Hydrotoxy
RESEARCH

Implementation of bioavailability-based metal guideline values for Australia and New Zealand

Part 1: Water chemistry data collation

Report prepared by Jenni Gadd, Hydrotoxy Research, Aleicia Holland, Jenny Stauber (La Trobe University), Rick van Dam (WQadvice)

For any information regarding this report please contact:
Jenni Gadd
Jenni@hydrotoxy.co.nz

This report should be cited as:

Gadd J.B., Holland A., Stauber J.L., van Dam R.A. (2026) Implementation of bioavailability-based metal guideline values for Australia and New Zealand. Part 1: Water chemistry data collation. Report prepared for Metals Environmental Research Associations. (47 pp).

Version	Version number	Date
Draft version for wca	1.0	8/11/2024
Draft version updated for comments	1.1	24/11/2024
Final version with sponsor feedback incorporated	1.2	20/03/2025
Correction of errors in Tables 3.4 and 3.5	1.3	11/10/2025
Further revised version including correction of errors	1.4	09/01/26
Further revised version including correction of minor errors	1.5	11/03/2026

Executive Summary

Bioavailability-based draft default guideline values (DGVs) for metals (i.e., copper, nickel, zinc) for use in Australia and New Zealand have recently been developed. As part of a complementary project to the development of the draft DGVs, a tiered assessment framework has been developed to assist with implementation and use of the DGVs throughout the region. This required development of a DGV for use at Tier 1 of the framework, to which all monitoring samples can be compared for an initial screening assessment. The DGV is to be developed following a similar process as used in Europe, whereby regionwide environmental quality standards were calculated from a probability distribution that identifies the waters with the highest metal bioavailability. The process for deriving the metal DGVs requires, firstly, the collation of water chemistry data from around Australia and New Zealand, and secondly, the calculation of bioavailability-adjusted protective concentration (BAPCx) values for each water chemistry combination to produce a probability distribution for each protective concentration (PC99, PC95, PC90, PC80) for selection of DGVs.

This Task 1 report describes the collation and analysis of the water chemistry dataset. A second (Task 2) report describes the calculation of BAPCx values using this dataset and the selection of DGVs corresponding to representative high bioavailability water quality conditions for Australia and New Zealand (Gadd et al., 2026).

The data collation process involved gathering water chemistry data from various state, territory and local government agencies, water utilities, and catchment management authorities in Australia and New Zealand. The key variables, in addition to site-specific location information, were pH, dissolved organic carbon (DOC), hardness, calcium and magnesium. The data were processed to ensure consistency, completeness and accuracy, and were screened for quality and relevance. Calcium and magnesium were not always reported along with hardness. Where necessary and possible, linear regressions were developed to predict calcium and magnesium concentrations from hardness, using state or regional regressions to account for geographic (and geological) differences in calcium and magnesium ratios. For all key variables, data older than 1 January, 2000, were excluded due to concerns over changes in analytical methods.

The final dataset included over 600,000 data points for Australia and nearly 60,000 for New Zealand. This included nearly 120,000 measurements of DOC (the variable needed to calculate copper BAPCx values and DGVs) in Australia and around 17,000 measurements of DOC in New Zealand.

Calculation of nickel and zinc DGVs requires measurement of pH, DOC and calcium and magnesium (or hardness for zinc) in the same sample. This matched dataset was substantially smaller than the complete dataset, with 20,784 values for Australia and 10,364 values for New Zealand. Each matched dataset was found to be fairly representative of the complete dataset on a national scale, although there were some limitations in geographic coverage. There were significant differences in water chemistry between states and regions, with up to an order of magnitude difference in median hardness and DOC.

Overall, a comprehensive and representative water chemistry dataset has been collated, to develop the BAPCx values for copper, nickel, and zinc, and to ensure these are protective of the range of water chemistries present in Australia and New Zealand.

The data collated and presented in this report are available in csv and Rdata files for future use.

Acknowledgements

The authors would like to thank the Metals Environment Research Associations (MERA) for funding the project titled "Implementation of bioavailability-based metal guideline values for Australia and New Zealand" that included the collation of these data. We thank the members of that group for providing guidance and their useful comments to improve the reporting.

Thanks to wca environment Ltd, for their project management, technical input and guidance throughout this project.

Andy McKenzie, formerly National Institute of Water and Atmospheric Research is thanked for his work in collating New Zealand data. We also thank the Ministry for the Environment, New Zealand, for allowing use of a previously collated database.

The authors thank the many providers of water chemistry data, as follows:

- Australia – Department of Water and Environmental Regulation, Northern Territory Department of Land Resource Management, Queensland Department of Regional Development, Manufacturing and Water, Department of Environment, Science and Innovation, WaterNSW, Murray Darling Basin Authority, SA Water, ACT Office of Water, Department of Energy, Environment and Climate Action, Melbourne Water, Environmental Protection Agency, Hydro Tasmania, Derwent Estuary Program.
- New Zealand – Auckland Council, Waikato Regional Council, Bay of Plenty Regional Council , Gisborne District Council, Hawkes Bay Regional Council, Taranaki Regional Council, Horizons Regional Council, Greater Wellington Regional Council, Tasman District Council, Environment Canterbury, Christchurch City Council, Otago Regional Council, NIWA and Bathurst Resources Limited.

We thank the staff at these agencies for both providing the water chemistry data and answering our questions about the data formats and analytical methods.

The authors also thank the members of the Focus and Consultative groups from Australia and New Zealand who assisted in guiding the project: Graeme Batley (CSIRO, Australia), Yulia Cuthbertson (DCCEEW, Australia), Rebecca Fisher (AIMS, Australia), Adam Friend (Tasmania EPA, Australia), Megan Gillmore (NSW Government, Australia), Lisa Golding (CSIRO, Australia), Coral Grant (Auckland Council, NZ), Brendan Haine (NSW Government, Australia), Andrew Harford (DCCEEW, Australia), Rhian Ingley (Auckland Council, NZ), Reinier Mann (Queensland Department of Environment and Science, Australia), Helen Nice (Department of Water & Environmental Regulation, WA), Ross Smith (Hydrobiology, Australia), Michele Stevenson (Environment Canterbury, NZ); Gwil Price (Australian Antarctic Division), Adam Ryan (International Zinc Association), Paula Sardina (Victoria EPA, Australia), Jeff Tsang (NSW Government, Australia).

Glossary and List of Acronyms and Abbreviations

Word/acronym/ abbreviation	Description
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
BAGV	Bioavailability-adjusted guideline value; a guideline value that has been adjusted to account for the influence of specific toxicity-modifying factors on the toxicity of the contaminant to aquatic organisms. Once it has been adjusted, it is no longer a default guideline value
BAPCx	A sample specific bioavailability-adjusted protective concentration value. These were derived as part of the process of determining the DGVs for copper, nickel and zinc in freshwater
Bioavailable metal	The measured concentration of metal adjusted based on the appropriate TMF concentrations and response slopes. The bioavailable metal concentration is compared directly with the metal DGV at Tier 2 of the tiered assessment framework
Ca	Calcium
Cu	Copper
default guideline value (DGV)	A guideline value recommended for generic application in the absence of a more specific guideline value (e.g., site-specific) in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Formerly known as a 'trigger value'
DOC	Dissolved organic carbon –a measurement of organic matter in solution, based on the carbon content (using a carbon analyser), after passing through a 0.45 µm filter
hardness	The sum of the measured concentrations of dissolved calcium and magnesium
index condition	Suite of toxicity modifying factors previously used to normalise toxicity data and for draft DGV calculations for nickel and zinc in freshwater. The index condition parameters for nickel and zinc were pH 7.5, hardness 30 mg/L and DOC 0.5 mg/L
Mg	Magnesium
Ni	Nickel
NZ	New Zealand
PCA	Principal components analysis, a statistical technique to reduce the number of variables in a large data set to simplify analysis
reference condition	The high metal bioavailability water chemistry condition at the default guideline values. At least 95% of waters in Australia and New Zealand would have lower bioavailability conditions than the reference condition. It is based on an extensive collation and analysis of data from freshwaters around Australia and New Zealand.
toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism
TMFs, Toxicity modifying factor(s)	The aspects of water chemistry that influence bioavailability. In this guidance use of the term TMF generally refers only to pH, hardness and DOC, though there are other variables that may influence bioavailability such as water temperature and alkalinity
Zn	Zinc

Table of Contents

1 Introduction 1

2 Data collation 3

2.1 Data requests and sources 3

2.1.1 Australia 3

2.1.2 New Zealand 4

2.2 Data processing 4

2.3 Initial data screening and quality assurance 6

2.3.1 Screening for relevant sites 7

2.3.2 Quality coding 7

2.3.3 Error checking and outliers 8

2.3.4 Treatment of censored data 8

2.4 Calculation of missing values and selection from duplicate measurements 9

2.4.1 pH 9

2.4.2 Hardness 9

2.4.3 Calcium and magnesium 9

2.4.4 DOC 15

2.5 Metadata acquisition 16

3 Analysis of water chemistry data 17

3.1 Complete dataset 17

3.1.1 Data included 17

3.1.2 Comparison of Australian and New Zealand data 20

3.1.3 Variability between states and regions 23

3.2 Matched datasets 27

3.2.1 Data availability and geographic distribution 27

3.2.2 Representativeness of the Australian matched dataset 29

3.2.3 Representativeness of the New Zealand matched dataset 31

3.2.4 Summary of water chemistry 34

3.2.5 Correlations in water chemistry 36

3.2.6 Variability between states and regions 38

4 Summary and next steps 43

5 References 44

List of tables

Table 2.1: Summary of data supplied by different organisations in Australia. Tick indicates availability of data for that variable, though not all variables may be measured at the same location and/or date. 3

Table 2.2: Summary of data supplied by different organisations in New Zealand. 5

Table 2.3: Measurement methods used by different organisations for each water quality variable. 6

Table 2.4: Summary of linear regression model parameters for predicting calcium concentration from hardness for Australia. 12

Table 2.5: Summary of reported and predicted hardness, calcium and magnesium data availability for each state in Australia. 12

Table 2.6: Summary of linear regression model parameters for predicting calcium concentration from hardness for parts of New Zealand. 14

Table 2.7: Summary of reported and predicted hardness, calcium and magnesium data availability for each region of New Zealand. 15

Table 3.1: Number of data points for water chemistry in each state in the Australian dataset. 17

Table 3.2: Number of data points for water chemistry in each region in New Zealand dataset 18

Table 3.3: Summary statistics for water chemistry data in the complete Australian and New Zealand datasets. 21

Table 3.4: Median and range (5^{th} to 95^{th} percentile) in water chemistry for each state in Australia, based on all available data 23

Table 3.5: Median and range (5^{th} to 95^{th} percentile) in water chemistry for each region of New Zealand, based on all available data. 25

Table 3.6: Summary of Australian dataset. 27

Table 3.7: Summary of New Zealand dataset. 28

Table 3.8: Summary statistics for water chemistry data in complete Australian dataset compared with the matched dataset 29

Table 3.9: Summary statistics for water chemistry data in complete New Zealand dataset compared with the matched dataset 31

Table 3.10: Summary statistics for water chemistry data in the matched Australian and New Zealand datasets. 34

List of figures

Figure 2.1: Calcium versus magnesium for all data in (a) Australia and (b) New Zealand, coloured by state or region 10

Figure 2.2: Calcium as a function of hardness for states in Australia where models were developed. 11

Figure 2.3: Calcium as a function of hardness for all data in Australia. 11

Figure 2.4: Calcium (left) and magnesium (right) as a function of hardness for all data in Australia, including predicted values. 12

Figure 2.5: Calcium as a function of hardness for regional and national data in New Zealand. 13

Figure 2.6: Calcium (left) and magnesium (right) as a function of hardness for all data in New Zealand, including predicted values. 14

Figure 2.7: DOC compared with TOC for all paired data in (a) Australia and (b) New Zealand....16

Figure 3.1: Distribution of data from around NZ....19

Figure 3.2: Comparison of pH, calcium, magnesium, hardness and DOC between Australia and New Zealand....20

Figure 3.3: Distribution of all available calcium, magnesium, DOC, hardness and pH data for Australia. 22

Figure 3.4: Distribution of all available calcium, magnesium, DOC, hardness and pH data for New Zealand. 22

Figure 3.5: Variation in pH, hardness and DOC within and between states of Australia. 24

Figure 3.6: Variation in pH, calcium, magnesium, hardness and DOC within and between regions of New Zealand....26

Figure 3.7: Distribution of matched data from around Australia....27

Figure 3.8: Distribution of matched data across time for each state of Australia....27

Figure 3.9: Distribution of matched data from around NZ....28

Figure 3.10: Distribution of matched data across time for each region of New Zealand. 29

Figure 3.11: Distribution of pH, DOC and calcium, magnesium in the matched dataset (orange) compared with the complete dataset (blue) for Australia. 30

Figure 3.12: Distribution of pH, DOC and calcium, magnesium in the matched dataset (orange) compared with the complete dataset (blue) for New Zealand. 32

Figure 3.13: Comparison of the dominant land cover in the upstream catchment of the matched dataset with that for all NZ river length. 33

Figure 3.14: Comparison of the Strahler stream order of the matched dataset with the Strahler stream order for all NZ river length. 33

Figure 3.15: Distribution of calcium, magnesium, DOC, hardness and pH data for Australia. 35

Figure 3.16: Distribution of calcium, magnesium, DOC, hardness and pH data for New Zealand....35

Figure 3.17: Relationships between pH, hardness (log-scale) and DOC (log-scale) for Australian (top) and NZ (bottom) data. 37

Figure 3.18: Principal components analysis biplot for pH, hardness (log-scale) and DOC (log-scale) for (a) Australian and (b) New Zealand data. 38

Figure 3.19: Variation in DOC, hardness and pH within and between states of Australia. 38

Figure 3.20: Variation in DOC, hardness and pH within and between regions of NZ. 39

Figure 3.21: Illustration of variation in pH, hardness and DOC within and between states of Australia. 40

Figure 3.22: Geographic variation in pH, hardness and DOC around NZ. 41

Figure 3.23: Illustration of variation in pH, hardness and DOC within and between regions of NZ..... 42

1 Introduction

This report represents the first task of a metals industry-funded project titled "Implementation of bioavailability-based metal guideline values for Australia and New Zealand" that comprised the following five tasks:

1. Build and quality check a database of physico-chemical parameters including pH, DOC, hardness (Ca, Mg) for Australian and New Zealand freshwaters (key variables required for assessing metal bioavailability);
2. Use that database to determine default guideline values (DGVs) for copper, nickel and zinc for Australian and New Zealand freshwaters to use in a Tier 1 screening assessment;
3. Develop a simplified tool for predicting the bioavailability of copper, nickel and zinc in freshwaters;
4. Build the overarching tiered assessment framework, develop a guidance document for practitioners and 'road test' it with a regulatory advisory (focus) group; and
5. Provide training for user groups and stakeholders across Australia and New Zealand.

Newly derived DGVs for metals (i.e., copper, nickel, zinc) in freshwater for use in Australia and New Zealand require information on water chemistry for their application (ANZG 2026a, 2026b, 2026c). This is to account for differing bioavailability and toxicity at different pH, hardness (or calcium and magnesium) and/or dissolved organic carbon (DOC) concentrations, and ensures that DGVs are protective in all water chemistries, but are not overly conservative. The DGVs are implemented using a tiered assessment framework originally conceptualised by Stauber and Ryan (2023) and formalised in Stauber et al. (2026). The tiered assessment framework is implemented through the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). The tiered approach comprises a screening level at Tier 1, where measured dissolved metal concentrations in a sample are compared with a high bioavailability DGV. If the DGV is exceeded at Tier 1, then at Tier 2, metal bioavailability based on the local water chemistry is taken into account. This can be done either by adjusting the metal concentration in the sample to represent the bioavailable fraction or the DGV can be adjusted for the sample water chemistry using a bioavailability model tool to calculate a bioavailability-adjusted guideline value (BAGV). If the sample still fails, then, at Tier 3, additional lines of evidence can be used to determine the implications of the exceedance. The tiered approach follows closely the approach recommended in Europe (European Commission 2019).

The requirement for additional water chemistry data can be an impediment for users that do not always have the monitoring data (particularly DOC) to enable adjustment of the DGVs. The draft DGVs for nickel and zinc were calculated at an 'index' condition, representing a set of water-chemistry parameters that represented a high metal bioavailability condition. The index condition was agreed between a group of experts to be a low water hardness of 30 mg/L $CaCO_3$, low DOC of 0.5 mg/L and pH of 7.5 (near the median pH for Australian and New Zealand waters) (Stauber et al. 2021). However, the index condition was not based on a large dataset (see below), and it was possible that the combination of values may never, or only rarely, exist naturally. Consequently, and following a workshop of scientists and regulators from Australian states and mainland territories and New Zealand regions in Sydney in April 2023 (Stauber and Ryan 2023), a more rigorous, data-driven approach was adopted for the final DGVs (herein referred to as the DGVs). The high bioavailability conditions under which the DGVs were to be derived were to be based upon analyses of the much larger water chemistry datasets compiled for Australia and New Zealand by Gadd et al. (2026) to identify the most sensitive (i.e. highest bioavailability) waters present in both countries. Moreover, the selected high bioavailability water chemistry conditions were re-named as 'reference' conditions, to align with terminology in Europe (European Commission 2019).

To develop the DGVs, water chemistry data from around Australia and New Zealand were needed from which to calculate the bioavailability-adjusted protective concentration (BAPCx) values and to produce a probability distribution and select a high bioavailability DGV[1]. This method follows a similar process as used in Europe, by which regionwide environmental quality standards were calculated from a probability distribution that identified waters with the highest metal bioavailability. While data had been collated for Australia from the project to derive zinc GVs (Stauber et al. 2023), and in New Zealand for a project on metal state and trends (Gadd et al. 2024), these had not been brought together and nor did they entirely cover each country. The water chemistry variables required to calculate BAPCx values or BAGVs differ for each metal. For copper, only DOC is required; for nickel pH, DOC, calcium and magnesium are needed; and for zinc, pH, DOC and hardness are required.[2]

This report outlines the collation of the water chemistry data for the purpose of calculating BAPCx values and selecting the DGVs for copper, nickel and zinc. Section 2 describes the data sources, processing, screening and calculations to fill missing data. Section 3 presents the data collated, including the data where all required variables were reported in a single sample (as needed to generate BAPCx values), and assesses their representativeness for each country. The data are presented in graphics and tables to enable future use of the data in deriving water quality guideline values.

[1] This DGV is therefore based on real waters, rather than a water chemistry combination that may not exist in each country.

[2] Hardness can be calculated from calcium and magnesium, but these cations are not required individually to calculate zinc guideline values.

2 Data collation

The data collation process included steps to ensure that: the datasets acquired from different sources were internally consistent (with consistent names and formats); site information was complete and accurate; consistent measurement procedures were used; and the data were as error free as possible.

2.1 Data requests and sources

The data requests included; the required variables (pH, DOC, hardness, calcium and magnesium); any available data on metal concentrations; quality coding information; and site metadata including site codes, site names and geographic coordinates.

2.1.1 Australia

Data were requested from state and territory government agencies, water utilities and catchment management authorities, with agencies that provided data listed in Table 2.1 (see Appendix A for contact details). Data from some sources such as the Bureau of Meteorology were viewed but not included in the collated database as they only contained one variable (e.g., pH and not hardness, DOC, Ca or Mg, which were also required). Data from research studies with matched datapoints for some sites in Queensland and Victoria were also included. Note that, hereafter, all Australian state and territories are referred to as states, and abbreviations as shown in Table 2.1 are used in all figures and tables.

Table 2.1: Summary of data supplied by different organisations in Australia. Tick indicates availability of data for that variable, though not all variables may be measured at the same location and/or date.

State/ organisation	Area covered by data	Abbreviation	pH	Hardness (or Ca/Mg)	DOC
Department of Water and Environmental Regulation	Western Australia	WA	✓	✓	✓
Northern Territory Department of Land Resource Management	Northern Territory	NT	✓	✓	✓
Queensland Department of Regional Development, Manufacturing and Water	Queensland	QLD	✓	✓	✓
Department of Environment, Science and Innovation	Queensland	QLD	✓	✓	✓
WaterNSW	New South Wales	NSW	✓	✓	✓
Murray Darling Basin Authority	New South Wales, South Australia	NSW	✓	✓	✓
SA Water	South Australia	SA	✓	✓	✓
ACT Office of Water	Australian Capital Territory	ACT	✓	✓	✓
Department of Energy, Environment and Climate Action	Victoria	VIC	✓	✓	✓
Melbourne Water	Victoria	VIC	✓	✓	✓
Environmental Protection Agency	Tasmania	Tas	✓	✓	✓
Hydro Tasmania	Tasmania	Tas	✓	✓	✓
Derwent Estuary Program	Tasmania	Tas	✓	✓	✓

2.1.2 New Zealand

The primary source of data for New Zealand was a database that had been collated for New Zealand's Ministry for the Environment (MfE) and Stats NZ, from council monitoring of dissolved copper and zinc (Gadd et al. 2024). That database also included pH, DOC and hardness where it had been measured at the same sites and on the same dates. MfE/Stats NZ provided permission to use the database for the current project (Lance Morrell, MfE, pers. comm). The sites with data were from the Auckland, Waikato, Bay of Plenty, Hawkes Bay, Wellington, Canterbury and Otago regions, and Christchurch City. The timeframe of the database was from the initiation of monitoring (anywhere between 1995 and 2018, depending on site) to December 2022.

Additional data were requested from the regional Councils that had previously provided data for the MfE/Stats NZ project. Updates for the same sites for the 2023 calendar year were provided by Auckland Council and Greater Wellington. Christchurch City Council could not provide the data within the timeframe needed for the project (however, there was already an extensive record for sites in Christchurch). Environment Canterbury provided an update with additional sites.

In addition, requests were made to regions that did not regularly measure copper and zinc (and hence where no data were included in the existing database) but might have the toxicity modifying factor (TMF; e.g., pH, hardness, DOC) data for other reasons. Additional data were provided by Bay of Plenty, Horizons, Taranaki and Southland Regional Councils and Gisborne and Tasman District Councils (Table 2.2). Additional data were provided by Bathurst Resources Limited (via C. Hickey, pers. comm) for locations in the West Coast of the South Island. Data were also collected from publicly available sources such as the NRWQN[3], LAWA[4] and MfE data service[5] (pH data for all NZ).

Table 2.2 provides a summary of the monitoring data received through the data requests. Note that there may be additional monitoring (ad hoc or regular) undertaken by other councils that did not respond to these data requests.

2.2 Data processing

All data were received in excel files or csv (comma-separated value) files. The data were collated into a single R data frame by importing each excel file received and manipulating within the RStudio software environment. Using R aimed to minimise copy/paste errors that can occur with manipulations in Microsoft Excel and to enable repetition of the collation with minor changes in the process (e.g., inclusion of additional variables).

[3] National River Water Quality Network, https://hydrowebportal.niwa.co.nz/Data/Dashboard/11, Smith, D. G. and R. Maasdam (1994). New Zealand National River Water Quality Network.1. Design and physico-chemical characterisation. *New Zealand Journal of Marine and Freshwater Research* 28(1): 19-35.

[4] Land, Air, Water Aotearoa, https://www.lawa.org.nz/; pH data from https://www.lawa.org.nz/download-data#river-water-quality

[5] https://data.mfe.govt.nz/

Table 2.2: Summary of data supplied by different organisations in New Zealand. Tick indicates availability of data for that variable, though not all variables may be measured at the same location and/or date.

Council / organisation	Area covered by data	pH	Hardness (or Ca/Mg)	DOC
Auckland Council	Auckland	✓	✓	✓
Waikato Regional Council	Waikato	✓	✓	✓
Bay of Plenty Regional Council	Bay of Plenty	✓	✓	✓
Gisborne District Council	Gisborne district	✓	✓	
Hawkes Bay Regional Council	Hawkes Bay	✓	✓	
Taranaki Regional Council	Taranaki	✓	✓	✓
Horizons Regional Council	Manawatu-Whanganui	✓	✓	✓
Greater Wellington Regional Council	Wellington region	✓	✓	✓
Tasman District Council	Tasman district	✓	✓	✓
Environment Canterbury	Canterbury	✓	✓	✓
Christchurch City Council	Christchurch	✓	✓	✓
Otago Regional Council	Otago	✓	✓	✓
Southland Regional Council	Southland	✓	✓	✓
NIWA	Across NZ	✓	✓	✓
Bathurst Resources Limited	West Coast	✓	✓	✓

The data collation included the following variables and metadata:

- Site name and site codes used by the relevant state/council and/or organisation
- Date and time of sample collection (if both provided, otherwise just date)
- Numeric values for pH, DOC, dissolved calcium, dissolved magnesium, total hardness, dissolved copper, dissolved zinc, dissolved nickel and total organic carbon (TOC)
- Indications of where numeric values were below detection (e.g., < symbols or comments in column)
- Quality codes (when provided).

A range of analytical methods were used for the water chemistry variables of interest (Table 2.3). Note that not all states or councils supplied information on the analytical methods used. All methods listed in Table 2.3 were considered acceptable. ACT also supplied pH data measured by volunteers with test kits. These data were not used as they were supplied to an accuracy of only 0.5 pH units.

Gisborne District Council (GDC) supplied calcium as "calcium hardness as $CaCO_3$ (mg/L)". These values were converted to a concentration of calcium by dividing by 2.497. Magnesium concentrations were then calculated from the total hardness supplied, and the calculated calcium concentration.

Table 2.3: Measurement methods used by different organisations for each water quality variable.

Variable	Measurement procedure(s)
pH	Measured in field by hand-held meter. APHA Method 4500-H+ B Measured in laboratory by meter. APHA Method 4500-H+ B
DOC	Dissolved non-purgeable organic carbon: Acidification, purging to remove inorganic C, super-critical persulphate oxidation at 375°C, IR detection. APHA 5310 C (modified) 23rd ed. 2017 Filtration, acidification, high temperature catalytic oxidation, IR detection. APHA 5310B Filtration, then TOC by subtraction i.e. Total Carbon (TC) – Total Inorganic Carbon (TIC)
TOC	TOC by subtraction i.e. Total Carbon (TC) – Total Inorganic Carbon (TIC), or Non-purgeable organic carbon (acidifying then purging CO_2 prior to analysis) measured in unfiltered samples Measurement of TC/TOC by either high temperature catalytic oxidation (APHA 5310B) or super-critical persulphate oxidation at 375°C (APHA 5310 C (modified)). IR detection
Hardness	Calculation from analysis of dissolved calcium and dissolved magnesium. APHA 2340B EDTA titrimetric method. APHA Method 2340C
Calcium	Filtered, ICP-MS, APHA 3125B Filtered, ICP-OES Filtered, AAS
Magnesium	Filtered, ICP-MS, APHA 3125B Filtered, ICP-OES
Copper	Filtered, ICP-MS, APHA 3125B Filtered, ICP-OES
Nickel	Filtered, ICP-MS, APHA 3125B Filtered, ICP-OES
Zinc	Filtered, ICP-MS, APHA 3125B Filtered, ICP-OES

2.3 Initial data screening and quality assurance

For some states and regions that supplied all available data, the datasets included data from more than 50 years ago. All data for samples collected prior to 1 January 2000 were removed, due to concerns over changes in analytical methods (especially for hardness and DOC), particularly where data providers did not supply that information. This removed nearly 30,000 values (mainly pH) for WA, NSW and NT where data extended as far back as 1940 and included numerous surveys from the 1970s and 1980s.

Consideration was given to reducing data to only the most recent 10 years to reduce the effect of broad-scale changes in water chemistry over time, which may affect the dataset. However, this resulted in removal of all samples from some sites and regions, and therefore the data from 2000 to 2013 were retained.

Data was initially screened using the Criteria for Reporting and Evaluating Exposure Datasets (CREED) approach with all data meeting the gateway criteria (Di Paolo et al. 2024). For the Australian data, not all data providers gave all information regarding collection methods, analytical data, and rationale for site selection. When screened using the CREED assessment approach, the dataset did not meet requirements

at the silver or gold levels. For New Zealand, the data met the silver level with restriction but did not meet the gold level. This classification was because:

- the requirements for date and time to be reported were only partly met (for some data only date was provided),
- the limits of quantitation were not always provided (though in most cases could be assumed from the provided data)
- not all laboratories were accredited; for accredited laboratories, not all methods were accredited; or no information was provided on accreditation;
- in some cases there was insufficient information on analytical methods.

The CREED assessment workbooks for New Zealand and Australia are available as Supplementary Information, upon request. Expert judgement was used to determine what data could be used so that BAPCx values and the resulting DGVs were based on as much data as possible. Future collection exercises will stress the importance of the additional information required to the data providers.

Some datasets included duplicate values, for example, where data were collected for multiple programs and were exported in state databases as two rows. These were removed after first checking these were true duplicates (same location, date, time, values). Where there were multiple values for the same site, depth, date and time, the median of these values was calculated and used in the analysis. A median was used as this measure is less affected by extremes in the data (Helsel et al. 2020).

2.3.1 Screening for relevant sites

Summary statistics and box plots were used to explore the collated data to identify outliers. This identified many sites that were not representative of freshwater ecosystems that were subsequently removed. All sites were removed that were:

- Saline, as indicated by site name (e.g., containing the word “coast”, “estuary”, “bay”), through site knowledge (including advice from data providers), by mapping location, or as indicated by high conductivity (>2000 µS/cm)
- Stormwater pipes, drains and pond outlets and other discharges as indicated by site name (e.g., containing the word “stormwater”, “detention basin”, “desalination” or for Australia “drain”[6]) or through knowledge of the location
- Groundwater, as indicated by coding or site name (e.g., “bore”, “pump”, “spring”)
- Soil or wastewater investigations that were included in the Western Australia dataset as indicated by site name (e.g., containing the word “soil”, “lysimeter”, “biofilter”, “filter”)
- Highly affected by geothermal activity, resulting in a pH of 2 to 3 (three sites in Waikato Region of NZ: "Whangaehu at u/s Winstone Pulp", "Whangaehu at Kauangaroa", "Waiotapu Stm: Campbell Rd Br").

2.3.2 Quality coding

Data from the state of Victoria included quality codes. All data with a quality code indicating poor quality data were removed. QLD also had a quality column next to each parameter with either a >, OK, ND, NA

[6] This was not used to screen sites in NZ as there are several locations referred to as drains that were once natural waterways but have been highly modified to develop land for farming or urban uses.

provided for each sample. WA also gave each reading a data quality rating with grades of excellent, good, fair, relative uncertainty and suspect.

In New Zealand, many regional councils use a quality code system for environmental monitoring data, provided by the National Environmental Monitoring Standards (NEMS)[7]. Data received from Auckland Council, Horizons and Greater Wellington Regional Councils used the NEMS system. Data with a quality code of 400 or less are identified as "poor quality", usually due to long transit times between sample collection and analysis, high sample temperature at arrival to the laboratory, issues with field instruments, sample label mix-ups or other chain of custody issues (NEMS 2019). Generally, data of lower quality (codes 400 or less) were excluded. However, for data provided by Auckland Council, some data with a quality code of 400 were retained, on advice by the Council, as they had determined that those data were acceptable (Rhian Ingley, Auckland Council, pers. comm). This approach was consistent with the Council's procedures. Where quality codes were not provided, all data were retained on the assumption that quality was acceptable.

2.3.3 Error checking and outliers

Several methods were used to explore the data and assess the suitability for calculating the BAPCx values and DGVs. These included summary statistics; box-whisker plots for each variable, by state or region, or site; and scatterplot matrices. These were used to identify the presence of zero values, errors (such as decimal point issues) and outliers.

Where possible, errors were corrected (for example, pH 786 changed to 7.86). Zero and negative values were interrogated to assess whether these were missing values or less than detection values. Where possible, these were corrected based on original data. If this correction could not be made, the values were deleted, due to uncertainty around 0 and negative values.

There remained many values where hardness was very high (e.g., >1000 mg/L as $CaCO_3$). After first checking whether there was an error in the units used, all values above 6570 mg/L (the hardness associated with saline water) were removed. This resulted in a loss of 284 matched data points (those with pH, DOC and hardness or calcium and magnesium) only, all from Western Australia. The freshwater GVs are applied to waters of 2 ppt or below[8] and a calcium limit based on a 2 ppt salinity was also considered as a possible upper limit. However, some inland waters in Australia have elevated salinity due to natural processes or land use change[9] and we did not want to exclude these waters from the initial analysis of water chemistry. High hardness values (e.g., >1000 mg/L) would not be included in all calculations of BAPCx values as these would be outside the applicability range for the metal based on the bioavailability models.

After the screening and quality checking described above, there remained many high DOC concentrations (>100 mg/L) including five from Western Australia and NSW that exceeded 200 mg/L. As there is potential for these to be real concentrations, for example, from wetlands or samples collected during black water events (Sobek et al. 2007), these were retained in the database.

2.3.4 Treatment of censored data

Based on the information included with the data provided by suppliers there were few censored values, that is, where data were below detection limits. The censored values generally comprised <1% of each dataset

[7] NEMS (2019). Water Quality Part 2 of 4: Sampling, Measuring, Processing and Archiving of Discrete River Water Quality Data. National Environmental Monitoring Standards. 85.

[8] https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants#guideline-values-for-other-water-types

[9] https://www.waterquality.gov.au/issues/salinity

and were mainly for DOC but also for calcium, magnesium and hardness. For a small proportion of the data supplied for Australia (Murray catchment data), it was not clear whether data were censored or not, as no symbology (e.g., < symbols) or flags were provided with the numeric data. However, as the data at low concentrations (e.g., reported as 0.5 or 1 mg/L DOC) comprised a small proportion of the total dataset, we opted to retain the data based on the face value.

Because of the low overall proportion of censoring in the dataset (<5% overall and per state/region), there was no advantage in using statistical methods for censored data to calculate summary statistics such as robust regression on order statistics (Helsel 2012). All summary statistics presented in this report from 5th percentile to maxima represent non-censored data. Where appropriate, minimum values presented in tables show the reported value, reflecting the censoring of that variable (e.g., for DOC, the minimum value is reported as <0.1 mg/L). In graphics, we used the numeric value (face value) of the reported limit of detection (i.e., if reported as <0.10 mg/L, this is plotted at 0.1 mg/L).

DOC concentrations reported as <0.2 or <0.5 mg/L were retained whereas concentrations reported as <1 mg/L were removed from the dataset (296 values for Australia, 3 values for New Zealand). We considered the limit of detection of 1 mg/L to be too high as it is above the DOC concentration measured in many surface waters.[10] Including these values based on the face value of 1 mg/L could skew the dataset towards higher overall DOC concentrations, and there were likely already some data included that were in fact censored values.

2.4 Calculation of missing values and selection from duplicate measurements

2.4.1 pH

For some samples, pH was measured both in the field and in the laboratory, resulting in two measurements for each date/time. In those cases, the laboratory measurement was preferentially used, in accordance with national standards in NZ (NEMS 2019).

2.4.2 Hardness

There were some samples where hardness was not provided, but both calcium and magnesium were provided. In such cases, hardness (as mg/L $CaCO_3$) was calculated as follows:

$$Hardness = 2.497 \times Calcium + 4.118 \times Magnesium$$

2.4.3 Calcium and magnesium

There were many samples and sites where hardness was reported but calcium and magnesium were not. The data were assessed to determine if these ions could be predicted based on the reported hardness. Calcium to magnesium ratios (and hence hardness to calcium) can differ between sites, regions and countries (Figure 2.1).

[10] Methods to estimate those values reported as <1 mg/L such as imputation using regression on order statistics (e.g., see Helsel 2016) were not considered appropriate for calculating guideline values. There would be high uncertainty in the probability distribution of guideline values based on imputed values.

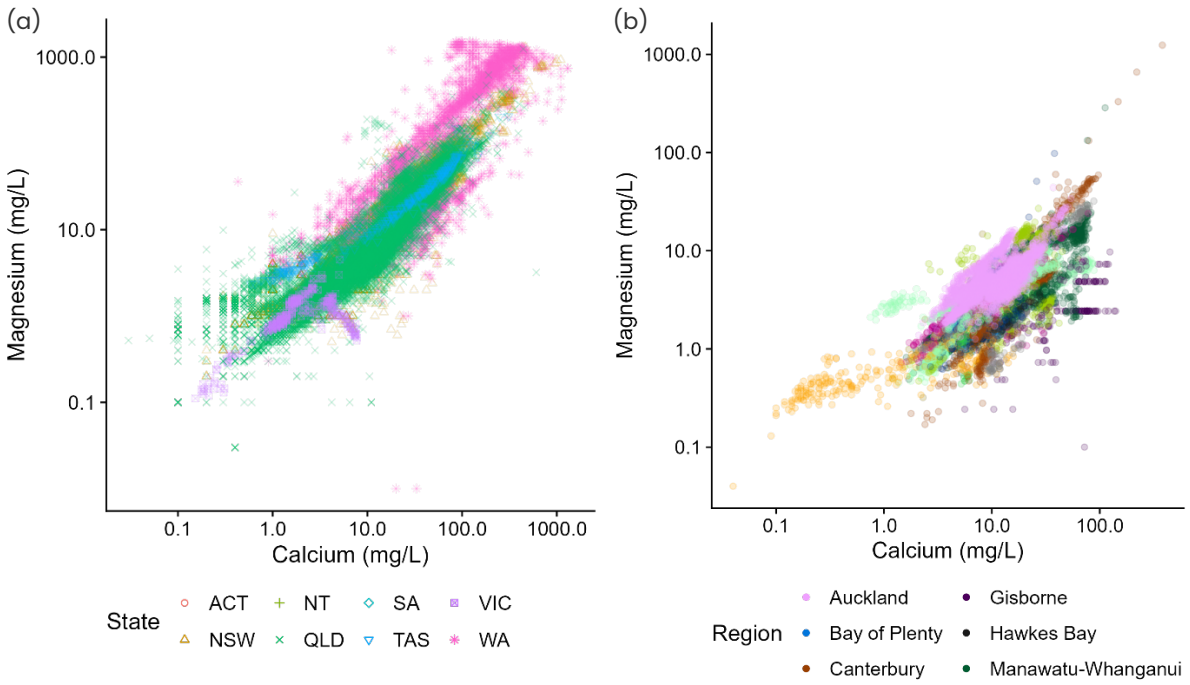


Figure 2.1: Calcium versus magnesium for all data in (a) Australia and (b) New Zealand, coloured by state or region.

Linear regressions were developed between hardness and calcium concentrations and used to calculate calcium from hardness. The hardness, calcium and magnesium datasets were first cleaned up to remove outliers that could leverage a regression (i.e., removed data for calcium >200 mg/L, magnesium >100 mg/L and <0.1 mg/L). State or regional relationships were developed and used where sufficient data were available (at least 100 paired data values).

Following calculation of calcium for each site, the magnesium concentration was calculated from the reported hardness and calcium concentrations.

$$Magnesium = Hardness - \frac{2.497 \times Calcium}{4.118}$$

Where magnesium was less than 0.1, a value of 0.1 mg/L was used and the value was indicated in the database as censored, to avoid adding extremely low (and likely unrealistic) values to the dataset.

There were five Australian states where state-specific relationships were developed: NSW, NT, SA, Queensland and WA (Table 2.4 and Figure 2.2). All data from Tasmania and Victoria already included measurements of calcium and magnesium. ACT data were missing calcium and magnesium for all but 5 samples, and so territory-based relationships could not be developed. A national model was developed to predict calcium and magnesium for this territory (Figure 2.3).

The resulting datasets (Figure 2.4) included around 40,000 extra combinations of calcium and magnesium (Table 2.5) that could potentially be used to calculate nickel DGVs (if there were corresponding pH and DOC values for the same samples).

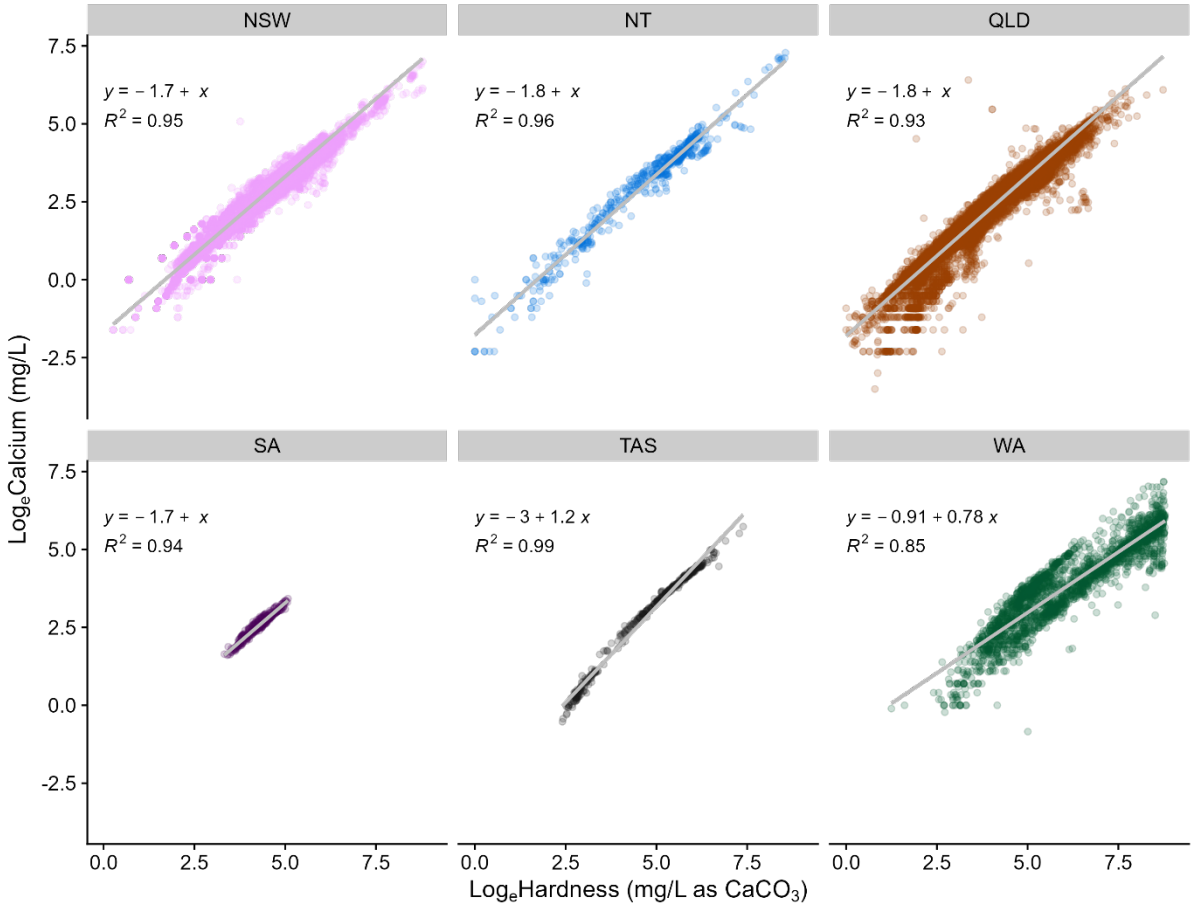


Figure 2.2: Calcium as a function of hardness for states in Australia where models were developed. Both variables were transformed using natural logarithm.

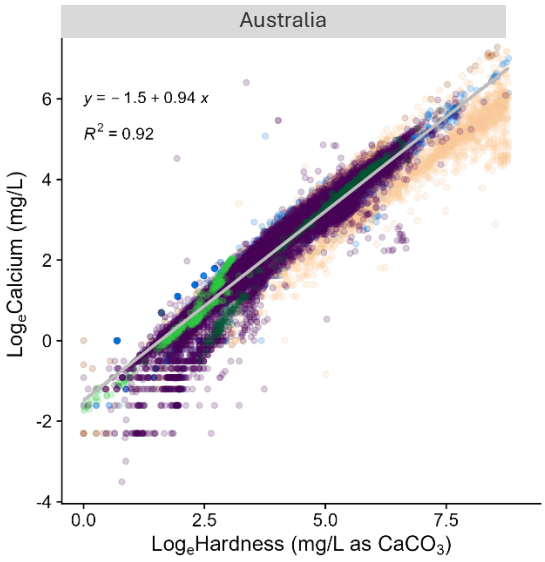


Figure 2.3: Calcium as a function of hardness for all data in Australia. Both variables were transformed using natural logarithm. Colours differ from those used in Figure 2.3.

Table 2.4: Summary of linear regression model parameters for predicting calcium concentration from hardness for Australia.

Model	N	Intercept (p-value)	Slope (log Hardness) (p-value)	R^2
SA	349	-1.72 (<0.0001)	1.00 (<0.0001)	0.94
NT	630	-1.76 (<0.0001)	1.03 (<0.0001)	0.96
WA	3146	-0.91 (<0.0001)	0.78 (<0.0001)	0.85
QLD	16932	-1.77 (<0.0001)	1.02 (<0.0001)	0.93
NSW	23772	-1.69 (<0.0001)	1.00 (<0.0001)	0.95
Australia	45672	-1.48 (<0.0001)	0.94 (<0.0001)	0.92

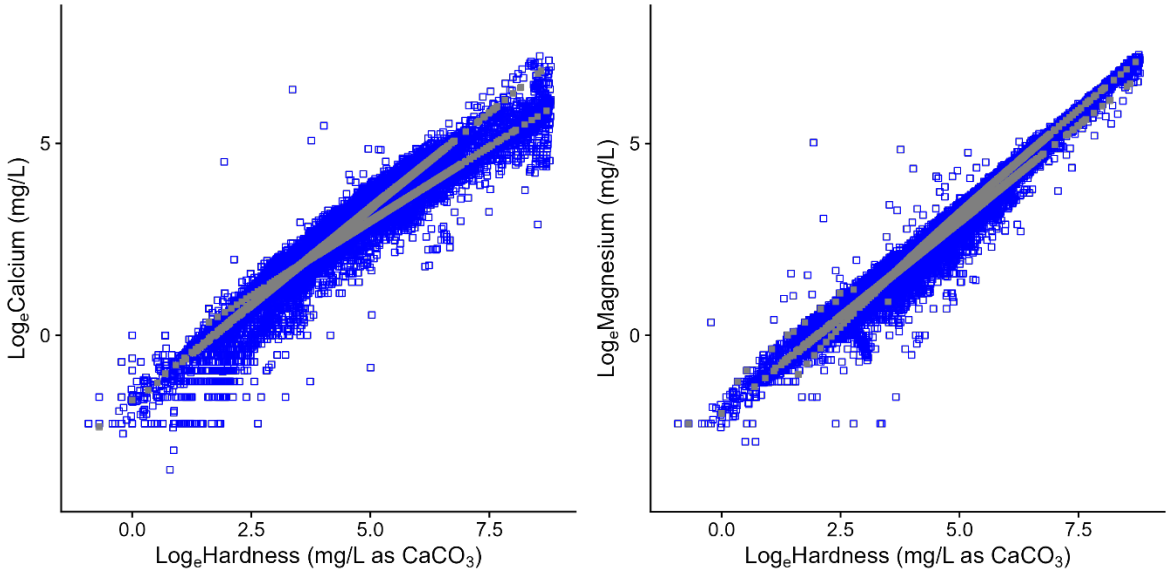


Figure 2.4: Calcium (left) and magnesium (right) as a function of hardness for all data in Australia, including predicted values. Both variables are transformed using natural logarithm. Measured data shown with blue outline, predicted values shown in grey. Grey points follow different lines as state-specific models used where possible.

Table 2.5: Summary of reported and predicted hardness, calcium and magnesium data availability for each state in Australia.

State	Reported hardness (total)	Reported calcium	Reported and predicted calcium	Reported magnesium	Reported and predicted magnesium
ACT	200	5	200	5	200
NSW	64327	23844	64398	24421	64769
NT	631	683	683	104	634
QLD	18294	17001	18294	17004	18294
SA	2705	350	2705	350	2705
TAS	391	391	391	391	391
VIC	444	444	444	444	444
WA	6152	2773	6155	2779	6161
Total Australia	**93,144**	**45,491**	**93,270**	**45,498**	**93,598**

For New Zealand, calcium and magnesium were sometimes but not always measured in Wellington and Canterbury and there were sufficient data to develop regional models (Figure 2.5, Table 2.6). For the other regions, a national model was used (Table 2.6), after first removing data from the Gisborne region due to the uncertainty of the magnesium values in this region.

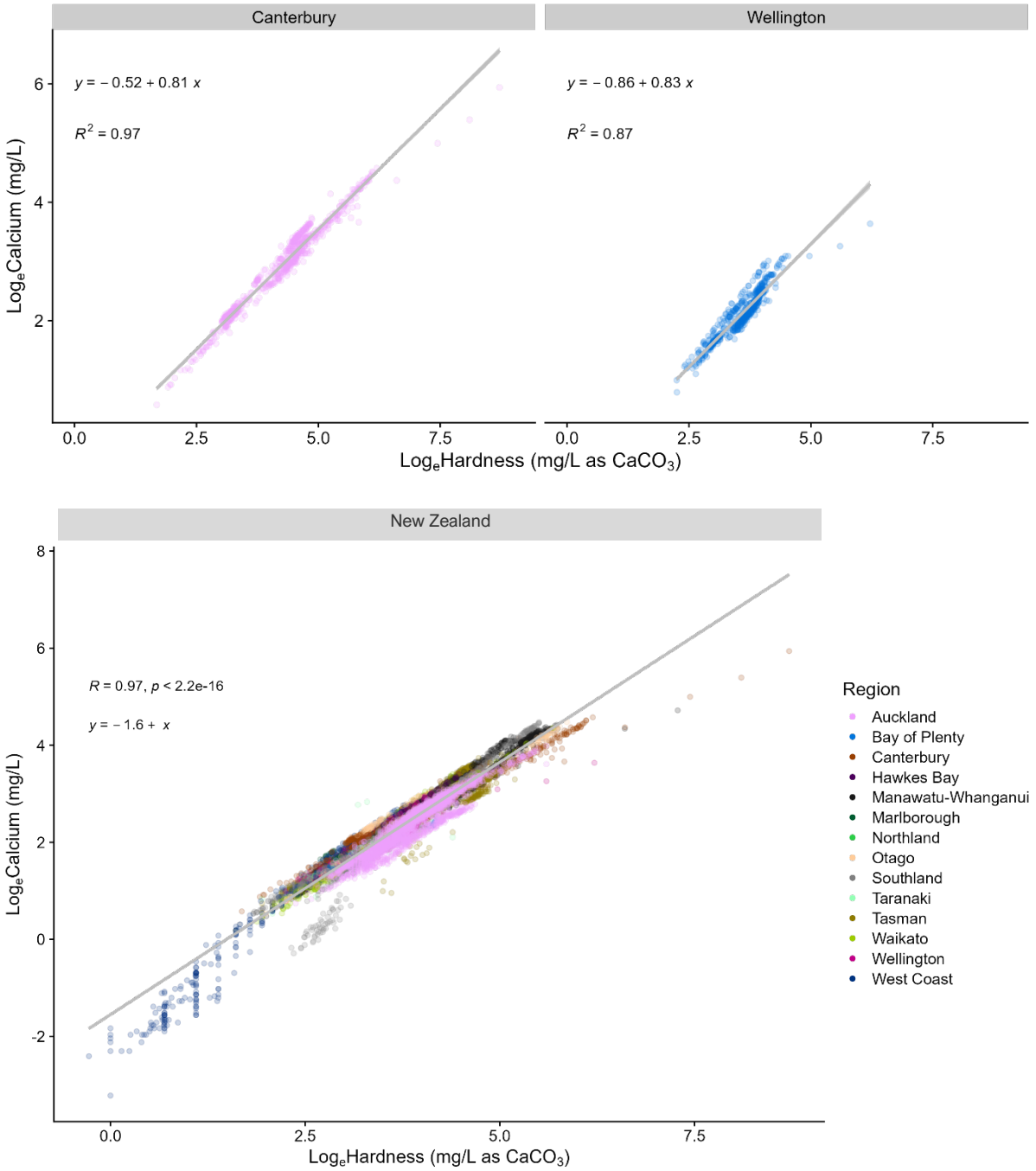


Figure 2.5: Calcium as a function of hardness for regional and national data in New Zealand. Both variables are transformed using natural logarithm. Outliers and data from the Gisborne region were excluded from the plot for the national model.

Table 2.6: Summary of linear regression model parameters for predicting calcium concentration from hardness for parts of New Zealand.

Model	N	Intercept (p-value)	Slope (log Hardness) (p-value)	R^2
Wellington region	552	-0.93 (<0.0001)	0.84 (<0.0001)	0.89
Canterbury region	584	-0.52 (<0.0001)	0.82 (<0.0001)	0.95
New Zealand	12722	-1.60 (<0.0001)	1.05 (<0.0001)	0.95

There were also several samples where magnesium was reported but not calcium (Manawatu-Whanganui region only), or where calcium was reported but not magnesium (Taranaki region only). These values were predicted from region-specific linear regressions between calcium and magnesium developed from the data that were available for those regions.

The final New Zealand dataset included around 13,000 reported and 4,000 predicted values (Figure 2.6, Table 2.7).

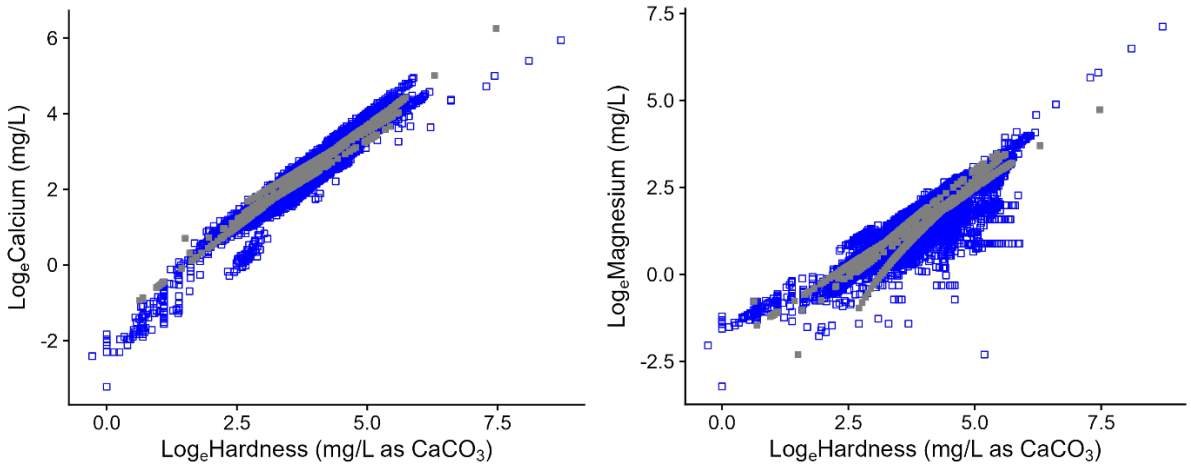


Figure 2.6: Calcium (left) and magnesium (right) as a function of hardness for all data in New Zealand, including predicted values. Both variables are transformed using natural logarithm. Measured data shown with blue outline, predicted values shown in grey. Grey points follow different lines as region-specific models used where possible.

Table 2.7: Summary of reported and predicted hardness, calcium and magnesium data availability for each region of New Zealand.

	Number of data points available				
State	**Hardness (total)**	**Reported calcium**	**Reported and predicted calcium**	**Reported magnesium**	**Reported and predicted magnesium**
Auckland	2795	2794	2795	2794	2795
Bay of Plenty	316	0	316	0	316
Canterbury	3690	584	3690	584	3690
Gisborne	144	139	144	135	140
Hawkes Bay	127	0	127	0	127
Manawatu-Whanganui	2823	2678	2824	2823	2823
Otago	325	325	325	325	325
Southland	3229	3229	3229	3229	3229
Taranaki	681	671	681	170	681
Tasman	672	672	672	672	672
Waikato	408	408	408	408	408
Wellington	1261	552	1261	552	1261
West Coast	248	241	248	243	248
Total NZ	**16,719**	**12,293**	**16,720**	**11,935**	**16,715**

2.4.4 DOC

DOC was not reported in the Hawkes Bay region, but hardness and pH were. The hardness data indicated somewhat higher hardness values in this region, and that this region should be represented in the analysis and in the calculation of DGVs. TOC (total organic carbon) data were available for this region, and for several other regions in New Zealand (Waikato, Wellington) where both DOC and TOC were measured.

The paired data (DOC and TOC) were used to investigate and develop relationships to enable estimation of DOC from TOC. For New Zealand, the median ratio was 0.83 and the 25th percentile was 0.71. The value of 0.71 was used to estimate DOC from TOC for the Hawkes Bay region, to enable its inclusion in the matched dataset. In Australia (Victoria data only) the median ratio was 0.93 and the 25th percentile was 0.8. However, there were no data in Australia (within the dates of interest) where TOC was reported and DOC was not, so no conversions were required.

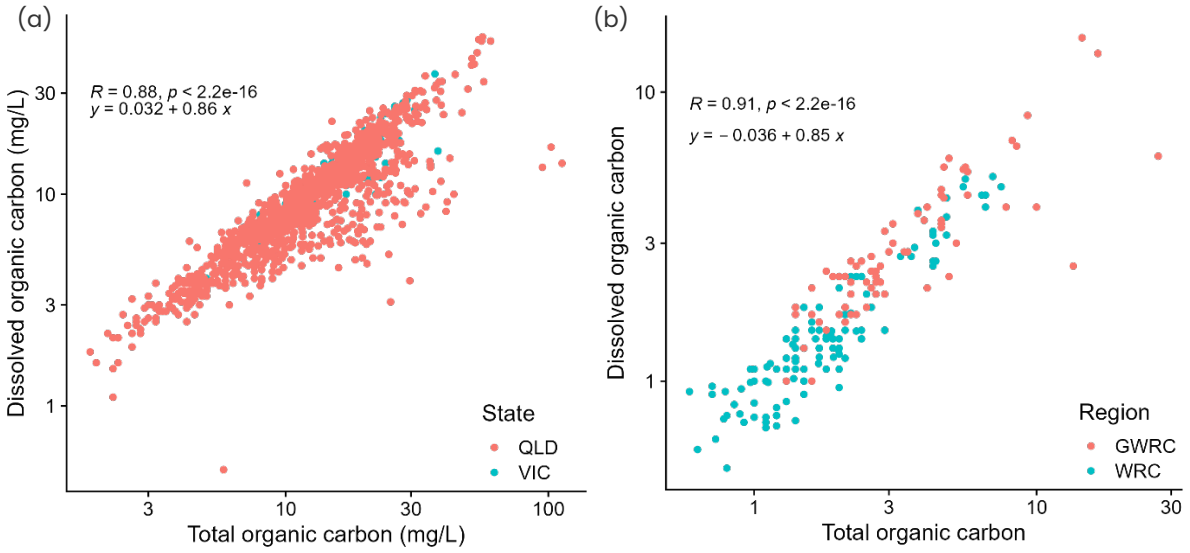


Figure 2.7: DOC compared with TOC for all paired data in (a) Australia and (b) New Zealand. All data in mg/L.

2.5 Metadata acquisition

Most, but not all, data were provided with coordinates and other information about the sites. Additional metadata were collated for New Zealand from MfE dataservice. These were joined to the water chemistry database by joining based on region, site names, site codes and locations to add metadata including land cover data and Strahler stream order[11].

[11] A system that defines stream size based on hierarchy. The headwaters are first-order streams; when two first-order streams join, this creates a second order stream. When two second order streams join, these become a third order stream, and so on.

3 Analysis of water chemistry data

3.1 Complete dataset

3.1.1 Data included

The collated Australian dataset included a total of 602,342 data points (Table 3.1) with measurements of pH, hardness and/or DOC. These data points were from 10,027 sites distributed across 7 states and territories[12]. The collated NZ dataset included 58,022 data points (Table 3.2) with measurements of pH, hardness and/or DOC. These data points were from 875 sites distributed across 15 regions [13] (Figure 3.1).

Table 3.1: Number of data points for water chemistry in each state in the Australian dataset. States are ordered from most hardness data to least.

State	Hardness (total)	Calcium (soluble)	Magnesium (soluble)	pH	DOC
NSW	64327	64398	64769	282696	75979
QLD	18294	18294	18294	29073	4979
WA	6152	6155	6161	86430	16009
SA	2705	2705	2705	12789	6989
NT	631	683	634	6779	161
VIC	444	444	444	91902	10670
TAS	391	391	391	391	391
ACT	200	200	200	11045	297
Australia	93,144	93,270	93,598	521,105	115,475

[12] Maps of the distribution of the complete pH, hardness and DOC dataset for Australia were unable to be produced because geographical coordinates for many of the data were either not provided or provided in a form that could not be readily used.

[13] There are 16 regions in NZ based on local government boundaries, which includes Nelson City Council, only 422 km^2 in area.

Table 3.2: Number of data points for water chemistry in each region in New Zealand dataset. Regions are ordered from most to least hardness data.

Region	Hardness (total)	Calcium (soluble)	Magnesium (soluble)	pH	DOC
Canterbury	3690	3690	3690	6964	5280
Southland	3229	3229	3229	3625	3633
Manawatu-Whanganui	2823	2824	2823	23905	1079
Auckland	2795	2795	2795	8895	2779
Wellington	1261	1261	1261	2717	2505
Taranaki	681	681	681	923	291
Tasman	672	672	672	2698	69
Waikato	408	408	408	1618	182
Otago	325	325	325	327	193
Bay of Plenty	316	316	316	488	336
West Coast	248	248	248	290	179
Gisborne	144	144	140	3090	14
Hawkes Bay	127	127	127	458	138
Marlborough	0	0	0	0	16
Northland	0	0	0	0	7
New Zealand	16,719	16,720	16,715	55,998	16,678

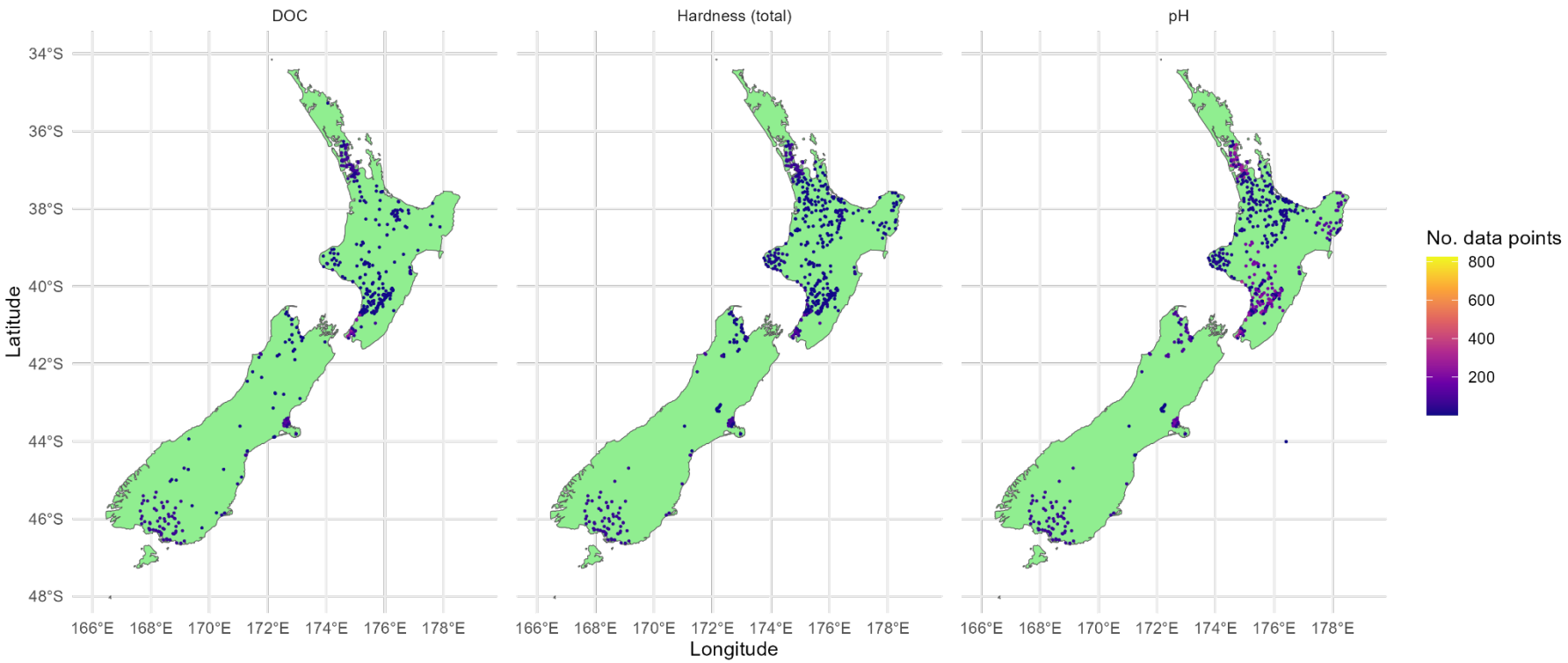


Figure 3.1: Distribution of data from around NZ. The colour of each point represents the number of data collected for each site, ranging from 1 to 825.

3.1.2 Comparison of Australian and New Zealand data

Overall, the pH of waters in Australia and New Zealand was very similar (Figure 3.2, Table 3.3). The median and range of calcium concentrations was also similar though slightly higher in New Zealand (median 11 mg/L compared with 9 mg/L in Australia) and there were some lower measurements in Australia compared to New Zealand. In contrast, magnesium concentrations were frequently higher in Australia than in New Zealand. Overall, the median and the range of total hardness was very similar between the two countries. Calcium, magnesium and hardness concentrations for Australia demonstrated a multimodal distribution, suggesting there may be differences between states or geographic areas. DOC concentrations showed the largest difference between countries, with a median of 2.4 mg/L in New Zealand compared with 5.0 mg/L in Australia.

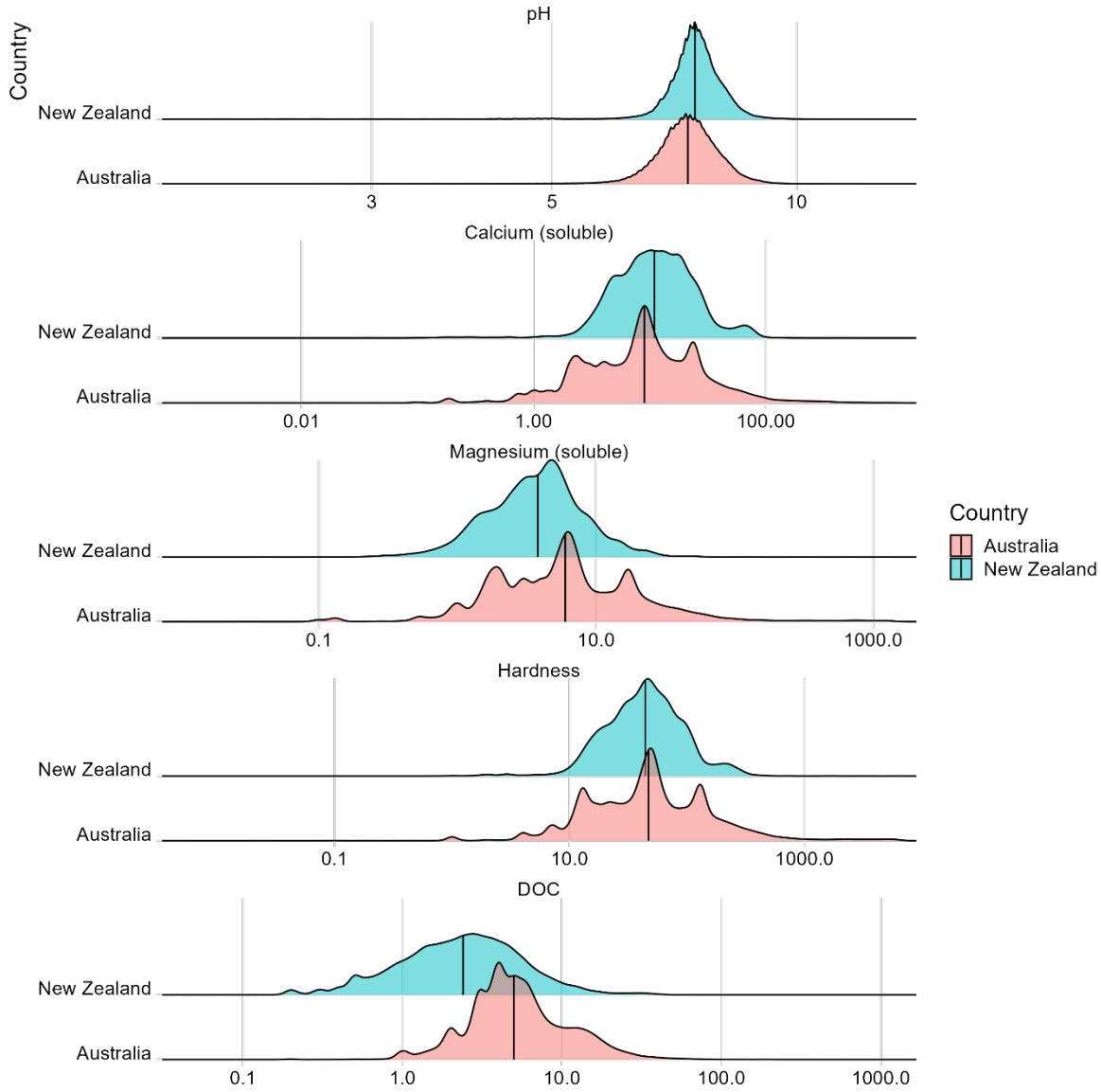


Figure 3.2: Comparison of pH, calcium, magnesium, hardness and DOC between Australia and New Zealand. Dashed vertical lines indicate the median value in each country for each variable. Values except pH are plotted on a log scale (base 10).

Table 3.3: Summary statistics for water chemistry data in the complete Australian and New Zealand datasets.

Statistic	pH	Calcium (soluble) (mg/L)	Magnesium (soluble) (mg/L)	Hardness (total) (mg/L)	DOC (mg/L)
Australia					
No. data points	542853	95987	96338	95859	118894
Minimum	2.2	<0.1	<0.1	<1	<0.1
5th percentile	6.4	1.2	1.0	7.0	1.8
10th percentile	6.6	2.0	1.6	12	2.2
25th percentile	7.0	3.7	2.6	20	3.3
50th percentile	7.4	8.8	5.9	46	4.9
75th percentile	7.7	18	12	98	7.0
90th percentile	8.1	33	26	190	13
95th percentile	8.4	54	46	322	18
Maximum	13.8	1455	1500	6568	1290
New Zealand					
No. data points	55998	16720	16715	16719	16701
Minimum	1.7	<0.1	<0.1	0.76	<0.1
5th percentile	6.8	3.3	1.1	13	0.5
10th percentile	7.0	4.2	1.4	17	0.7
25th percentile	7.2	6.6	2.4	28	1.3
50th percentile	7.5	11	4.0	46	2.4
75th percentile	7.8	19	6.1	72	4.2
90th percentile	8.2	28	9.8	110	6.7
95th percentile	8.4	40	14	156	9.3
Maximum	12.6	518	1240	6100	58

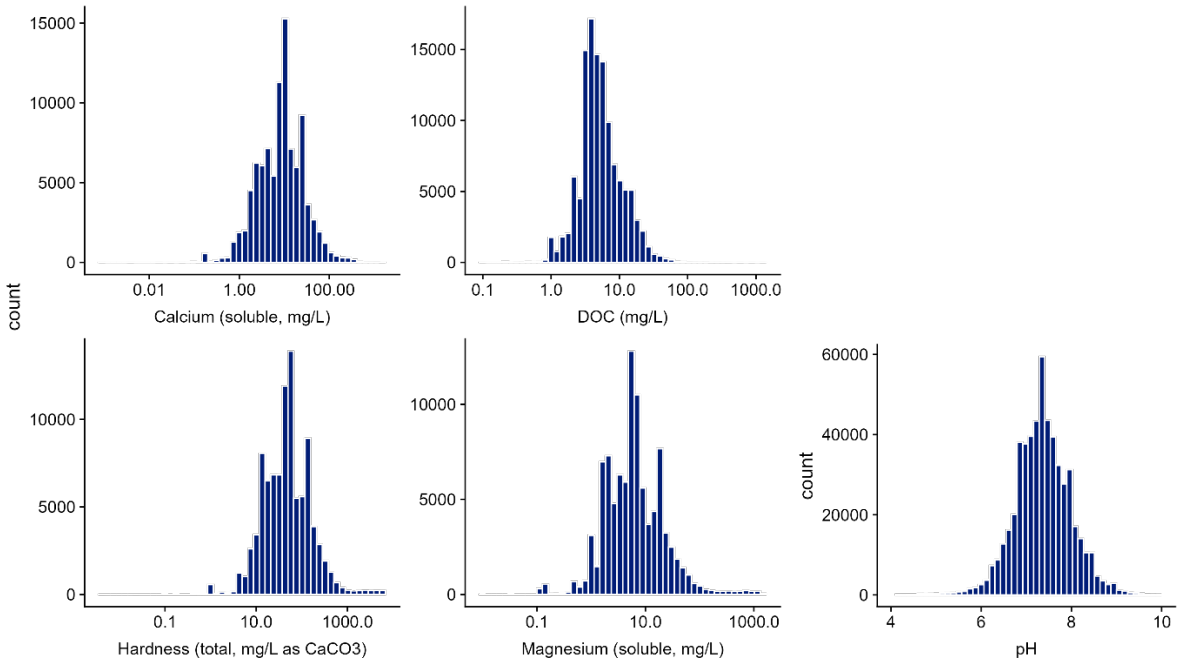


Figure 3.3: Distribution of all available calcium, magnesium, DOC, hardness and pH data for Australia.

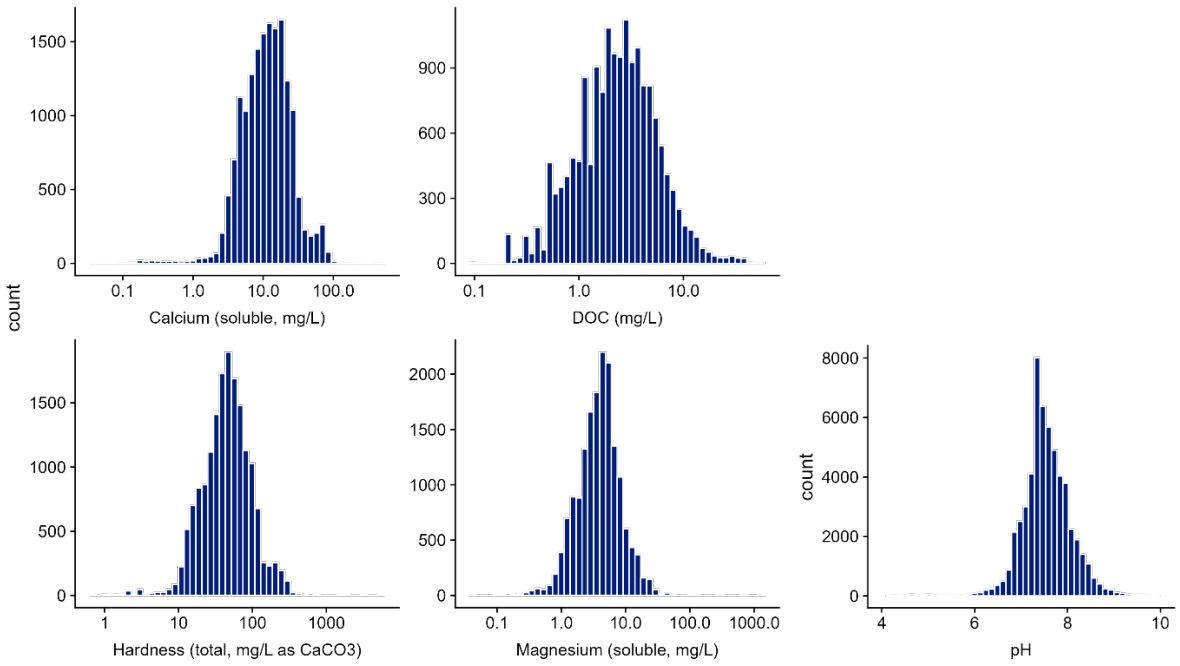


Figure 3.4: Distribution of all available calcium, magnesium, DOC, hardness and pH data for New Zealand.

3.1.3 Variability between states and regions

There were only minor differences in pH between states (Figure 3.5), with slightly higher median pH measured in South Australia and NT (7.7), compared to other states (7.2-7.4, Table 3.4). There was greater difference in hardness and DOC between states, for example, the median hardness for Victoria was only 9.9 mg/L, compared to 207 mg/L for NT. Median DOC ranged from a low of 1.9 mg/L in NT to a high of 13 mg/L in WA.

Table 3.4: Median and range (5th to 95th percentile) in water chemistry for each state in Australia, based on all available data.

State	pH	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as $CaCO_3$)	DOC (mg/L)
ACT	7.4 (6.6-8.6) (n=11045)	6.3 (3.2-13.0147) (n=200)	4.5 (2.2-9.81045) (n=200)	34 (17-71.84) (n=200)	6 (3-12) (n=297)
NSW	7.4 (6.4-8.39) (n=282696)	7.9 (1.3-34) (n=64398)	5.3 (1-24.9626) (n=64769)	42 (7-189) (n=64327)	4.4 (1.9-10.2) (n=75979)
NT	7.7 (5.6-8.38) (n=6779)	40 (0.9-109) (n=683)	26 (0.78-99.2617) (n=634)	210 (5.4-583.05) (n=631)	1.9 (0.6-5) (n=161)
QLD	7.4 (6.4-8.22) (n=29073)	12 (0.8-62.735) (n=18294)	6.2 (0.8-52) (n=18294)	55 (6.1-361) (n=18294)	8.2 (1.3-24) (n=4979)
SA	7.7 (7.2-8.5) (n=12789)	12 (6.5-22.4629) (n=2705)	8.7 (4.8-16.8) (n=2705)	66 (36-125.133) (n=2705)	4.7 (2.8-12.6) (n=6989)
TAS	7.2 (6.5-7.965) (n=391)	29 (1.2-90.4) (n=391)	20 (3-70.4) (n=391)	160 (16-523.806) (n=391)	7.3 (2-17.5) (n=391)
VIC	7.2 (6.5-8.4) (n=91902)	1.6 (0.33-6.6085) (n=444)	1 (0.29-2) (n=444)	9.9 (2-20.0331) (n=444)	3.1 (1.2-15) (n=10670)
WA	7.4 (6.2-8.42) (n=86430)	23 (6.2-257) (n=6155)	26 (5.9-860) (n=6161)	170 (43-4222.63) (n=6152)	13 (3.7-36) (n=16009)
Australia	7.4 (6.4-8.4) (n=521105)	8.8 (1.2-54) (n=93270)	5.9 (1.0-46) (n=93598)	46 (7.0-322) (n=93144)	4.9 (1.8-18) (n=115475)

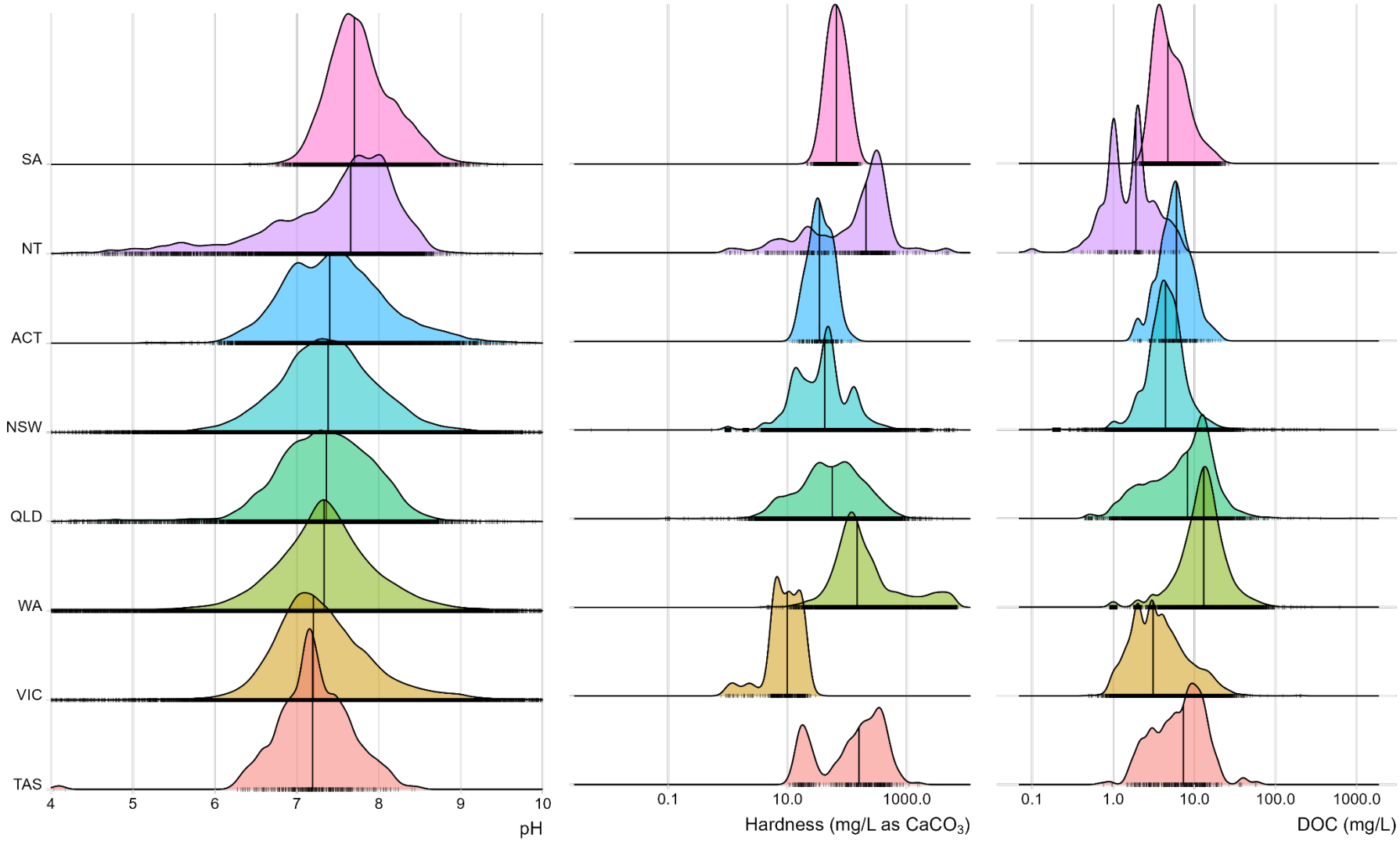


Figure 3.5: Variation in pH, hardness and DOC within and between states of Australia. All values except pH are plotted on a log scale (base 10).

There were greater differences in pH between regions of New Zealand (Figure 3.6), with a median pH of 5.2 for the West Coast and a median of 8.2 in Gisborne region (Table 3.5). Water hardness was also the lowest (7 mg/L, West Coast) and highest (163 mg/L Gisborne) in these two regions. DOC varied less between regions, with around a factor of 4-5 difference between the lowest (0.8 mg/L) and highest (3.6 mg/L) median concentrations.

Table 3.5: Median and range (5th to 95th percentile) in water chemistry for each region of New Zealand, based on all available data. Number of available data shown below range.

State	pH	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as $CaCO_3$)	DOC (mg/L)
Auckland	7.4 (6.7-7.9) (n=8895)	12 (4.5-24) (n=2795)	4.9 (2.5-11) (n=2795)	50 (22-100) (n=2795)	3.5 (1.2-8) (n=2779)
Bay of Plenty	7.2 (6.7-7.8) (n=488)	4.1 (0.84-16) (n=316)	1.8 (0.44-6) (n=316)	18 (3.9-65) (n=316)	2.0 (0.5-13) (n=336)
Canterbury	7.4 (6.8-7.9) (n=6964)	19 (10-35) (n=3690)	5.8 (1.7-15) (n=3690)	74 (33-140) (n=3690)	1.4 (0.34-7.5) (n=5280)
Gisborne	8.2 (7.5-8.9) (n=3090)	60 (10-110) (n=144)	2.4 (0.49-7.3) (n=140)	170 (29-300) (n=144)	2.8 (1.4-16) (n=14)
Hawkes Bay	7.9 (7-8.5) (n=458)	64 (17-79) (n=127)	20 (6.1-23) (n=127)	240 (67-290) (n=127)	3.1 (0.65-9.9) (n=138)
Manawatu-Whanganui	7.6 (6.8-8.5) (n=23905)	8 (3.3-61) (n=2824)	2.5 (1-15) (n=2823)	31 (13-210) (n=2823)	2.1 (0.8-7.3) (n=1079)
Marlborough	0	0	0	0	0.8 (0.17-4.9) (n=16)
Northland	0	0	0	0	3 (2.1-7.5) (n=7)
Otago	7.8 (7.5-8.3) (n=327)	16 (6.5-70) (n=325)	4.1 (1.5-25) (n=325)	52 (27-280) (n=325)	2.3 (0.3-9.9) (n=193)
Southland	7.4 (6.8-8) (n=3625)	8.4 (3.1-27) (n=3229)	3.3 (0.98-7.3) (n=3229)	35 (12-96) (n=3229)	3.4 (1-15) (n=3633)
Taranaki	7.5 (6.8-8) (n=923)	8 (2.4-16) (n=681)	2.9 (0.96-6.9) (n=681)	32 (9.9-66) (n=681)	1.8 (0.5-5.8) (n=291)
Tasman	7.7 (7.1-8.2) (n=2698)	15 (5.5-34) (n=672)	3.6 (1.1-16) (n=672)	58 (20-130) (n=672)	2.2 (0.94-6.7) (n=69)
Waikato	7.3 (6.6-7.8) (n=1618)	8.3 (2.7-19) (n=408)	2.7 (1.2-7.2) (n=408)	33 (12-70) (n=408)	1.4 (0.72-5) (n=182)
Wellington	7.3 (6.7-8.1) (n=2717)	8.3 (4.5-14) (n=1261)	4.1 (1.6-6.7) (n=1261)	37 (18-60) (n=1261)	2.3 (0.78-10) (n=2505)
West Coast	5 (4.6-7.3) (n=290)	0.81 (0.14-6.1) (n=248)	0.55 (0.26-1.9) (n=248)	4 (1.5-23) (n=248)	3.6 (1.3-7.4) (n=179)
New Zealand	7.5 (6.8-8.4) (n=55998)	11 (3.3-40) (n=16720)	3.8 (1.1-14) (n=16715)	46 (13.5-156) (n=16719)	2.4 (0.5-9.3) (n=16701)

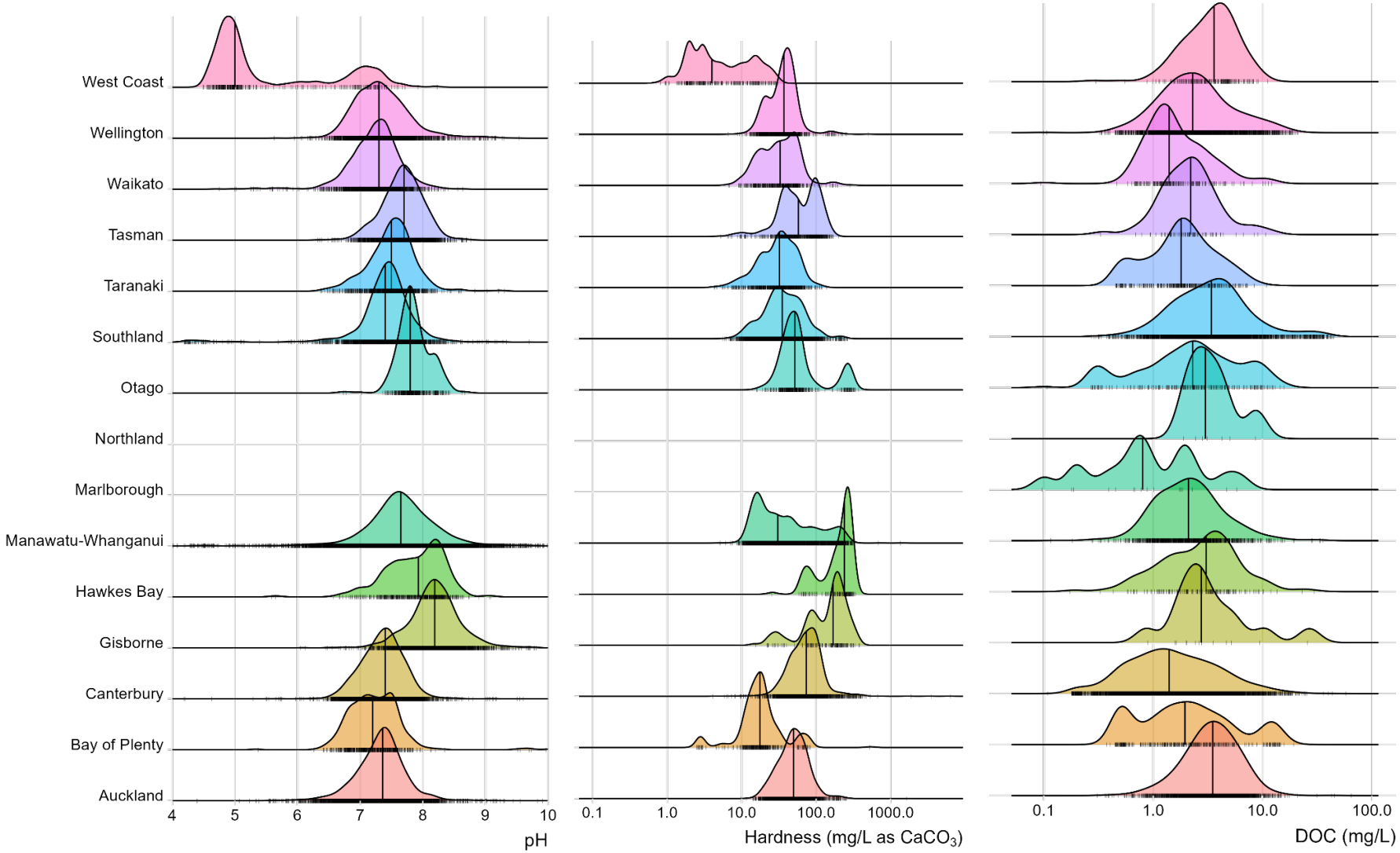


Figure 3.6: Variation in pH, calcium, magnesium, hardness and DOC within and between regions of New Zealand. Vertical lines indicate median value for each region. All values except pH are plotted on a log scale (base 10).

3.2 Matched datasets

3.2.1 Data availability and geographic distribution

From the total dataset, there were 20,784 data points from Australia (Figure 3.7, Table 3.6) where pH, hardness, calcium, magnesium and DOC were measured (or estimated) on the same site, date and time (termed matched data). These were from 673 different sites distributed across all 7 states/territories for which water chemistry data were obtained. Around half of the data (52%) were from measurements since January 2014: 10,637 samples from 283 sites (Figure 3.8).

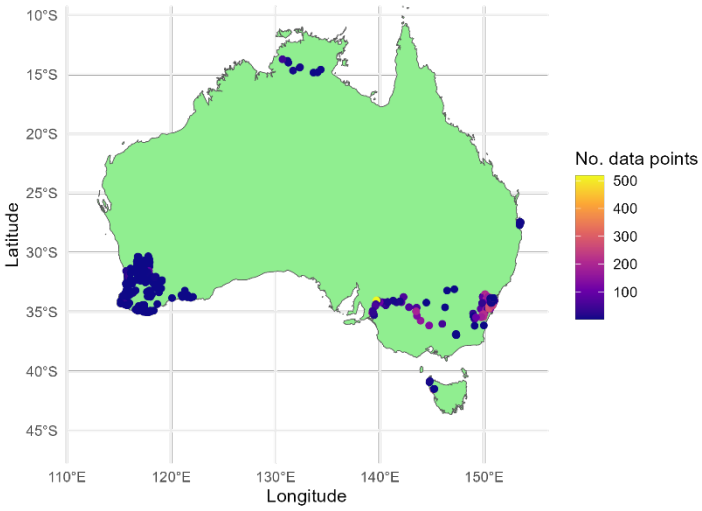


Figure 3.7: Distribution of matched data from around Australia. The colour of each point represents the number of data collected for each site, ranging from 1 to 600.

Table 3.6: Summary of Australian dataset.

	Matched only	
State	No. data	No. sites
NSW	15725	189
SA	2428	28
WA	1415	384
VIC	428	23
TAS	391	14
QLD	181	21
ACT	148	5
NT	68	9
Australia	**20784**	**673**

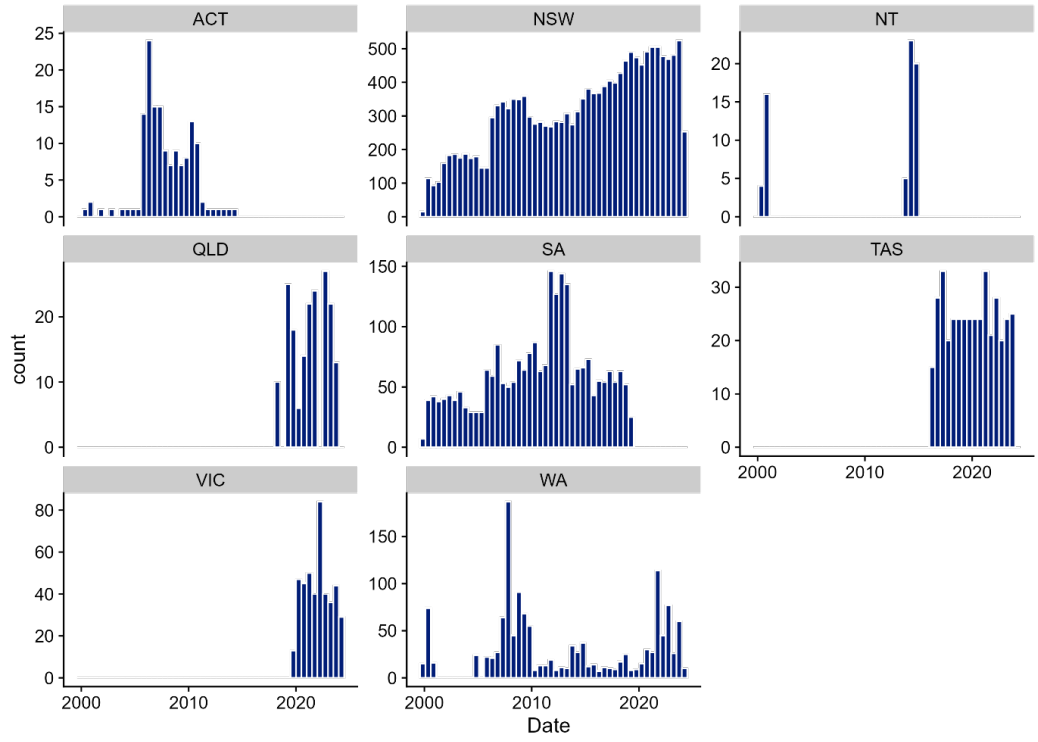


Figure 3.8: Distribution of matched data across time for each state of Australia. No data before 2000 were included for this analysis.

For New Zealand, there were 10,364 data points where pH, hardness, calcium, magnesium and DOC were measured (or estimated) on the same site, date and time (Figure 3.9). These were from 450 different sites distributed across 12 regions (Table 3.7). Three regions with water chemistry data (Northland, Gisborne and Marlborough) were not included as the only available data from those regions were where pH, hardness and DOC were measured on different dates at the same sites, or at different sites.

Most of the data (92%) were from measurements within the last 10 years: from 2014 onwards there were 9,549 samples from 415 sites (Figure 3.10). Data from all years (from 1 January 2000, see section 2.3) were retained to keep a broader geographical coverage. When the dataset was clipped to the most recent 10 years, this excluded data from the Waikato (sites sampled once in 1995), Hawkes Bay (sites sampled 2010-11) and Tasman (sites sampled only in 2013) regions.

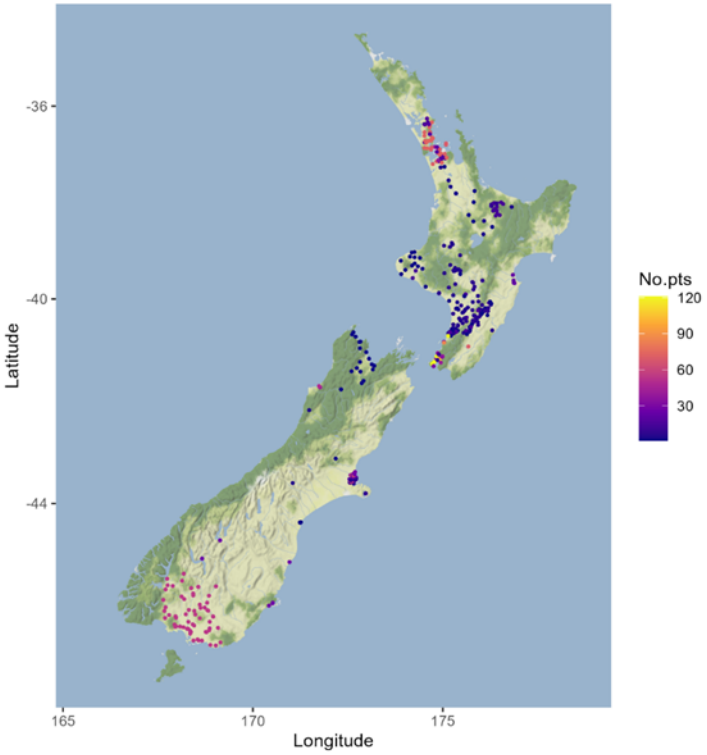


Figure 3.9: Distribution of matched data from around NZ. The colour of each point represents the number of data collected for each site, ranging from 1 to 121.

Table 3.7: Summary of New Zealand dataset.

	Matched only	
Region	No. data	No. sites
Auckland	2764	52
Bay of Plenty	183	20
Canterbury	1622	57
Hawkes Bay	109	5
Manawatu-Whanganui	928	180
Otago	153	6
Southland	3227	60
Taranaki	37	15
Tasman	21	21
Waikato	15	12
Wellington	1175	18
West Coast	130	4
New Zealand	10364	450

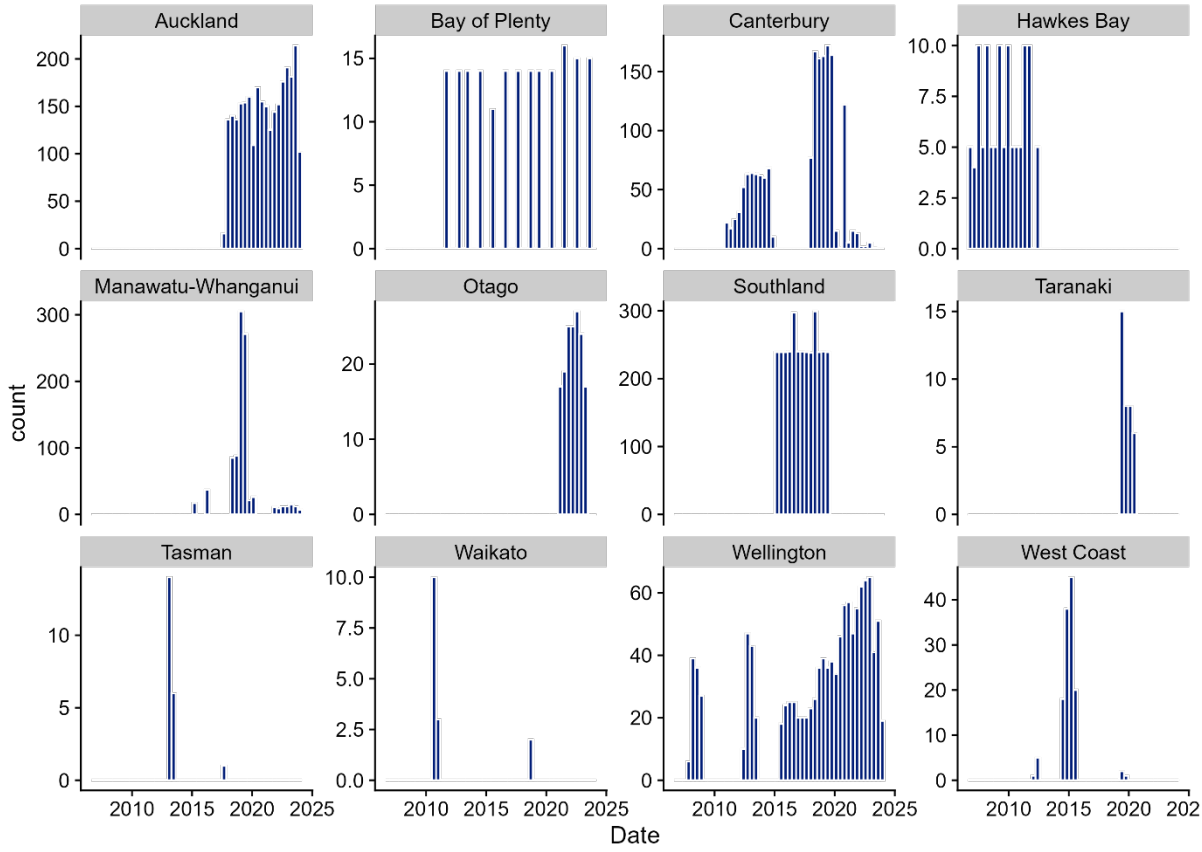


Figure 3.10: Distribution of matched data across time for each region of New Zealand. No data before 2000 were included in this analysis.

3.2.2 Representativeness of the Australian matched dataset

There were minor differences between the matched dataset and the complete dataset for Australia (Table 3.9). In particular, there was a tendency to slightly lower pH, hardness and DOC values in the matched dataset (Figure 3.11). The summary statistics for hardness and DOC are similar to, but slightly lower than, those previously presented for Australia (Stauber et al. 2023). The changes reflect additional sites included within Queensland, ACT and Tasmania, and additional data for sites in WA. The median pH was 7.4 (complete) and 7.2 (matched) for both datasets, respectively.

Table 3.8: Summary statistics for water chemistry data in complete Australian dataset compared with the matched dataset.

	pH	Calcium (soluble)	Magnesium (soluble)	Hardness (total)	DOC
No. data points in complete dataset	521,105	93,270	93,598	93,144	115,475
No. data points in matched dataset	20,784	20,784	20,784	20,784	20,784
Median (range) complete dataset	7.4 (2.2-13.8)	8.8 (<0.1-1455)	5.9 (<0.1-1500)	46 (<0.1-6568)	4.9 (0.1-1290)
Median (range) matched dataset	7.2 (2.8-13.8)	6.0 (<0.1-941)	4.5 (<0.1-1500)	33 (0.5-6559)	4.5 (0.2-385)

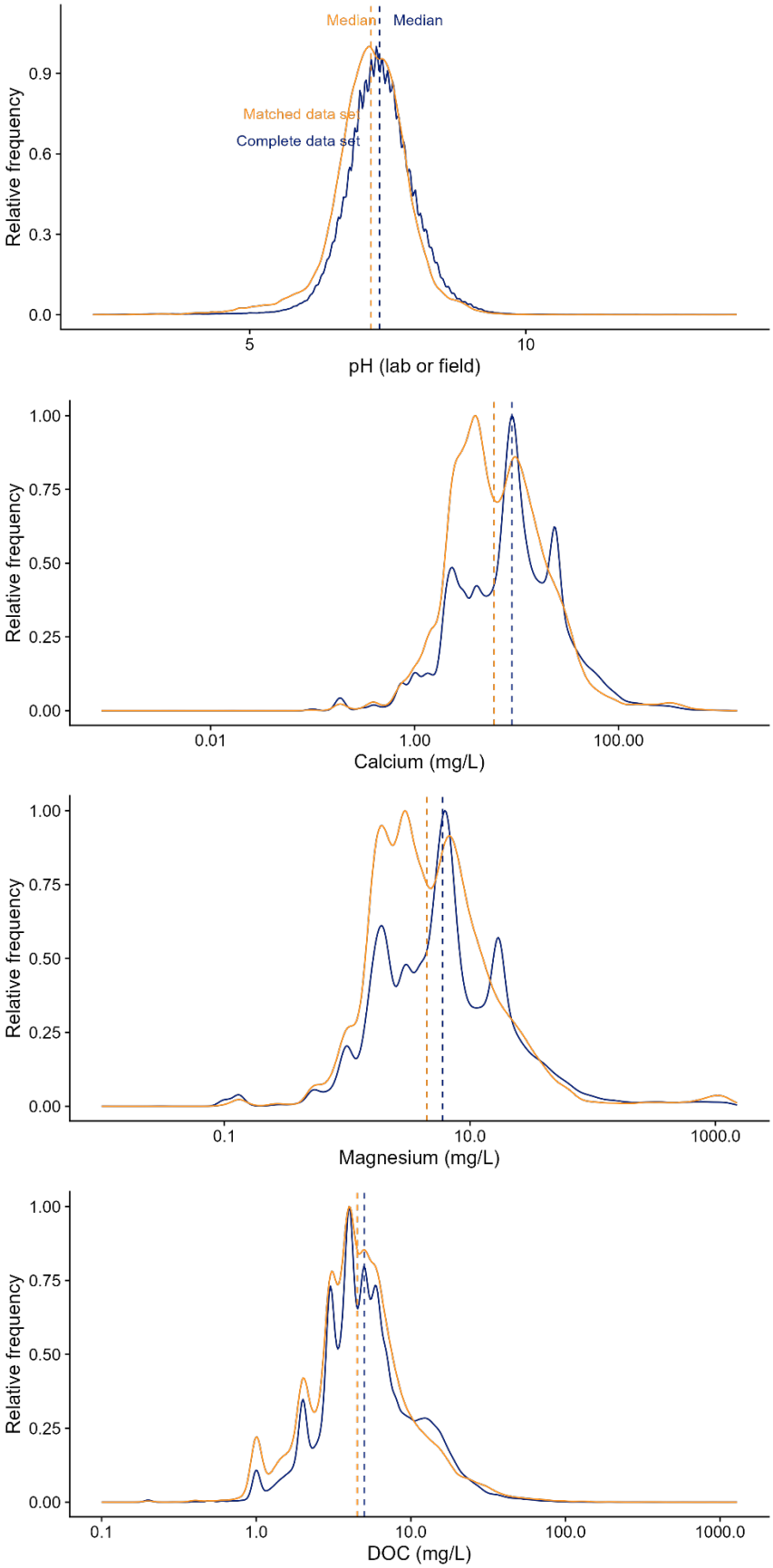


Figure 3.11: Distribution of pH, DOC and calcium, magnesium in the matched dataset (orange) compared with the complete dataset (blue) for Australia. Median values for each dataset shown by dashed vertical lines.

3.2.3 Representativeness of the New Zealand matched dataset

There were only very minor differences between the matched dataset and the complete dataset for New Zealand (Figure 3.12, Table 3.9). The median pH, calcium and magnesium were very similar in both datasets and DOC was slightly higher in the matched dataset than in the complete dataset.

Table 3.9: Summary statistics for water chemistry data in complete New Zealand dataset compared with the matched dataset.

	pH	Calcium (soluble)	Magnesium (soluble)	Hardness (total)	DOC
No. data points in complete dataset	55998	16720	16715	16719	16701
No. data points in matched dataset	10364	10364	10364	10364	10364
Median (range) complete dataset	7.5 (1.7-12.6)	11 (<0.1-518)	4.0 (<0.1-1240)	4 (0.8-6100)	2.4 (<0.1-58)
Median (range) matched dataset	7.4 (2.4-9.7)	11 (<0.1-518)	4.1 (<0.1-133)	44 (1-1760)	2.8 (<0.2-58)

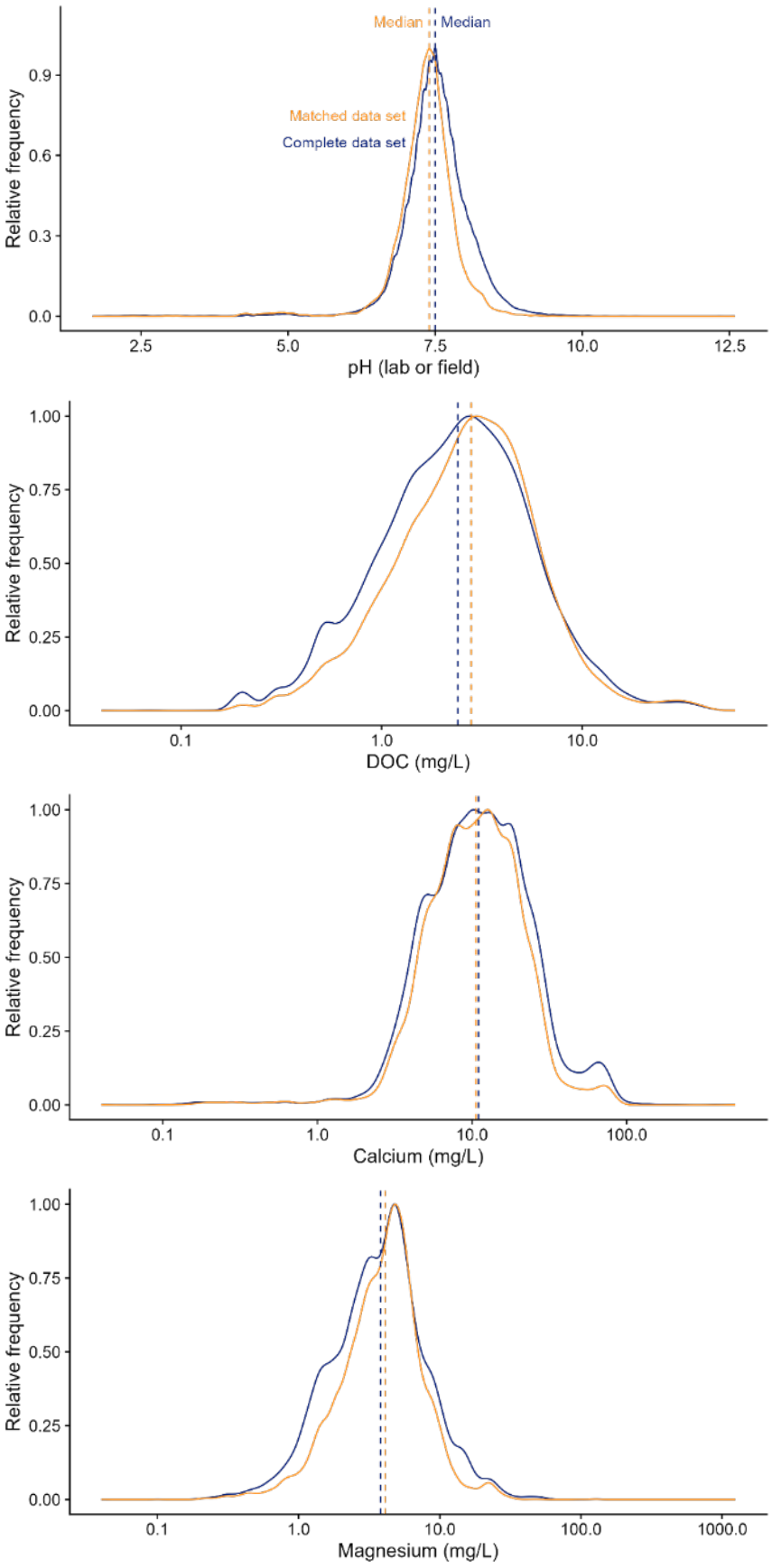


Figure 3.12: Distribution of pH, DOC and calcium, magnesium in the matched dataset (orange) compared with the complete dataset (blue) for New Zealand. Median values for each dataset shown by dashed vertical lines.

Metadata were used to assess the possible representativeness of the matched dataset compared with all streams in New Zealand (Figure 3.13 and Figure 3.14). The matched dataset is broadly representative in terms of the proportion of streams with native and exotic forest or pastoral land cover in the upstream catchment. There is a much larger proportion of streams with urban land cover in the matched dataset, compared to all river lengths. It has previously been shown that the network of river water quality monitoring sites in New Zealand is over-represented by sites in catchments dominated by pastoral land cover and under-represented by sites in catchments dominated by native forest (Larned and Unwin 2012, Whitehead 2019). However, this dataset is more over-represented by urban sites. This reflects the monitoring of urban streams for metals, and that councils have begun to collect hardness and DOC concentrations in these locations. The matched dataset includes a lower proportion of first order streams than those present across New Zealand. This is because these first order streams are less frequently monitored by councils, as monitoring generally aims to cover a greater catchment area. This type of analysis was not feasible for the Australian dataset as the metadata required for matching and for comparison was not readily accessible.

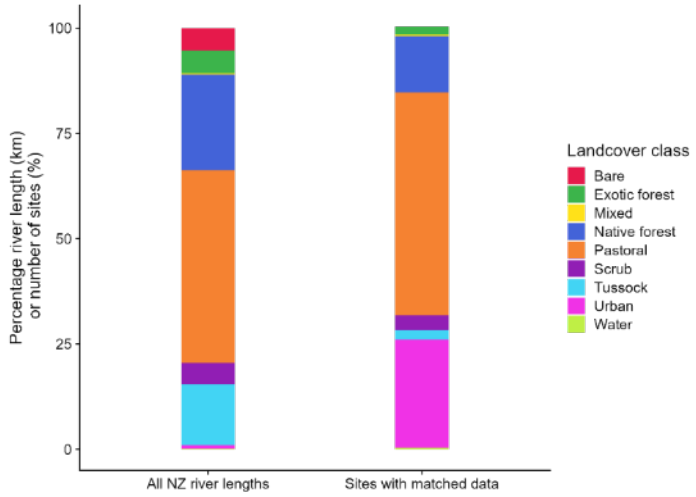


Figure 3.13: Comparison of the dominant land cover in the upstream catchment of the matched dataset with that for all NZ river length. The matched dataset includes fewer first order streams as these are more rarely monitored by councils.

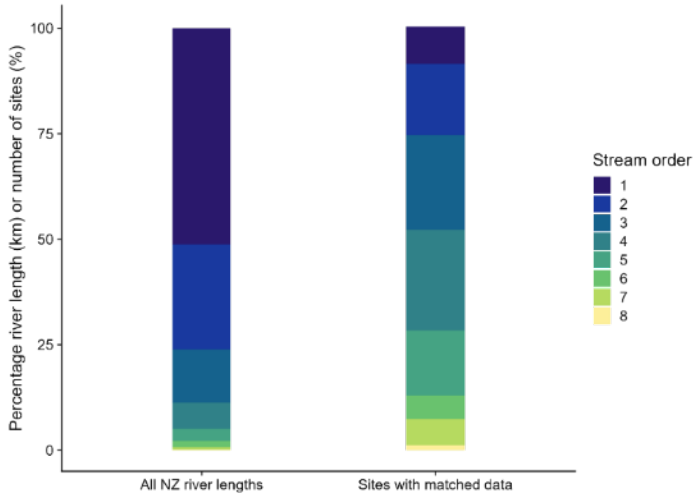


Figure 3.14: Comparison of the Strahler stream order of the matched dataset with the Strahler stream order for all NZ river length. The matched dataset includes fewer first order streams as these are more rarely monitored by councils.

3.2.4 Summary of water chemistry

Summary statistics for both countries are provided in Table 3.9, and histograms of the data are provided in Figure 3.15 for Australia and in Figure 3.16 for New Zealand. The calcium, magnesium, hardness and DOC concentrations are log-normally distributed in both countries. As for the complete dataset, the pH was similar between countries, though there was a greater proportion of values less than 7.0 in Australia than in New Zealand.

The calcium concentrations were lower in Australia than in New Zealand. For the matched dataset, median magnesium was very similar between the two countries, although the distributions were quite different: the Australian dataset was right-skewed, with many values between 10 and 100 mg/L (Figure 3.15), whereas the New Zealand dataset was left-skewed with few values above 10 mg/L (Figure 3.16). DOC was higher in Australia than in New Zealand, with nearly 25% of the data above 10 mg/L in Australia, compared to around 5% greater than 10 mg/L in New Zealand.

Table 3.10: Summary statistics for water chemistry data in the matched Australian and New Zealand datasets.

Statistic	pH	Calcium (soluble)	Magnesium (soluble)	Hardness (total)	DOC
Australia					
No. data points	20784	20784	20784	20784	20784
Minimum	2.8	<0.1	<0.1	0.5	<0.2
5th percentile	6.0	1.3	1.0	8	1.3
10th percentile	6.4	2.0	1.5	11	2.0
25th percentile	6.8	3.0	2.2	17	3.0
50th percentile	7.2	6.0	4.2	33	4.5
75th percentile	7.6	13	9.0	69	6.8
90th percentile	8.0	25	19	145	11.9
95th percentile	8.2	36	32	223	17
Maximum	13.8	941	1500	6559	385
New Zealand					
No. data points	10364	10364	10364	10364	10364
Minimum	2.4	<0.1	<0.1	1	<0.2
5th percentile	6.7	3.5	1.2	14	0.6
10th percentile	6.9	4.5	1.6	19	0.9
25th percentile	7.1	6.6	2.6	29	1.6
50th percentile	7.4	10.6	4.1	44	2.8
75th percentile	7.6	16.8	5.7	65	4.5
90th percentile	7.8	24.0	8.4	93	6.8
95th percentile	8.1	29.1	10.3	112	9.0
Maximum	9.7	518	133	1760	58

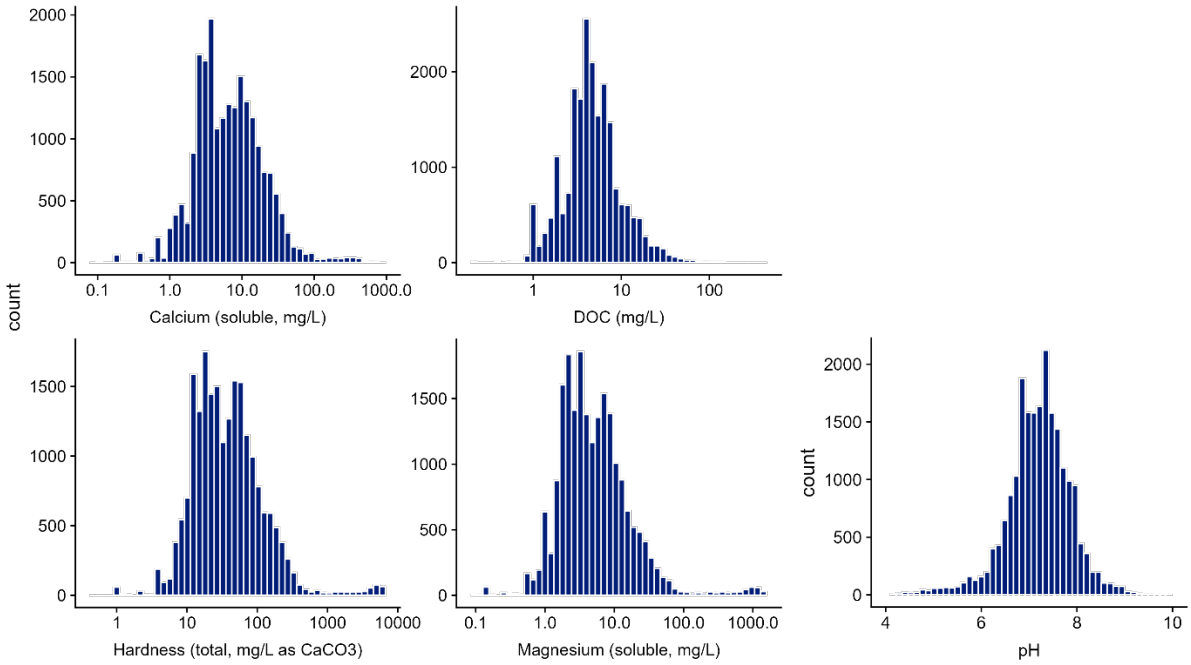


Figure 3.15: Distribution of calcium, magnesium, DOC, hardness and pH data for Australia. Data only included where all three variables were measured or estimated from other data.

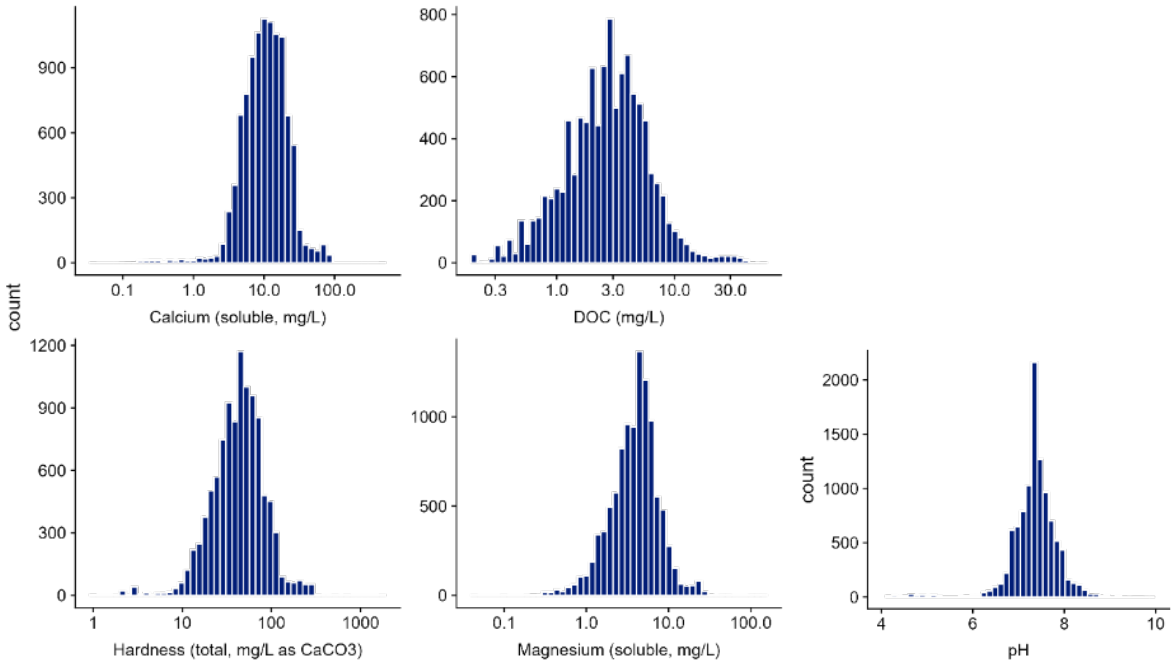


Figure 3.16: Distribution of calcium, magnesium, DOC, hardness and pH data for New Zealand. Data only included where all three variables were measured or estimated from other data.

3.2.5 Correlations in water chemistry

Figure 3.17 shows scatterplot matrices between the combinations of pH, DOC and hardness (on a log-scale) for each country. There is considerable scatter in the values for both countries and no strong correlations between pairs of water chemistry variables.

The 'index' condition that was used to define the DGVs in the original draft Australian and New Zealand metal DGV technical briefs, is also shown (pH 7.5, hardness 30 mg/L as $CaCO_3$ and DOC 0.5 mg/L). This index condition is well within the range of the Australian water chemistry data for pH and hardness but is outside the range of most samples for DOC (lower than most DOC measurements). This was a deliberate decision, to ensure the index condition was representative of high metal bioavailability. For New Zealand, the index condition is within the range for natural water chemistry in New Zealand, though it is at the lower end for DOC and hardness.

The principal components analysis (PCA, Figure 3.18) also demonstrates that the 'index' condition is within the range of the data collated from around both Australia and New Zealand.

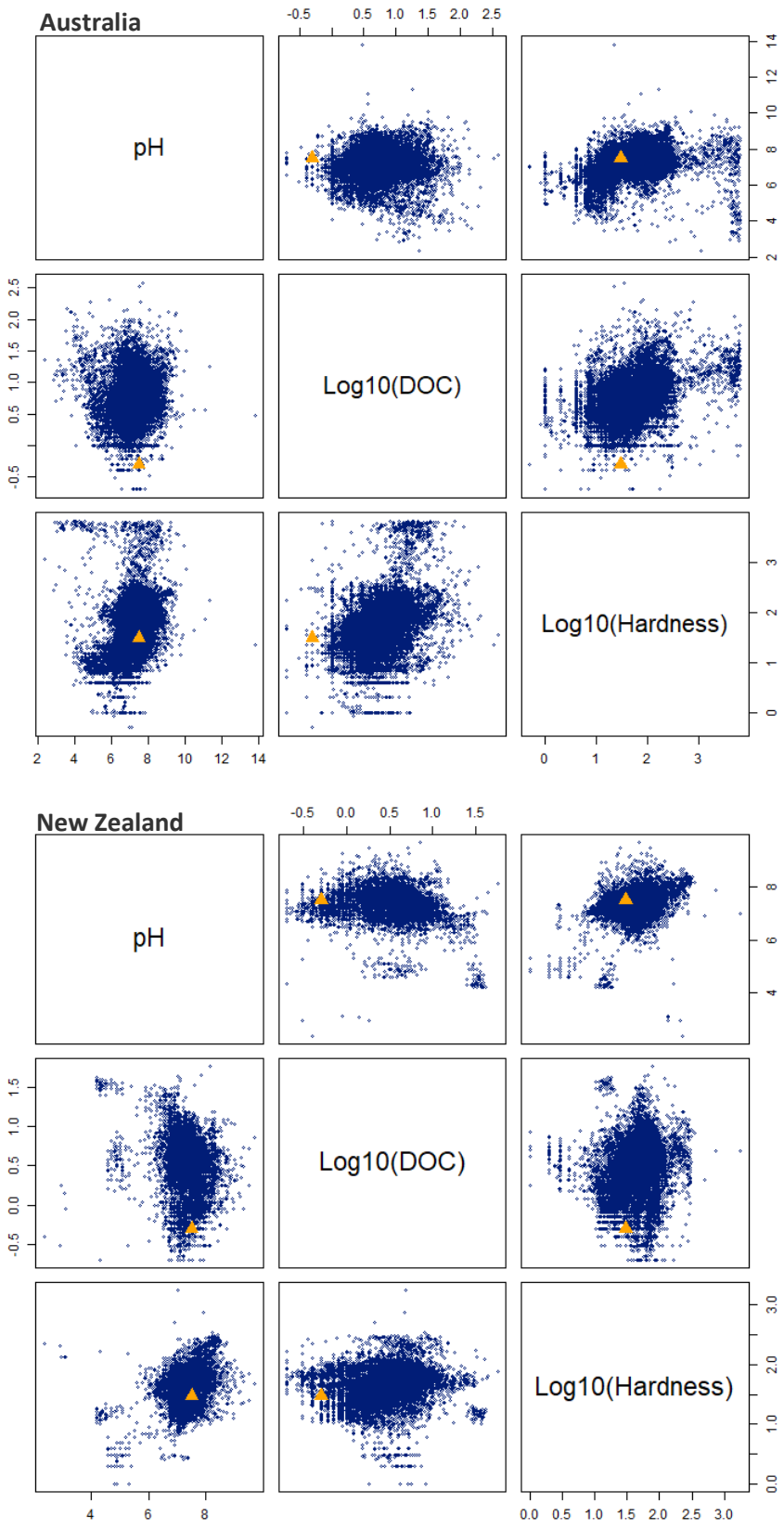


Figure 3.17: Relationships between pH, hardness (log-scale) and DOC (log-scale) for Australian (top) and NZ (bottom) data. Individual squares represent bivariate plots of the variable named to the left or right and at the top or bottom. For example, top centre plot shows pH vs $\log_{10}$DOC. Axis tick marks are log values for hardness and DOC. Orange triangle indicates the 'index' condition used for the original draft nickel and zinc DGVs in ANZG technical briefs. Data only included where all three variables were measured or estimated from other data. Upper and lower panels show same data with axes are transposed.

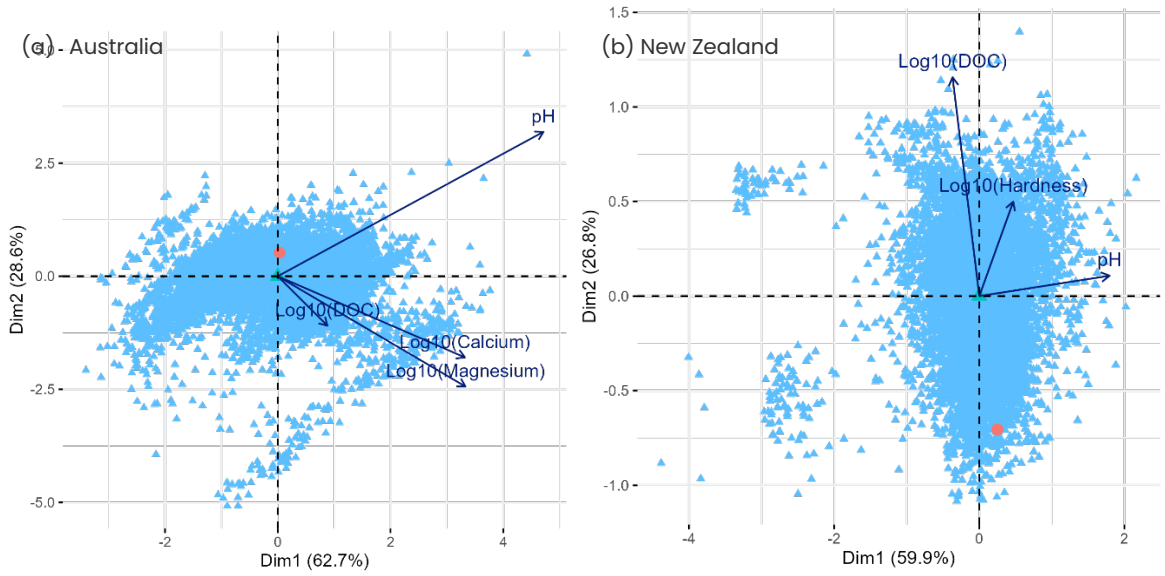


Figure 3.18: Principal components analysis biplot for pH, hardness (log-scale) and DOC (log-scale) for (a) Australian and (b) New Zealand data. Data only included where all three variables were measured or estimated from other data. Orange circle indicates the index condition used for nickel and zinc DGVs.

3.2.6 Variability between states and regions

There was a broad range in the measurements for all of the water chemistry variables and variation both within and between states of Australia (Figure 3.19 and Figure 3.21) and regions of New Zealand (Figure 3.20 and Figure 3.22).

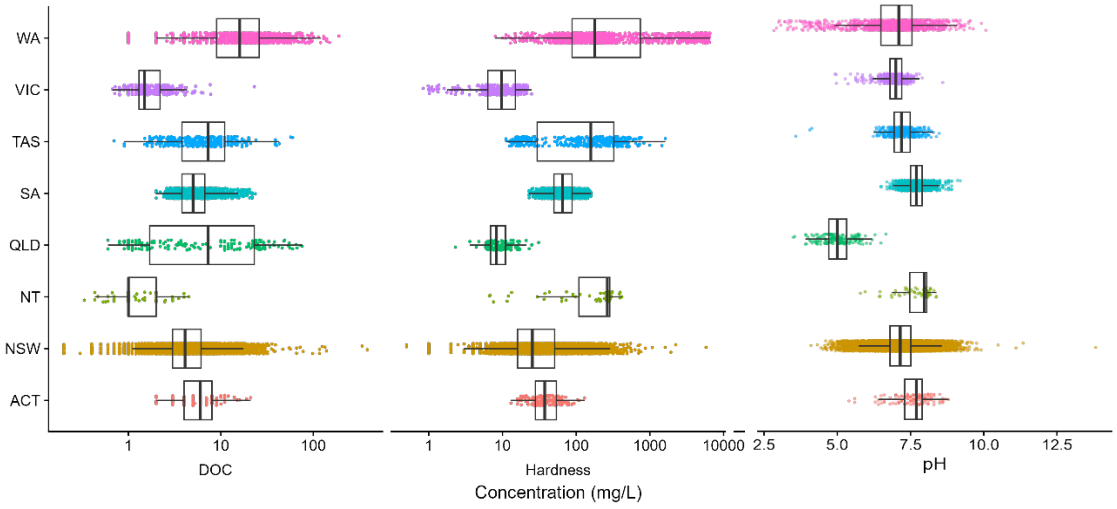


Figure 3.19: Variation in DOC, hardness and pH within and between states of Australia. Data only included where all three variables were measured or estimated from other data.

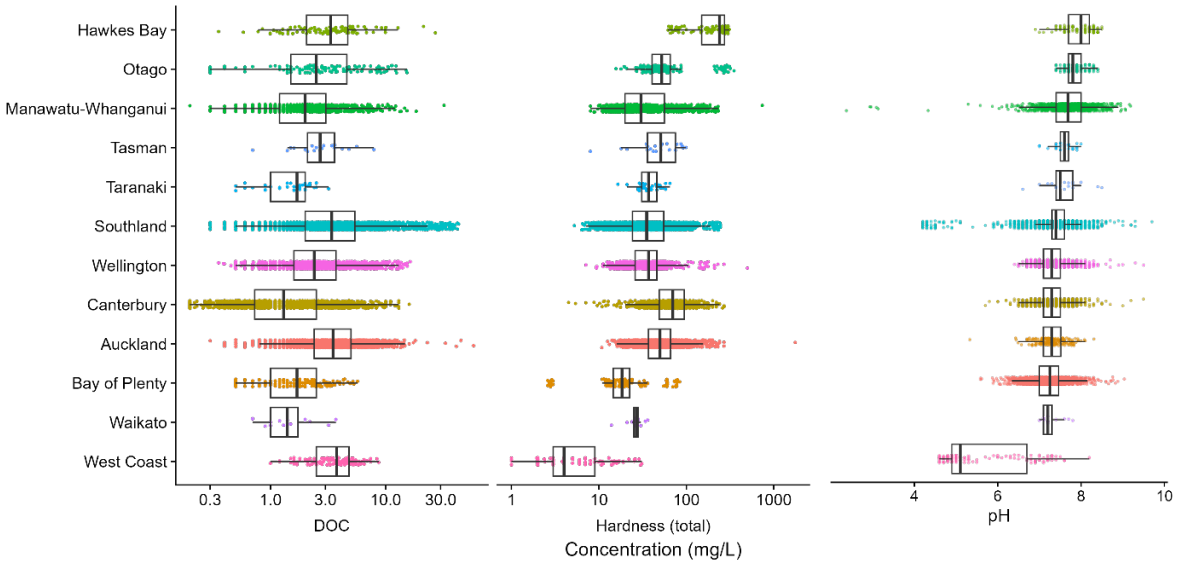


Figure 3.20: Variation in DOC, hardness and pH within and between regions of NZ. Data only included where all three variables were measured or estimated from other data.

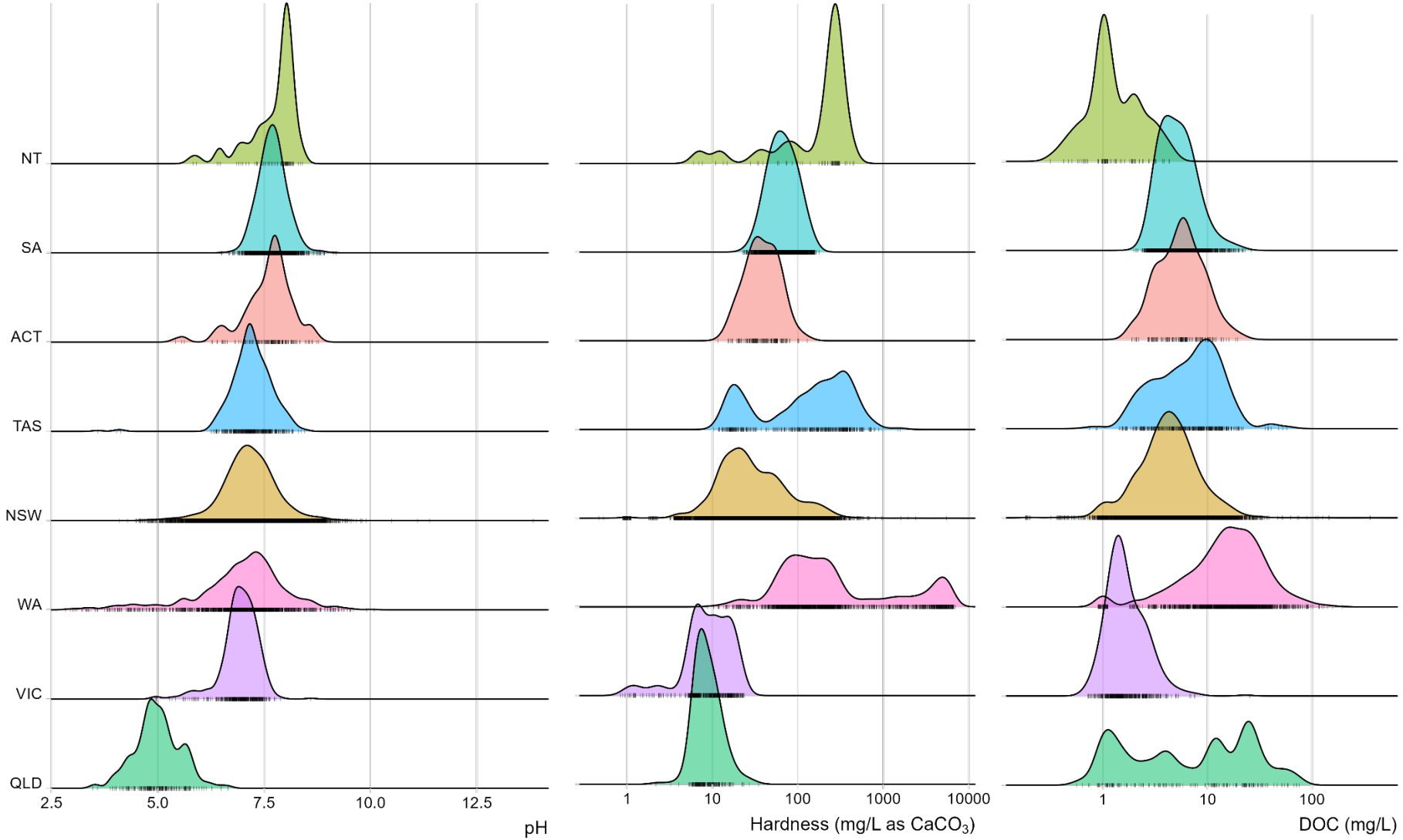


Figure 3.21: Illustration of variation in pH, hardness and DOC within and between states of Australia. Data only included where all three variables were measured or estimated from other data.

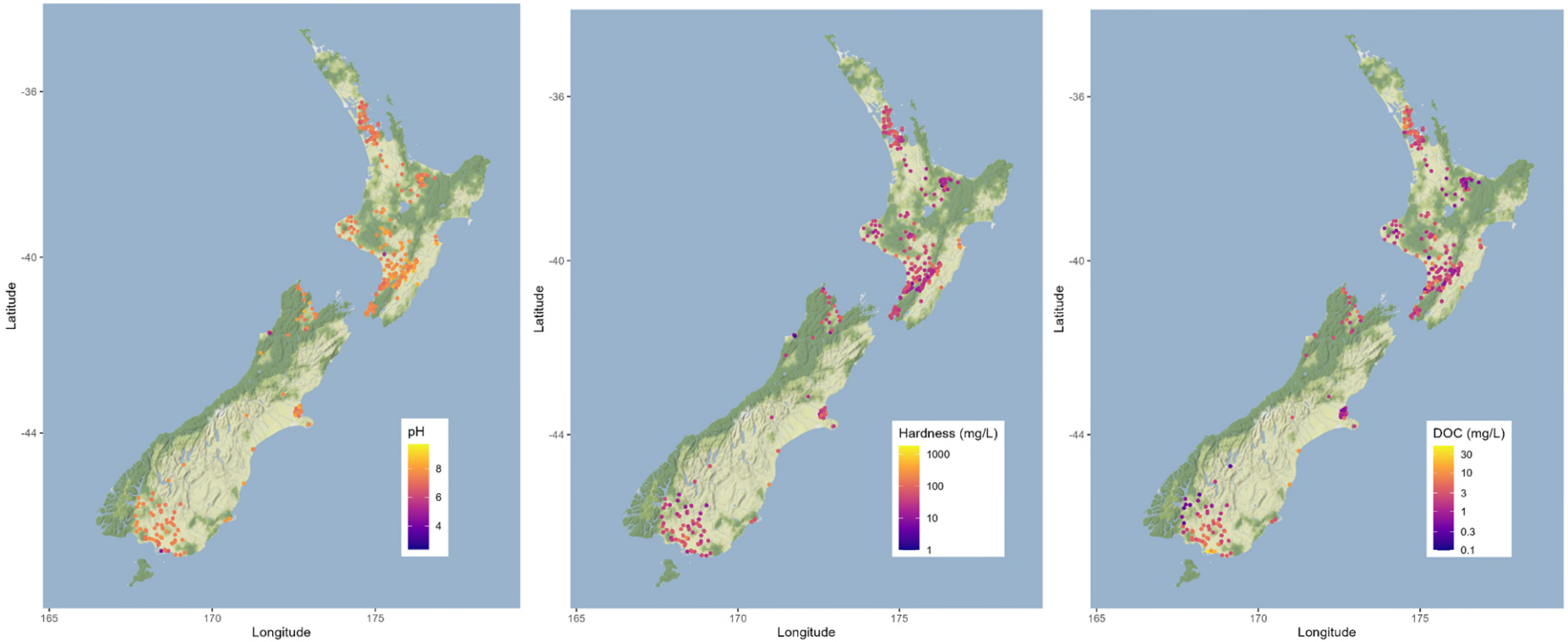


Figure 3.22: Geographic variation in pH, hardness and DOC around NZ. Data only included where all three variables were measured or estimated from other data.

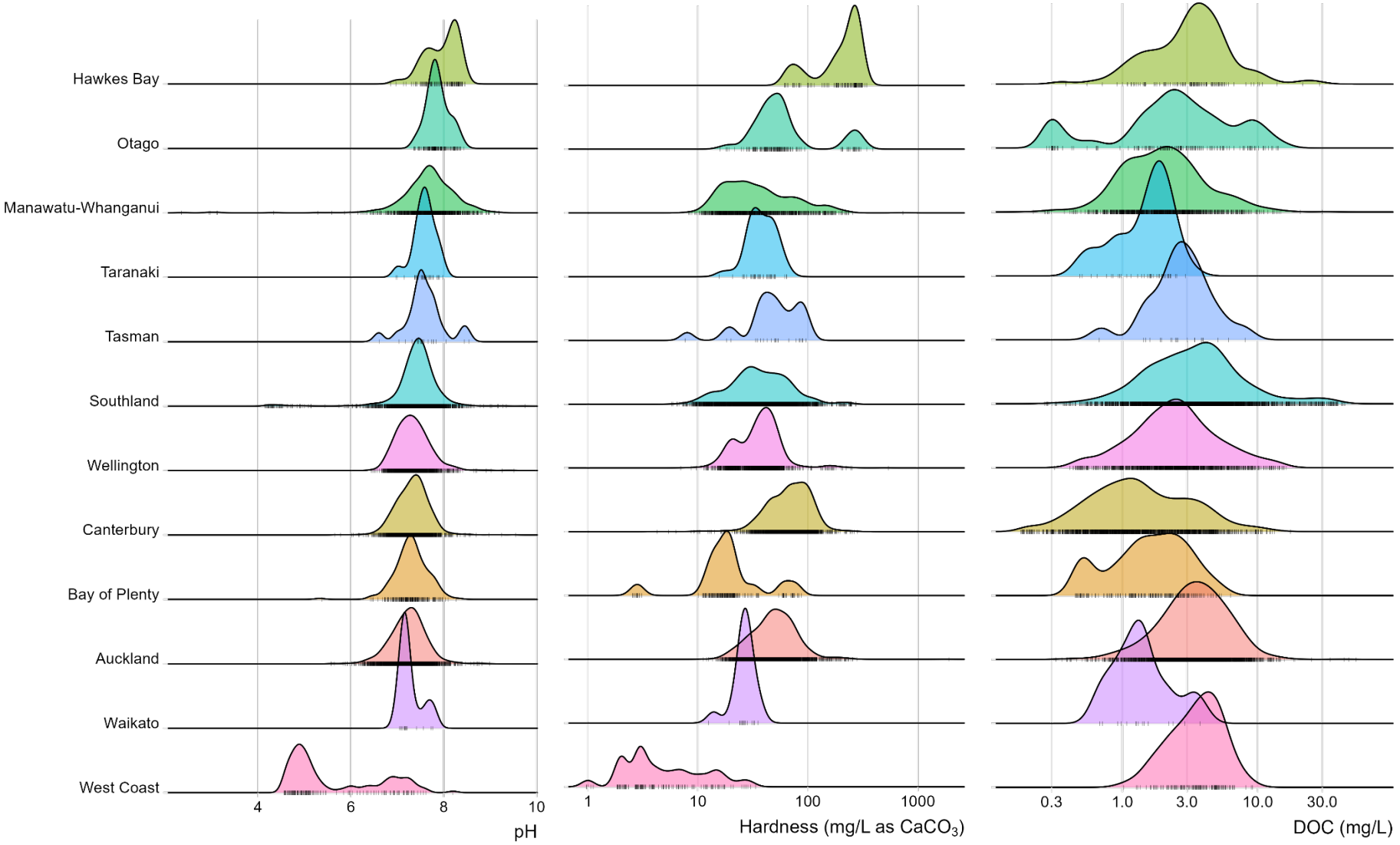


Figure 3.23: Illustration of variation in pH, hardness and DOC within and between regions of NZ. Data only included where all three variables were measured or estimated from other data.

4 Summary and next steps

A large dataset was collated from sites located around Australia and New Zealand, with over 600,000 data points for Australia and nearly 60,000 for New Zealand. pH was the variable most frequently monitored by all states and regions. In Australia, there were more measurements of DOC than hardness (or calcium and magnesium), whereas in New Zealand, there were more measurements of hardness than DOC.

For DOC (the variable needed to calculate copper GVs), there were nearly 120,000 data points for Australia and around 17,000 for New Zealand. DOC was generally higher in Australia (median of 5.0 mg/L) than in New Zealand (median of 2.4 mg/L) based on the available data. There were some limitations in the datasets for both countries, with fewer data available for NT and ACT in Australia, and for Marlborough, Northland, Gisborne and Tasman in New Zealand, compared to the other states and regions.

Calculation of nickel and zinc BAPCx values to develop DGVs requires measurement of pH, DOC, calcium and magnesium (or hardness for zinc) in the same sample. This matched dataset was substantially smaller than the complete dataset, with about 21,000 values for Australia and about 10,000 values for New Zealand. Again, there were limitations in the geographic coverage. For example, for Australia, there were limited data from ACT (5 sites only) NT (9 sites only) and TAS (14 sites only). For New Zealand, there were limited data from West Coast (4 sites only), Hawkes Bay (5 sites only) and Otago (6 sites only).

The matched data has been used in task 2 of the project to calculate BAPCx values and select DGVs for copper, nickel and zinc. There were only minor differences between the matched dataset and the full dataset on a national scale, indicating that, overall, the data to be used for calculating the DGVs is representative of the data available for each country.

There were many differences in water chemistry when comparing between states and regions, with up to an order of magnitude differences in median hardness and median DOC between states and regions. There were also differences between Australia and New Zealand, although the pH was relatively similar between countries. Calcium concentrations were lower in Australia than in New Zealand, and magnesium concentrations were frequently higher in Australia than in New Zealand. As mentioned, DOC was higher in Australia than in New Zealand.

The data collated and presented in this report are available in csv and Rdata files.

5 References

ANZG (2018). Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Governments, Canberra, ACT, Australia. https://www.waterquality.gov.au/anz-guidelines/.

ANZG (2026a) Toxicant default guideline values for aquatic ecosystem protection: Copper in freshwater. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. CC BY 4.0. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia.

ANZG (2026b) Toxicant default guideline values for aquatic ecosystem protection: Nickel in freshwater. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. CC BY 4.0. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia.

ANZG (2026c), Toxicant default guideline values for aquatic ecosystem protection: Zinc in freshwater. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. CC BY 4.0. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia.

Di Paolo, C., I. Bramke, J. Stauber, C. Whalley, R. Otter, Y. Verhaegen, L. H. Nowell and A. C. Ryan (2024). Implementation of the CREED approach for environmental assessments. *Integrated Environmental Assessment and Management* 20: 1019-1034. https://doi.org/10.1002/ieam.4909

European Commission (2019). *Common Implementation Strategy. Guidance Document No. 38 Technical Guidance for implementing Environmental Quality Standards (EQS) for metals. Consideration of metal bioavailability and natural background concentrations in assessing compliance*, European Commission.

Gadd, J., A. McKenzie, C. Fraser and T. Snelder (2024). Heavy metals state and trends in New Zealand rivers. Analyses of national data ending in 2022. National Institute of Water & Atmospheric Research Ltd, Auckland, New Zealand.March 2024. 52.

Gadd, J. B., A. Holland, J. L. Stauber and R. A. van Dam (2026). Implementation of bioavailability-based metal guideline values for Australia and New Zealand. Part 2: Selection of copper, nickel and zinc is there a freshwater DGVs for Australia and New Zealand Report prepared for Metals Environmental Research Associations. (36 pp).

Helsel, D. R. (2012). *Statistics for censored environmental data using Minitab and R*. New York, Wiley.

Helsel, D. R., R. M. Hirsch, K. R. Ryberg, S. A. Archfield and E. J. Gilroy (2020). Statistical methods in water resources. Techniques and Methods. 4-A3Reston, VA. 484.

Larned, S. T. and M. Unwin (2012). Representativeness and statistical power of the New Zealand river monitoring network. National Environmental Monitoring and Reporting: Network Design, Step 2. Prepared for Ministry for the Environment. NIWA Client Report CHC2012-079 Christchurch.April. 60.

NEMS (2019). Water Quality Part 2 of 4: Sampling, Measuring, Processing and Archiving of Discrete River Water Quality Data. National Environmental Monitoring Standards. 85.

Smith, D. G. and R. Maasdam (1994). New Zealand National River Water Quality Network.1. Design and physico-chemical characterisation. *New Zealand Journal of Marine and Freshwater Research* 28(1): 19-35.

Sobek, S., L. J. Tranvik, Y. T. Prairie, P. Kortelainen and J. J. Cole (2007). Patterns and regulation of dissolved organic carbon: An analysis of 7,500 widely distributed lakes. *Limnology and Oceanography* 52(3): 1208-1219.

Stauber, J. L. Golding, A. Peters, G. Merrington, M. Adams, M. Binet, G. Batley, F. Gissi, K. McKnight, E. Garman E. Middleton, J. Gadd and C. E. Schlekat (2021). Application of bioavailability models to derive chronic

guideline values for nickel in freshwaters of Australia and New Zealand. *Environmental Toxicology and Chemistry* 40(1):, 100-112.

Stauber, J. and A. Ryan (2023). Bioavailability-based guidelines for metals: Outcomes of the Workshop in April 2023. CSIRO Report EP2023-2105 CSIRO, Australia.June 2023.

Stauber, J. L., J. Gadd, G. A. V. Price, A. Evans, A. Holland, A. Albert, G. E. Batley, M. T. Binet, L. A. Golding, C. Hickey, A. Harford, D. Jolley, D. Koppel, K. S. McKnight, L. G. Morais, A. Ryan, K. Thompson, E. Van Genderen, R. A. Van Dam and M. S. J. Warne (2023). Applicability of chronic multiple linear regression models for predicting zinc toxicity in Australian and New Zealand freshwaters. *Environmental Toxicology and Chemistry* 42(12): 2614-2629.

Stauber, J.L., J.B. Gadd, A. Holland and R. van Dam (2026). Guidance on using bioavailability-based metal guideline values in Australia and New Zealand. Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. CC BY 4.0. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia.

Whitehead, A. (2019). Spatial modelling of river water-quality state: incorporating monitoring data from 2013 to 2017. NIWA Client Report. 2018360CH. Ministry for the Environment, Christchurch.

Appendix A Details of data requests

Table A.1: Details of data sources at different organisations in Australia and New Zealand.

State/ organisation	Website if applicable	Email contact
Department of Water and Environmental Regulation, WA	https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx	
Northern Territory Department of Land Resource Management		
Queensland Department of Regional Development, Manufacturing and Water	https://water-monitoring.information.qld.gov.au/	
Queensland Department of Environment, Science and Innovation	https://apps.des.qld.gov.au/water-data-portal/	
WaterNSW		
Murray Darling Basin Authority		
SA Water		
Office of Water, ACT		officeofwater@act.gov.au
Department of Energy, Environment and Climate Action, Victoria		
Melbourne Water		
Environmental Protection Agency		
Hydro Tasmania		
Derwent Estuary Program		
Auckland Council	https://environmentauckland.org.nz/Data	environmentaldata@aklc.govt.nz
Waikato Regional Council		https://bps.waikatoregion.govt.nz/online-services/new/RequestForService/step/1/
Bay of Plenty Regional Council		EDS.JobRequests@boprc.govt.nz
Gisborne District Council		
Hawkes Bay Regional Council	https://www.hbrc.govt.nz/services/maps-and-gis/	info@hbrc.govt.nz
Taranaki Regional Council		https://onlineservices.trc.govt.nz/online-services/new/lgoima-online-form/step/1
Horizons Regional Council		Science.DataRequests@horizons.govt.nz
Greater Wellington Regional Council	https://graphs.gw.govt.nz/envmon?view=map	
Tasman District Council	https://www.tasman.govt.nz/my-region/environment/environmental-data/river-water-quality-data	
Environment Canterbury	https://www.ecan.govt.nz/data/water-quality-data/	waterqualitydata@ecan.govt.nz
Christchurch City Council	https://ccc.govt.nz/environment/water/waterways/waterway-monitoring	

Otago Regional Council	https://envdata.orc.govt.nz/AQWebPortal/Data	hydrodatarequests@orc.govt.nz
Environment Southland		service@es.govt.nz
Bathurst Resources Limited		Pers. comm C. Hickey
NIWA	https://hydrowebportal.niwa.co.nz/Data/Dashboard/11	
LAWA	https://www.lawa.org.nz/download-data#river-water-quality	
MfE data service	https://data.mfe.govt.nz/data/	