of the Heathcote and Avon Rivers/Ihutai at the Eastern Tip by Beachville Road	May 2020
The Operational Area of the Port of Lyttelton	Lyttelton Port at the Small Wharf Opposite Voelas Road	May 2020
Cass Bay	Eastern Side of Cass Bay off the Cass Bay Walkway	May 2020
Akaroa Harbour	Akaroa Harbour at the Termination of Rue Balguerie	May 2020

Appendix B

Table i. Parameters analysed in surface water samples and the corresponding guideline levels. Guidelines are compared to median levels, unless otherwise indicated. Relevant waterway classifications for comparison to guideline levels are presented in Table 1 of Section 2.1 (Monitoring Sites). ANZG = Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2022); HMGV = Hardness Modified Guideline Value; LWRP = Land and Water Regional Plan (Environment Canterbury, 2015); NPS-FM = National Policy Statement for Freshwater Management (New Zealand Government, 2020); RCEP = Regional Coastal Environment Plan (Environment Canterbury, 2012).

Parameter	Environmental Concern	Waterway Guideline Level	Coastal Guideline Level
Dissolved copper	Negatively affect fecundity, maturation, respiration, physical structure, and behaviour of aquatic species (Harding, 2005)	ANZG (2022) (95th percentile, not medians): • Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments (90% species protection: ≤0.0018 mg/L • Huritini-Halswell, Pūharakekenui-Styx and Ōtūkaikino River catchments (95% species protection): ≤0.0014 mg/L • Cashmere Stream and Banks Peninsula waterways (99% species protection): ≤0.001 mg/L	ANZG (2022) (95th percentile, not medians): • ≤0.0013 mg/L
Dissolved lead		ANZG (2022) HMGV (95th percentile, not medians): • Ōtākaro-Avon River catchment (90% species protection): ≤0.01539 mg/L • Ōpāwaho-Heathcote River catchment (90% species protection): ≤0.02388 mg/L • Cashmere Stream (99% species protection): ≤0.00427 mg/L • Huritini-Halswell River catchment (95% species protection): ≤0.01089 mg/L • Pūharakekenui-Styx River catchment (95% species protection): ≤0.00601 mg/L • Ōtūkaikino River catchment (95% species protection): ≤0.00414 mg/L	ANZG (2022) (95th percentile, not medians): • ≤0.0044 mg/L

		• Stream Reserve Drain & Aylmers Stream (Banks Peninsula): ≤0.00293 mg/L • Balguerie Stream (Banks Peninsula): ≤0.00254mg/L	
Dissolved zinc		ANZG HMGV (95th percentile, not medians): • Ōtākaro-Avon River catchment (90% species protection): ≤0.02951 mg/L • Ōpāwaho-Heathcote River catchment (90% species protection): ≤0.0396 mg/L • Cashmere Stream (99% species protection: ≤0.00634 mg/L • Huritini-Halswell River catchment (95% species protection): ≤0.01743 mg/L • Pūharakekenui-Styx River catchment (95% species protection): ≤0.01172 mg/L • Ōtūkaikino River catchment (95% species protection): ≤0.00912 mg/L • Stream Reserve Drain & Aylmers Stream (Banks Peninsula): ≤0.00135 mg/L • Balguerie Stream (Banks Peninsula): ≤0.00109 mg/L	ANZG (2022) (95th percentile, not medians): • ≤0.008 mg/L
Total water hardness and Dissolved Organic Carbon (DOC)	These parameters are mostly relevant to determine the toxicity of other parameters, such as metals	No guidelines exist	Not sampled
pH	Appropriate pH levels are essential for the physiological functions of biota, such as respiration and excretion (Environment Canterbury, 2009)	LWRP: • All waterways: 6.5 - 8.5	ANZG[20]: • 7.0 - 8.5
Conductivity	May indicate presence of such parameters as nutrients, metals and salinity	No guidelines exist	No guidelines exist

[20] These values are from the ANZECC (2000) guidelines for estuaries of South-East Australia; the guidelines recommend these values are used for New Zealand while no other guidelines are available, but they should be used with caution due to the differing ecosystems between countries and replaced with national guidelines should they become available

Salinity	The amount of salt dissolved in a body of water – relevant to tidal, estuarine and coastal sites	No guidelines exist (only tested at the salinity affected sites: Avon River at Bridge Street Bridge, Heathcote River at Tunnel Road, Heathcote River at Ferrymead Bridge, Steamwharf Stream upstream of Dyers Road, Styx River at Harbour Bridge and Linwood Canal)	No guidelines exist
Total Suspended Solids (TSS)	Elevated levels in the water column decrease the clarity of the water and can adversely affect aquatic plants, invertebrates and fish (Crowe & Hay, 2004; Ryan, 1991)	Hayward et al., 2009; Stevenson et al., 2010: • All waterways: ≤25 mg/L	No guidelines exist
Turbidity	Turbidity decreases the clarity of the water and can negatively affect stream biota (Ryan, 1991)	ANZG: • All waterways: ≤5.6 NTU	ANZG[21]: • ≤10 NTU
Water clarity	Low clarity of the water can affect aesthetics and negatively affect stream biota	NPS-FM: • ≥1.55 m[22] Only tested at Styx Living Laboratory Trust sites and using a clarity tube which is only 1m in length, so it is not possible to ever comply with this guideline value	Not sampled
Dissolved Oxygen (DO)	Adequate DO levels are essential for aquatic animals, such as fish and invertebrates	LWRP: • 'Spring-fed – plains – urban' and 'spring-fed – plains waterways:' ≥70 % • Banks Peninsula waterways: ≥90	RCEP: • ≥ 80 %
Water temperature	Water temperature that is too low or high can adversely impact aquatic animals, such as fish and invertebrates	LWRP: • All waterways: ≤20°C	RCEP: • ≤25°C
Biochemical Oxygen Demand (BOD_5)	High BOD_5 values indicate the potential for bacteria to deplete oxygen levels in the water	Ministry for the Environment (1992): • All waterways: ≤2 mg/L	RCEP, excluding The Operational Area of the Port of Lyttelton: • ≤2 mg/L

[21] These values are from the ANZG (2000) guidelines for estuaries of South-East Australia; the guidelines recommend these values are used for New Zealand while no other guidelines are available, but they should be used with caution due to the differing ecosystems between countries and replaced with national guidelines should they become available

[22] Suspended fine sediment attribute – Band B, Sediment Class 1

Total ammonia (ammoniacal nitrogen)	High levels can have toxic effects on aquatic ecosystems	LWRP:
		• Banks Peninsula waterways: ≤0.32 mg/L
		• All other waterways determined by median catchment pH:
		  ○ Ōtākaro-Avon River catchment: ≤1.75 mg/L
		  ○ Opāwaho-Heathcote River catchment: ≤1.88 mg/L
		  ○ Linwood Canal catchment: ≤1.61 mg/L
		  ○ Huritini-Halswell River catchment: ≤1.75 mg/L
		  ○ Pūharakekenui-Styx River catchment: ≤1.88 mg/L
		  ○ Ōtūkaikino River catchment: ≤1.99 mg/L
			Not sampled

Nitrate nitrogen	Can be toxic to stream biota at high concentrations (Hickey, 2013)	LWRP: • Banks Peninsula waterways: Median: ≤1.0 mg/L; 95th percentile: ≤1.5 mg/L NPS-FM (2020): • Median: ≤2.4 mg/L; 95th percentile: ≤3.5 mg/L[23]	Not sampled
Dissolved Inorganic Nitrogen (DIN)	High levels can contribute to eutrophication (enrichment of water by nutrient salts that causes prolific growth of algae and aquatic plants)	LWRP: • 'Spring-fed – plains – urban' and 'spring-fed – plains' waterways: ≤1.5 mg/L • Banks Peninsula waterways: ≤0.09 mg/L	Not sampled
Nitrite nitrogen		No guidelines exist	Not sampled
Dissolved Reactive Phosphorus (DRP)	High levels can contribute to eutrophication (enrichment of water by nutrient salts that causes prolific growth of algae and aquatic plants)	LWRP: • 'Spring-fed – plains – urban' and 'spring-fed – plains' waterways: ≤0.016 mg/L • Banks Peninsula waterways: ≤0.025 mg/L	Not sampled
Escherichia coli	An indicator of faecal contamination in freshwater and therefore health risk from contact recreation (Ministry for the Environment, 2003)	LWRP: • All waterways: ≤550 CFU/100ml (95th percentile, not medians)	No guidelines exist; only tested at Ihutai - Avon-Heathcote Estuary, as enterococci more relevant at the other coastal sites
Enterococci	An indicator of faecal contamination in freshwater and therefore health risk from contact recreation	Ministry for the Environment (2013): • At all measured sites: ≤500 CFU/100 ml (95th percentile, not medians)	Ministry for the Environment (2013)[24]:

[23] National bottom line – to be used for all waterway sites, except those in Banks Peninsula
[24] These values are more stringent for coastal areas where swimming is likely to occur

		(only tested at the salinity affected sites: Avon River at Pages Road, Avon River at Bridge Street Bridge, Heathcote River at Tunnel Road, Heathcote River at Ferrymead Bridge, Steamwharf Stream upstream of Dyers Road, Styx River at Harbour Bridge and Linwood Canal)	• Ihutai - Avon-Heathcote Estuary, Cass Bay and Akaroa Harbour: ≤200 CFU/100 ml (95th percentile, not medians) • Lyttelton Harbour: ≤500 CFU/100 ml (95th percentile, not medians)
Faecal coliforms	An indicator of faecal contamination in freshwater and therefore health risk from contact recreation	Not relevant and not sampled	Ministry for the Environment (2013): • Akaroa Harbour: 14 CFU /100 mL (median) and 43 CFU /100 mL (not exceeded in more than 10% of samples – i.e., 90th percentile) Not sampled at the remaining coastal sites

Appendix C

Table i. Laboratory methods used over time to calculate parameter concentrations. N/A = Not Applicable. Due to high salinity concentrations, samples collected from coastal sites were diluted to allow dissolved metals analysis.

Group	Parameter	Limit of Detection	Date	Analysis Method
Metals	Total copper	<0.001 mg/L	1 July 2018 - current day	APHA 3125 B modified, (Varian7900 ICP- MS). Digestion APHA 3030 E
		Varies between <0.001-<0.005 mg/L	5 May 2016 - 30 June 2018	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters. Digestion APHA 3030 E
		Varies between <0.001-<0.005 mg/L	Sampling instigation – 4 May 2016	
	Dissolved copper	<0.0001 mg/L	October 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.002 mg/L	December 2008 – September 2016	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.004 mg/L	2007 - November 2008)	Graphite furnace (GFAA - graphite furnace atomic absorption, Varian) using acid washed GF/F filters
	Total lead	<0.001 mg/L	1 July 2018 - current day	APHA 3125 B modified (Varian7900 ICP- MS). Digestion APHA 3030 E
		Varies between <0.004 - <0.0015 mg/L	Sampling instigation - 30 June 2018	APHA 3125 B modified (Varian7900 ICP- MS). Digestion APHA 3030 E
	Dissolved lead	<0.0001 mg/L	October 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.0015 mg/L	December 2008 - September 2016	APHA 3125 B modified (Varian7900 ICP- MS), using nylon 0.45um filters. Digestion APHA 3030 E
		<0.006 mg/L	2007 - November 2008	APHA 3125 B modified (Varian7900 ICP- MS), using nylon 0.45um filters. Digestion APHA 3030 E
	Total zinc	<0.005 mg/L	1 July 2018 - current day	APHA 3125 B modified, (Varian7900 ICP- MS). Digestion APHA 3030 E
		<0.001 mg/L	5 May 2016 – 30 June 2018	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.001 mg/L	March 2009 – 4 May 2016	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters

Group	Parameter	Limit of Detection	Date	Analysis Method
		<0.006 mg/L	Sampling instigation - February 2009	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
	Dissolved zinc	<0.0001 mg/L	October 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.001 mg/L	5 May 2016 – September 2016	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.001 mg/L	March 2009 – 4 May 2016	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
		<0.006 mg/L	Sampling instigation - February 2009	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
Nutrients	Total nitrogen	<0.010mg/L	1 July 2018 - current day	APHA 4500-N C (persulphate digestion and continuous flow analyser)
		<0.01 mg/L	10 July 2014 - 30 June 2018	APHA 4500-N C 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
		<0.05 mg/L	4 March 2009 - 9 July 2014	
		<1.0 mg/L	Sampling instigation - 3 March 2009	
	Nitrate nitrogen	0.002 mg/L	1 July 2018 - current day	4500-NO3 F, Automated Cadmium Reduction Method
		<0.003 mg/L	9 September 2014 - 30 June 2018	APHA 4500-NO3 F (Continuous Flow Autoanalyser)
		<0.05 mg/L	Sampling instigation - 8 September 2014	APHA 4500-NO3 H (Hydrazine Reduction Discrete Analyser)
	Nitrite nitrogen	<0.001 mg/L	1 July 2018 - current day	APHA 4500-NO3 F (continuous flow analyser)
		<0.001 mg/L	9 September 2014 - 30 June 2018	APHA 4500-NO3 F 22nd Ed. 2012 (cadmium reduction and continuous flow analyser)
		<0.005 mg/L	Sampling instigation - 8 September 2014	APHA 4500-NO2 B (Discrete Analyser)
	Nitrate Nitrite Nitrogen (NNN)	<0.002mg/L	1 July 2018 - current day	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
		<0.01 mg/L	27 July 2011 - 30 June 2018	APHA 4500-NO3 E (Continuous Flow Autoanalyser)

Group	Parameter	Limit of Detection	Date	Analysis Method
		<0.05 mg/L	3 April 2009 - 26 July 2011	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
		<0.05 mg/L	Sampling instigation – 2 April 2009	Nitrate + Nitrite
	Dissolved Inorganic Nitrogen (DIN)	<0.007 mg/L	1 July 2018 - current day	Total ammonia + Nitrite-Nitrate-Nitrogen
		<0.02 mg/L	Sampling instigation - 30 June 2018	Total ammonia + Nitrite-Nitrate-Nitrogen
	Total ammonia (ammoniacal nitrogen)	<0.005 mg/L	4 September 2014 - current day	APHA 4500-NH3 G (Continuous Flow Autoanalyser)
		<0.01 mg/L	sampling instigation - 3 September 2014	4500-NH3 F (Discrete Analyser)
	Total phosphorus	<0.001 mg/L	1 July 2018 - current day	APHA 4500-P J (persulphate digestion and continuous flow analyser)
		<0.003 mg/L	10 July 2014 - 30 June 2018	APHA 4500-P J 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
		<0.02 mg/L	17 November 2009 - 09 July 2014	APHA 4500-P J (Discrete Analyser)
		<0.06 mg/L	Sampling instigation - 16 November 2009	APHA 4500-P J (Discrete Analyser)
	Dissolved Reactive Phosphorus (DRP)	<0.001 mg/L	1 July 2018 - current day	APHA 4500-P F (Continuous Flow Autoanalyser)
		<0.003 mg/L	22 December 2010 - 30 June 2018	APHA 4500-P F (Continuous Flow Autoanalyser)
		<0.02 mg/L	1 December 2010 - 21 December 2010	4500-P E (Discrete Analyser)
		<0.003 mg/L	17 November 2009 - 30 November 2010	4500-P E (Discrete Analyser)
		<0.01 mg/L	Sampling instigation - 16 November 2009	4500-P E (Discrete Analyser)
Bacteria	*Escherichia coli*	<1 and >24,000 MPN/100ml	1 July 2018 - current day	Colilert APHA 4500 9223 B
		Varies depending on required dilution	Sampling instigation - 30 June 2018	Colilert APHA 4500 9223 B
	Enterococci	<10 and >24,000 MPN/100ml	sampling instigation - current day	Enterolert APHA 9230 D
	Faecal coliforms	<1 MPN/100ml	sampling instigation - current day	APHA 9222D
Clarity		<1 mg/L	1 July 2018 - current day	APHA 2540 D

Group	Parameter	Limit of Detection	Date	Analysis Method
	Total Suspended Solids (TSS)	<3 mg/L	September 2010 - 30 June 2018	APHA 2540 D
		<5 mg/L	Sampling instigation - August 2010	APHA 2540 D
	Turbidity	<0.1 FNU	1 December - current day	ISO7027
		<0.1 NTU	28 August 2018 - 30 November 2020	TL230 ISO 7027 (concurrent testing)
		<0.1 NTU	Sampling instigation - current day	APHA 2130 B, (turbidity meter Hach 2100AN) (concurrent testing)
Other	Dissolved Oxygen (DO)	N/A	1 July 2018 - current day	APHA 4500-O G, YSI Pro ODO meter
		N/A	Sampling instigation - 30 June 2018	APHA 4500-O G
	Biochemical Oxygen Demand (BOD_5)	<1.0 mg/L	Sampling instigation- current day	APHA 5210 B
	Total water hardness	N/A	Sampling instigation- current day	APHA 2340 B calculation from calcium and magnesium measured by APHA 3125 B modified (Varian7900 ICP- MS,) using nylon 0.45um filters
	Conductivity	N/A	Sampling instigation- current day	APHA 2510 B
	Salinity	<2	May 2020 – current day	APHA 2520 B
	pH	N/A	Sampling instigation- current day	APHA 4500-H+ B
	Water temperature	N/A	Sampling instigation- current day	APHA 2550 B.YSI Pro ODO meter
	TPH[25]	<0.3 mg/L	Sampling instigation- current day	Extraction DCM (GC-FID)

[25] Analysed by Watercare Laboratory (IANZ accredited)

Appendix D

Hardness Modified Guideline Values for Metals in Christchurch City and Bank Peninsula Waterways

Introduction

The Australian and New Zealand guidelines for fresh and marine water quality provide a set of default guideline values for dissolved metals (ANZG, 2022). If measured concentrations of toxicants are below the default guideline values, then there is a low risk of adverse environmental effects.

The guidelines also provide a process of modifying the default guideline values for local environmental conditions, namely hardness, which can affect the toxicity of metals (excluding copper) and therefore increase the risk of adverse biological effects (Warne et al., 2018). The default guideline values for metals assume that water is soft (hardness 0–59 mg/L as $CaCO_3$). However, as water hardness increases, the toxicity of some metals decreases and therefore the guideline value may increase, without increasing the risk of adverse biological effects.

Hardness Modified Guideline Values (HMGV), formerly known as Hardness Modified Trigger Values, have been previously calculated by Christchurch City Council (Dewson, 2012; Margetts & Marshall, 2015). It is considered that hardness values are unlikely to change over the years, so these values can be reassessed approximately every five years.

A 2020 memorandum by Marshall & Margetts (2020) included the first five-yearly update of these values for Christchurch City waterways under the Comprehensive Stormwater Network Discharge Consent (CRC190445) and reflected the recommendation that copper is no longer modified by hardness (Warne *et al*., 2018). This current memorandum is an update to the 2020 memorandum to include Banks Peninsula waterway values. To have the assessments all in one place, this memorandum includes the 2020 City waterways values, as well as the Banks Peninsula values. The next review will be undertaken in 2025 – this will include Banks Peninsula values, even though this will be less than five years, to bring them into the same scheduling.

Methods

For waterway sites within Christchurch City, water samples were collected monthly in 2019 from 36 non-tidal sites across the five main river catchments within the City (Avon, Heathcote, Styx, Ōtūkaikino and Halswell Rivers), as well as a tidal site within Linwood Canal, giving a total of 12 samples for each of the 37 sites (Appendix A, Tables i and ii). Tidal sites within the wider monitoring programme[26] were excluded from the analyses, as tidal sites typically have high hardness levels, which would skew the results for each catchment, resulting in inappropriately higher guideline levels. As there was only one site for Linwood Canal, it did not matter that this site was tidal. However, it has since been established that coastal guideline values are more appropriate for Linwood Canal and therefore hardness modification is not required.

For Banks Peninsula waterway sites, water samples were collected in 2021 from three sites (Zephyr Stream, Balguerie Stream, and Aylmers Stream). Five samples were collected at Stream Reserve Drain and Balguerie Stream, and four samples were collected at Aylmers Stream.

[26] Avon River at Pages/Seaview Bridge, Avon River at Bridge Street, Heathcote River at Catherine Street, Heathcote River at Tunnel Road and Heathcote River at Ferrymead Bridge.

Boxplots of the water hardness data were created in RStudio (version 1.2.5033), to show the median and interquartile range. The dark line in the boxplots represents the median, and the bottom and top lines of the box represent the 25th and 75th percentiles (the interquartile range), respectively. The T-bars that extend from the box approximate the location of the 5th and 95th percentiles (using HAZEN methodology).

To calculate the HMGV, the following species protection levels were chosen, as per ECan (2018).

- Avon River, Heathcote River, and Linwood Canal catchments: 90% (Spring-fed – plains – urban)
- Styx, Ōtūkaikino, and Halswell River catchments: 95% (Spring-fed – plains)
- Cashmere Stream and Banks Peninsula catchments: 99% (Banks Peninsula)

These default guideline values were then modified by the median catchment hardness, as per the below formula (Warne *et al.*, 2018).

$$\boldsymbol{Lead\ HMGV = Default\ Guideline\ Value\ x} \left(\frac{\boldsymbol{hardness}}{\boldsymbol{30}}\right)^{\boldsymbol{1.27}}$$

$$\boldsymbol{Zinc\ HMGV = Default\ Guideline\ Value\ x} \left(\frac{\boldsymbol{hardness}}{\boldsymbol{30}}\right)^{\boldsymbol{0.85}}$$

Results and Conclusions

Median water hardness in the five main river catchments in Christchurch City (Avon, Heathcote, Styx, Ōtūkaikino and Halswell Rivers) ranged from 'soft' to 'moderate'; however, Linwood Canal fell between the 'very hard' and 'extremely hard' categories (Table 1; Figures 1–2). Median water hardness at the three Bank Peninsula sites (Zephyr Stream, Balguerie Stream, and Aylmers Stream) was soft (Table 1; Figure 3). The HMGV are all greater than the default guideline values in each of the waterways, as the default values assume water is 'soft' to conservatively protect aquatic ecosystems (Table 1).

Table 1. Default and Hardness Modified Guideline Values (HMGV; ANZG, 2022) for dissolved zinc and lead in Christchurch City and Banks Peninsula waterways.

Catchment	Median hardness (mg/L)	Species protection level (ECan, 2018)	Zinc guideline		Lead guideline	
			Default (mg/L)	HMGV (mg/L)	Default (mg/L)	HMGV (mg/L)
Heathcote River – Cashmere Stream	94.0	99%	0.0024	0.00634	0.0010	0.00427
Halswell River	75.0	95%	0.0080	0.01743	0.0034	0.01089
Styx River	47.0	95%	0.0080	0.01172	0.0034	0.00601
Ōtūkaikino River	35.0	95%	0.0080	0.00912	0.0034	0.00414
Avon River	66.5	90%	0.0150	0.02951	0.0056	0.01539
Heathcote River – remainder	94.0	90%	0.0150	0.03960	0.0056	0.02388
Linwood Canal	370.0	90%	0.0150	0.12691	0.0056	0.13610
Stream Reserve Drain	38.0	99%	0.0024	0.00293	0.0010	0.00135
Balguerie Stream	32.0	99%	0.0024	0.00254	0.0010	0.00109
Aylmers Stream	38.0	99%	0.0024	0.00293	0.0010	0.00135

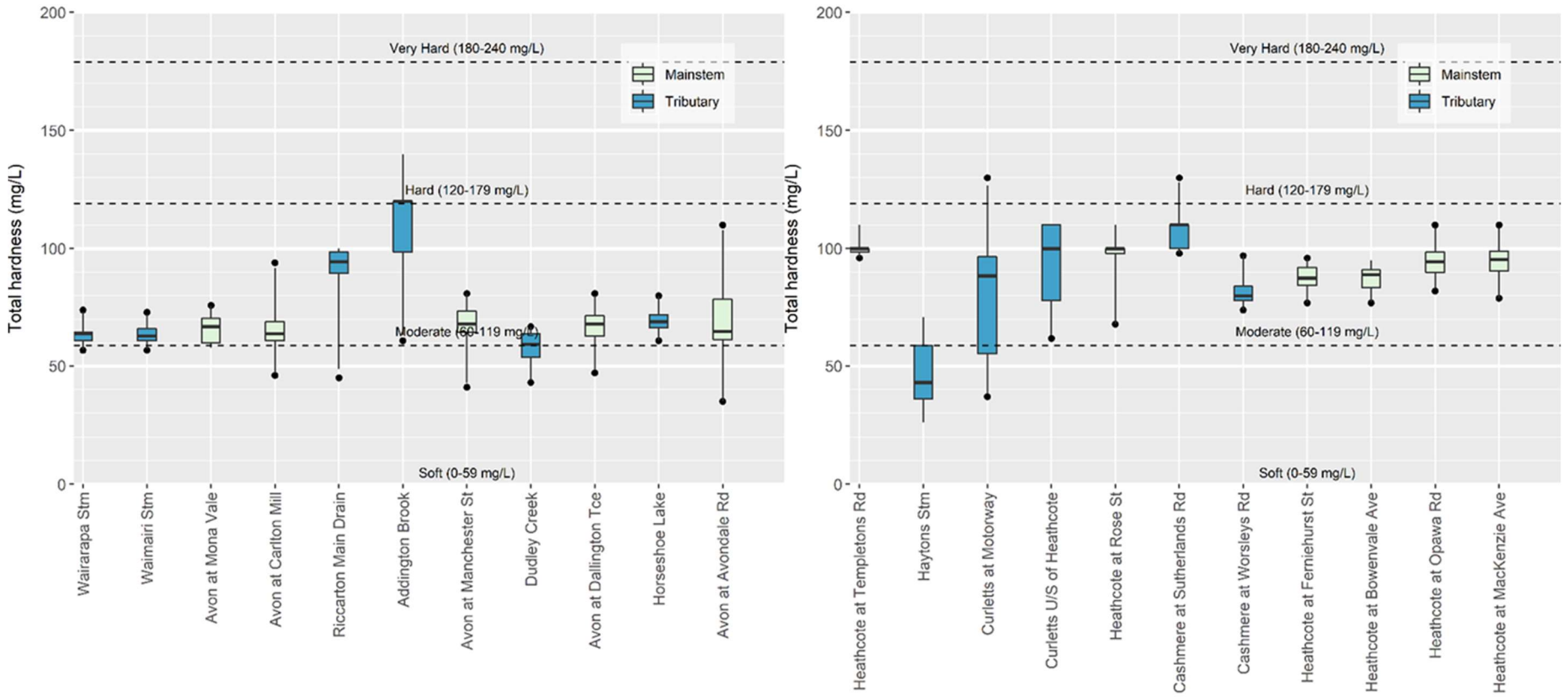

Figure 1. Total hardness (as $CaCO_3$) levels in water samples taken monthly from non-tidal sites within the Ōtākaro/Avon (left graph) and Ōpāwaho/Heathcote (right graph) River sites, for the monitoring period January to December 2019. No monitoring was undertaken at the Haytons Stream site in March and June, as the site was dry. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC (2000) delineations between water hardness categories.

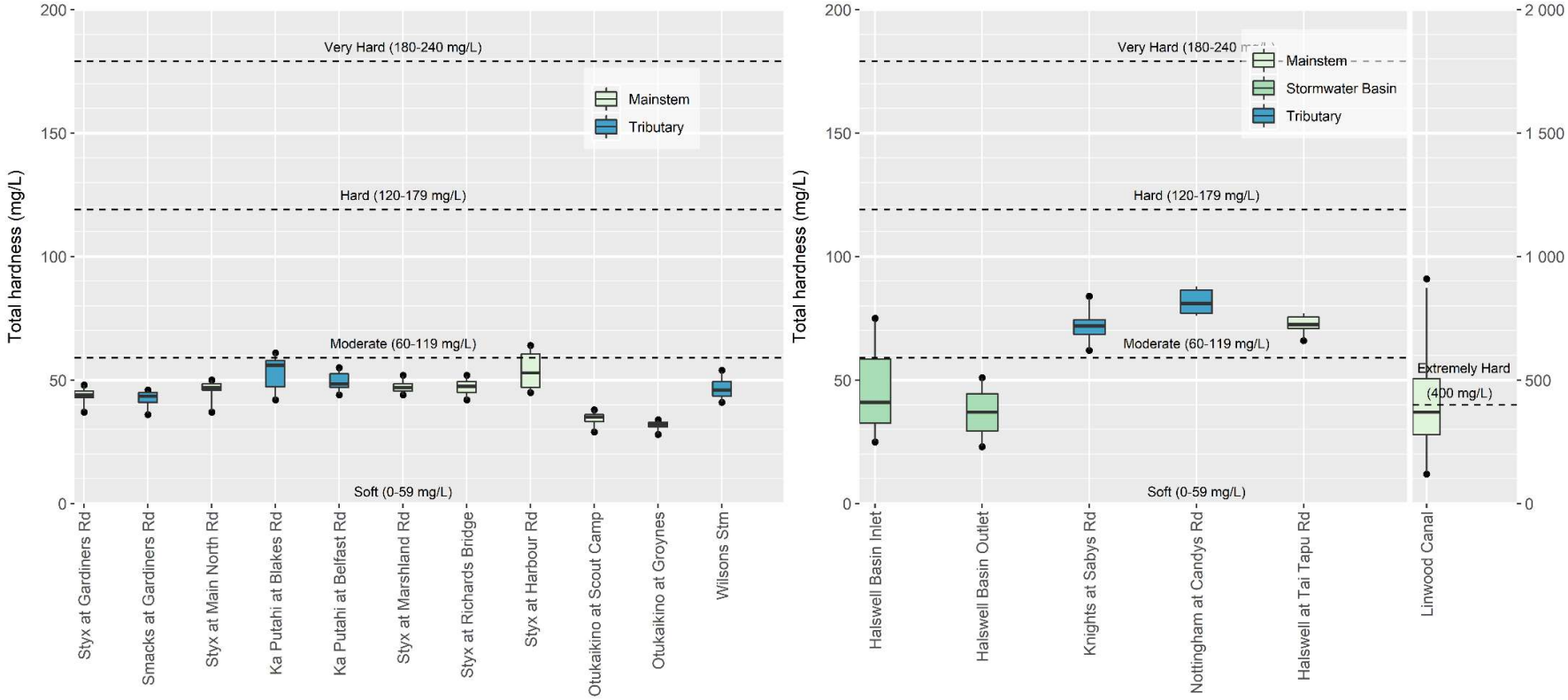

Figure 2. Total hardness (as $CaCO_3$) levels in water samples taken monthly from non-tidal sites within the Pūharakekenui/Styx and Ōtūkaikino Rivers (left graph), and the Huritini/Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2019. No monitoring was undertaken at the Kā Pūtahi Creek at Blakes Road site in August and the Ōtūkaikino Creek at Omaka Scout Camp site in February, as these sites could not be accessed. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZG (2000) delineations between water hardness categories.

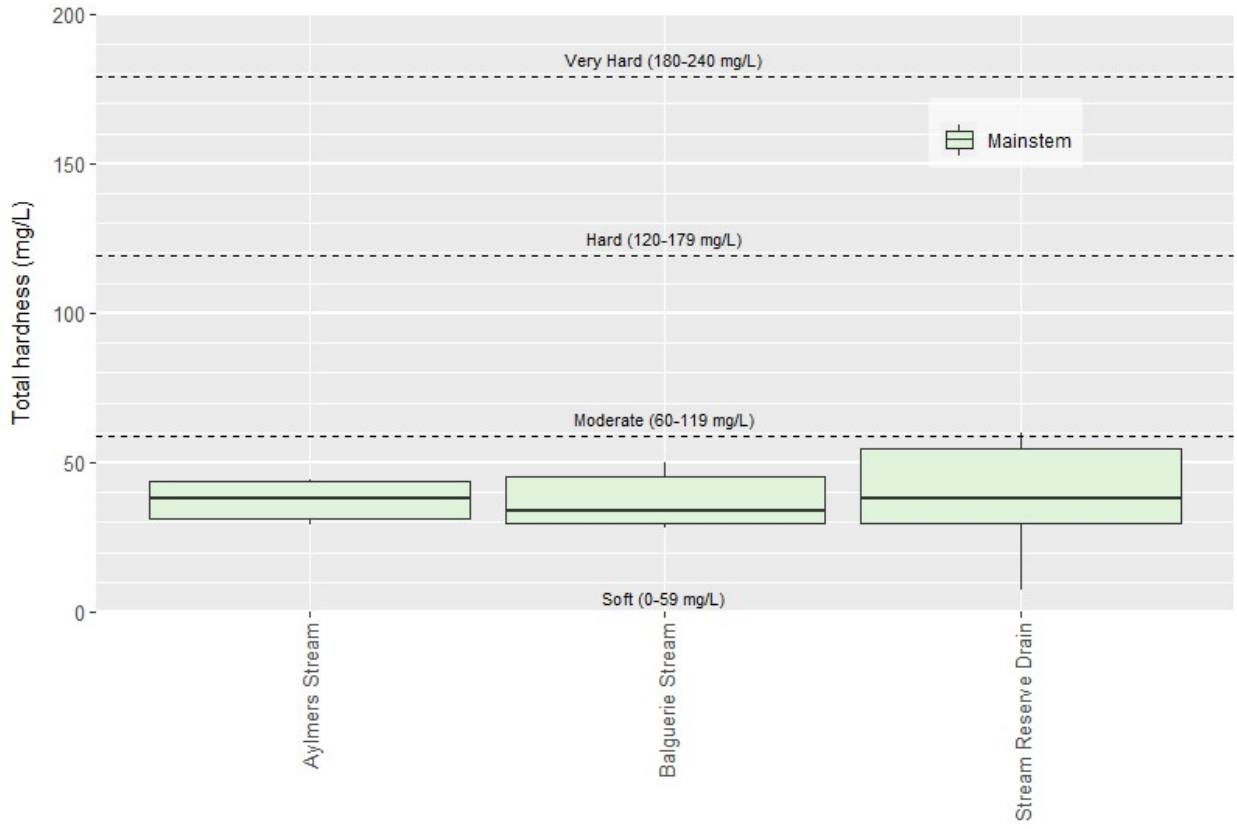

Figure 3. Total hardness (as $CaCO_3$) levels in water samples taken from three waterway sites in Bank Peninsula (Zephyr Stream, Balguerie Stream, and Aylmers Stream) for the monitoring period January to December 2021. The dashed lines represent the ANZG (2000) delineations between water hardness categories.

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Dr Belinda Margetts

Christchurch City Council
Principal Waterways Ecologist
Three Waters and Waste

Dr Salina Poudyal

Christchurch City Council
Environmental Compliance Officer
Three Waters and Waste

Winsome Marshall

Environmental Consultant
Aquatic Ecology Limited

29th June 2022

Appendix A: Site locations

Table i. Water quality monitoring sites for the water hardness investigations in the Avon and Heathcote River catchments.

Catchment	Site	Easting (NZTM)	Northing (NZTM)
Ōtākaro/ Avon	Avon River at Dallington Terrace/Gayhurst Road	1573560	5181210
	Avon River at Manchester Street	1570890	5180481
	Wairarapa Stream	1568250	5181303
	Waimairi Stream	1568233	5181172
	Avon River at Mona Vale	1568334	5181046
	Riccarton Main Drain	1568683	5180019
	Addington Brook	1569427	5179826
	Dudley Creek	1572574	5182150
	Horseshoe Lake Discharge	1574342	5183294
	Avon River at Carlton Mill Corner	1569737	5181259
	Avon River at Avondale Road	1574752	5183557
Ōpāwaho/ Heathcote	Heathcote River at Opawa Road/Clarendon Terrace[4]	1573071	5177615
	Heathcote River at Bowenvale Avenue	1571198	5175780
	Cashmere Stream at Worsleys Road	1569030	5175155
	Heathcote River at Rose Street	1568701	5175918
	Heathcote River at Ferniehurst Street	1569157	5175612
	Heathcote River at Templetons Road	1565915	5176897
	Haytons Stream at Retention Basin	1566020	5177596
	Curletts Road Stream Upstream of Heathcote River Confluence	1566928	5177711
	Heathcote River at Mackenzie Avenue Footbridge	1573520	5177917
	Curletts Road Stream at Southern Motorway	1566405	5178358
	Cashmere Stream at Sutherlands Road	1566086	5173988

Table ii. Water quality monitoring sites for the water hardness investigations in the Styx River, Halswell River, Ōtūkaikino River and Linwood Canal catchments.

Catchment	Site	Easting (NZTM)	Northing (NZTM)
Pūharakekenui/ Styx	Smacks Creek at Gardiners Road near Styx Mill Road	1566804	5187956
	Styx River at Gardiners Road	1566790	5187226
	Styx River at Main North Road	1569066	5187219
	Kā Pūtahi Creek at Blakes Road	1570401	5188030
	Kā Pūtahi Creek at Belfast Road	1572194	5188267
	Styx River at Marshland Road Bridge	1572358	5187778
	Styx River at Richards Bridge	1573975	5189640
	Styx River at Harbour Road Bridge	1574998	5194749
Huritini/ Halswell	Halswell Retention Basin Inlet	1561701	5177022
	Halswell Retention Basin Outlet	1561796	5176914
	Nottingham Stream at Candys Road	1564532	5173080
	Halswell River at Akaroa Highway (Tai Tapu Road)	1564446	5171721
	Knights Stream at Sabys Road	1563723	5172852
Ōtūkaikino	Ōtūkaikino River at Groynes Inlet	1567878	5188869
	Wilsons Drain at Main North Road	1571241	5190793
	Ōtūkaikino Creek at Omaka Scout Camp	1565664	5188038
Linwood	Linwood Canal/City Outfall Drain	1575952	5178026

Table iii. Water quality monitoring sites for the water hardness investigations within Banks Peninsula waterways (Zephyr Stream, Balguerie Stream, and Aylmers Stream).

Catchment	Site	Easting (NZTM)	Northing (NZTM)
Zephyr Stream	Stream Reserve Drain Above Outfall to Governors Bay	2482036	5731805
Balguerie Stream	Balguerie Stream Downstream of Settlers Hill (road)	2507759	5711175
Aylmers Stream	Aylmers Stream Downstream of Rue Jolie, Next to Bruce Terrace	2506930	5710693

Appendix E

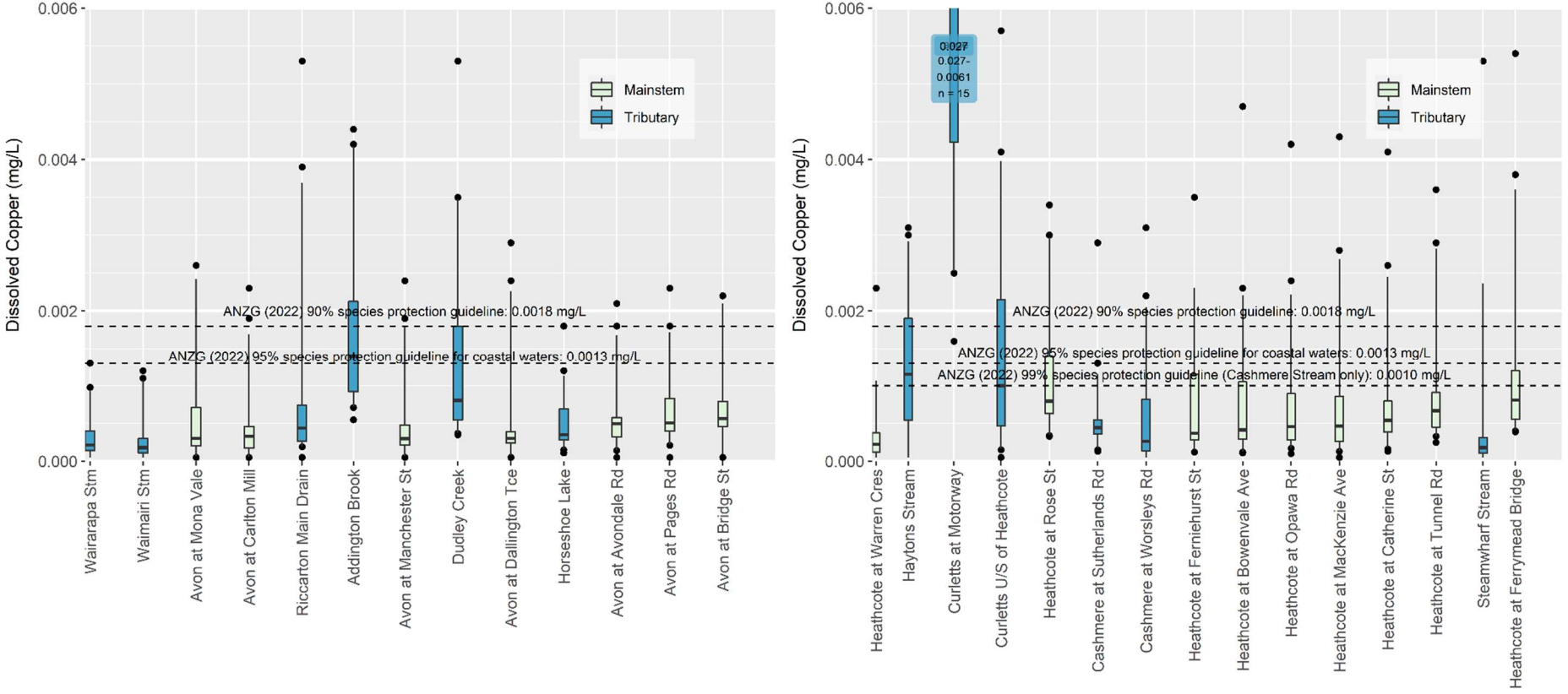

Figure i (a). Dissolved copper concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZG (2022) guideline values. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

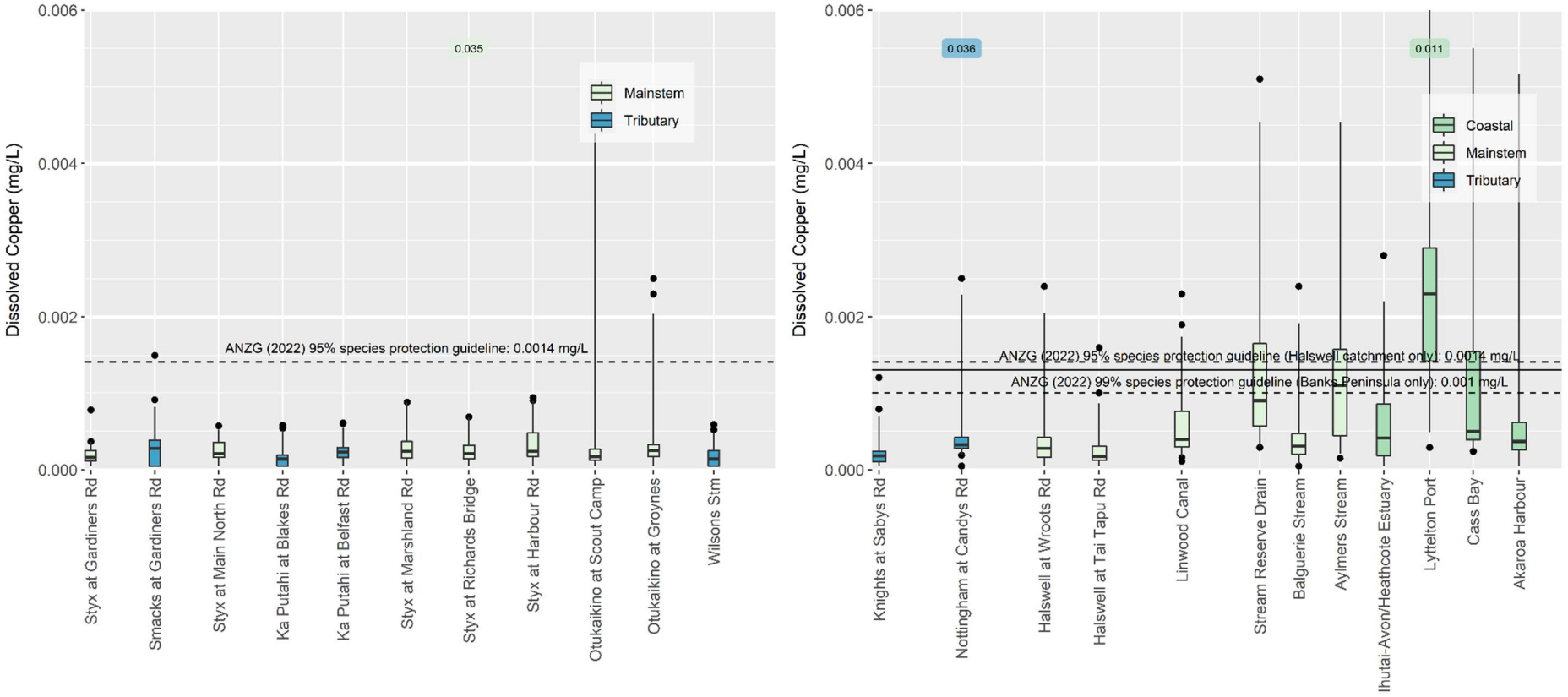

Figure i (b). Dissolved copper concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula, and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZG (2022) waterway guideline values. The solid line represents the ANZG (2022) coastal guideline. The strongly tidal Linwood Canal site should be compared to the more conservative coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

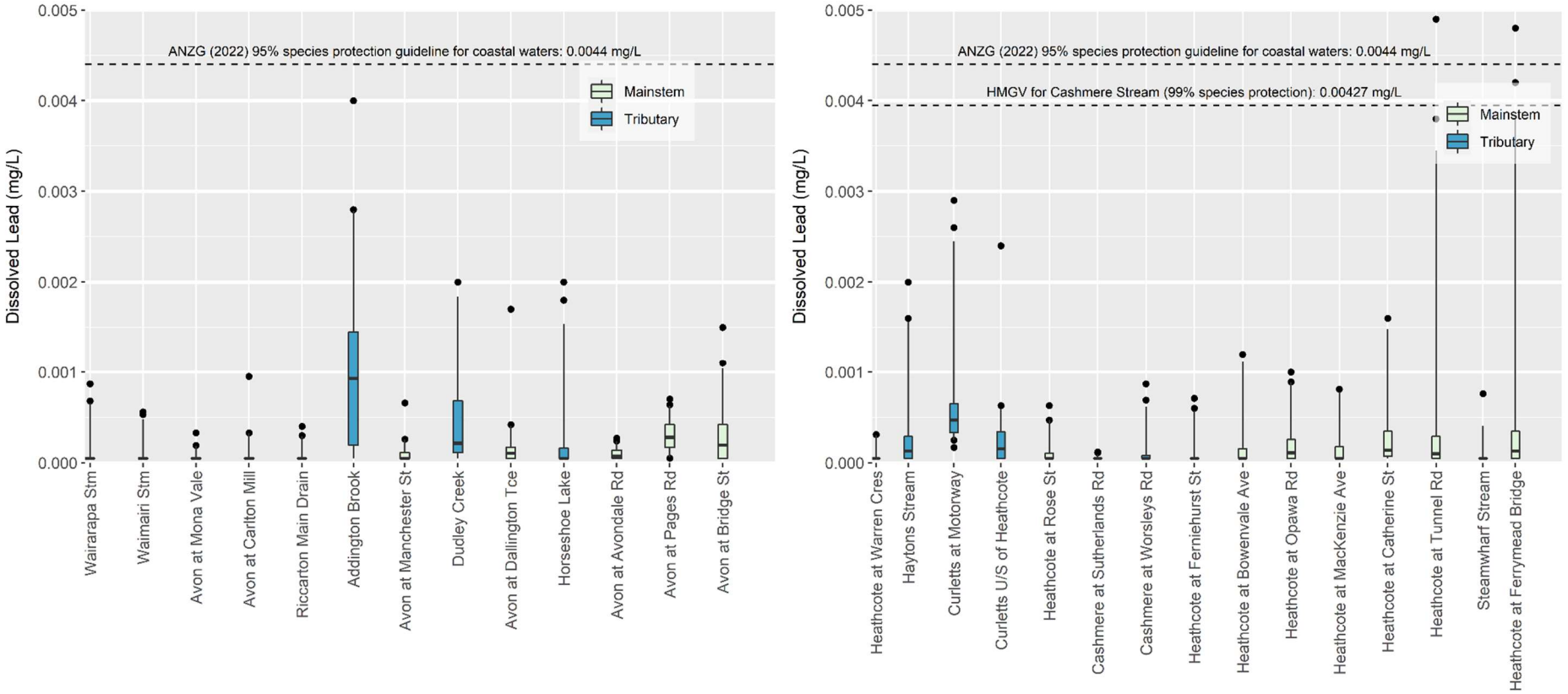

Figure ii (a). Dissolved lead concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The 90% protection HMGV for the Ōtākaro-Avon River (0.01539 mg/L) and the Ōpāwaho-Heathcote River (0.02388 mg/L) are not shown as they are off the scale. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

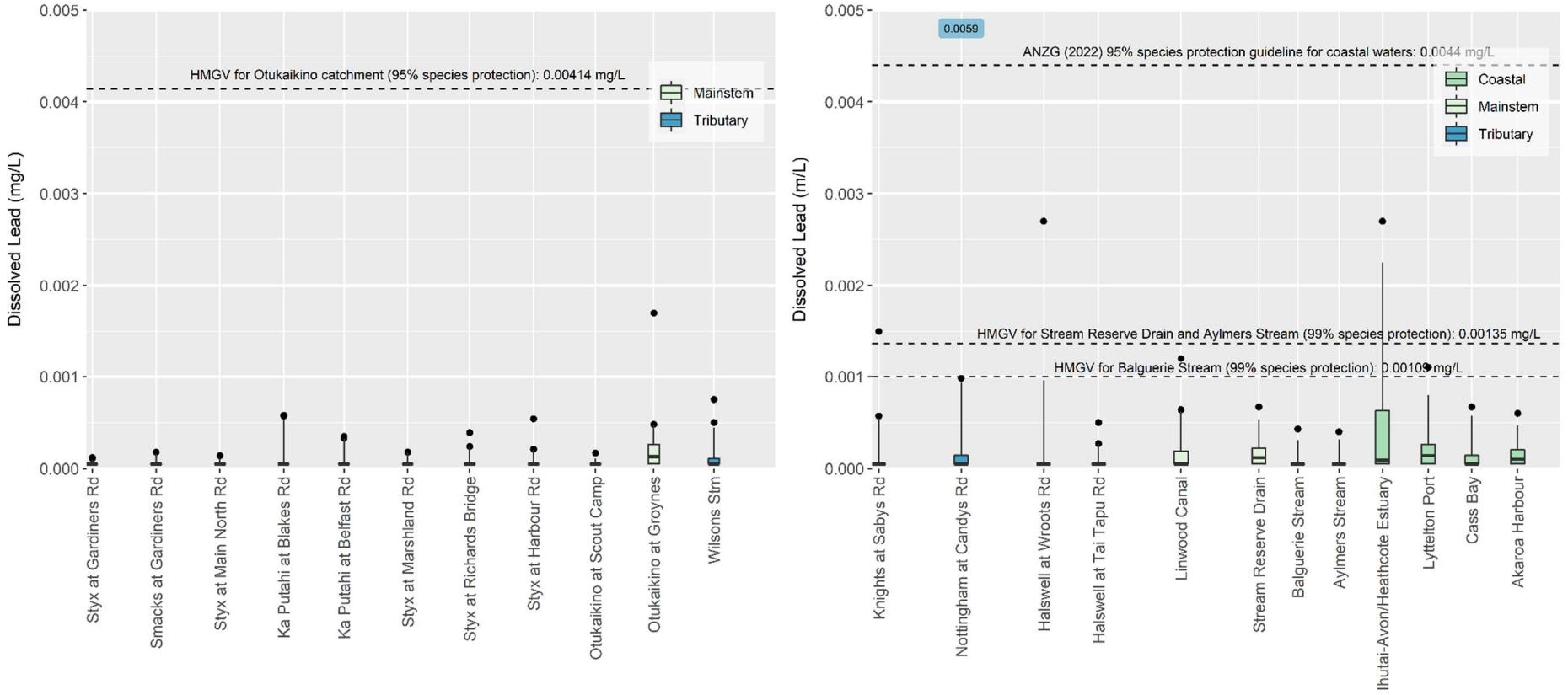

Figure ii (b). Dissolved lead concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. The 95% protection HMGV for the Pūharakekenui-Styx River (0.00601 mg/L) and the Huritini-Halswell River (0.01089 mg/L) are not shown as they are off the scale. The strongly tidal Linwood Canal site is compared to the more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

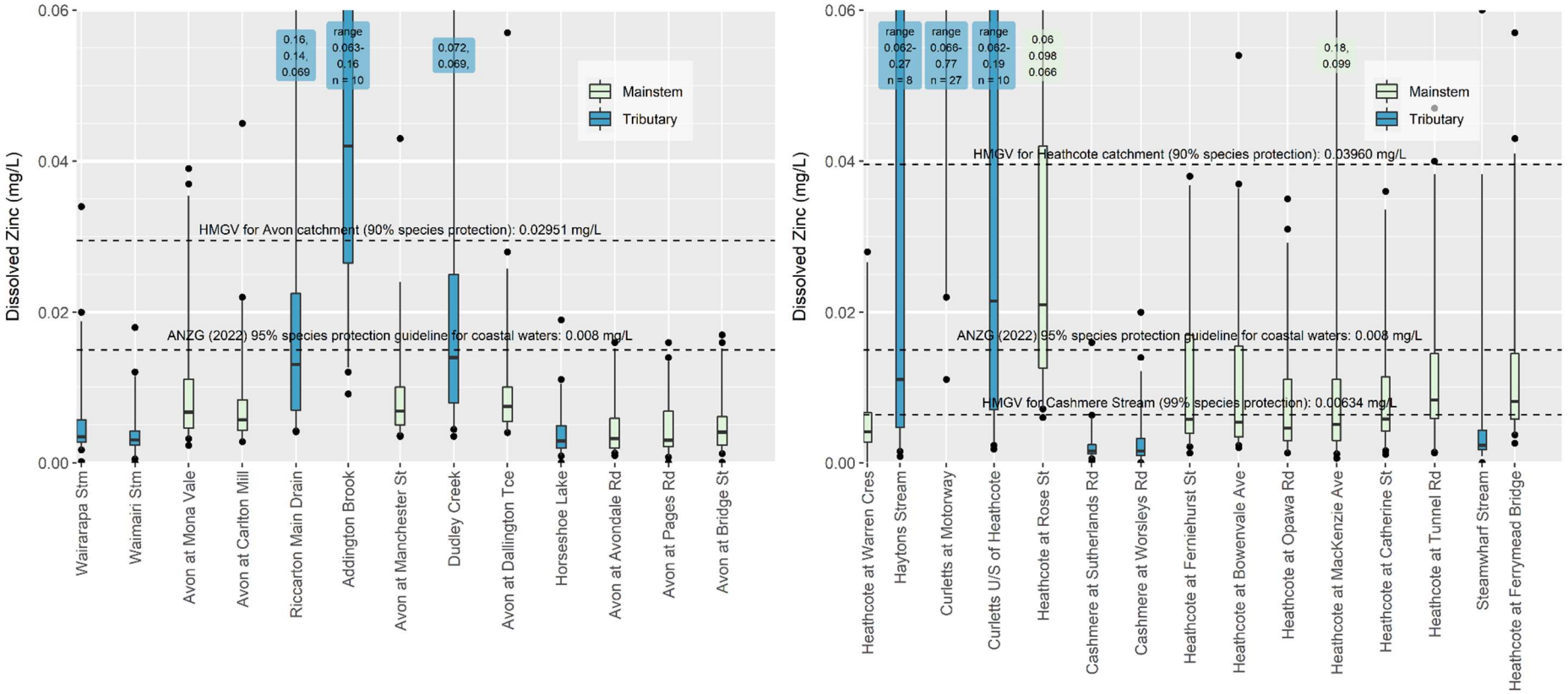

Figure iii (a). Dissolved zinc concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

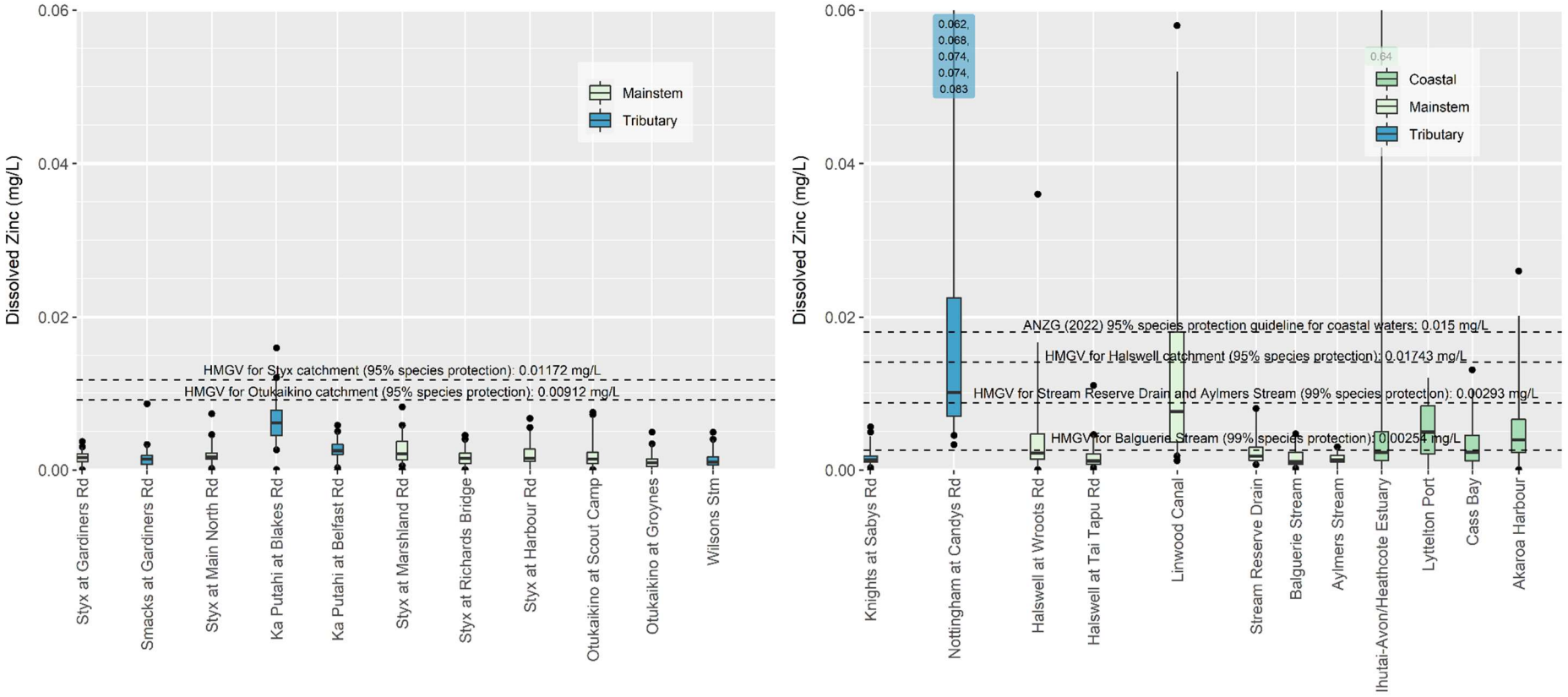

Figure iii (b). Dissolved zinc concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZG (2022) guideline values. The strongly tidal Linwood Canal site is compared to the more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

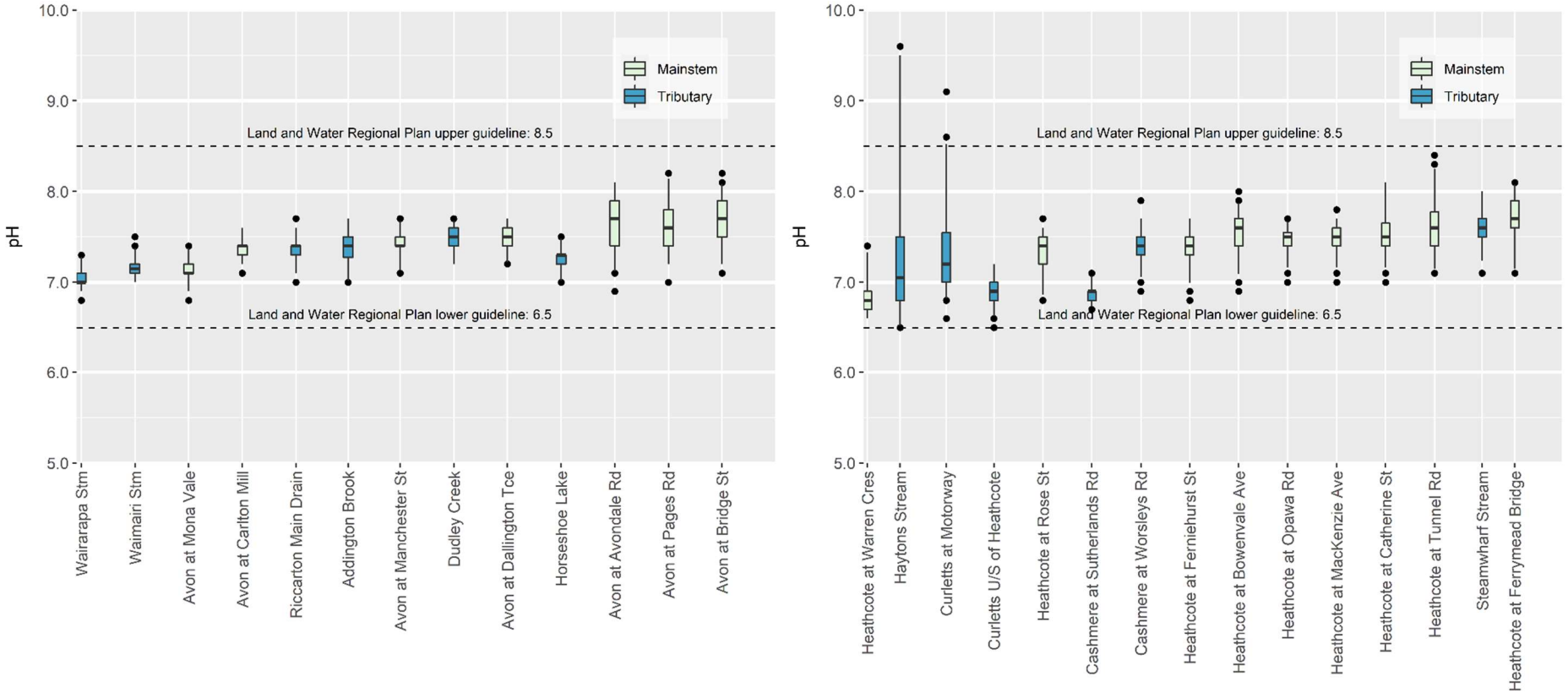

Figure iv (a). pH levels in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019) for waterway sites.

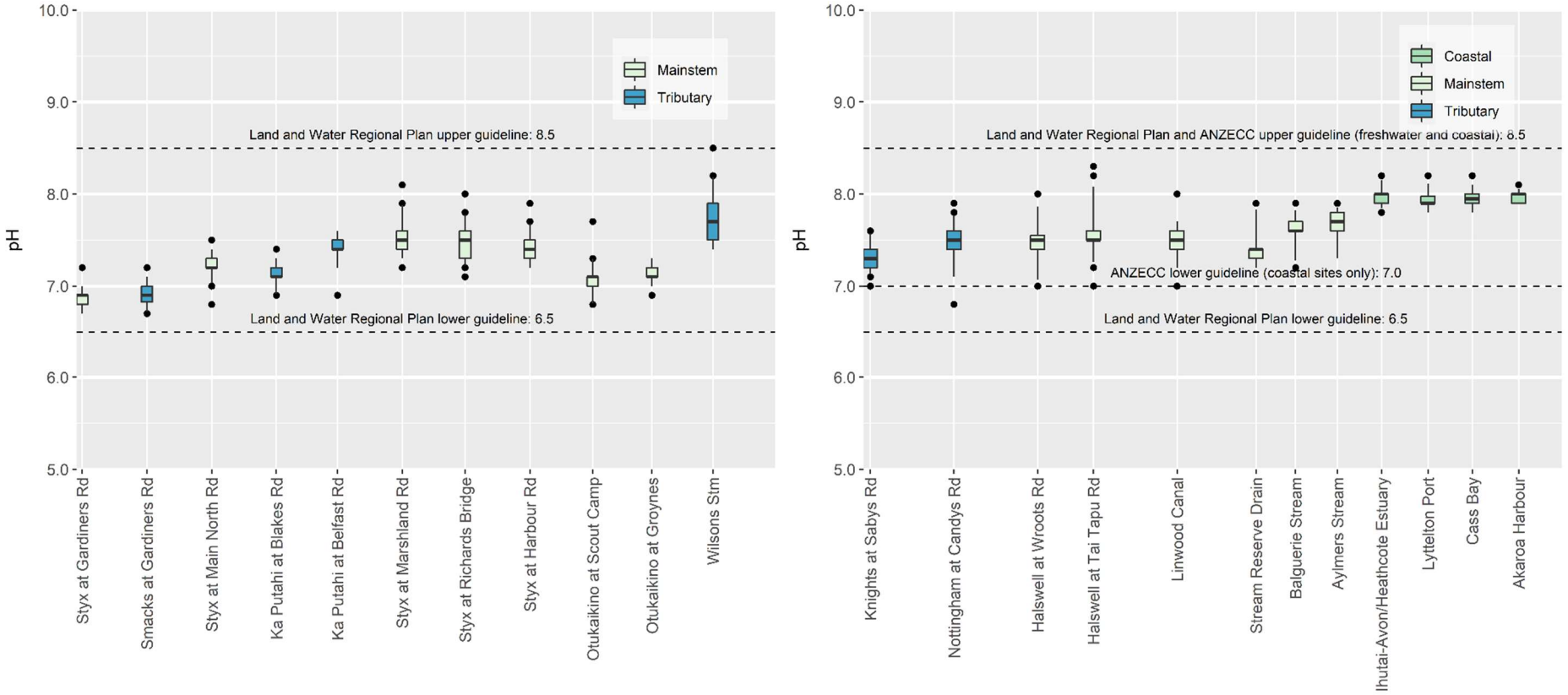

Figure iv (b). pH levels in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019) for waterway sites, and the ANZECC (2000) lower (7.0) and upper (8.5) limits for coastal sites.

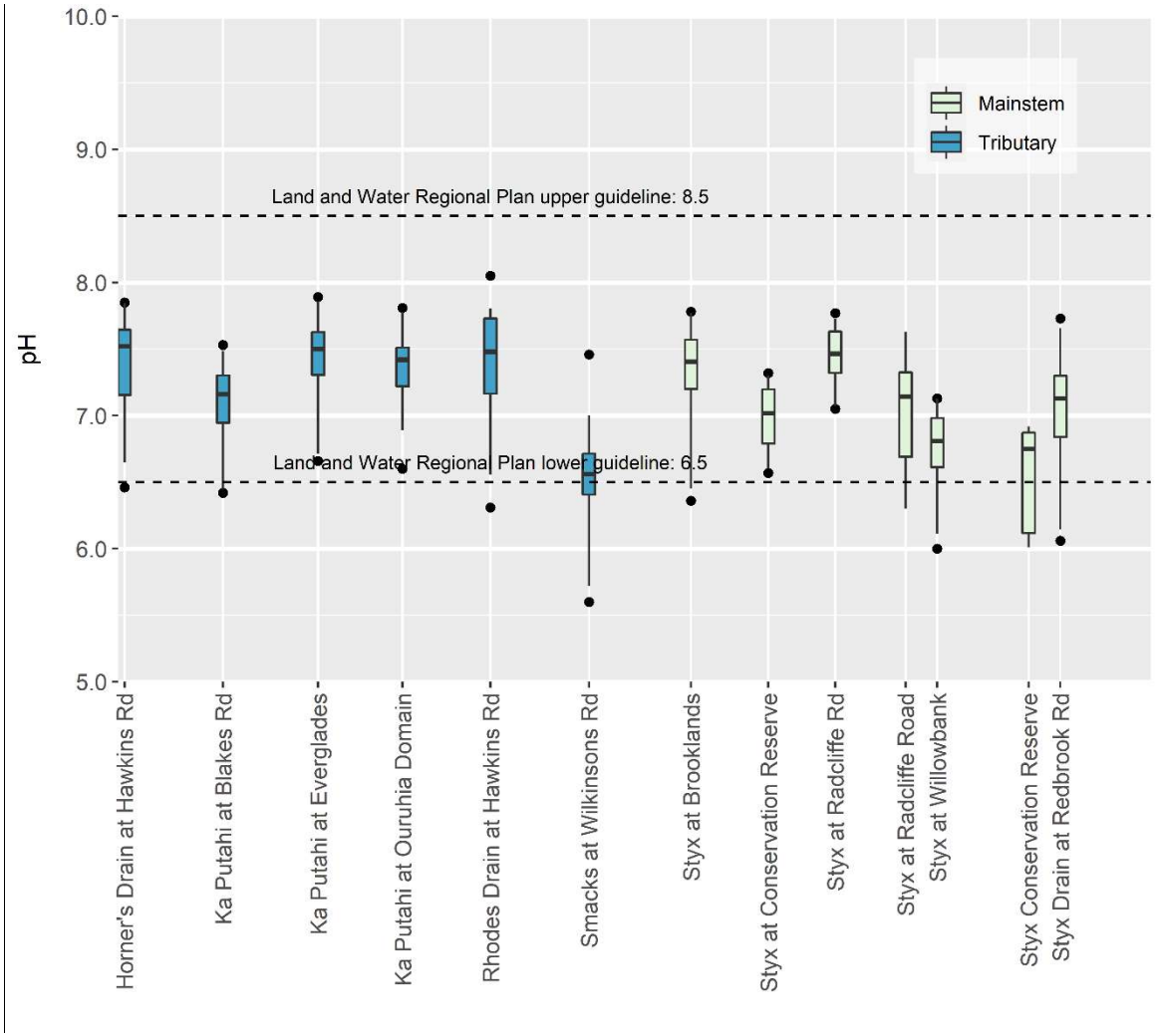

Figure iv (c). pH levels in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019).

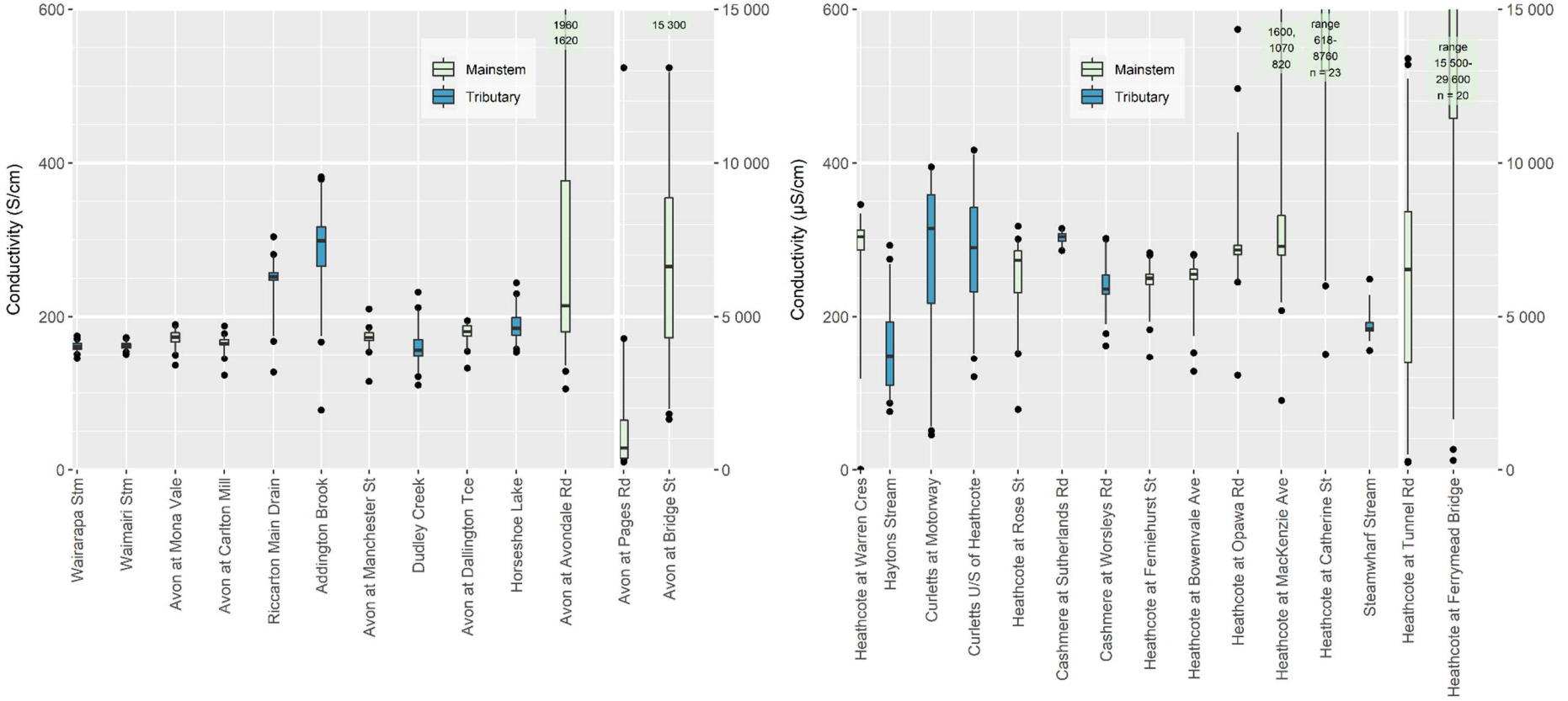

Figure v (a). Conductivity levels in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. Given the large differences in concentrations within catchments, some sites are presented with an alternate scale on the secondary (right) axis following the vertical, thick, white line. The numbers in shaded boxes indicate samples that exceeded the y-axis.

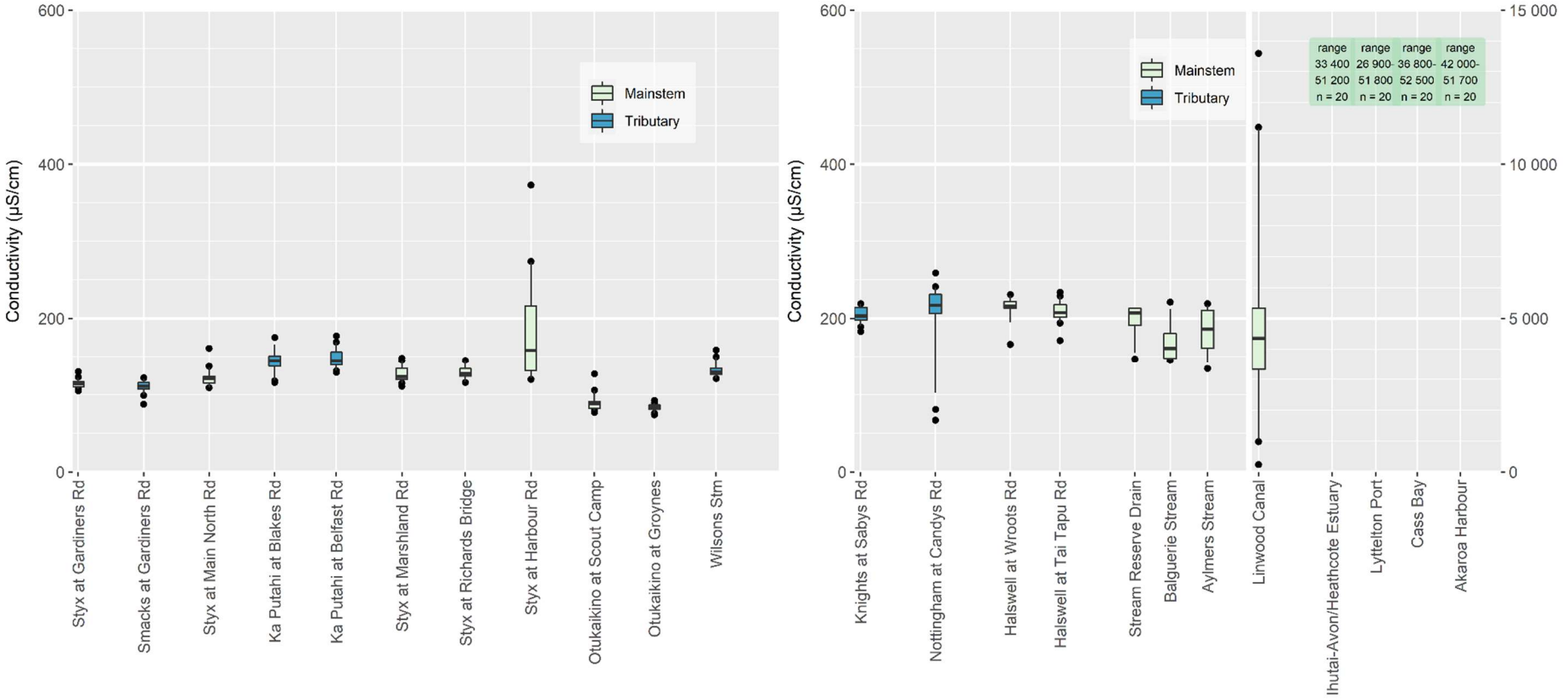

Figure v (b). Conductivity levels in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. Sites with an asterisk indicate where sampling began in 2020. All conductivity graphs have the same scale presented on the primary (left) axis. Given the large differences in concentrations within catchments, some sites are presented with an alternate scale on the secondary (right) axis following the vertical, thick, white line. The numbers in shaded boxes indicate samples that exceeded the y-axis.

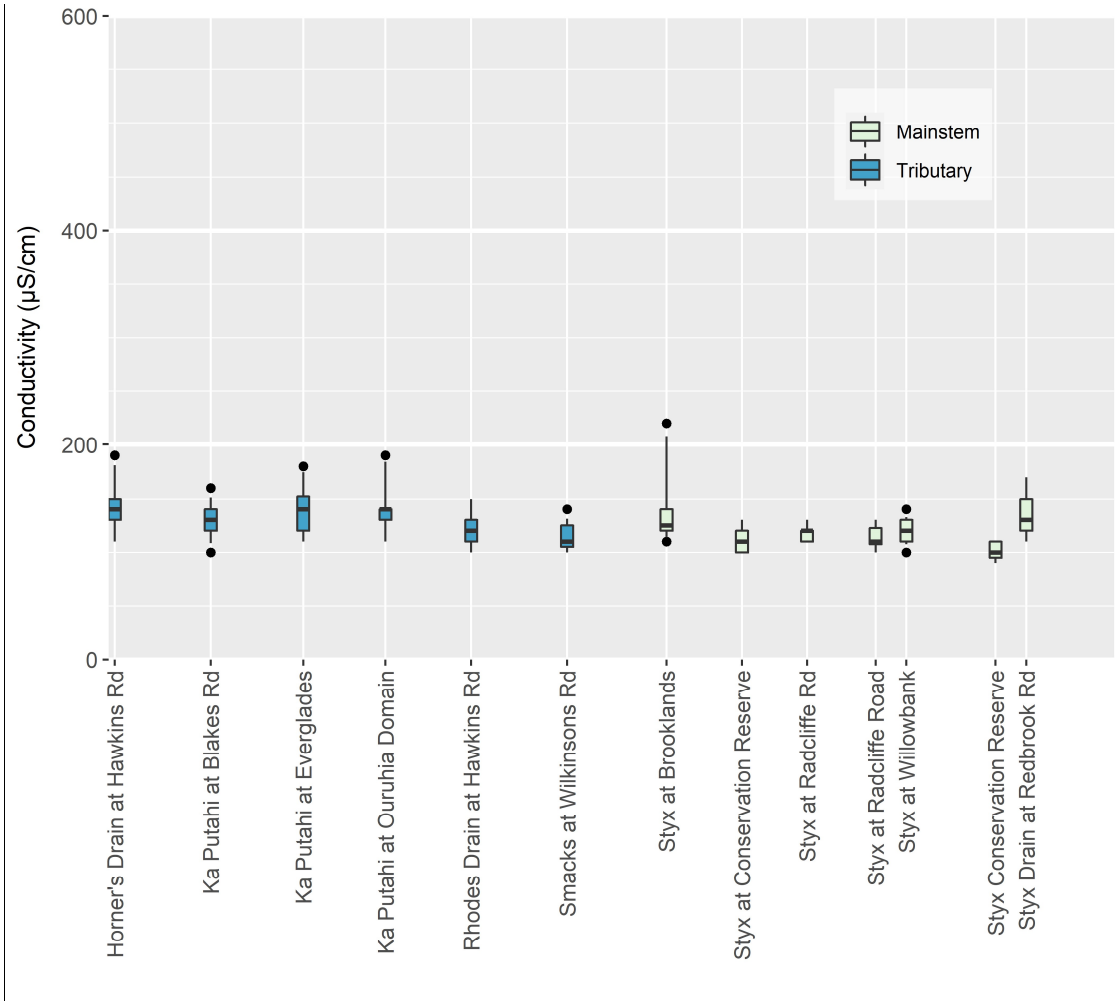

Figure v (c). Conductivity concentrations in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2019 to December 2021.

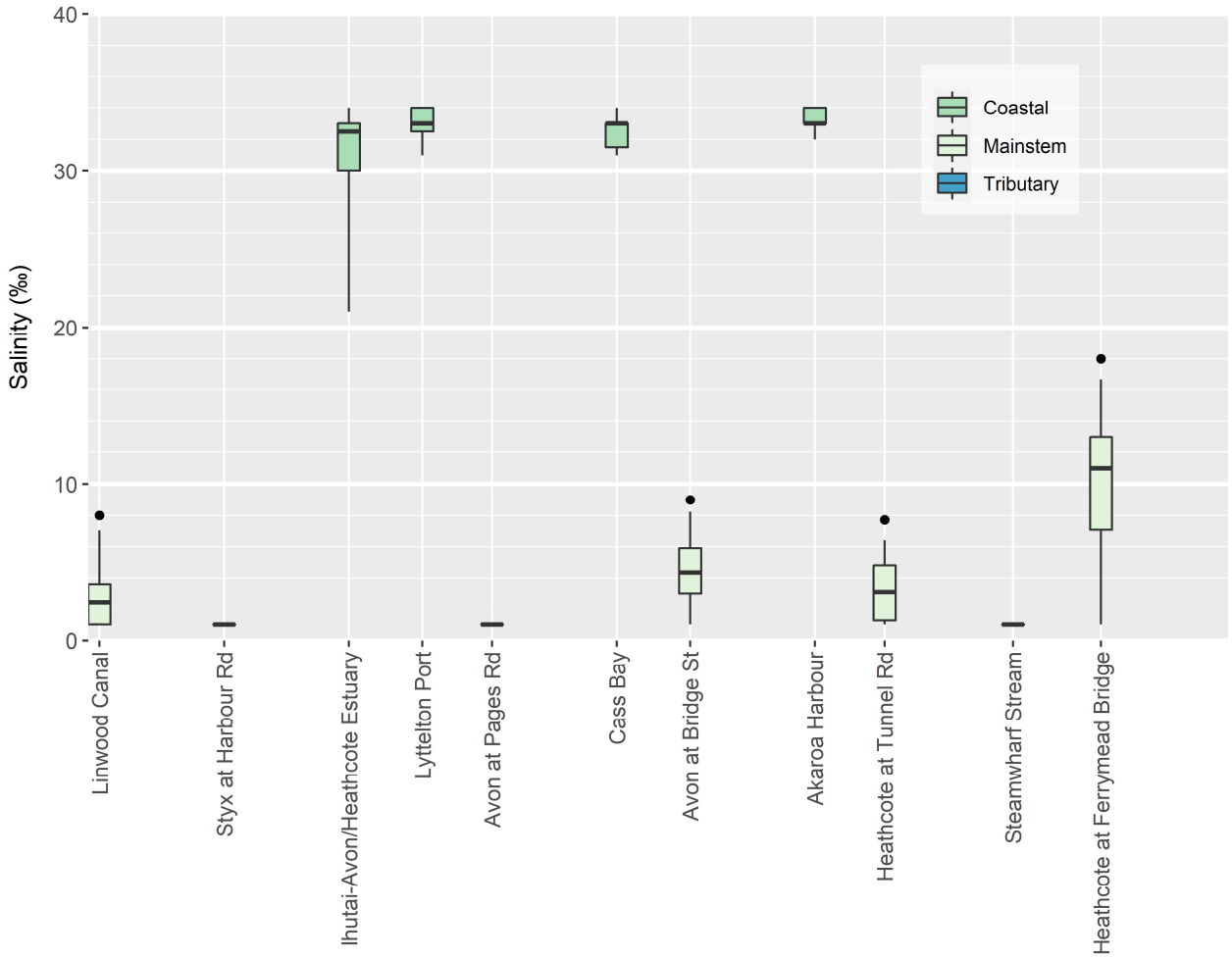

Figure vi. Salinity concentrations in water samples taken from lower tidal waterway and coastal sites, for the monitoring period January to December 2020. Salinity monitoring at these sites was implemented in January 2020, except for Steamwharf Stream (July 2020) and coastal sites (May 2020). The Laboratory Limit of Detection was 2.0% – graphed as half this value (1.0%).

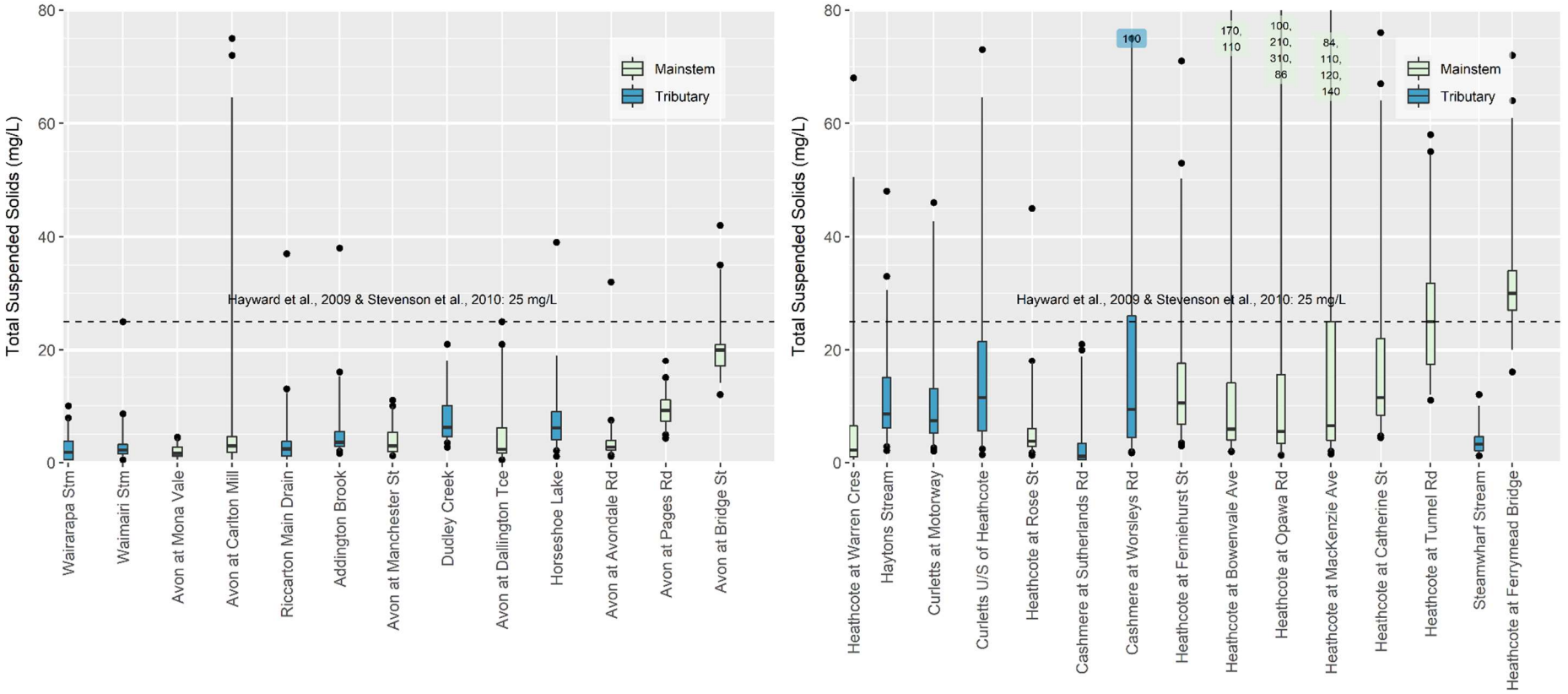

Figure vii (a). Total Suspended Solid (TSS) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

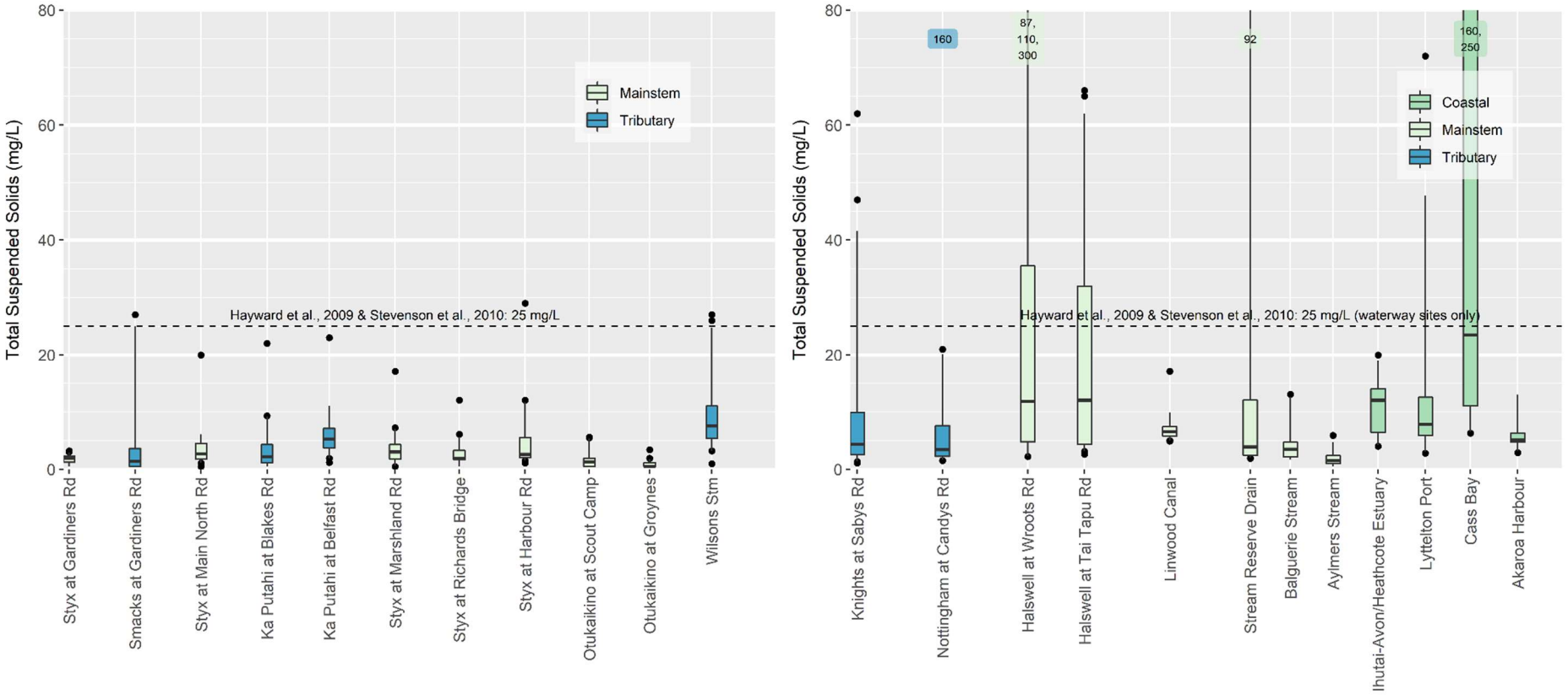

Figure vii (b). Total Suspended Solid (TSS) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the waterway guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

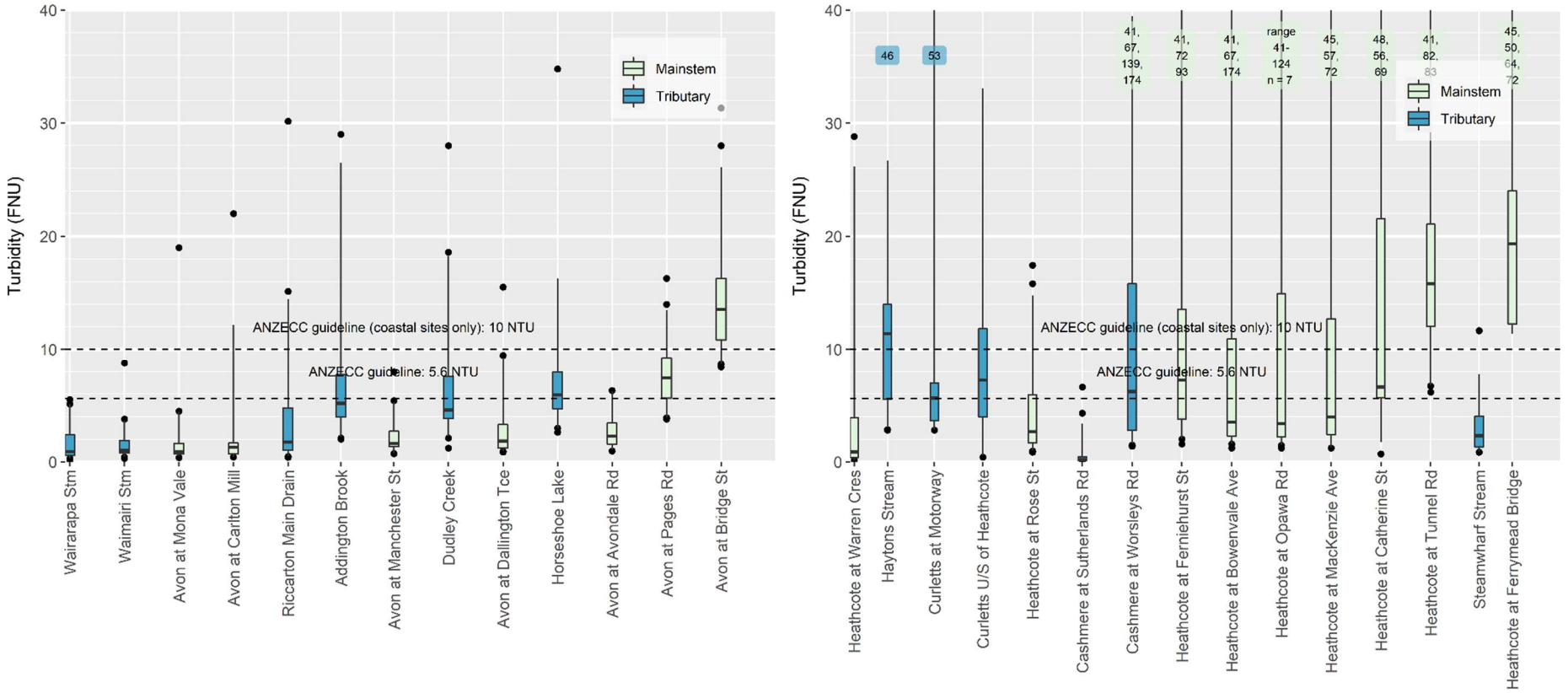

Figure viii (a). Turbidity concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZECC (2000) guideline values of 5.6 Nephelometric Turbidity Units (NTU) for waterway sites, or 10 NTU for coastal sites. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the coastal water guideline. The Laboratory Limit of Detection was 0.1 FNU – graphed as half this value (0.05 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

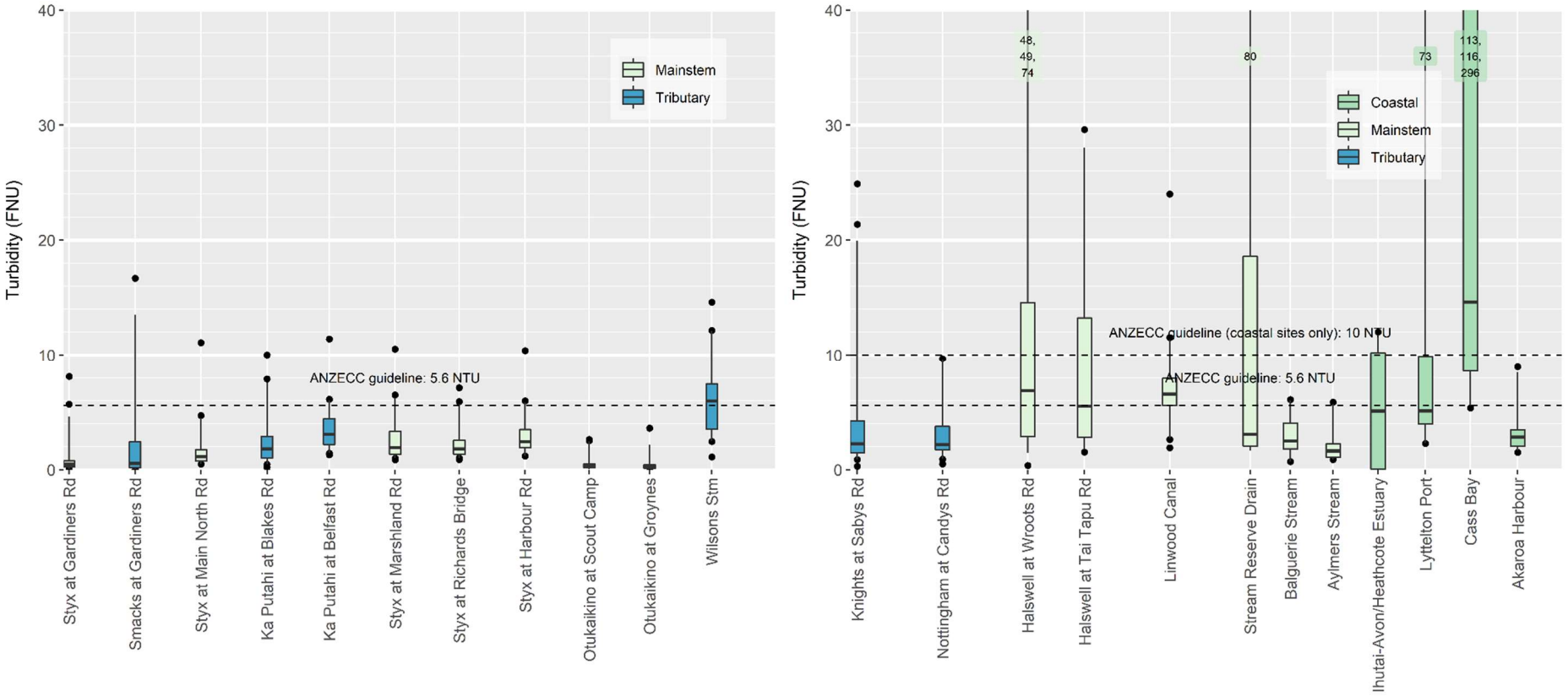

Figure viii (b). Turbidity concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the ANZECC (2000) guideline values of 5.6 Nephelometric Turbidity Units (NTU) for waterway sites, or 10 NTU for coastal sites. The strongly tidal Linwood Canal site should be compared to the coastal water guideline. The Laboratory Limit of Detection was 0.1 FNU – graphed as half this value (0.05 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

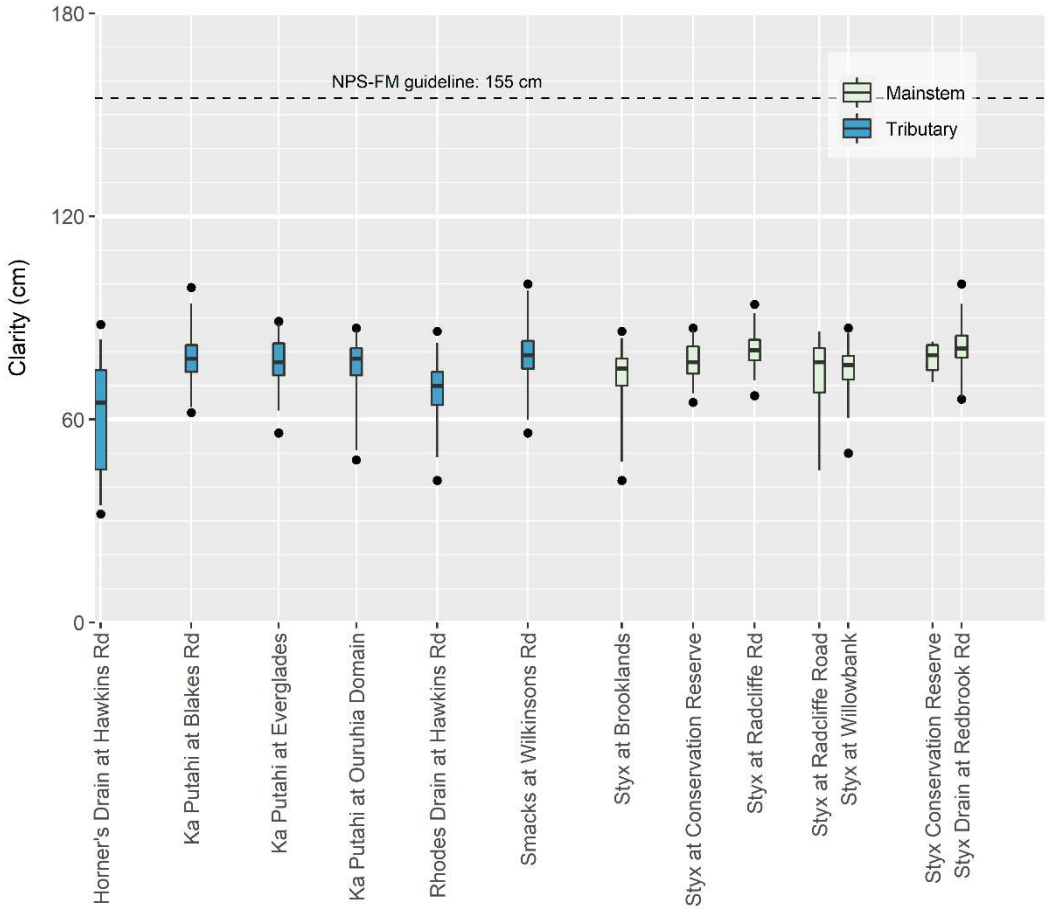

Figure ix. Water clarity levels in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2019 to December 2021. The dashed line represents the NPS-FM (2020) guideline value of 155 cm for attribute band B.

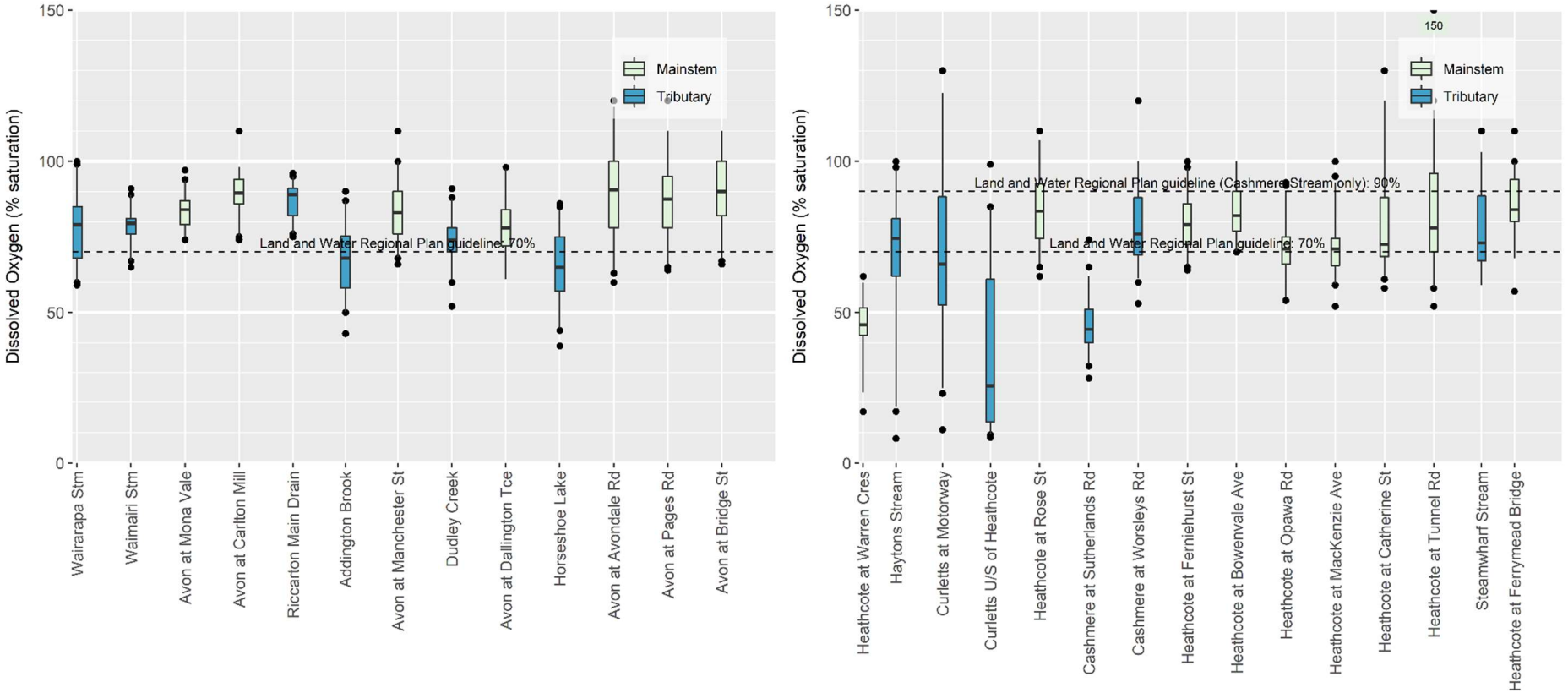

Figure x (a). Dissolved oxygen concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The lower and upper dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%), and Banks Peninsula waterways (90%; Cashmere Stream only), respectively (Environment Canterbury, 2019). The numbers in shaded boxes indicate samples that exceeded the y-axis.

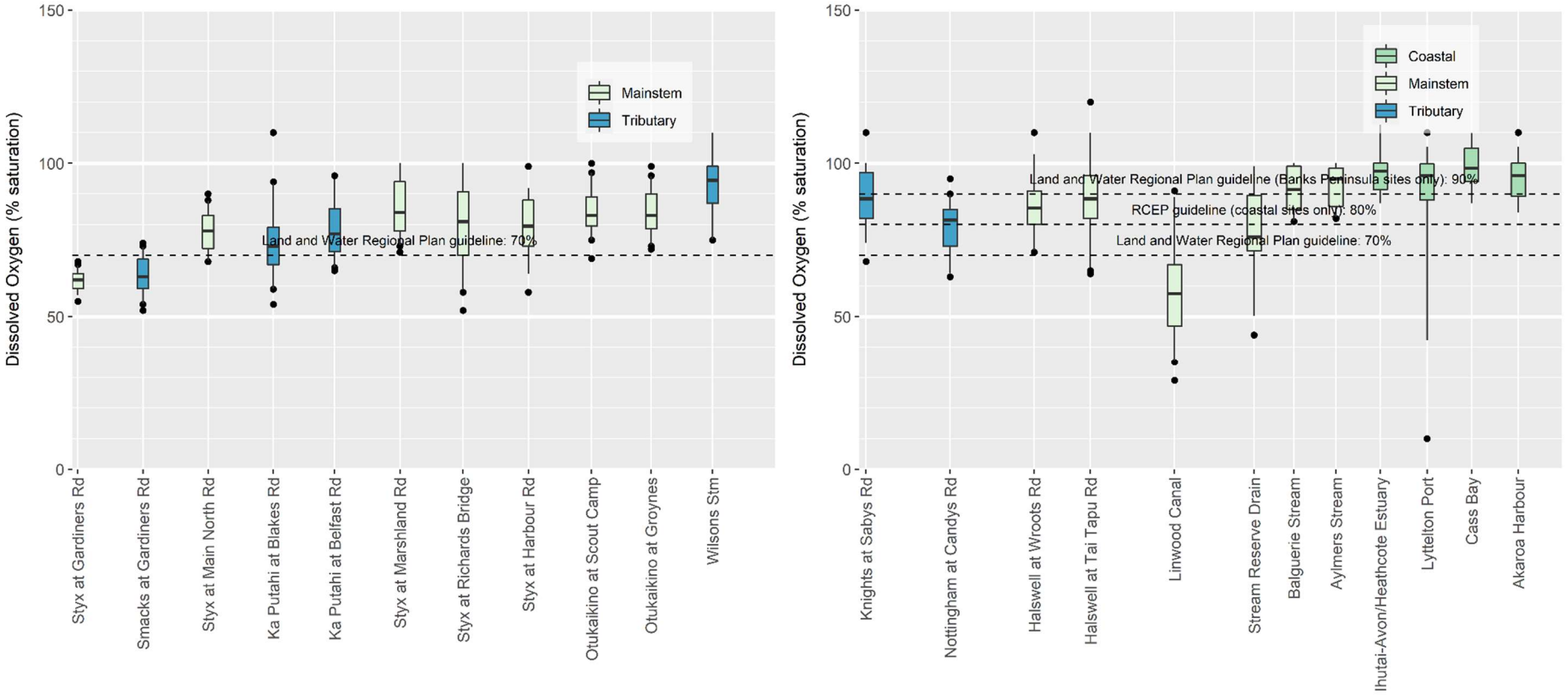

Figure x (b). Dissolved oxygen concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%), Banks Peninsula waterways (90%), and coastal sites (80%), respectively (Environment Canterbury, 2019; RCEP, 2012).

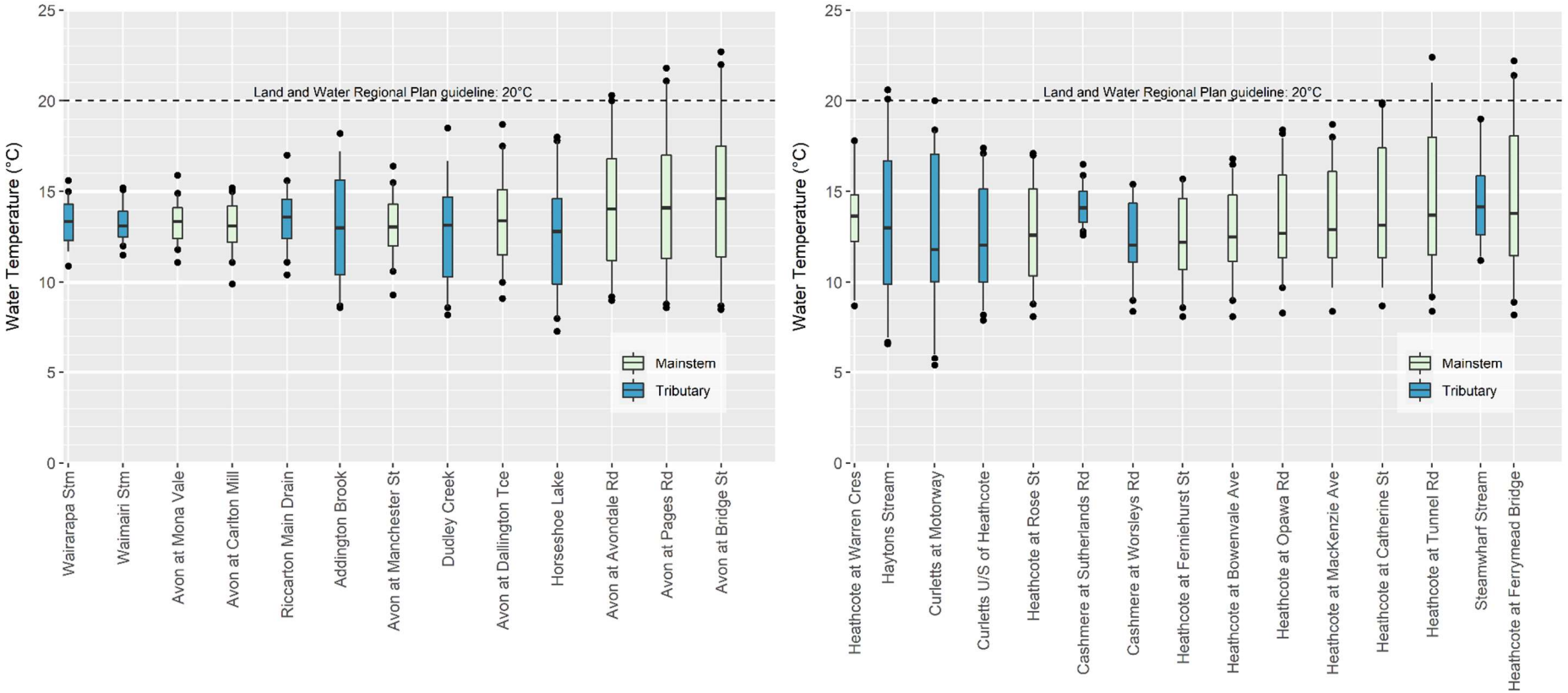

Figure xi (a). Temperature at the time of sampling at the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed line represents the Land and Water Regional Plan maximum guideline value (20°C, Environment Canterbury, 2019). The numbers in shaded boxes indicate samples that exceeded the y-axis.

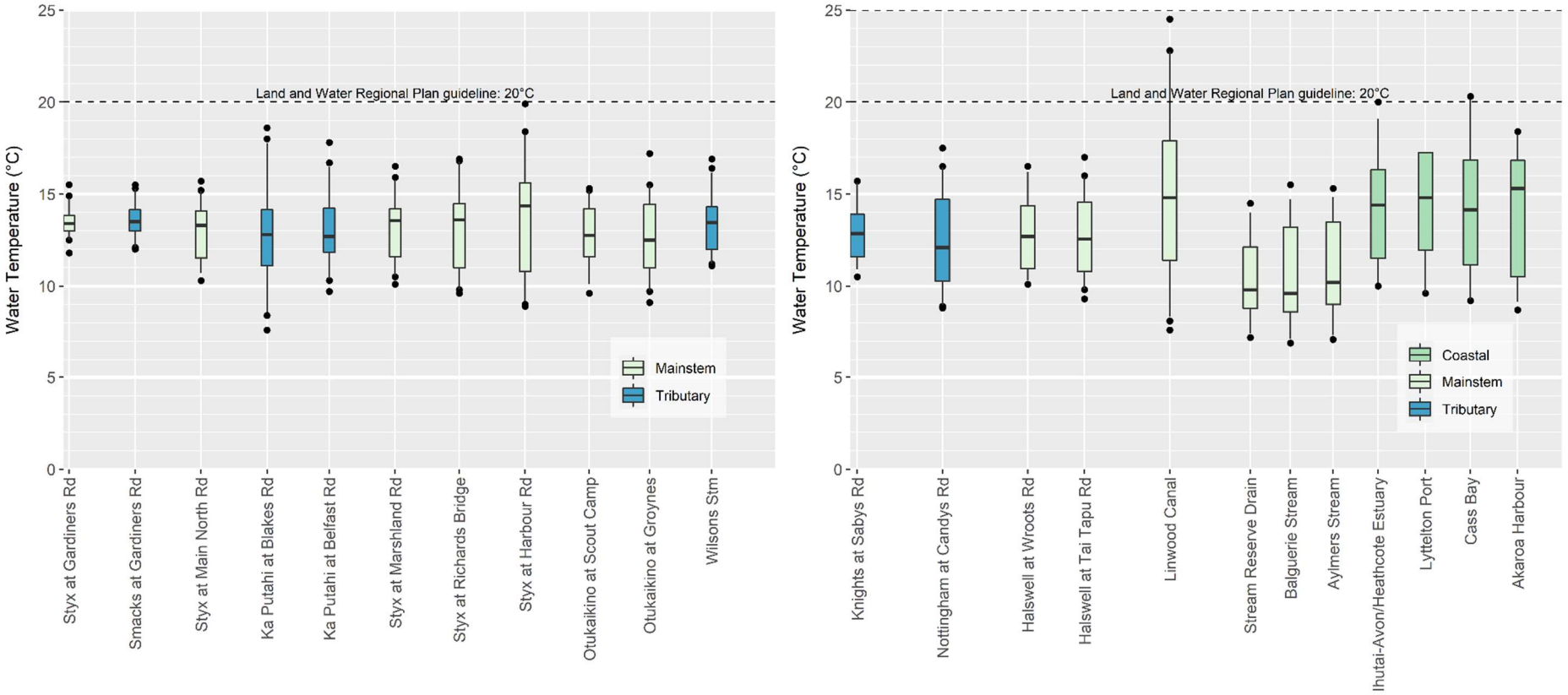

Figure xi (b). Temperature of the water at the time of sampling at the water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan maximum guideline value for waterway sites (20°C), and coastal sites (25°C), respectively (Environment Canterbury, 2019; RCEP, 2012).

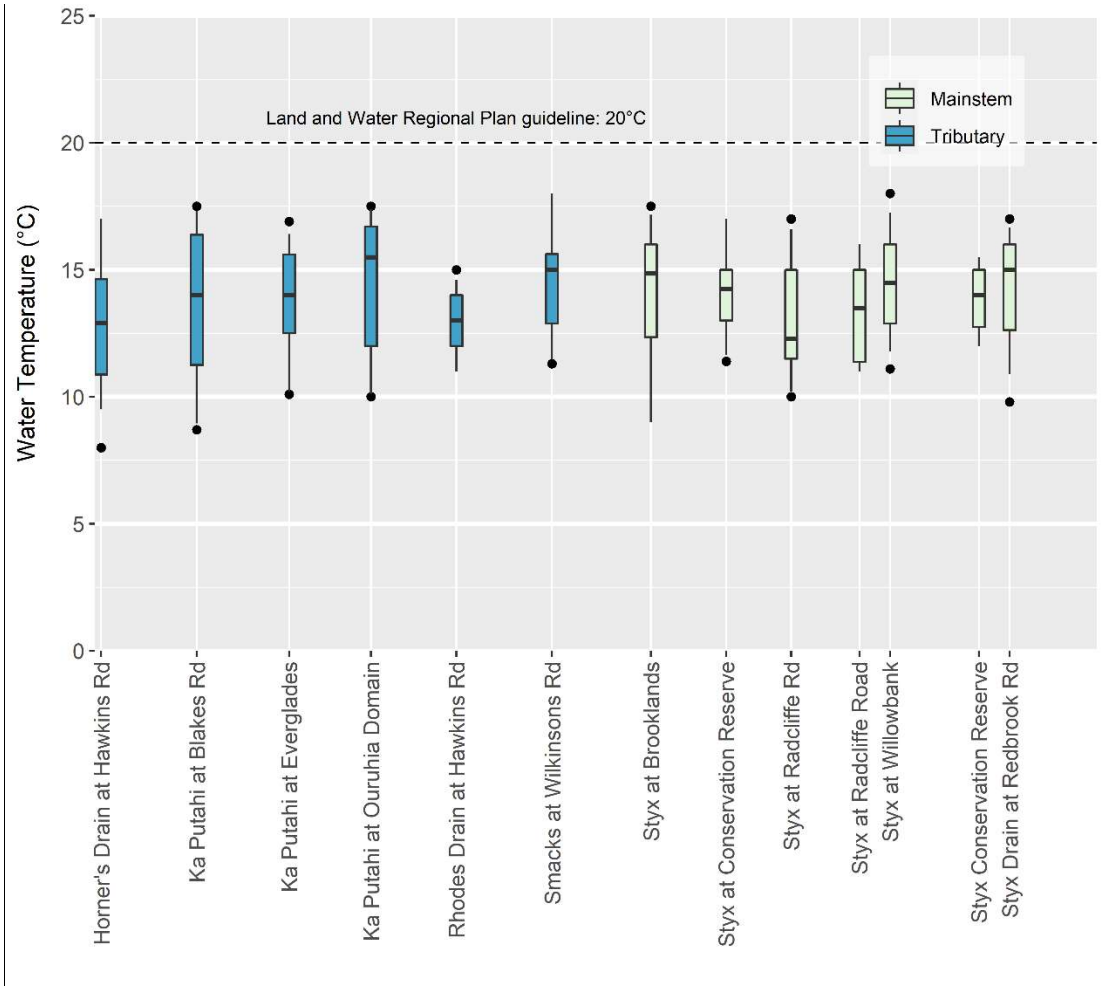

Figure xi (c). Temperature of the water at the time of sampling by the Styx Living Laboratory Trust volunteers for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan maximum guideline value (20 °C, Environment Canterbury, 2019).

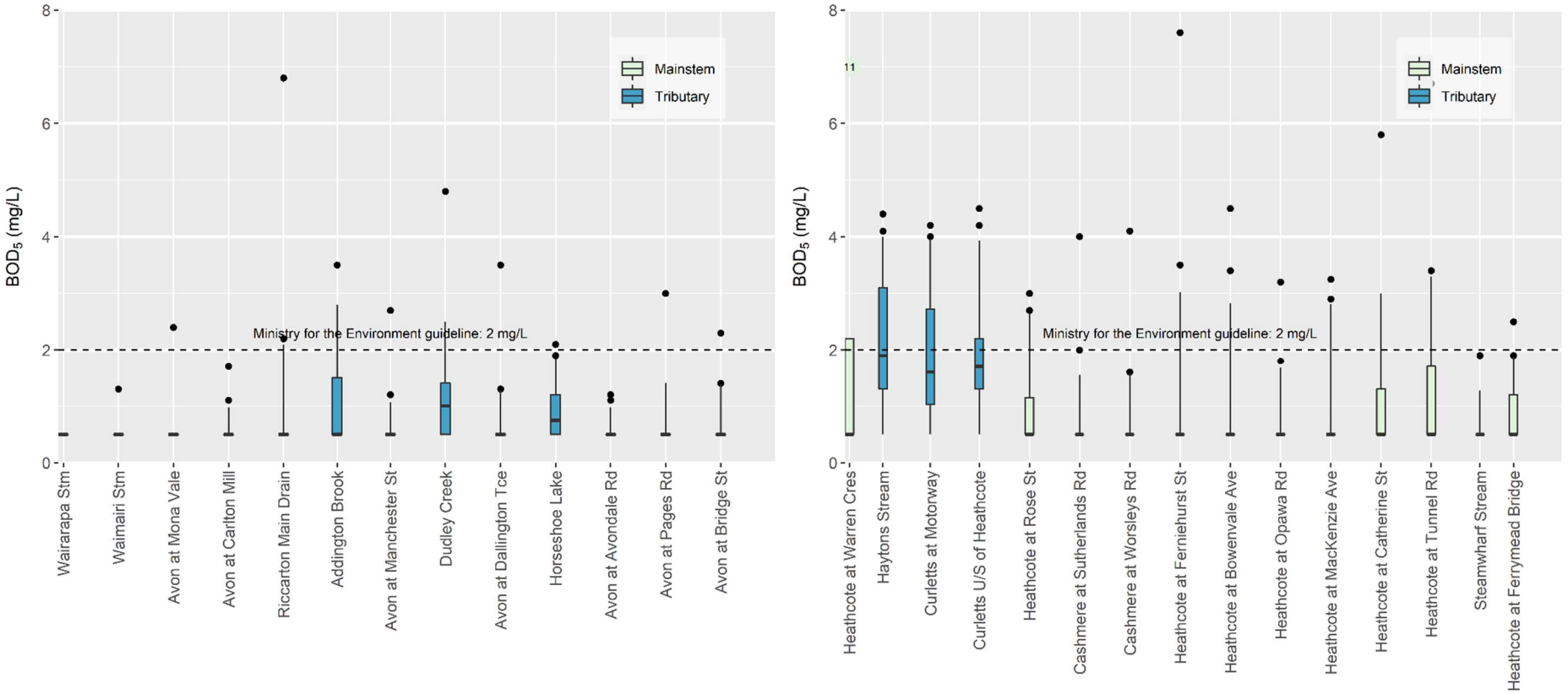

Figure xii (a). Biochemical Oxygen Demand (BOD_5) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the Ministry for the Environment guideline value (Ministry for the Environment, 1992). The Laboratory Limit of Detection was 1.0 mg/L, graphed as half this value (0.5 mg/L).

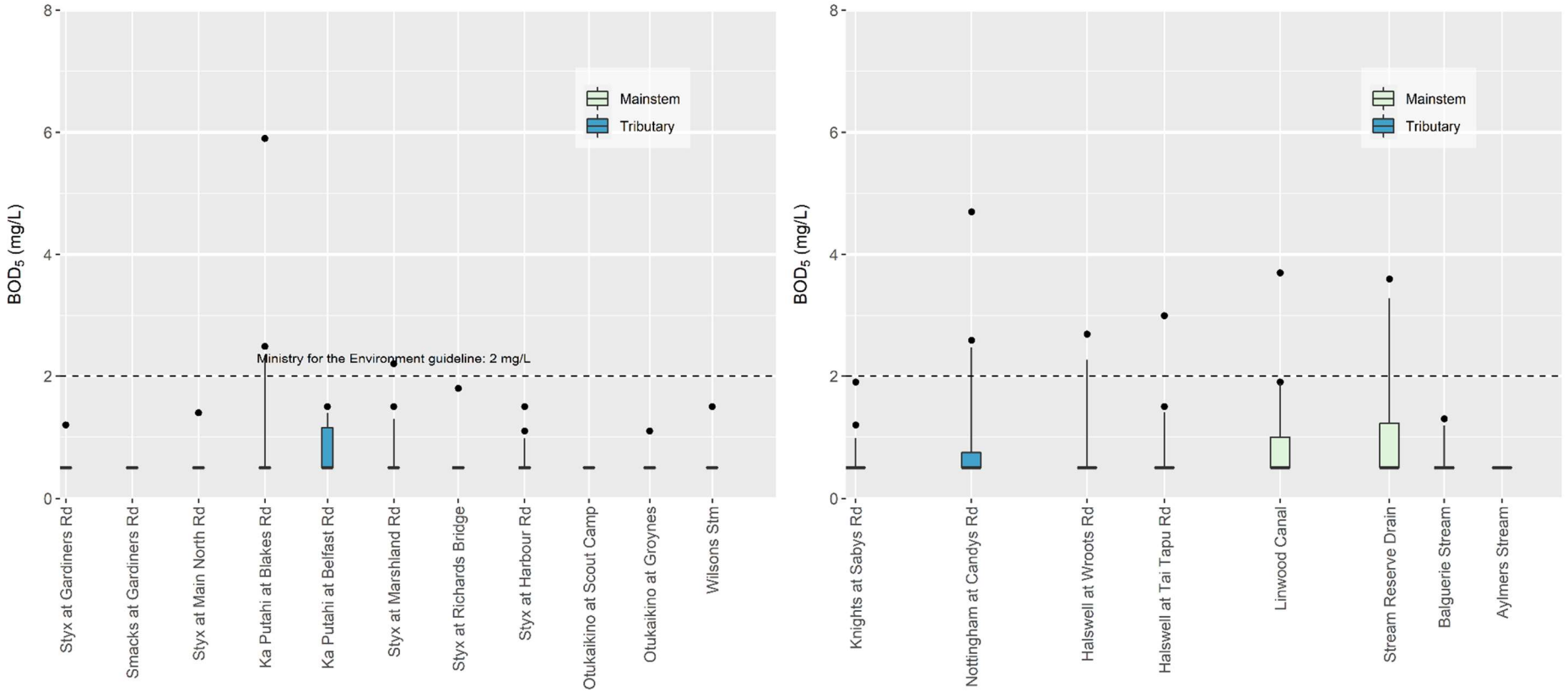

Figure xii (b). Biochemical Oxygen Demand (BOD_5) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the Ministry for the Environment guideline value (2 mg/L; Ministry for the Environment, 1992). The Laboratory Limit of Detection was 1.0 mg/L, graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

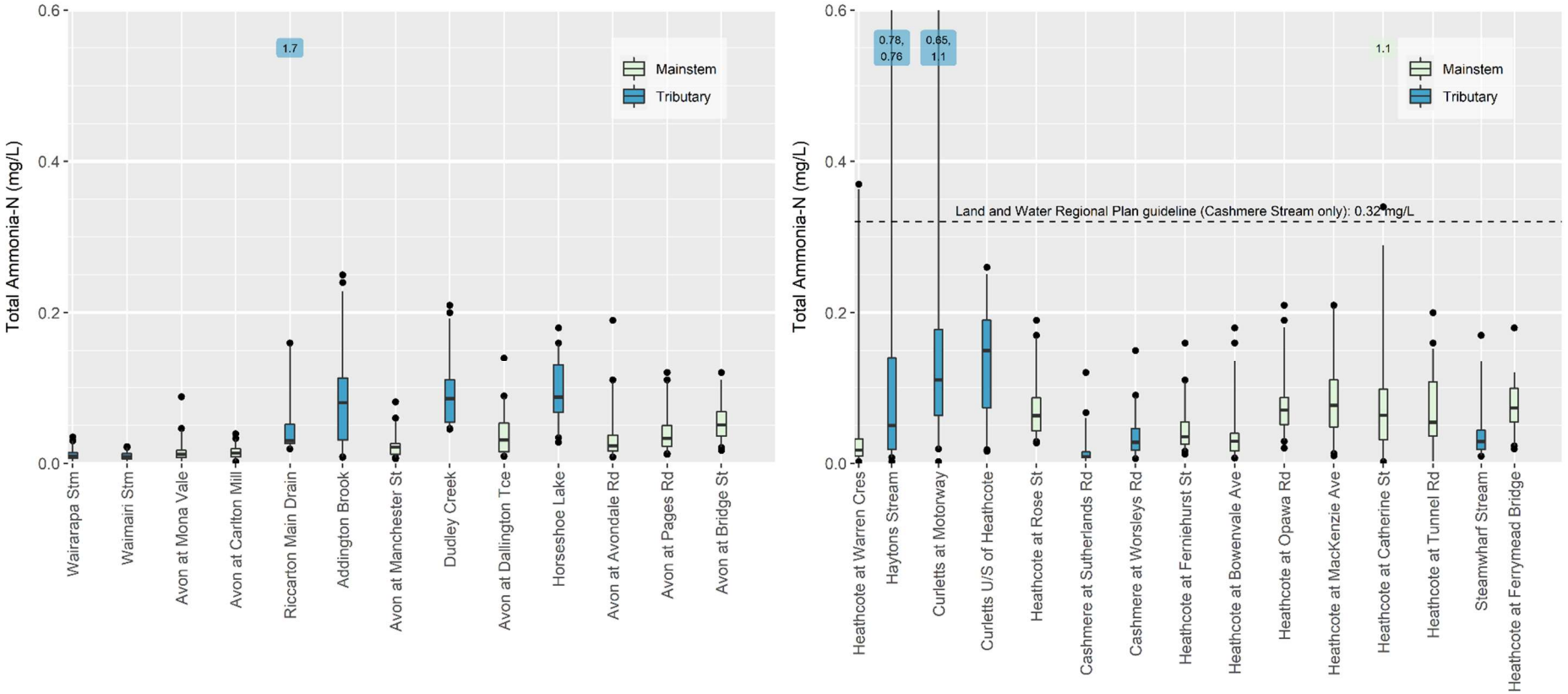

Figure xiii (a). Total ammonia concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The Land and Water Regional Plan guideline value (Ōtākaro-Avon catchment: 1.75 mg/L, Ōpāwaho-Heathcote: 1.88 mg/L, Environment Canterbury, 2019), which has been adjusted in accordance with median pH levels for the monitoring period (Ōtākaro-Avon catchment: 7.4, Ōpāwaho-Heathcote catchment: 7.3), are not presented on the graph as they are off the scale. The dashed line represents the Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L, Cashmere Stream only; Environment Canterbury, 2019). The Laboratory Limit of Detection was 0.005 mg/L – graphed as half this value (0.0025 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

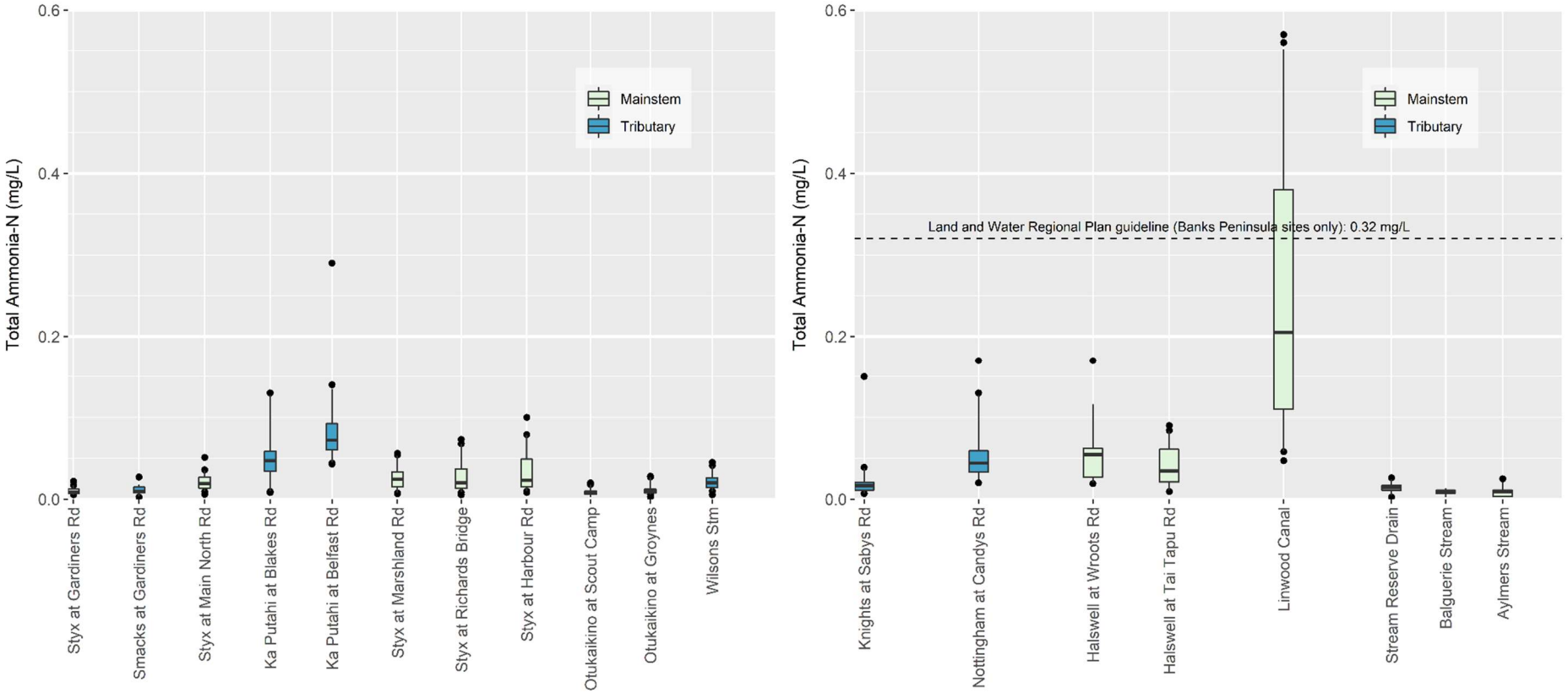

Figure xiii (b). Total ammonia concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2019 to December 2021. The Land and Water Regional Plan guideline values (Pūharakekenui-Styx catchment: 1.88 mg/L, Ōtūkaikino catchment: 1.99 mg/L, Huritini-Halswell catchment: 1.75 mg/L, Linwood Canal: 1.61 mg/L; Environment Canterbury, 2019), adjusted in accordance with median pH levels for the monitoring period (Pūharakekenui-Styx catchment: 7.2, Ōtūkaikino catchment: 7.2, Huritini-Halswell catchment: 7.4, Linwood Canal: 7.5), are not presented on the graph as they are off the scale. The Laboratory Limit of Detection was 0.005 mg/L – graphed as half this value (0.0025 mg/L).

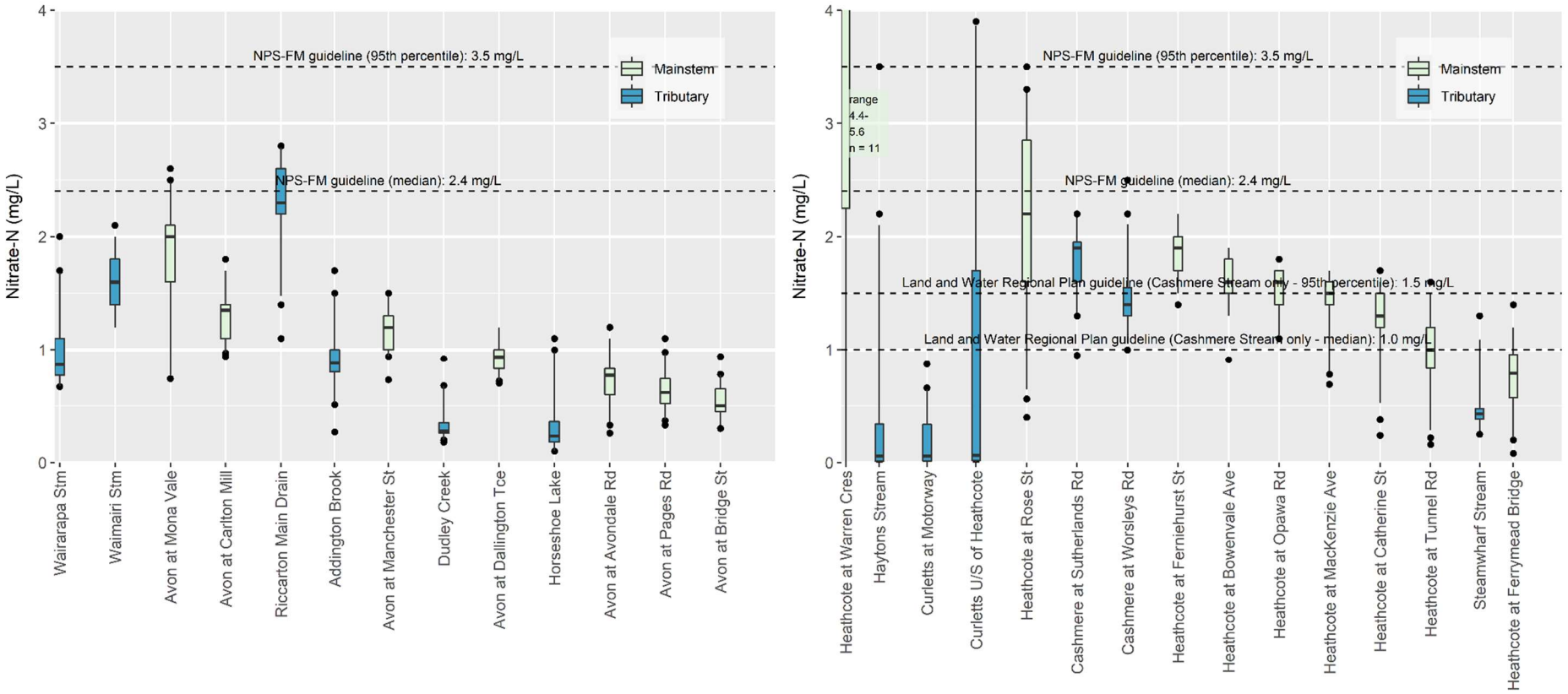

Figure xiv (a). Nitrate-nitrogen concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the NPS-FM median (2.4 mg/L) and 95th percentile (3.5 mg/L) guideline levels, or the Land and Water Regional Plan median (1.0 mg/L) and 95th percentile (1.5 mg/L) guideline for Cashmere Stream. The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

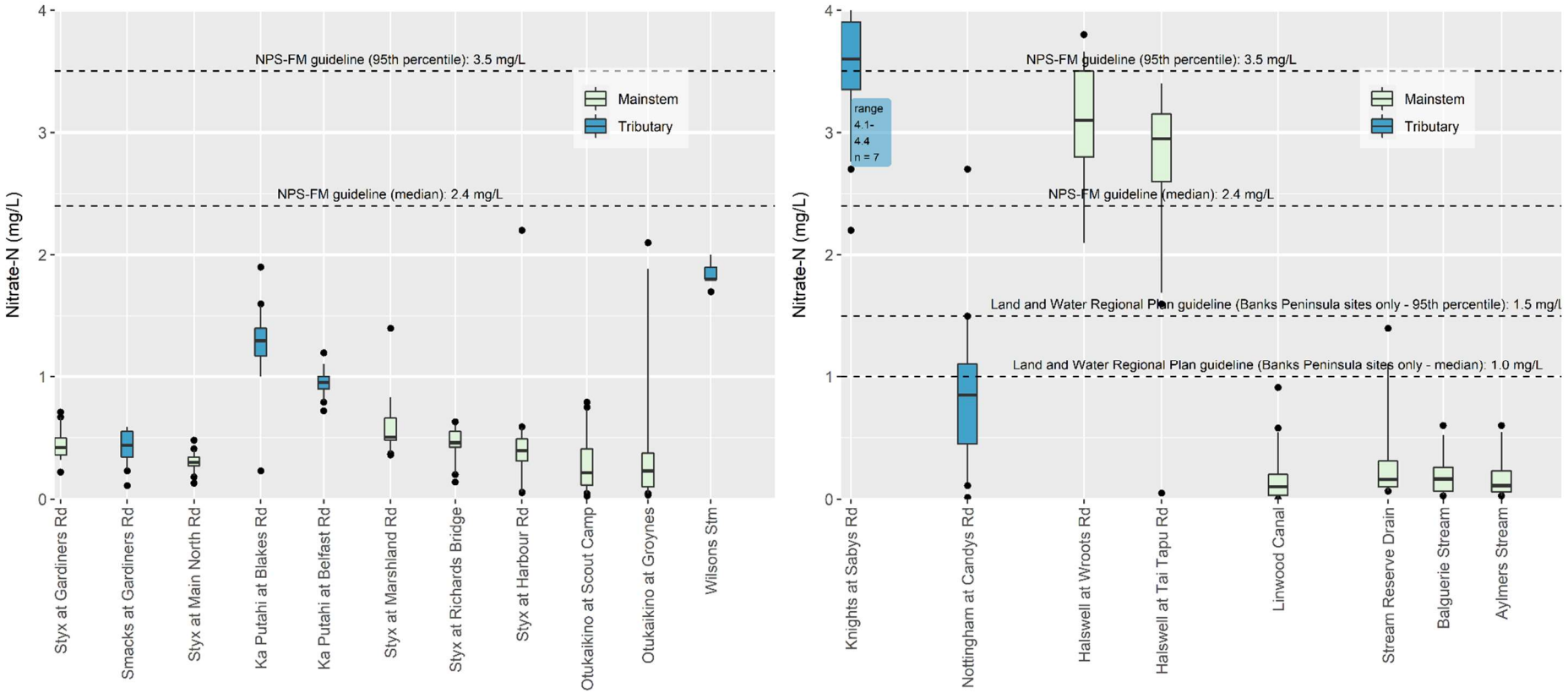

Figure xiv (b). Nitrate concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the NPS-FM median (2.4 mg/L) and 95th percentile (3.5 mg/L) guideline levels, or the Land and Water Regional Plan median (1.0 mg/L) and 95th percentile (1.5 mg/L) guideline for Banks Peninsula sites. The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

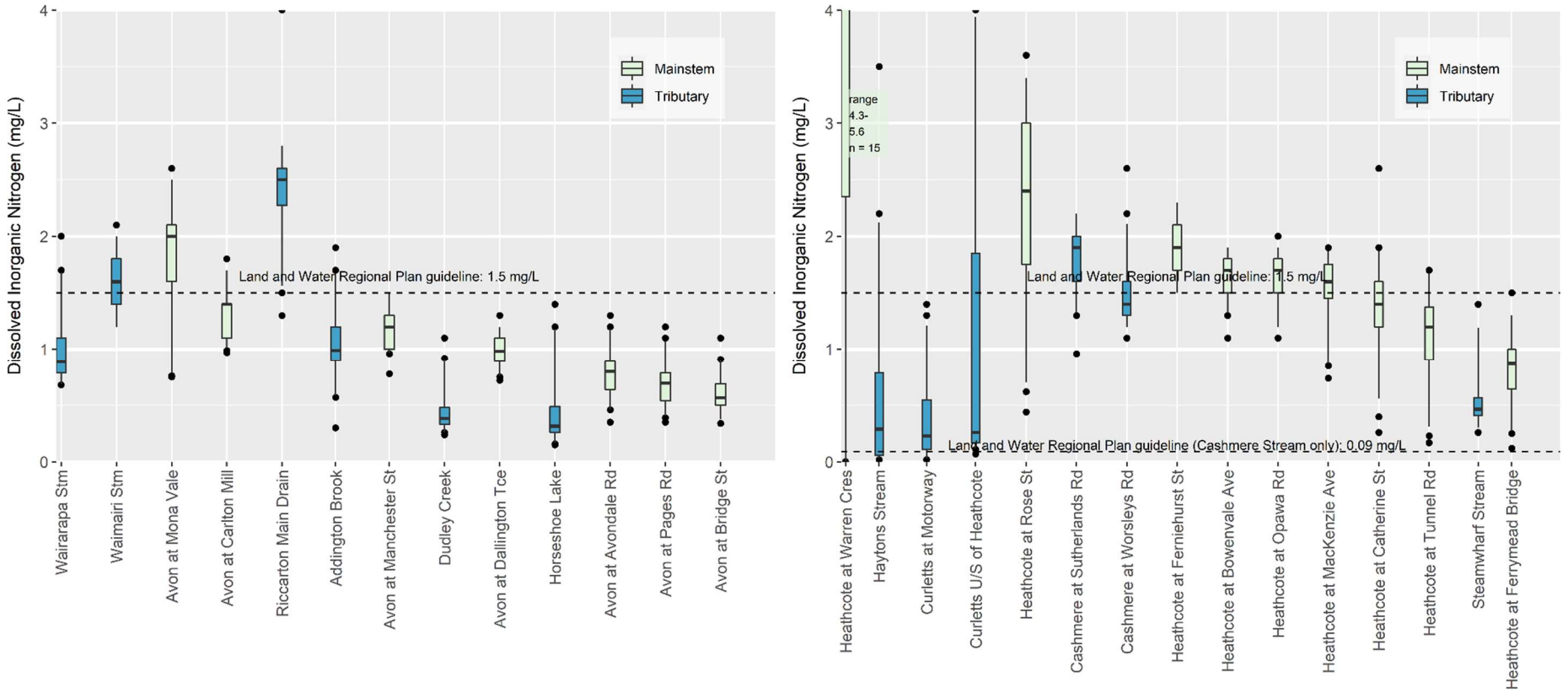

Figure xv (a). Dissolved Inorganic Nitrogen (DIN) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan guideline value of 1.5 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and 0.09 mg/L for Banks Peninsula waterways (Cashmere Stream only), respectively (Environment Canterbury, 2019). The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

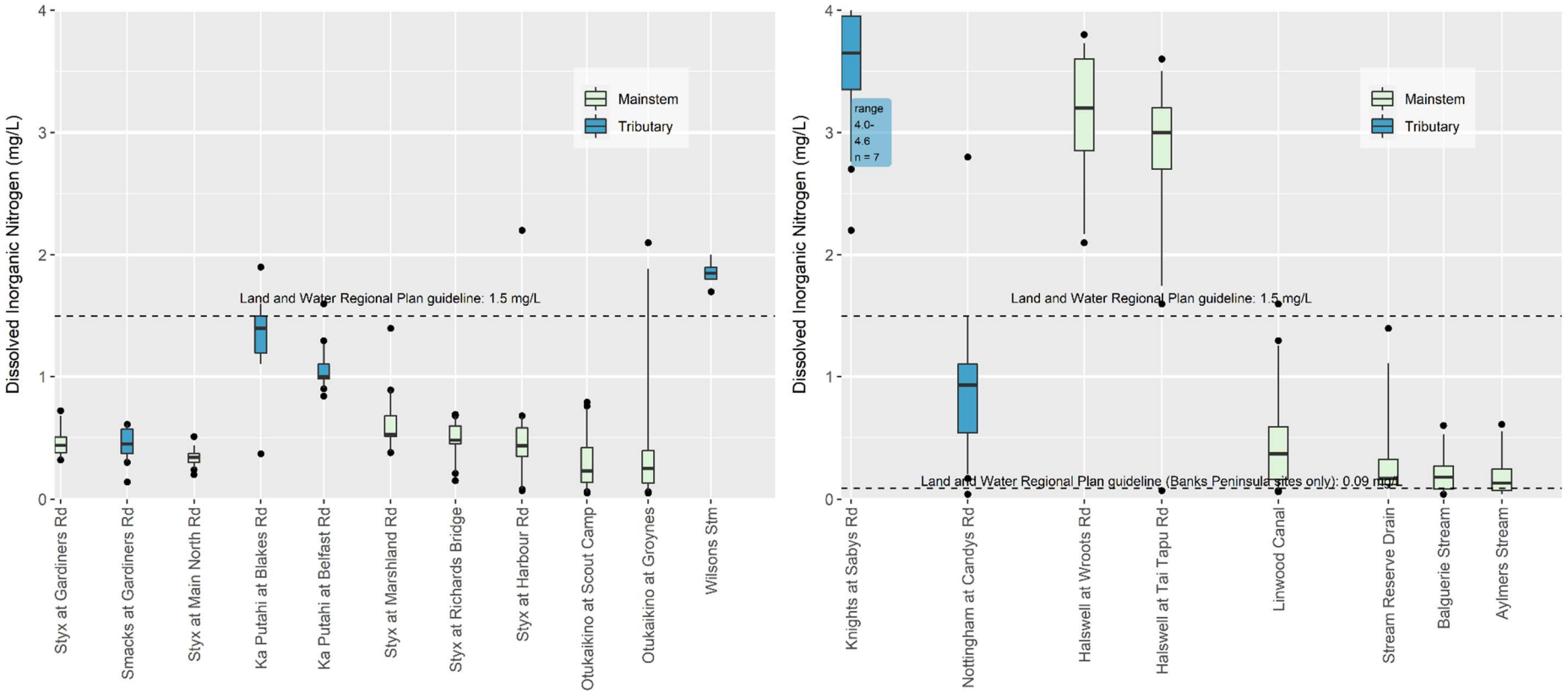

Figure xv (b). Dissolved Inorganic Nitrogen (DIN) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan guideline value of 1.5 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and 0.09 mg/L for Banks Peninsula waterways, respectively (Environment Canterbury, 2019). The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

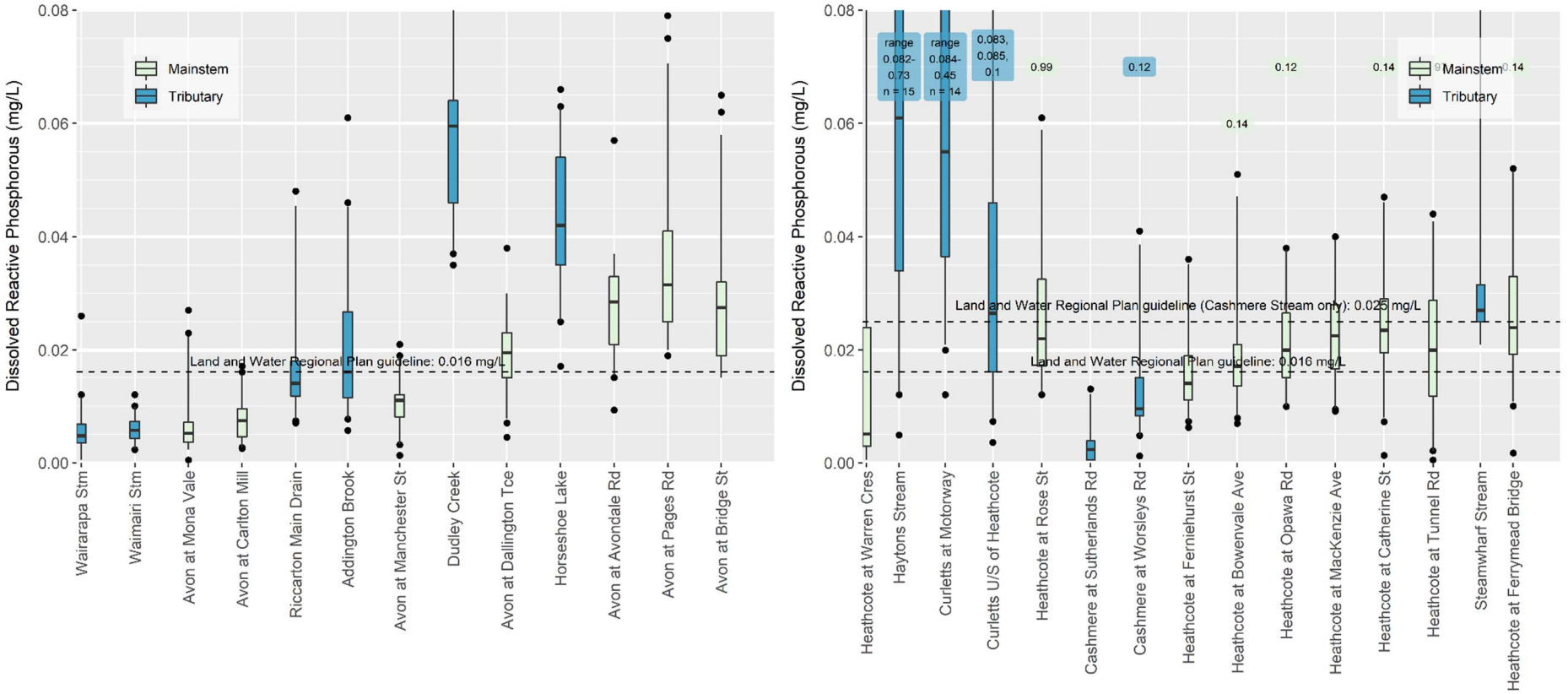

Figure xvi (a). Dissolved Reactive Phosphorus (DRP) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent either the Land and Water Regional Plan guideline value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, or the Land and Water Regional Plan guideline value of 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), (Environment Canterbury, 2019). The Laboratory Limit of Detection was 0.001 mg/L, graphed as half this value (0.0005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

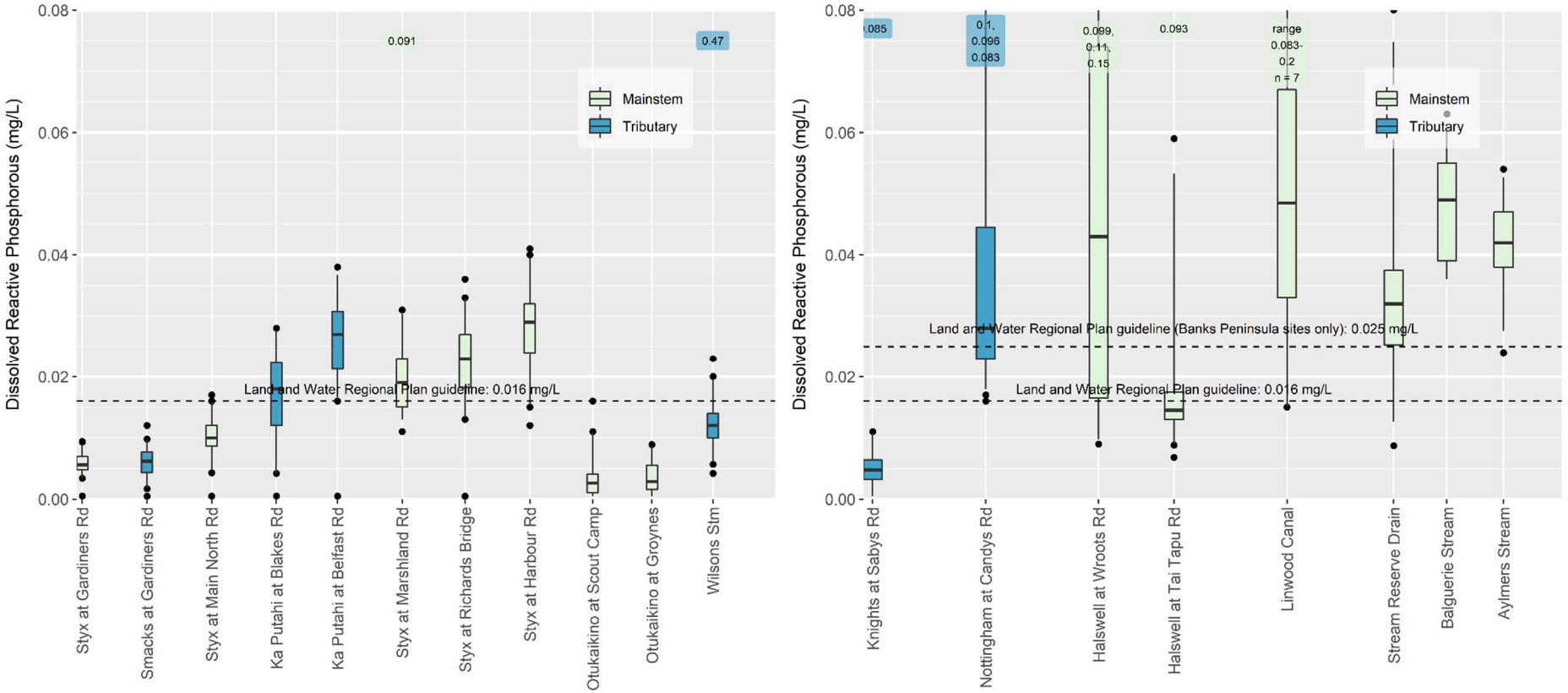

Figure xvi (b). Dissolved Reactive Phosphorus (DRP) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2019 to December 2021. The dashed lines represent either the Land and Water Regional Plan guideline value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, or the Land and Water Regional Plan guideline value of 0.025 mg/L for Banks Peninsula waterways, (Environment Canterbury, 2019). The Laboratory Limit of Detection was 0.001 mg/L, graphed as half this value (0.0005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

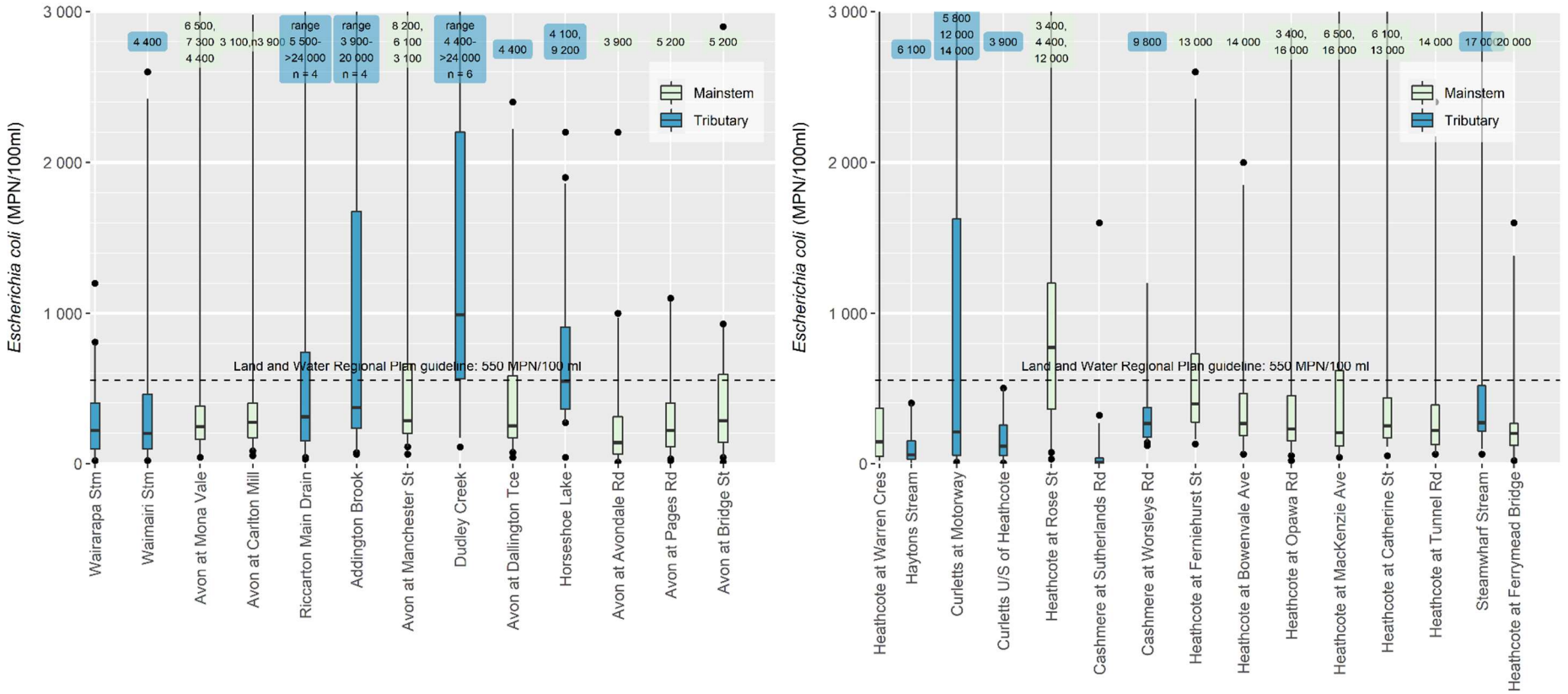

Figure xvii (a). *Escherichia coli* concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2019 to December 2021. The dashed lines represent the Land and Water Regional Plan guideline value of 550 MPN/100ml for 95% of samples for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2019). The Laboratory Limit of Detection varied depending on the necessary dilution of the sample, but all were graphed as half this value. The numbers in shaded boxes indicate samples that exceeded the y-axis.

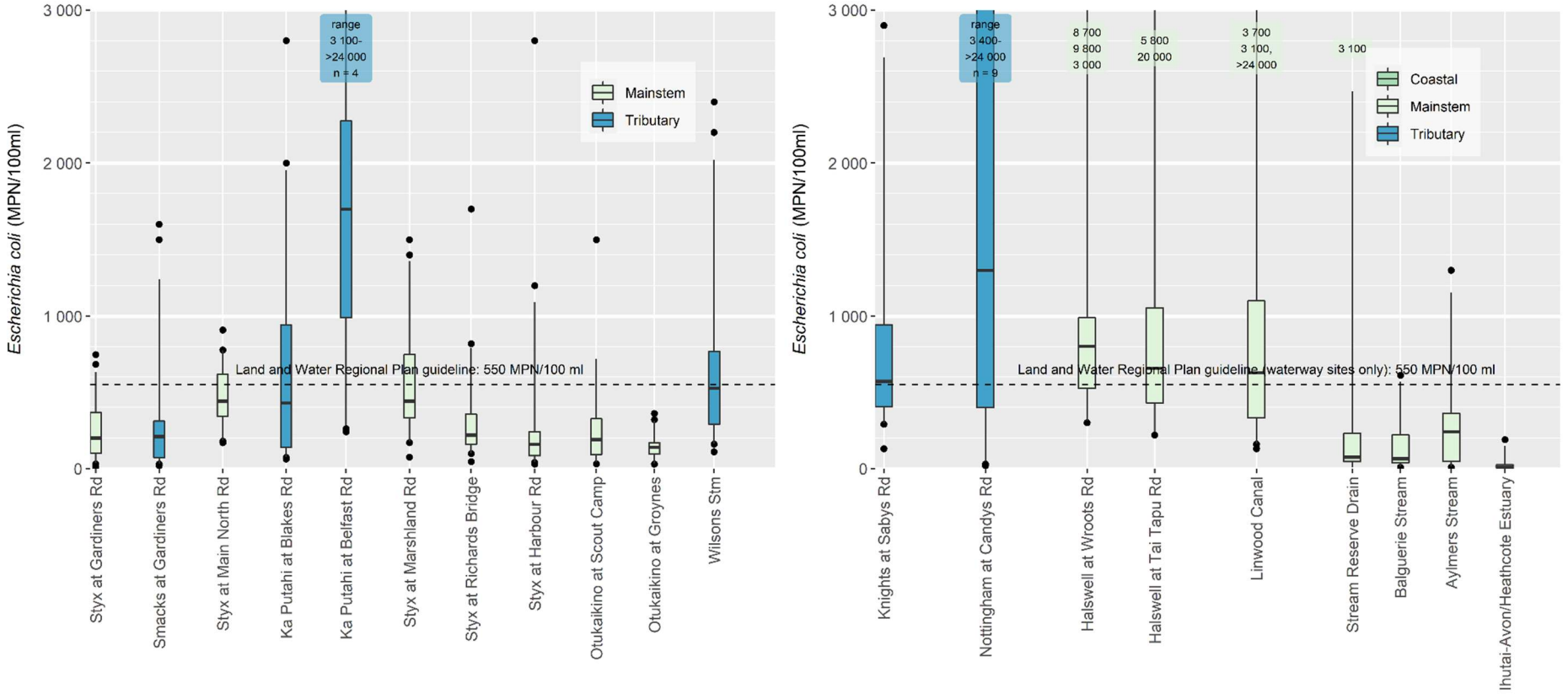

Figure xvii (b). *Escherichia coli* concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2019 to December 2021. Only one coastal site is monitored for this parameter. The dashed lines represent the Land and Water Regional Plan guideline value of 550 MPN/100ml for 95% of samples for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2019). No guideline for coastal areas exists. The Laboratory Limit of Detection varied depending on the necessary dilution of the sample, but all were graphed as half this value. The numbers in shaded boxes indicate samples that exceeded the y-axis.

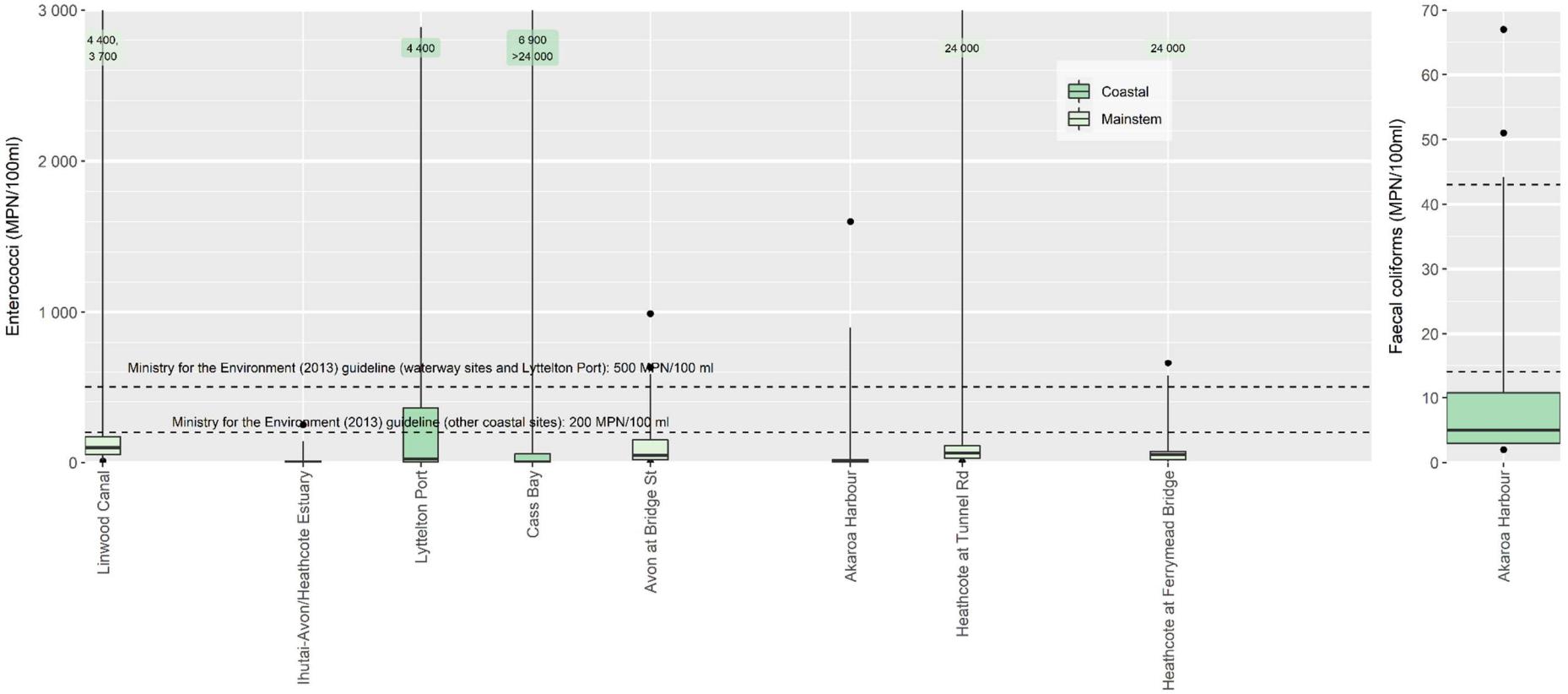

Figure xviii. Enterococci (left graph) and faecal coliforms (right graph) concentrations in water samples taken from the relevant strongly tidal and coastal sites for the monitoring period January 2019 to December 2021. On the left graph the dashed lines either represent the Ministry for the Environment guideline value of 500 MPN/100ml for waterway and Lyttelton Port sites, or the Ministry for the Environment guideline value of 200 MPN/100ml for coastal sites (Ministry for the Environment, 2013). On the right graph, the top dashed line represents the 90th percentile guideline (43 MPN/100ml) and the bottom dashed line represents the Ministry for the Environment median guideline (14 MPN/100ml) for Akaroa Harbour (Ministry for the Environment, 2013). Laboratory Limit of Detections for enterococci and faecal coliforms was 10 MPN/100ml and 1 MPN/100ml, respectively, graphed as half this value (5 MPN/100ml and 0.5 MPN, respectively). The numbers in shaded boxes indicate samples that exceeded the y-axis.

Appendix F

Table i. Direction of significant temporal trends for parameters monitored monthly at each of the sites in the Ōtākaro-Avon River catchment. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. N/A = Not Applicable due to not having enough long-term monitoring data, or not being tested for that parameter.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	DIN	*E. coli*	Enterococci
Wairarapa Stm			↓ 12%	↓ 9%							↓		↓ 1%		N/A
Waimairi Stm				↓ 7%							↓		↓ 2%		N/A
Avon at Mona Vale				↓ 7%							↓		↓ 2%		N/A
Avon at Carlton Mill				↓ 8%				N/A	↓ 1%		↓		↓ 3%		N/A
Riccarton Main Drain				↓ 6%		↑ 2%				↑ 1%	↓		↑ 2%		N/A
Addington Brook			↑ 7%	↓ 3%					↓ 1%		↓	↓ 4%	↓ 1%	↑ 5%	N/A
Avon at Manchester St				↓ 6%						↑ 1%	↓	↓ 4%	↓ 3%	↓ 2%	N/A
Dudley Creek		↓ 12%				↓ 1%			↓ 1%	↑ 1%	↓ 2%	↓ 4%	↓ 4%		N/A
Avon at Dallington Tce							↓ 2%	↓ 5%	↑ 1%	↑ 1%	↓	↓ 5%	↓ 2%		N/A
Horseshoe Lake			↓ 7%								↓	↓ 2%	↓ 3%		N/A
Avon at Avondale Rd				↓ 3%				N/A			↓	↓ 4%	↓ 5%		N/A
Avon at Pages Rd			↓ 8%	↓ 2%		↑ 5%		↓ 2%	↑ 1%	↑ 1%	↓	↓ 3%	↓ 3%	↑ 4%	N/A
Avon at Bridge St				↓ 5%	↑ 1%	↑ 5%			↑ 1%	↑ 1%	↓	↓ 7%	↓ 3%	↑ 4%	↓ 6%

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Table ii. Direction of significant temporal trends analyses for parameters monitored monthly at each of the sites in the Ōpāwaho-Heathcote River catchment. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. N/A = Not Applicable due to not having enough long-term monitoring data, or not being tested for that parameter.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	DIN	*E. coli*	Enterococci
Haytons Stream				↓14%	↓1%		↑ 3%	↑ 5%	↓ 2%		↓5%	↓ 9%	↓11%		
Curlett at Motorway	↑ 10%		↑ 16%			↑ 2%	↑ 8%	N/A	↓ 2%				↓24%		N/A
Curlett U/S of Heathcote	↓13%	↓13%	↓11%						↓ 3%				↓3%	↓ 12%	N/A
Heathcote at Rose St	↓3%			↓ 8%							↓ 7%		↓ 1%		N/A
Cashmere at Sutherlands Rd			↓ 10%	↓ 16%					↓ 2%		↓		↓ 3%		N/A
Cashmere at Worsleys Rd				↓ 6%							↓		↓ 1%	↓ 3%	N/A
Heathcote at Ferniehurst St				↓ 7%							↓		↓ 1%		N/A
Heathcote at Bowenvale Ave				↓ 6%							↓				N/A
Heathcote at Opawa Road				↓ 6%					↓ 1%		↓				N/A
Heathcote at Mackenzie Ave				↓ 8%				N/A		↑ 1%	↓				N/A
Heathcote at Catherine St				↓ 8%		↑ 5%		N/A		↑ 1%	↓	↓ 3%	↓ 1%		N/A
Heathcote at Tunnel Rd				↓ 11%		↑ 7%	↓ 3%	↓ 5%		↑ 1%	↓	↓ 8%			N/A
Heathcote at Ferrymead Bridge			↑ 10%	↓ 15%				↓ 2%	↑ 1%	↑ 1%	↓ 3%	↓ 13%	↓ 3%		↓ 11%

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Table iii. Direction of significant trends for parameters monitored monthly at each of the sites in the Huritini-Halswell River catchment and Linwood Canal. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. N/A = Not Applicable due to not having enough long-term monitoring data, or not being tested for that parameter.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	DIN	*E. coli*	Enterococci
Knights at Sabys Rd			↓ 8%	↓ 9%		↓ 2%					↓	↓ 7%	↓ 4%		N/A
Nottingham at Candys Rd			↑ 6%			↓ 3%				↑ 1%	↓		↓ 6%	↑ 5%	N/A
Halswell River at Tai Tapu Rd			↓ 10%	↓ 2%		↓ 1%	↑ 5%		↑ 1%	↑ 1%	↓		↓ 3%	↑ 10%	N/A
Linwood Canal				↓ 4%		↑ 8%		↓ 4%	↓ 1%	↑ 1%	↓ 8%		↓ 5%		↓ 13%

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Table iv. Direction of significant trends for parameters monitored monthly at each of the sites in the Pūharakekenui-Styx and Ōtūkaikino River catchments. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. N/A = Not Applicable due to not having enough long-term monitoring data.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	DIN	*E. coli*
Styx at Gardiners Rd			↓ 10%	↓ 6%		↓ 1%					↓		↓ 7%	↑ 7%
Smacks at Gardiners Rd			↓ 12%	↓ 5%		↓ 1%		↓ 8%		↑ 1%	↓		↓ 3%	
Styx at Main North Rd				↓ 3%		↓ 1%		↓ 4%	↓ 1%		↓	↓ 2%	↓ 5%	↑ 2%
Kā Pūtahi at Blakes Rd						↑ 1%		↑ 3%		↓ 1%	↓			
Kā Pūtahi at Belfast Rd				↓ 4%				↓ 3%	↑ 1%	↑ 1%	↓ 4%	↓ 4%	↑ 1%	
Styx at Marshland Rd				↓ 2%					↑ 1%	↑ 1%	↓			
Styx at Richards Bridge				↓ 4%		↓ 1%			↑ 1%	↑ 1%	↓		↓ 1%	
Styx at Harbour Rd				↓ 2%						↑ 1%	↓		↓ 3%	
Ōtūkaikino at Groynes			↓ 13%	↓ 14%				↓ 16%	↓ 1%	↑ 1%	↓	↓ 3%	↓ 5%	
Ōtūkaikino at Scout Camp				↓ 13%	↓ 1%				↓ 1%				↑ 10%	↑ 25%
Wilsons Stm						↑ 1%	↑ 13%	↑ 16%				↑ 6%	↑ 4%	↑ 14%

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD5 = Biochemical Oxygen Demand, and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Table v. Direction of significant trends for parameters monitored by the Styx Living Laboratory Trust, with sufficient data to run Time Trends analysis.

Site	Clarity	pH	EC	Temp
Smacks at Wilkinsons Rd		↓ 1%		
Styx at Willowbank	↓ 1%	↑ 1%		↑ 1%
Styx at Conservation Reserve		↑ 1%	↑ 1%	↑ 1%
Styx Drain			↓ 11%	
Styx at Radcliffe Rd	↓ 1%	↑ 1%		↑ 1%
Kā Pūtahi at Blakes Rd		↓ 2%	↓ 8%	
Kā Pūtahi at Ouruhia Domain		↑ 1%	↑ 1%	↑ 1%
Kā Pūtahi at Everglades		↑ 1%	↑ 1%	↑ 1%
Styx at Brooklands	↓ 1%	↑ 1%		↑ 1%

Notes: EC = Electrical Conductivity. Blank cells indicate no significant upwards or downwards trends.

Appendix G

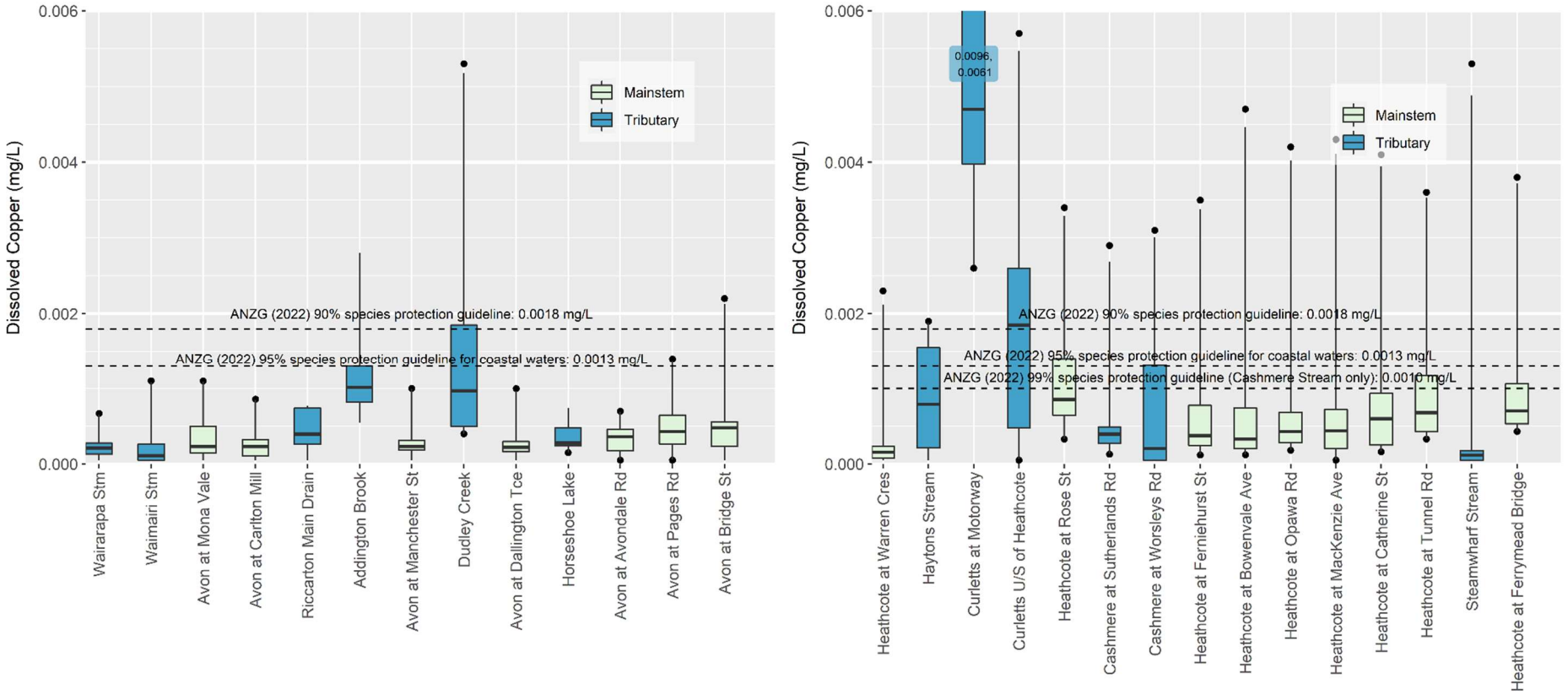

Figure i (a). Dissolved copper concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2021. The dashed lines represent the ANZG (2022) guideline values. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

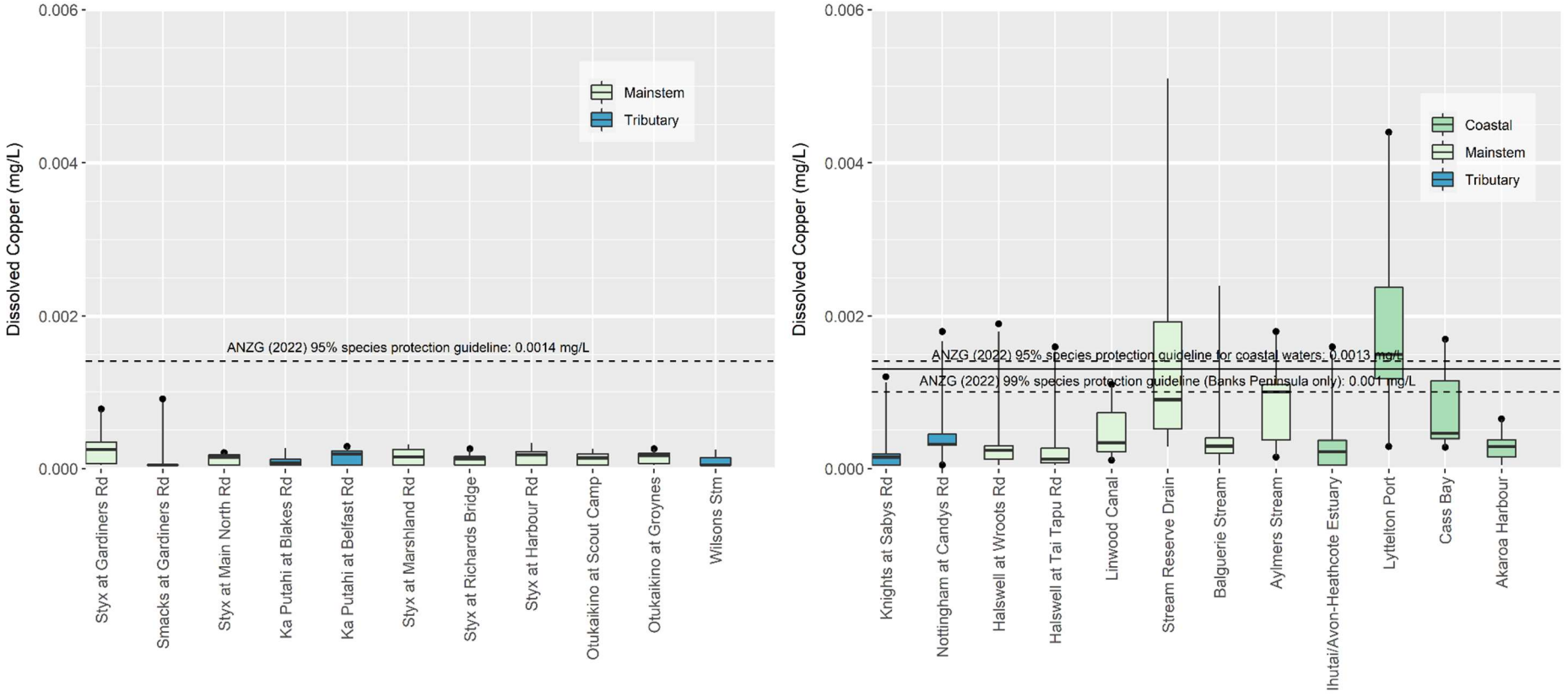

Figure i (b). Dissolved copper concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula, and coastal sites (right graph), for the monitoring period January to December 2021. The dashed lines represent the ANZG (2022) waterway guideline values. The solid line represents the ANZG (2022) coastal guideline. The strongly tidal Linwood Canal site should be compared to the more conservative coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L).

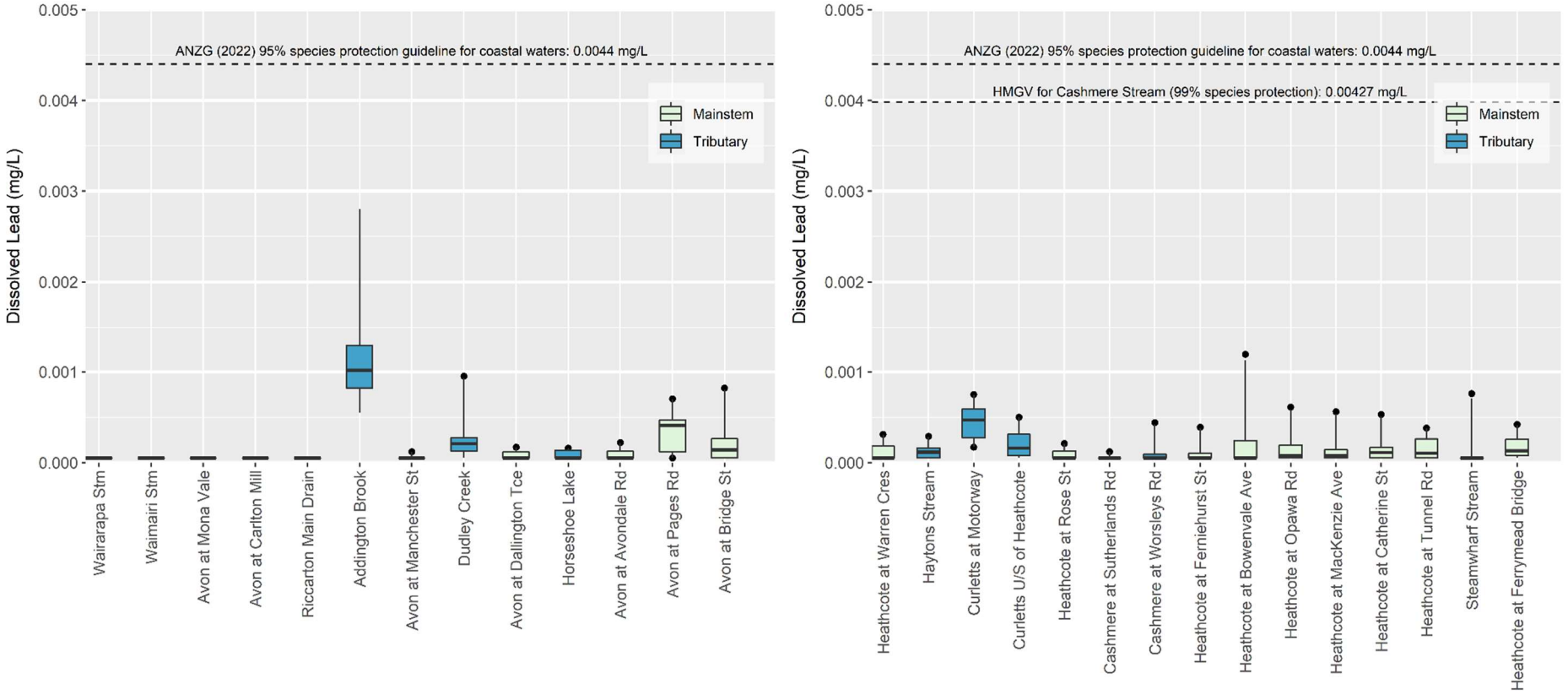

Figure ii (a). Dissolved lead concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2021. The dashed lines represent the ANZG (2022) Hardness Modified Guideline Values (HMGV). The 90% protection HMGV for the Ōtākaro-Avon River (0.01539 mg/L) and the Ōpāwaho-Heathcote River (0.02388 mg/L) are not shown as they are off the scale. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L).

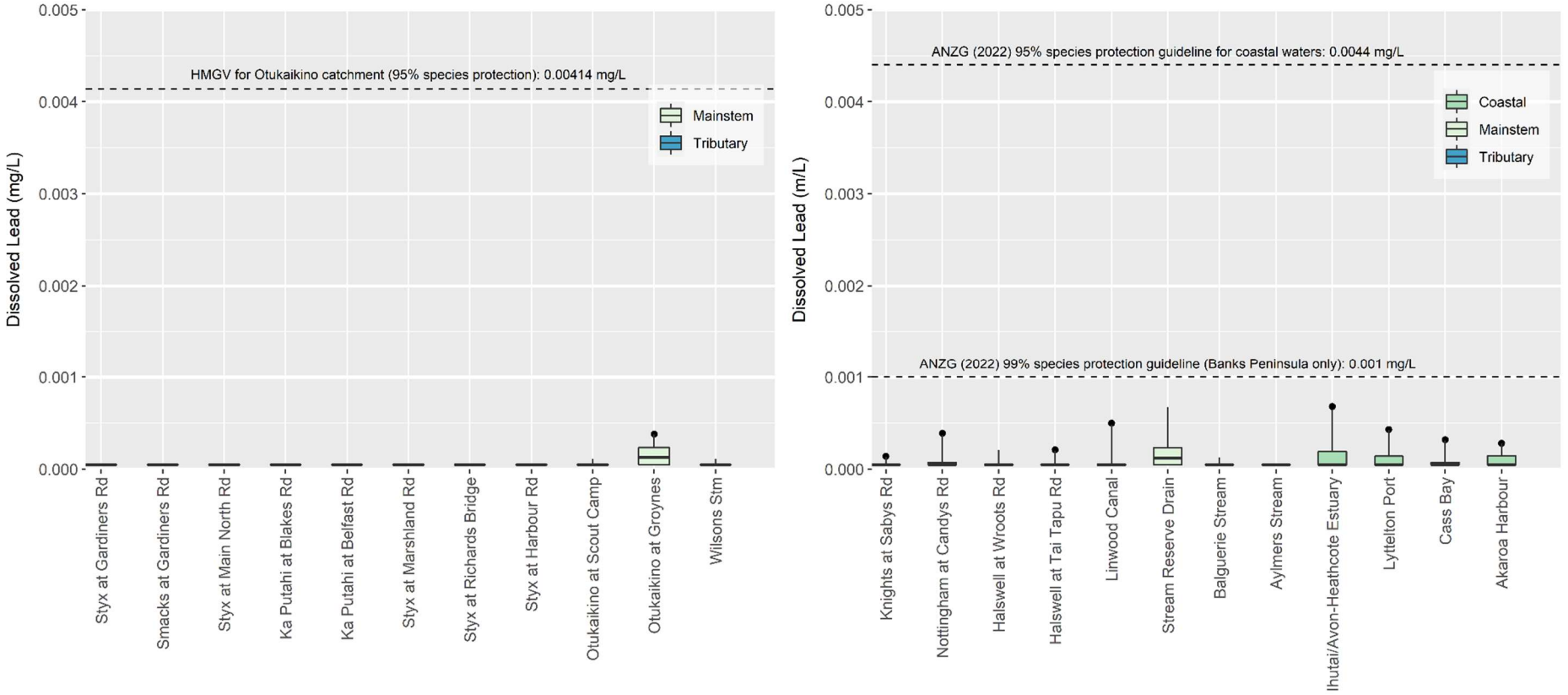

Figure ii (b). Dissolved lead concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2020. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. The 95% protection HMGV for the Pūharakekenui-Styx River (0.00601 mg/L) and the Huritini-Halswell River (0.01089 mg/L) are not shown as they are off the scale. The strongly tidal Linwood Canal site is compared to the more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L).

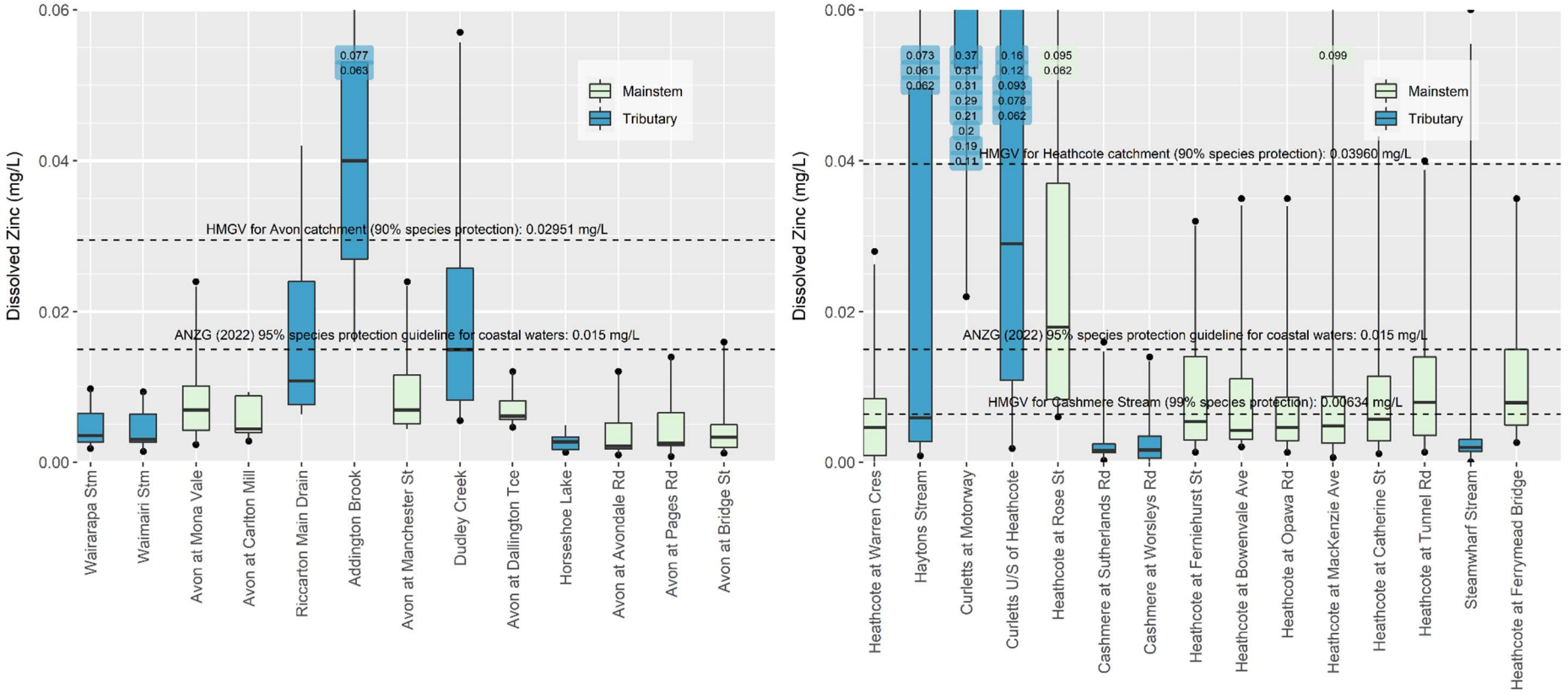

Figure iii (a). Dissolved zinc concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2021. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

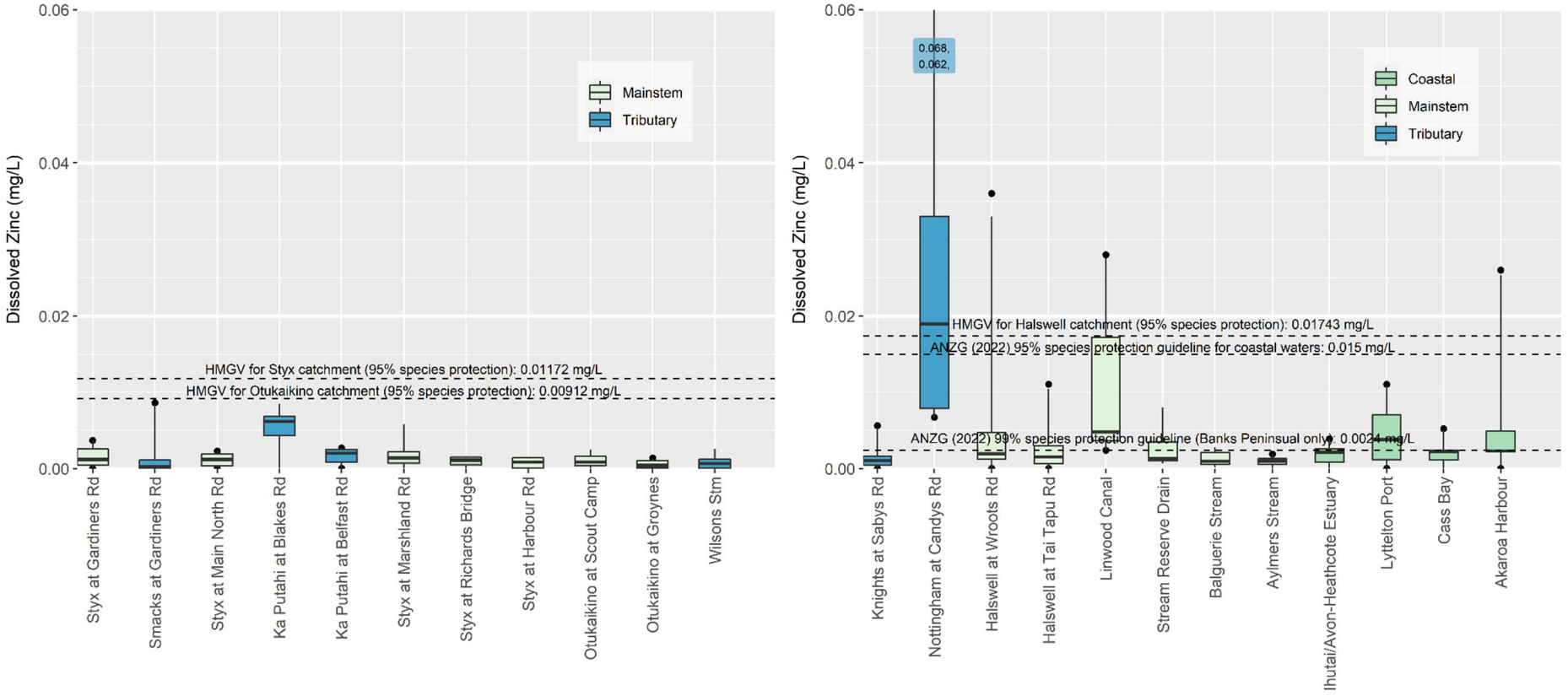

Figure iii (b). Dissolved zinc concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2021. The dashed lines represent the ANZG (2022) guideline values. The strongly tidal Linwood Canal site is compared to the more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

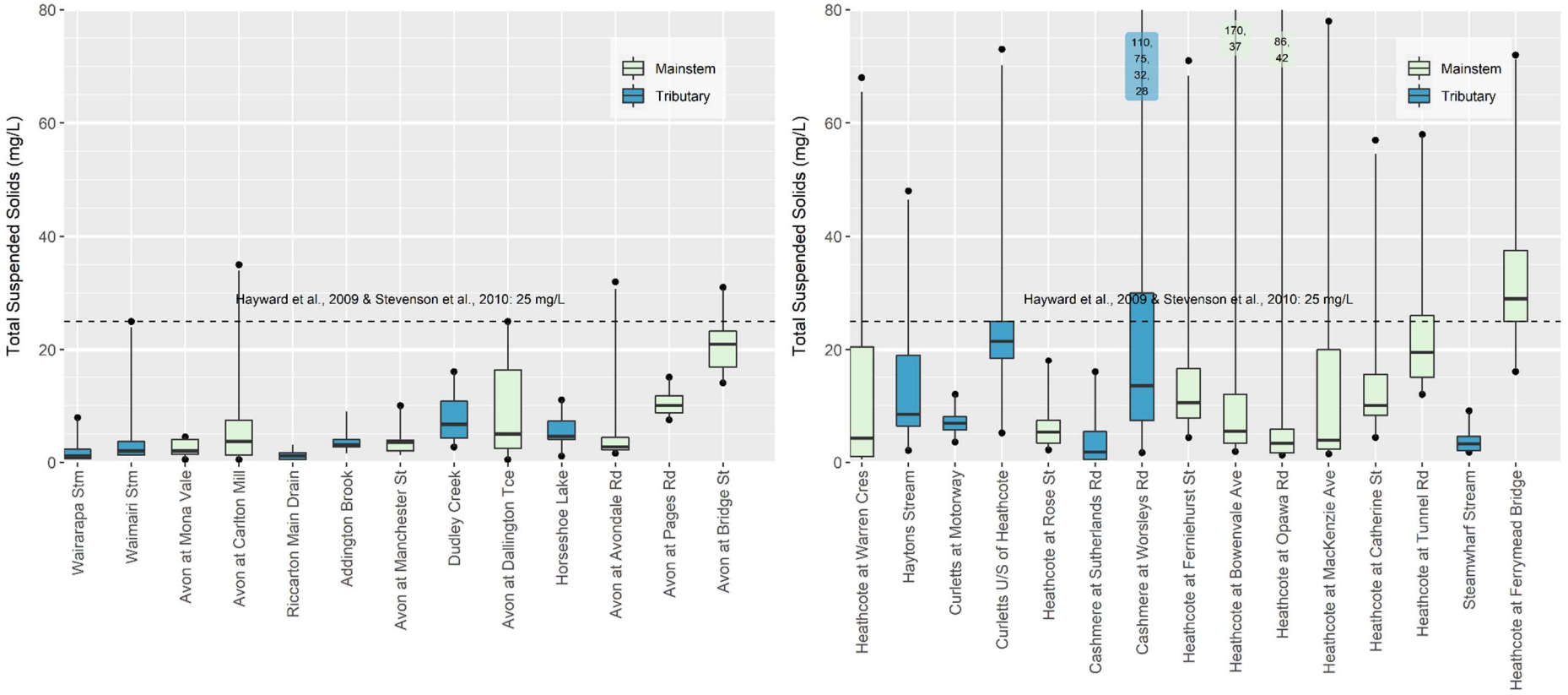

Figure vi (a). Total Suspended Solid (TSS) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2021. The dashed lines represent the guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

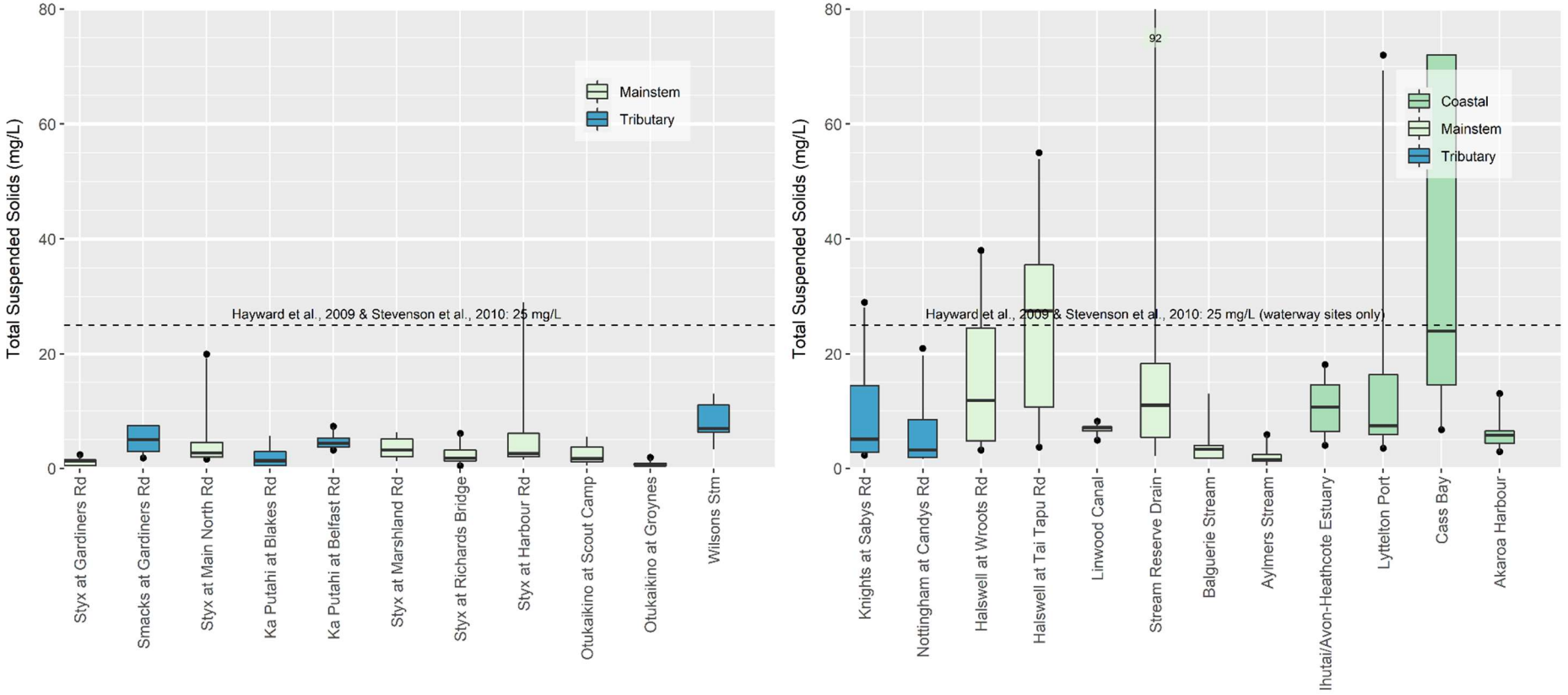

Figure vi (b). Total Suspended Solid (TSS) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2021. The dashed lines represent the waterway guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.