Hydrotoxy
RESEARCH

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

Part 2: Selection of copper, nickel and zinc freshwater DGVs for Australia and New Zealand

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 2: Selection of copper, nickel and zinc freshwater DGVs for Australia and New Zealand. Report prepared for Metals Environmental Research Associations. (36 pp).

Version	Version number	Date
Draft version for wca	1.0	7/11/2024
Draft version updated for comments	1.1	24/11/2024
Final version incorporating sponsor comments	1.2	22/03/2025
Revised version including zinc and incorporating updates to copper derivation	1.3	30/11/2025
Further revised version including zinc and incorporating updates to copper derivation	1.4	16/12/2025
Further revised version including correction of errors	1.5	09/01/26
Further revised version including correction of minor errors	1.6	11/03/2026
Updated hardness boundary for copper from 2 mg/L to 5 mg/L resulting in minor adjustments to number of data in plots and tables	1.7	22/08/2026

Executive Summary

Bioavailability-based default guideline values (DGVs) and associated bioavailability-adjusted guideline values (BAGVs) 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 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 was 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 required, 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.

The collation and analysis of the water chemistry dataset from around Australia and New Zealand was reported in the Task 1 report (Gadd et al., 2026). The complete dataset included nearly 120,000 measurements of DOC (i.e. the variable needed to calculate copper BAPCx, DGVs and associated BAGVs) in Australia and around 17,000 measurements of DOC in New Zealand. A matched dataset that included pH, DOC, measured calcium and magnesium and/or estimates of calcium and magnesium based on reported hardness (i.e. the variables needed to calculate nickel and zinc BAPCx, DGVs and associated BAGVs), from the same sample, was substantially smaller than the complete dataset, with approximately 21,000 values for Australia and 10,000 values for New Zealand. Analyses of the data indicated differences in water chemistries and metal bioavailability between the two countries and that separate DGVs would be required for Australia and New Zealand for some metals.

This Task 2 report describes (i) the calculation of sample-specific BAPCx values for copper, nickel and zinc in freshwater for each region based on the collated water chemistry dataset, (ii) the probability distributions of those BAPCx values to identify the waters in Australia and New Zealand with the highest metal bioavailability, and (iii) the subsequent selection of DGVs for use in the tiered assessment framework.

The complete dataset for DOC was used to calculate sample-specific BAPCx values for copper using the DOC adjustment described in the copper (freshwater) technical brief and using the ssdtools package with model averaging to calculate guideline values. BAPCx values were removed when the reported DOC, pH or hardness was outside the range recommended for the copper DGVs. Copper BAPCx values were generally lower in New Zealand than in Australia, as DOC is also generally lower in New Zealand. However, there was a broad range in the distribution of $BAPC_{95}$ values (i.e., BAPCx values at 95% species protection) at between states in Australia (including the mainland territories) and regions in NZ. A weighted percentile, based on the number of repeated measurements at each site, was used to calculate the 5^{th} percentile for each state (in Australia) or region (in New Zealand).

Calculation of nickel BAPCx values requires measurement of pH, DOC, calcium and magnesium in the same sample. The matched dataset was used to calculate sample-specific BAPCx values for nickel using the multiple MLR adjustments as published in the nickel (freshwater) technical brief, and using the ssdtools package with model averaging. Water chemistry values within the applicability range of the models were used to produce distributions of nickel $BAPC_{95}$ values for each country. The distributions of calculated nickel $BAPC_{95}$ values in Australia and New Zealand were similar, with a slightly lower median and 5^{th} percentile for New Zealand. Again, there was a broad range in the nickel $BAPC_{95}$ values, particularly across states of Australia, where median values ranged from 6.1 to 22 µg/L (3.6 to 8.2 µg/L across New Zealand). As for copper, a weighted percentile was used to calculate the 5^{th} percentile for each state and region. In

approximately half of the matched values, calcium and/or magnesium were outside of (below) the applicability range for the nickel MLRs. If these were included, the distributions of nickel BAPCs were lower than the distributions with only data in the model applicability range.

Zinc BAPCx values require measurement of pH, DOC and hardness in the same sample. The matched dataset was used to calculate sample-specific BAPCx values for zinc using the multiple MLR adjustments as published in the zinc (freshwater) technical brief, and using the ssdtools package with model averaging. Approximately half of the samples contained hardness, pH or DOC outside the applicability range for the zinc MLRs. If these were included, the distributions of zinc BAPCx values were lower than the distributions with only data in the model applicability range. Water chemistry values within the applicability range of the model were used to produce distributions of zinc BAPCx values for each country. The distributions of calculated zinc $BAPC_{95}$ values in Australia were slightly higher than those in New Zealand. There was a broad range in the zinc $BAPC_{95}$ values particularly across states of Australia, where median values ranged from 7.7 to 18 µg/L (6.3 to 12 µg/L across New Zealand).

For each metal and country, the 5th percentile (weighted by number of samples at each site) of the BAPCx values from the most sensitive state/region was selected as the DGVs. These values (Table 1) are designed to be protective of 80 to 99% of species in 95% of waters throughout Australia and New Zealand. However, as the collated water chemistry dataset was limited, particularly for some states and regions, there may be a need to update the DGVs over time as more water chemistry data are collected. More data are particularly needed in Queensland (where there was no matched data within the range of the nickel models), Victoria and the Northern Territory and in West Coast and northern parts of the South Island, New Zealand.

Table 1: Recommended DGVs at varying levels of species protection, based on sampling frequency weighted 5th percentiles from most sensitive regions or states.

Species protection	**Copper**		**Nickel**		**Zinc**	
	Australia	New Zealand	Australia	New Zealand	Australia	New Zealand
99% protection	0.53	0.53	0.66	0.39	1.9	1.5
95% protection	0.73	0.73	3.4	2.3	5.2	4.1
90% protection	0.89	0.89	6.9	5.0	8.2	6.4
80% protection	1.4	1.4	14	11	15	11

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.

The authors 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
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'
dissolved metal concentration	Operationally defined as the concentration remaining after filtration through a 0.45 µm pore filter
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
MLR	Multiple linear regression – a type of statistical model increasingly used to assess metal bioavailability
NZ	New Zealand
Ni	Nickel
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.
site-specific guideline value	A GV that has been specifically developed to account for relevant chemical, physical and/or ecological conditions that occur at a site of interest (modified from van Dam et al. 2019)
Species sensitivity	A method that plots the cumulative frequency of species' sensitivities to a toxicant and fits a statistical distribution to the data. From the distribution, the concentration

distribution (SSD)	that should theoretically protect a selected percentage of species can be determined
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
toxicity test	The means by which the toxicity of a chemical or other test material is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical) for a specified test period
Zn	Zinc

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1 Introduction

This report represents the second 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 most 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 originally 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, 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).

The first step required collation of water chemistry data from around Australia and New Zealand, as described by Gadd et al. (2026). This report outlines the remaining steps to select the DGVs as follows:

i. the calculation of bioavailability-adjusted protective concentration values at varying levels of protection (BAPCx) for copper, nickel and zinc based on the collated data for all samples at all sites where data were available;

ii. the construction of probability distributions of those BAPCx values to identify the waters in Australia and New Zealand with the highest metal bioavailability; and

iii. the selection of DGVs for use in screening within the tiered assessment framework. The selection of the DGVs was based on the 5th percentile of BAPCx values in the most sensitive areas of Australia and New Zealand – i.e. aiming to protect at least 95% of waters in each country.

2 Methods to calculate BAPCx values

2.1 Overall approach

Briefly, BAPCx values were calculated for each combination of measured water chemistry included in the Australian and New Zealand databases. For copper, the BAPCx values were calculated based on a simple equation based on the DGVs at high bioavailability (minimal DOC) and the DOC of the sample. The approach for nickel and zinc was more complex and is depicted in Figure 2.1 and summarised as follows. The bioavailability-adjustment was based on four trophic-level or species-level specific multiple linear regression (MLR) models. As these adjust the toxicity data for species at different trophic levels in different ways, this necessitated remodelling the species sensitivity distribution (SSD) for each water chemistry combination in the database, before calculating the BAPC values from each of those SSDs. BAPCs were calculated for each of the four levels of species protection (i.e., 80%, 90%, 95% and 99%) used in the Australian and New Zealand guidelines[1]. Once calculated, the BAPCx values for each water chemistry combination were aggregated and the distributions used to determine DGVs to use at Tier 1 (see sections 3 and 4 for more details).

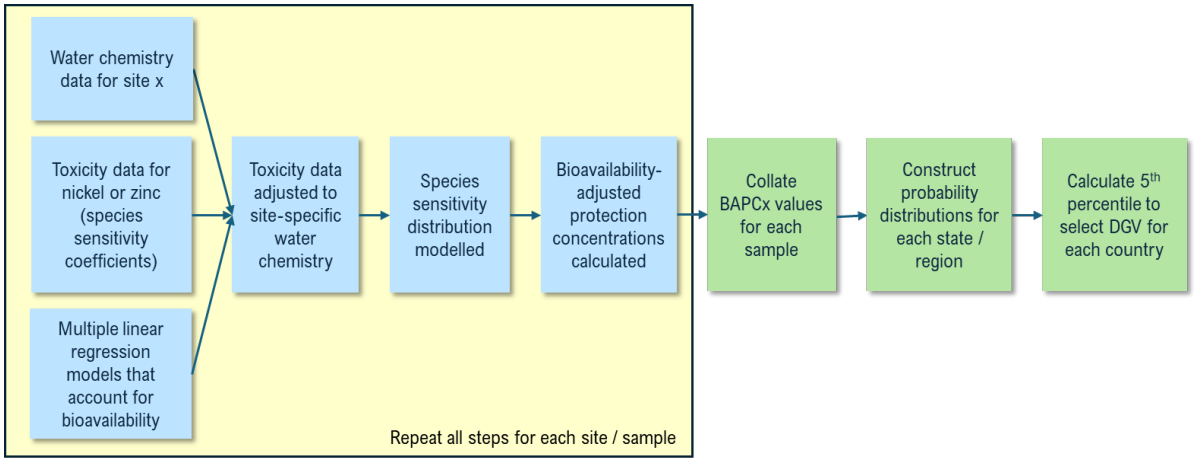


Figure 2.1: Approach to calculating BAPCx values and DGVs.

All calculations were undertaken using the R statistical computing environment (R Core Team 2023) and the ssdtools package (v2.4.0, Thorley et al. 2025) was used to fit SSDs and calculate model-averaged BAPCx values.

2.2 Toxicity data and models

Toxicity data were collated and bioavailability models were developed as described in the DGV technical briefs for each of the three metals (ANZG 2026a, 2026b, 2026c). For copper, the BAPCx values were calculated based on a simple equation based on the DGVs at high bioavailability (minimal DOC) and the DOC of the sample (Equation 2.1). Those high bioavailability DGVs were derived from a species sensitivity distribution modelled using ssdtools, with the six default distributions recommended for Australia and New Zealand (log-logistic, log-normal, Gamma, log-Gumbel, Weibull, and log-normal/log-normal mixture, see Warne et al. (2025)) and the model averaging method used to calculate the BAPCx values.

[1] See https://www.waterquality.gov.au/anz-guidelines/resources/key-concepts/level-of-protection

$$BAPCx = DGV_{0.5} \times \left(\frac{DOC}{0.5}\right)^{0.70}$$ Equation 2.1

where the DGV0.5 (at 0.5 mg/L DOC) differs according to the level of species protection; and the DOC is in mg/L. When DOC concentrations are less than 0.5 mg/L, the DGV is not adjusted.

The nickel BAPCx values were calculated from trophic-level-specific MLR bioavailability models developed by Peters et al. (2021) that account for the influence of pH, calcium, magnesium and DOC on nickel toxicity. There are four different MLR models (Table 2.1), each with values for the different water chemistry variables. Calculation of the BAPCx values requires the MLR equations and the sensitivity coefficient for each of the 26 species used in the SSD (Appendix A). The fish MLR was applied to the chronic fish data, the invertebrate MLR to chronic invertebrate data, the aquatic plant MLR to chronic duckweed data, and the algae MLR to chronic algal data. As for copper, the resulting species-specific toxicity dataset was then modelled using ssdtools with the default distributions for Australia and New Zealand (see Warne et al. (2025)) with the model averaging method used to calculate the BAPCx values.

Table 2.1: Trophic-level-specific MLRs used for nickel DGVs.

Trophic level	MLR [a]
Fish	$Log_e(EC10)$ = Sensitivity – 1.05.log_e[DOC] + 3.55.log_e[Mg] – 0.07.pH + 0.19.log_e[DOC].pH – 0.42.log_e[Mg].pH
Invertebrates	$Log_e(EC10)$ = Sensitivity + 2.09.log_e[DOC] + 0.19.log_e[Ca] + 0.40.log_e[Mg] – 0.40.pH – 0.24.log_e[DOC].pH
Aquatic plants	$Log_e(EC10)$ = Sensitivity + 0.96.log_e[DOC] – 1.44.pH
Algae	$Log_e(EC10)$ = Sensitivity [b] + 0.28.log_e[DOC] +0.50.log_e[Mg] – 0.20.pH

Note: [a] The parameters in the MLR equations have been rounded up to two decimal places.
[b] Sensitivity is a species-specific coefficient calculated as the difference between the observed (experimental) value (logeEC10expt) and the MLR predicted value (logeEC10pred) for each species at each water chemistry combination tested (see Peters et al. 2021)

The zinc BAPCx values were calculated from trophic-level and species-level MLR bioavailability models developed that account for the influence of pH, hardness and DOC on zinc toxicity. There are four different MLR models (Table 2.2), each with values for the different water chemistry variables. Calculation of the BAPCs requires the MLR equations and the sensitivity coefficient for each of the 25 species used in the SSD (Appendix A). As for the nickel BAPCs, the fish MLR was applied to the chronic fish data, the invertebrate MLR to chronic invertebrate data, the *Chlorella* MLR to chronic data for two species of *Chlorella* and the green microalgal MLR to other green microalgal data. The resulting species-specific toxicity dataset was then modelled using ssdtools and BAPCx values calculated using model averaging, as for copper and nickel. However, unlike copper and nickel, the log-normal/log-normal distribution was not included for calculating the zinc BAPCs due to dataset artefacts (see ANZG 2026c).

Table 2.2: Trophic-level-specific MLRs used for zinc DGVs.

Trophic level	MLR [a]
Fish	$Log_e(EC10)$ = Sensitivity[b] + 0.27.log_e[DOC]+ 0.84.loge[Hardness]
Invertebrates	$Log_e(EC10)$ = Sensitivity – 1.4.log_e[DOC] – 0.52.pH + 0.31.log_e[Hardness] + 0.24.log_e[DOC].pH
***Chlorella* sp.**	$Log_e(EC10)$ = Sensitivity + 0.35.log_e[DOC] – 0.36.pH + 0.35.log_e[Hardness]
Other green microalgae	$Log_e(EC10)$ = Sensitivity + 0.21.log_e[DOC] – 0.87.pH

Note: [a] The parameters in the MLR equations have been rounded up to two decimal places.
[b] Sensitivity is a species-specific coefficient calculated as the difference between the observed (experimental) value (logeEC10expt) and the MLR predicted value (logeEC10pred) for each species at each water chemistry combination tested (see Peters et al. 2021)

2.3 Water chemistry data

Water chemistry data were collated from around Australia and New Zealand, as described by Gadd et al. 2026). The collated dataset included over 600,000 data points for Australia and over 60,000 for New Zealand. This included nearly 120,000 measurements of DOC (the variable needed to calculate copper GVs) in Australia and around 17,000 measurements of DOC in New Zealand. Calculation of nickel and zinc GVs requires measurement of pH, DOC, and calcium and magnesium, or collectively measured as hardness for zinc. A matched dataset with pH, DOC, calcium and magnesium measured in the same sample was produced and was substantially smaller than the complete dataset, with 20,784 values for Australia and 10,364 values for New Zealand. The matched dataset was found to be 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 the Australian states/mainland territories and the New Zealand regions (herein referred to simply as states and regions), with up to an order of magnitude difference in median hardness and DOC.

BAPCx values for copper, nickel and zinc were calculated at each water chemistry combination collated in the Australia and New Zealand databases. This required measurement of DOC for copper; measurement of pH, DOC, calcium and magnesium for nickel; and measurement of pH, DOC and hardness for zinc. For copper, BAPCx values were calculated for all available DOC data (118,894 values for Australia and 16,748 for New Zealand), then reduced to those where DOC was within the applicable range (see section 2.4). For nickel, the matched dataset with measurement of pH, DOC, calcium and magnesium was used. A large proportion (67%) of the Australian calcium and magnesium data used in these calculations was estimated, based on reported hardness and typical relationships between hardness and calcium. A smaller proportion of the New Zealand calcium and magnesium data was also estimated (26%). All matched values were first calculated, then reduced to those in the applicability range for either nickel or zinc.

The datasets included a small number of censored values, mainly for DOC (Australia and New Zealand) but also for calcium, magnesium and hardness (Australia only). DOC concentrations that were reported as <1 mg/L were removed from the dataset (296 values for Australia, 3 values for New Zealand) as this limit of detection is above measured values in each country. DOC concentrations reported as <0.2 or <0.5 mg/L were included based on the numeric value, i.e., 0.2 or 0.5 mg/L for these examples. For copper, the BAPCx does not differentiate between DOC values of 0.2, <0.2, <0.5 and 0.5 mg/L. For nickel, values less than 0.5 mg/L were removed as these were outside the model applicability range (see below) though values reported as <0.5 mg/L were retained and calculated as 0.5 mg/L. This decision likely results in a slightly lower distribution of calculated BAPCx values. The alternative option of using an imputation method for these values reported as <0.5 mg/L would result in their removal from the dataset (as they would be outside the model range), which would skew the distribution of calculated BAPCx values towards higher values.

2.4 Applicability ranges

The copper DGVs are applicable to, and can be adjusted for, DOC up to 20 mg/L. This range is based on the model used to adjust for DOC concentration. At DOC >20 mg/L, a BAGV based on adjustment to 20 mg/L should be used. The copper DGVs technical brief (ANZG 2026a) also states that the DGVs apply to water within a pH range of 6–8.5 and hardness range of 5–400 mg/L as $CaCO_3$. The pH and hardness ranges were based on the data used to develop the DGVs, which aimed to use toxicity data from tests in waters with moderate to high bioavailability, and the dataset used to develop the DOC slope.

Each of the nickel MLR models has a specific range of applicability (Table 2.3), based on the data used to develop the models. The overall range of applicability was selected as the range where the MLRs for algae, invertebrates, and vertebrates were all applicable. The plant MLR was excluded from this assessment

because it has a particularly narrow applicability range, and concerns have been raised about its applicability (Peters et al. 2021). Furthermore, the majority of bioavailability-based assessment approaches have used models for either algae or invertebrates for the assessment of aquatic plants. The range used for the suite of nickel bioavailability models is provided in Table 2.3. This was a pragmatic decision as the aquatic plant MLR had a narrow range compared to the other models and applied only to two species of the 26 included in the SSD.

Table 2.3: Water chemistry applicability ranges for each of the trophic-level MLRs used for nickel DGVs.

Model	pH	DOC (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Calculated hardness (mg/L as $CaCO_3$)
Fish	5.5–8.5	0.5–18	3.7–110	1.1–286	14–1450
Invertebrate	5.9–8.2	0.3–17	0.1–88	0.2–72	1–516[a]
Plant	6.9–8.3	0.7–7.1	3-72	0.8–21	12–266
Algae	6.0–8.0	0.3–26	3–144	3–115	20–833
Overall range	**6.0-8.0**	**0.5-17**	**3.7-88**	**3-72**	**20-516**

Note: [a] This number is corrected from a typographical error of 316 reported by Stauber et al. (2021).

Similar to the nickel MLR models, each of the zinc MLR models has a specific range of applicability (Table 2.4), based on the data used to develop the models. The overall range of applicability was generally based on the range where all MLRs for fish, invertebrates and algae were applicable, except for pH where that would have resulted in a very narrow range (6.7 to 8.1). The range was extended below the lower pH boundary for the fish and *Chlorella* models (6.2 and 6.7 respectively) to increase the applicability to natural waters. The fish model does not have an adjustment for pH and *Chlorella* is less sensitive to zinc toxicity at low pH. The lower pH range was therefore set at 6.0 (Table 2.4), the lower bound of the invertebrate model. The pH range was also extended above the upper range of the fish model (8.1), as the sensitivity of fish is not influenced by the pH in the MLR model. This range was not extended above the maximum for the *Chlorella* model because that species is more sensitive to zinc at higher pH. The overall ranges for all three metals are shown in Table 2.5.

Table 2.4: Water chemistry applicability ranges for each of the trophic- and species- level MLRs used for zinc DGVs.

Model	pH	DOC (mg/L)	Calculated hardness (mg/L as $CaCO_3$)
Fish	6.2–8.1	0.3–23	23–399
Invertebrate	6.0–8.5	0.3–40	26–370
***Chlorella* sp.**	6.7–8.3	0.5–15	5–402
Other green microalgae	5.6–8.5	0.3–22	7–529
Overall range	**6.0-8.3**	**0.5-15**	**26-370**

It should be noted that few, if any, bioavailability models can account for all water chemistry conditions. This is because the applicability ranges of the models are determined in no small part by the tolerances of the test species that are used for the ecotoxicity tests. Importantly, these tests do not cover all natural water chemistry conditions. Therefore, some water chemistry conditions will fall outside the model applicability ranges. Some of these waters are likely to have relatively unique ecological assemblages that reflect these 'different' water chemistry conditions (i.e. low pH, low hardness, etc.). The DGV technical briefs, Stauber et al. (2026) and ANZG (2018) provide guidance on what to do in the event local water chemistry is outside the applicability ranges for the DGVs.

Table 2.5: Water chemistry applicability ranges adopted for the copper, nickel and zinc DGVs.

Variable	Copper	Nickel	Zinc
pH	6-8.5	6.0-8.0	6.0-8.3
DOC (mg/L)	0-20	0.5-17	0-15
Calcium (mg/L)	Not specified	3.7-88	Not specified
Magnesium (mg/L)	Not specified	3.0-72	Not specified
Calculated hardness (mg/L as $CaCO_3$)	5-400	Approximately 20-516a	26-370

Note: [a] Hardness is not used in determining applicability for nickel GVs; illustrative range only.

2.5 Analysis of BAPCx values

The calculated BAPCx values were compared between countries, states and regions using summary statistics and graphical analyses. Probability distributions were then used to compare between states and regions and to calculate 5th percentiles for each state and region, to identify waters with the highest metal bioavailability. The water chemistry datasets included repeated measurements at some locations and single measurements at others. A weighted percentile approach was used to account for the unbalanced dataset.

As stated, all calculations were undertaken using the R statistical computing environment (R Core Team 2023), with the use of the following packages:

1. tidyverse v2.0.0 (Wickham et al. 2019) to streamline data processing and visualise data
2. ssdtools v2.4.0 (Thorley et al. 2025) to model SSDs
3. modi v0.1.3 (Hulliger 2023) to calculate weighted percentiles.

3 Distributions of calculated BAPCx values in Australia and New Zealand

3.1 Summary of calculated BAPCx values

Over 130,000 copper BAPCx values were calculated from DOC data measured around Australia and New Zealand (Table 3.1). This included values where DOC was out of range and, for these initial calculations, the maximum applicable DOC was used; for example, for a DOC of 32 mg/L, a BAPCx was calculated using a DOC of 20 mg/L. Only around 21% of the BAPCx values calculated across both countries were within the applicability range for copper (DOC 0-20 mg/L, pH 6-8.5, hardness 5-400 mg/L as $CaCO_3$, Table 3.1, Figure 3.1). There were approximately 95,000 additional values for Australia and a further 500 values for New Zealand that were potentially within the range but where pH and/or hardness were not reported, and these values were deemed inapplicable. Where reported water chemistry was outside the range, this was most frequently for pH in Australia (e.g., around 950 values were pH less than 6) and for hardness in New Zealand.

Table 3.1: Number of copper, nickel, and zinc BAPCx values calculated for Australia and New Zealand, the median and the number of samples within the applicability range. Range shown is 1st and 99th percentile to avoid including extreme outliers.

Country / Statistic	Copper	Nickel	Zinc
Australia			
Number of BAPCx values calculated	115,179	20,780	20,780
Median (range) of 95% species protection BAPCx values including those out of range	3.6 (0.73-9.6) µg/L	6.6 (1.7-95) µg/L	9.4 (3.6-44) µg/L
Number of samples within the applicability range	18,253 (16%)	10,607 (51%)	10,104 (49%)
Median (range) of 95% species protection BAPCx values (only those within applicability range)	3.3 (0.73-9.6) µg/L	8.2 (3.3-34) µg/L	11.5 (5.9-24) µg/L
New Zealand			
Number of BAPCx values calculated	16,745	10,364	10,364
Median (range) of 95% species protection BAPCx values including those out of range	2.2 (0.73-9.6) µg/L	5.2 (1.4-27) µg/L	8.4 (3.2-19) µg/L
Number of samples within the applicability range	10,042 (60%)	6,432 (62%)	7,730 (75%)
Median (range) of 95% species protection BAPCx values (only those within applicability range)	2.4 (0.73-9.6) µg/L	6.5 (2.5-19) µg/L	9.4 (4.1-18) µg/L

Fewer nickel or zinc BAPCx values were calculated (Table 3.1) as these required pH, DOC, and calcium and magnesium for nickel and hardness for zinc for the same sample. A total of 31,500 nickel BAPCx values were calculated from water chemistry data from both Australia and New Zealand. Of these, around 54% were within the applicability range for nickel (DOC 0.5-17 mg/L, pH 6-8.0, calcium 3.7-88 mg/L, magnesium 3-72 mg/L, Table 3.1, Figure 3.1). For the Australian waters, water chemistry was most often outside the range for calcium and magnesium (Figure 3.2), with approximately 6,800 and 7,300 values (respectively) below the applicability range for these two cations. The vast majority of these (>6,000) were from samples collected in NSW. Many of those samples also had low pH, below the applicable range for the nickel GVs. For New Zealand waters, magnesium was the TMF most often outside the applicability range, with >3,000 measurements less than 3 mg/L. These were distributed in 11 regions around the country. This suggests there could be a need to extend the model range. It is possible that model extension could be based on toxicity

data for low hardness waters that have been published since the models were developed, or this may require additional toxicity testing.

Around half of the zinc BAPCx values calculated for Australia and 25% for New Zealand were outside the applicability ranges (Table 3.1). Similar to nickel, for most of these samples (~8700 samples for Australia and ~2100 samples for New Zealand), this was due to hardness being below the applicability range. There were relatively few samples where hardness was above the applicability range (Figure 3.1).

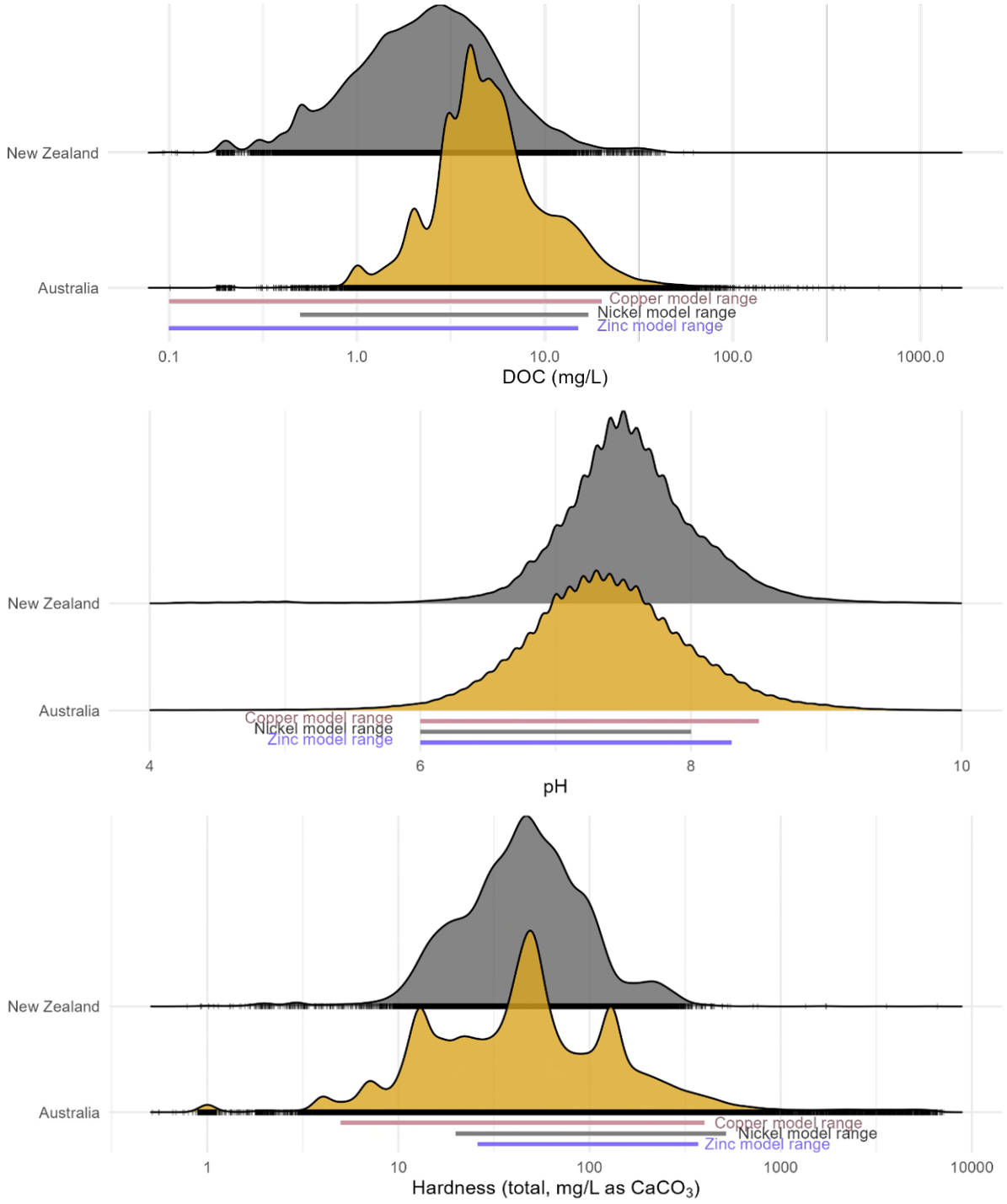


Figure 3.1: Water chemistry in Australia and New Zealand (all available data) compared with the model applicability ranges for each TMF and metal (pink = copper, grey = nickel; blue = zinc).

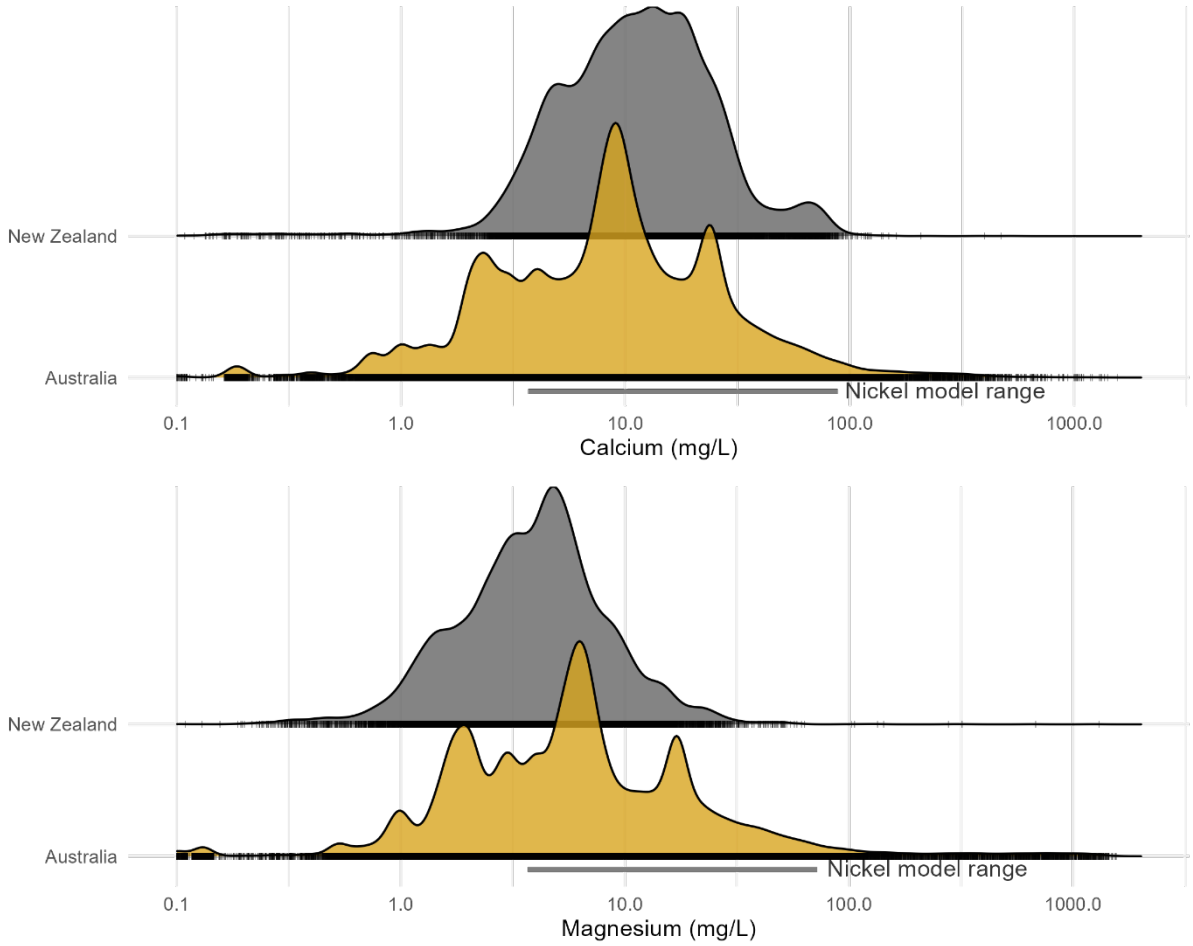


Figure 3.2: Calcium and magnesium in Australia and New Zealand (all available data) compared with the nickel model applicability ranges. The DGVs for copper and zinc do not specify applicability ranges for calcium or magnesium.

Figure 3.3 compares the calculated $BAPC_{95}$ values (95% species protection) within and outside the applicability ranges for both copper and nickel. For Australia, there were slightly more copper $BAPC_{95}$ values near 10 µg/L in the full dataset than in the "in range" dataset. This reflects sites with higher DOC, and where pH and/or hardness were not measured. There appears to be little difference between the two copper $BAPC_{95}$ values datasets for New Zealand. There was a small difference between the 5th percentile values calculated for all data and those where the TMFs were within the applicability range. For example, for Australia, the 5th percentile of all calculated $BAPC_{95}$ values was 1.8 µg/L, compared to 1.5 µg/L from those within range.

For nickel, the entire dataset included some lower $BAPC_{95}$ values, likely those samples where calcium and/or magnesium where below the applicability range. The 5th percentile based on all calculated $BAPC_{95}$ values (2.8 µg/L) was lower than the 5th percentile from the $BAPC_{95}$ values that were within the model applicability range (4.2 µg/L).

Calculated $BAPC_{95}$ values outside the applicability ranges for each metal (or without reported pH and hardness for copper) were excluded from further analysis due to the low reliability of the bioavailability correction under these conditions.

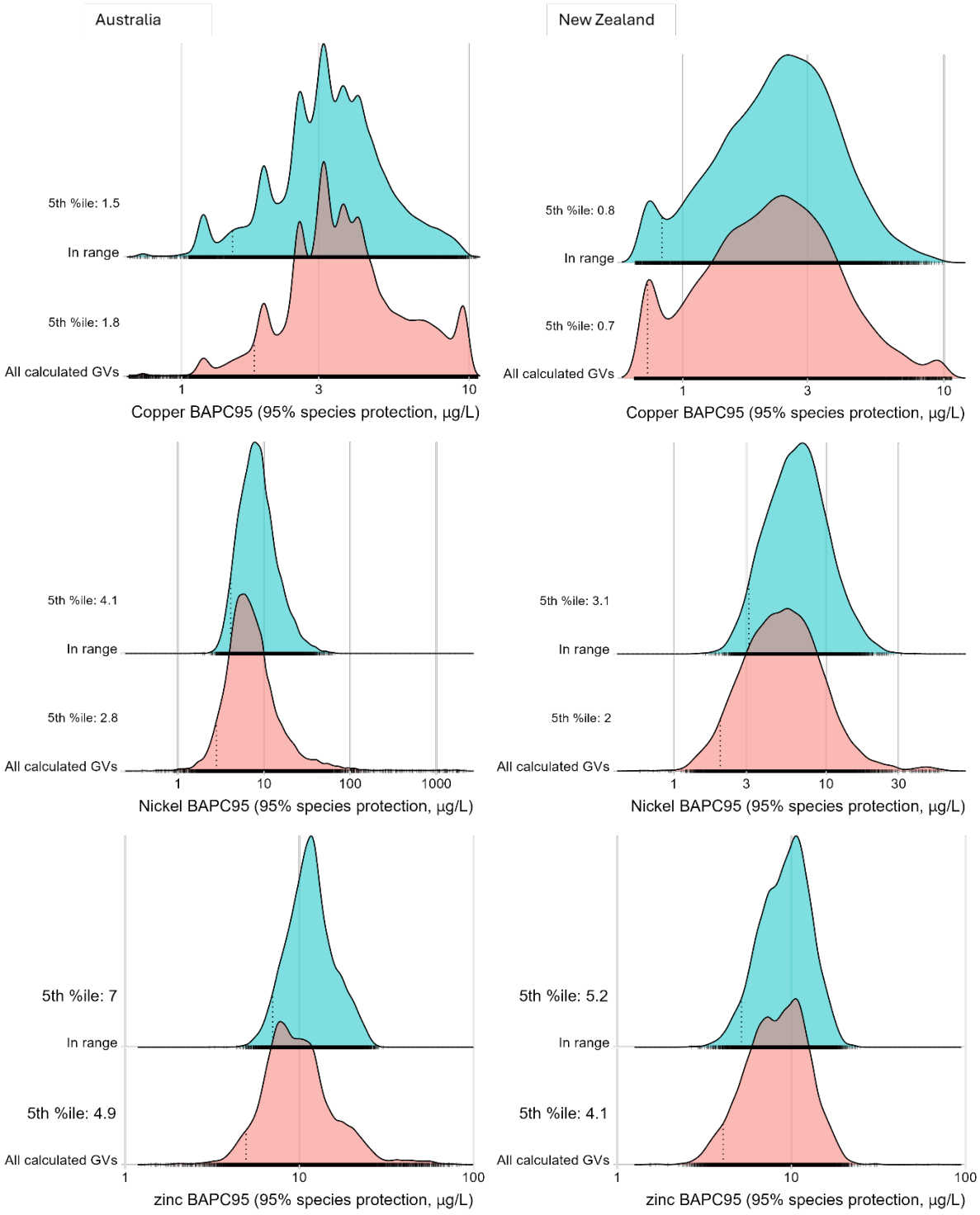


Figure 3.3: Comparison of copper, nickel and zinc BAPCs (both at 95% species protection) for all those calculated (pink) and only those within the applicability range for each metal (teal). 5th percentile shown with vertical dashed line and annotated on plot.

3.2 Copper

3.2.1 Variation between countries

The copper BAPCx values were generally lower in New Zealand than in Australia (Figure 3.4a, Table 3.2), reflecting a tendency towards lower DOC in New Zealand (Figure 3.4b). The 5th percentile of the copper BAPC values (95% species protection) for Australia (1.5 µg/L) was nearly twice the value for New Zealand (0.8 µg/L). Similarly, the median BAPCx values for Australia were higher than that for New Zealand.

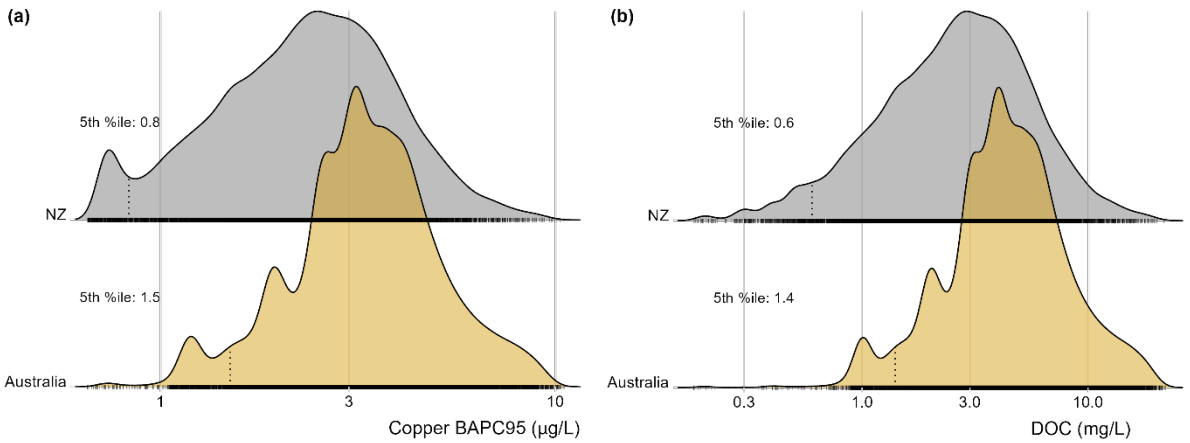


Figure 3.4: Comparison between Australia (gold) and New Zealand (grey) of (a) copper BAPC values (at 95% species protection) and (b) DOC. 5th percentile of each distribution shown with vertical dashed line and annotated on plot.

Table 3.2: Comparison of 5th percentile BAPCx values and median **copper** BAPCx values for each level of species protection.

	5th percentile		Median	
	Australia	**New Zealand**	**Australia**	**New Zealand**
99% protection	1.1	0.60	2.4	1.7
95% protection	1.5	0.83	3.3	2.4
90% protection	1.8	1.0	4.0	2.9
80% protection	2.8	1.6	6.2	4.5
N. data	18253	10042	18253	10042

3.2.2 Variation within Australia and New Zealand

There are differences in the copper BAPCx values between states and regions (Figure 3.5), which arise because of the different water chemistry characteristics of the waters sampled in each state. Differences are greatest between states in Australia, with a 5-fold difference between the state with the highest and lowest BAPCx values. For example, the median copper $BAPC_{95}$ value in Northern Territory (NT) was 1.2 µg/L, compared to the highest median, in Western Australia (WA), of 5.5 µg/L (Table 3.3). There was only a three-fold difference between regions of New Zealand, with the lowest median of 1.9 µg/L (Canterbury) compared to 5.2 µg/L for Auckland and the West Coast (Table 3.3).

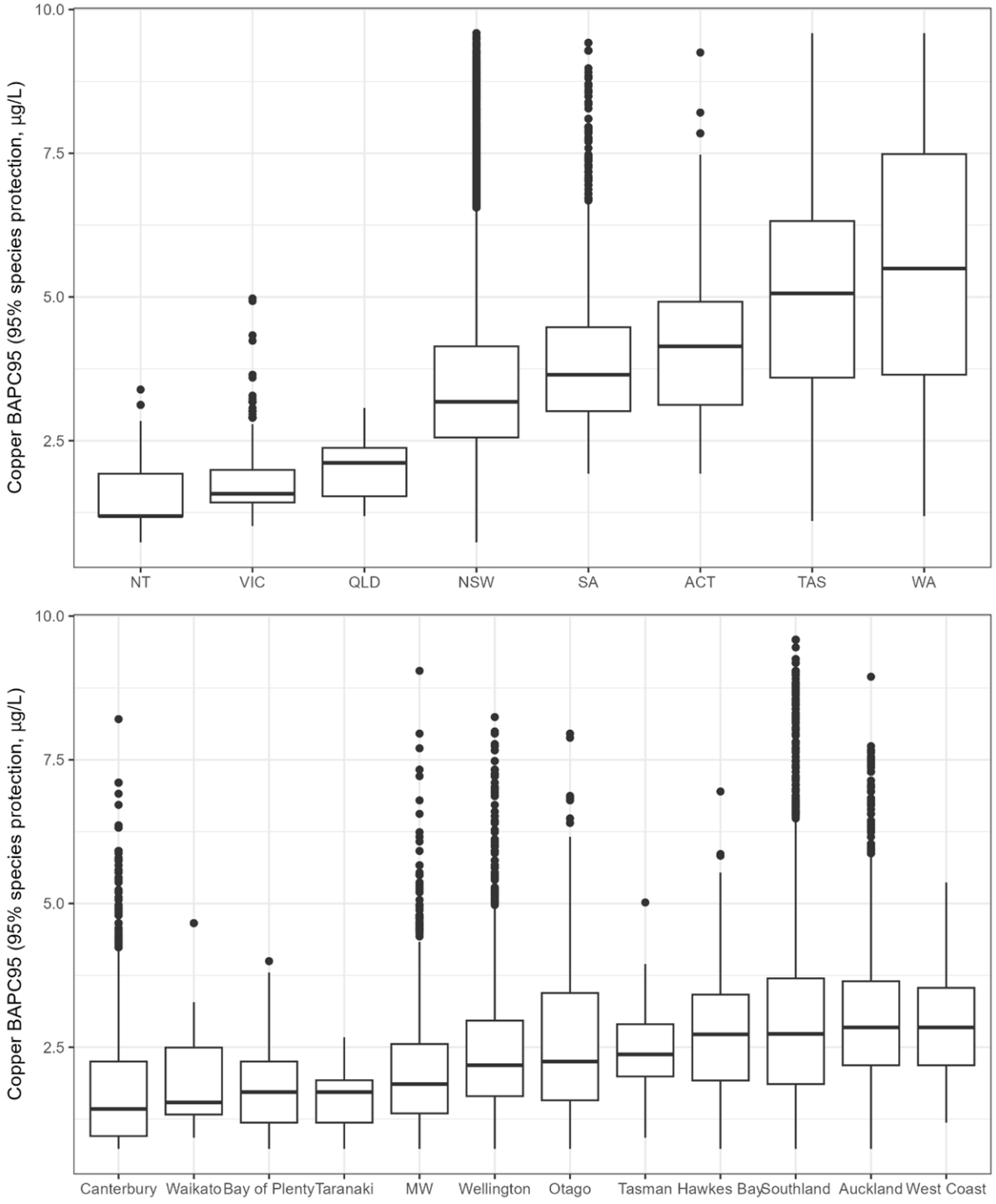


Figure 3.5: Comparisons between states and regions of all 'in range' copper BAPC values at 95% species protection.

Table 3.3: Variation in **copper** BAPC values at 95% species protection between states and regions, data ordered by 5th percentile (Q5).

State / region	Minimum	Q5	Q25	Median	Q75	Q95	Maximum	N
Australia	0.73	2.6	2.6	2.6	2.6	2.6	2.6	18253
NT	0.73	0.73	1.2	1.2	1.9	2.8	3.4	65
VIC	1.0	1.2	1.4	1.6	2.0	2.8	5.0	379
QLD	1.2	1.2	1.5	2.1	2.4	2.9	3.1	6
WA	1.2	1.2	3.6	5.5	7.5	9.3	9.6	533
NSW	0.73	1.5	2.6	3.2	4.1	6.5	9.6	14412
SA	1.9	2.6	3.0	3.6	4.5	6.1	9.4	2395
ACT	1.9	2.5	3.1	4.1	4.9	6.7	9.3	138
TAS	1.1	2.4	3.6	5.1	6.3	8.6	9.6	325
New Zealand	0.73	0.83	1.6	2.4	3.3	5.2	9.6	10042
Canterbury	0.73	0.73	1.0	1.4	2.3	3.8	8.2	1614
Bay of Plenty	0.73	0.73	1.2	1.7	2.3	3.3	4	169
Otago	0.73	0.73	1.6	2.3	3.4	6.1	8	153
Taranaki	0.73	0.81	1.2	1.7	1.9	2.3	2.7	37
Manawatu-Whanganui	0.73	0.93	1.3	1.9	2.6	4.5	9	865
Wellington	0.73	0.93	1.6	2.2	3	5.2	8.2	1167
Southland	0.73	1.1	1.9	2.7	3.7	5.8	9.6	3101
Hawkes Bay	0.73	1.2	1.9	2.7	3.4	5.1	6.9	107
Waikato	0.93	1.3	1.3	1.5	2.5	4.5	4.7	24
Auckland	0.73	1.3	2.2	2.8	3.6	5.1	8.9	2740
Tasman	0.93	1.5	2	2.4	2.9	3.9	5	21
West Coast	1.2	1.6	2.2	2.8	3.5	4.1	5.4	44

3.2.3 Probability distributions and 5th percentiles

The method to select the DGVs required calculating probability distributions from the calculated BAPCx values for each level of species protection (within the applicability ranges) for each state and region and using the 5th percentile from the most sensitive state and region. This is the same method previously recommended by the European Commission for use in Europe (European Commission 2019). Cumulative frequency plots of copper $BAPC_{95}$ values for each state and region with the 5th percentile values marked are shown in Figure 3.6 The same data are shown as probability distributions in Figure 3.7.

The plots indicate the following states and regions that have waters where copper would be most toxic (low DOC waters): Northern Territory (NT, 5th percentile of $BAPC_{95}$ = 0.73 µg/L),Victoria and Queensland (VIC, QLD 1.2 µg/L) and New South Wales (NSW, 1.5 µg/L) in Australia; and Bay of Plenty, Canterbury and Otago (5th percentile of $BAPC_{95}$ = 0.73 µg/L) in New Zealand. For these states and regions, the 5th percentile of the copper $BAPC_{95}$ values were lower than the 5th percentile calculated for data from across the entire country (national 5th percentile), whereas the 5th percentile from other states and regions was higher than or closer to the national 5th percentile.

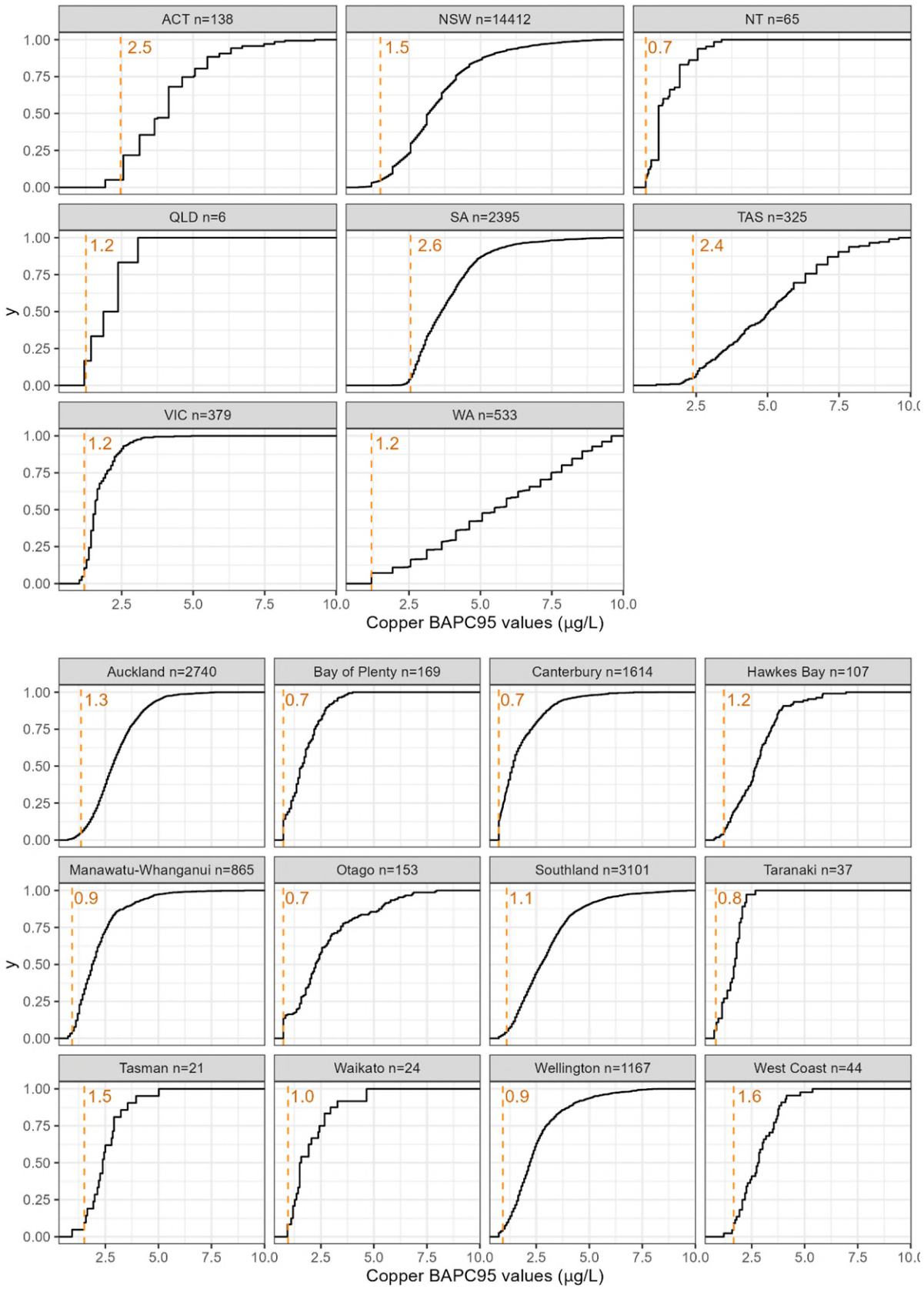


Figure 3.6: Comparisons between states and regions for copper BAPC values at 95% species protection. The 5th percentile of calculated $BAPC_{95}$ values for each state/region is shown with dashed orange line and in orange text.

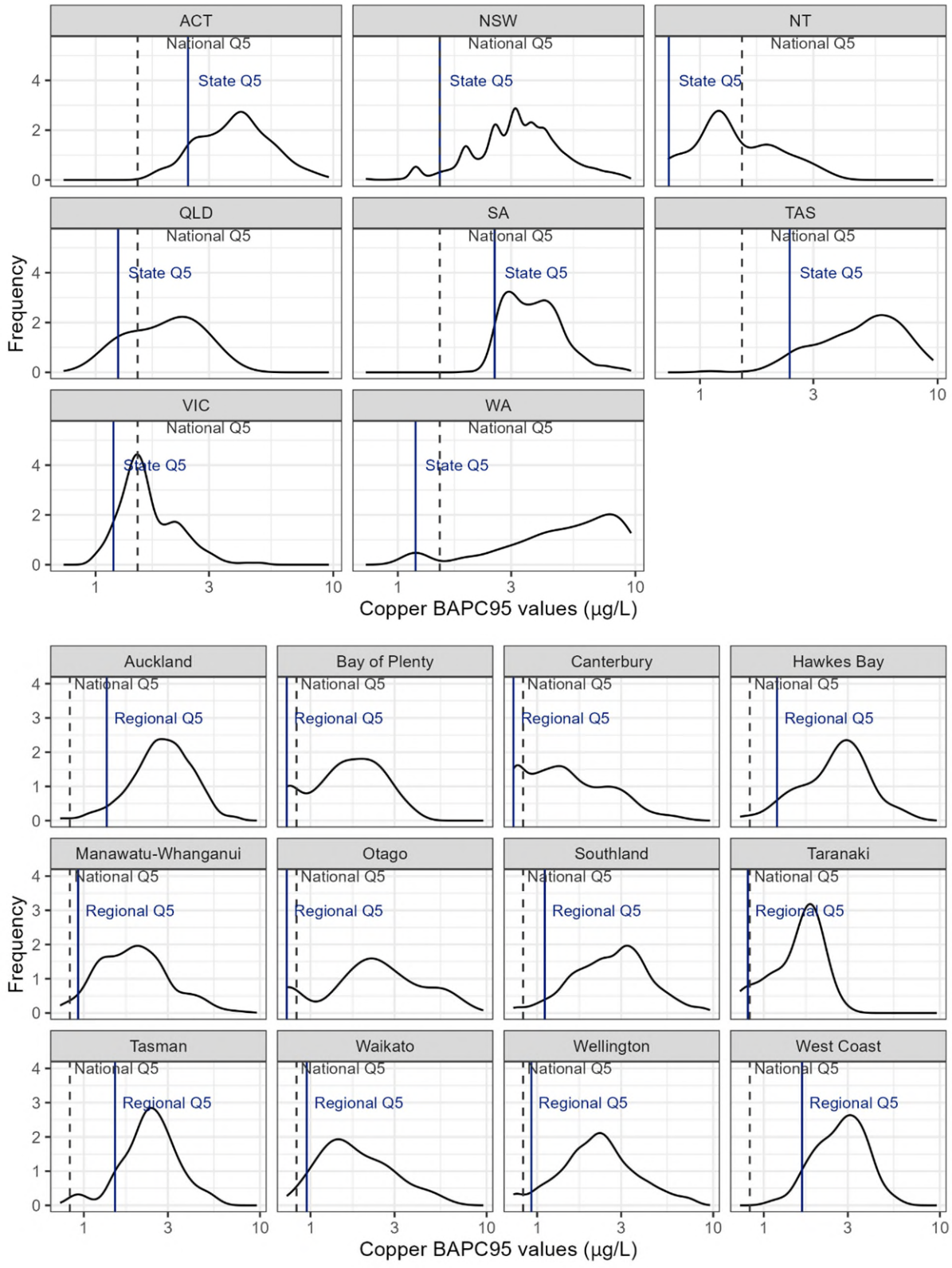


Figure 3.7: Comparisons between states and regions for copper BAPC values at 95% species protection. The 5th percentile of calculated $BAPC_{95}$ values is shown for each state in blue and for each country in dark grey.

3.3 Nickel

3.3.1 Variation between countries

The nickel BAPCx values were generally lower in New Zealand than in Australia (Figure 3.8, Table 3.4), which may (as for copper) reflect the tendency towards lower DOC in New Zealand. The 5th percentile of the nickel $BAPC_{95}$ values for Australia (4.2 µg/L) was somewhat higher than the value for New Zealand (3.1 µg/L), although this difference was much smaller than the nearly two-fold difference between countries for copper.

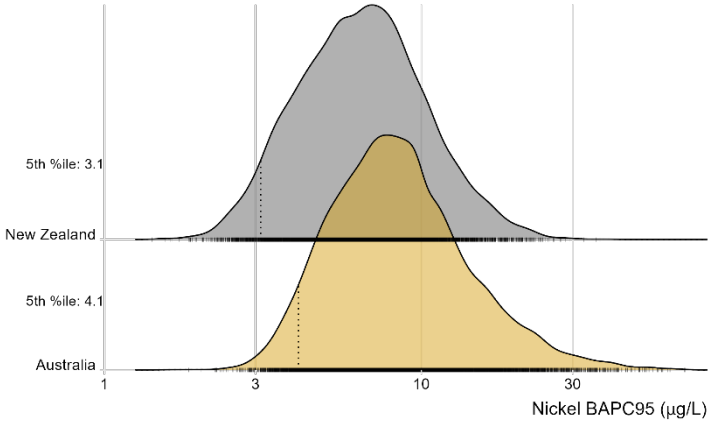


Figure 3.8: Comparison between Australia (gold) and New Zealand (grey) of nickel BAPC values at 95% species protection. 5th percentile shown with vertical dashed line and is annotated on plot. Note BAPCx values are plotted on a log scale (base 10).

Table 3.4: Comparison of 5th percentile and median **nickel** BAPCx values for each level of species protection.

	5th percentile		Median	
	Australia	**New Zealand**	**Australia**	**New Zealand**
99% protection	0.79	0.57	1.7	1.3
95% protection	4.1	3.1	8.2	6.5
90% protection	8.2	6.4	16.0	12.7
80% protection	17.0	13.6	33.0	25.9
N. data	10607	6436	10607	6436

3.3.2 Variation within Australia and New Zealand

There are some large differences in the nickel BAPC values at the 95% species protection level between states in Australia (Figure 3.9), with highest $BAPC_{95}$ values in Western Australia (WA, median of 19 µg/L, Table 3.5) and lowest in Northern Territory (NT, 5.7 µg/L). This represents a three to four-fold difference between the lowest median and the highest – much less variation than noted for copper (section 3.2.2). There was only a little over two-fold difference on $BAPC_{95}$ values between regions of New Zealand, with the lowest median of 3.6 µg/L (Taranaki) compared to 8.2 µg/L for Hawkes Bay (Table 3.5). However, within many regions, there was a wide range of calculated nickel $BAPC_{95}$ values, presumably reflecting the range in water chemistries within a region.

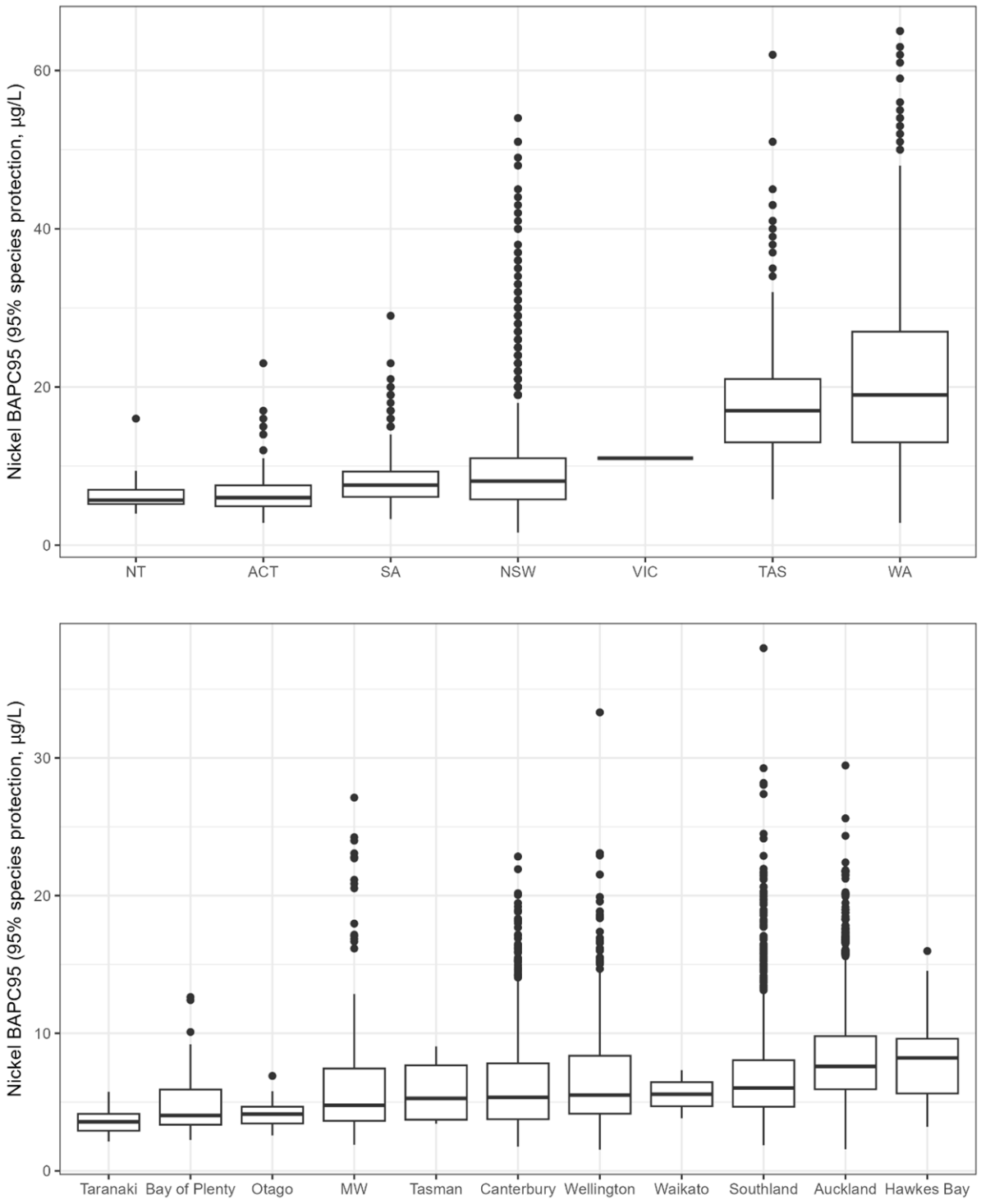


Figure 3.9: Comparisons between states and regions of all 'in range' nickel BAPC values at 95% species protection).

Table 3.5: Variation in **nickel** BAPC values at 95% species protection between states and regions.

State / region	Minimum	Q5	Q25	Median	Q75	Q95	Maximum	N
Australia	1.6	4.2	6.1	8.3	12	22	64	10603
NSW	1.6	3.9	5.8	8.1	11	19	54	7677
ACT	2.8	3.6	4.9	6.0	7.6	14	23	98
WA	2.8	6.0	13	19	27	43	65	437
SA	3.3	4.6	6.1	7.6	9.3	13	29	2104
NT	4.0	4.8	5.2	5.7	7.0	9.2	16	47
TAS	5.8	9.3	13	17	21	35	62	243
VIC	11	11	11	11	11	11	11	1
New Zealand	1.5	3.1	4.7	6.5	8.8	14.0	38	6432
Wellington	1.5	2.8	4.2	5.5	8.4	14	33	760
Auckland	1.6	4.1	5.9	7.6	9.8	14	29	2445
Canterbury	1.8	2.9	3.8	5.3	7.8	13	23	1171
Southland	1.9	3.3	4.7	6.0	8.0	14	38	1669
Manawatu-Whanganui (MW)	1.9	2.6	3.6	4.8	7.4	17	27	205
Taranaki	2.1	2.4	2.9	3.6	4.1	4.5	5.7	23
Bay of Plenty	2.2	2.3	3.4	4.0	6.0	11	13	32
Otago	2.6	3.0	3.4	4.1	4.7	5.5	6.9	62
Hawkes Bay	3.2	3.6	5.6	8.2	9.6	14	16	53
Tasman	3.4	3.5	3.7	5.3	7.7	8.7	9.0	10
Waikato	3.8	4.0	4.7	5.6	6.4	7.1	7.3	2

3.3.3 Probability distributions and 5th percentiles

The method to select the DGVs for nickel was as described in Section 3.2.3 for copper. Cumulative frequency plots of nickel $BAPC_{95}$ values for each state and region with the 5th percentile values marked are shown in Figure 3.10. The same data are shown as probability distributions in Figure 3.11.

The plots indicate the following states and regions that have waters where nickel would be most toxic (e.g., low DOC, calcium and magnesium waters): Australian Capital Territory (ACT, 5th percentile = 3.6 µg/L) and NSW (3.9 µg/L) in Australia; and Bay of Plenty (2.3 µg/L) and Taranaki (2.4 µg/L) in New Zealand. For these states and regions, the 5th percentile of the nickel $BAPC_{95}$ values was lower than the overall national 5th percentile (Figure 3.11), whereas in other states and regions the 5th percentile is higher than or closer to the national 5th percentile.

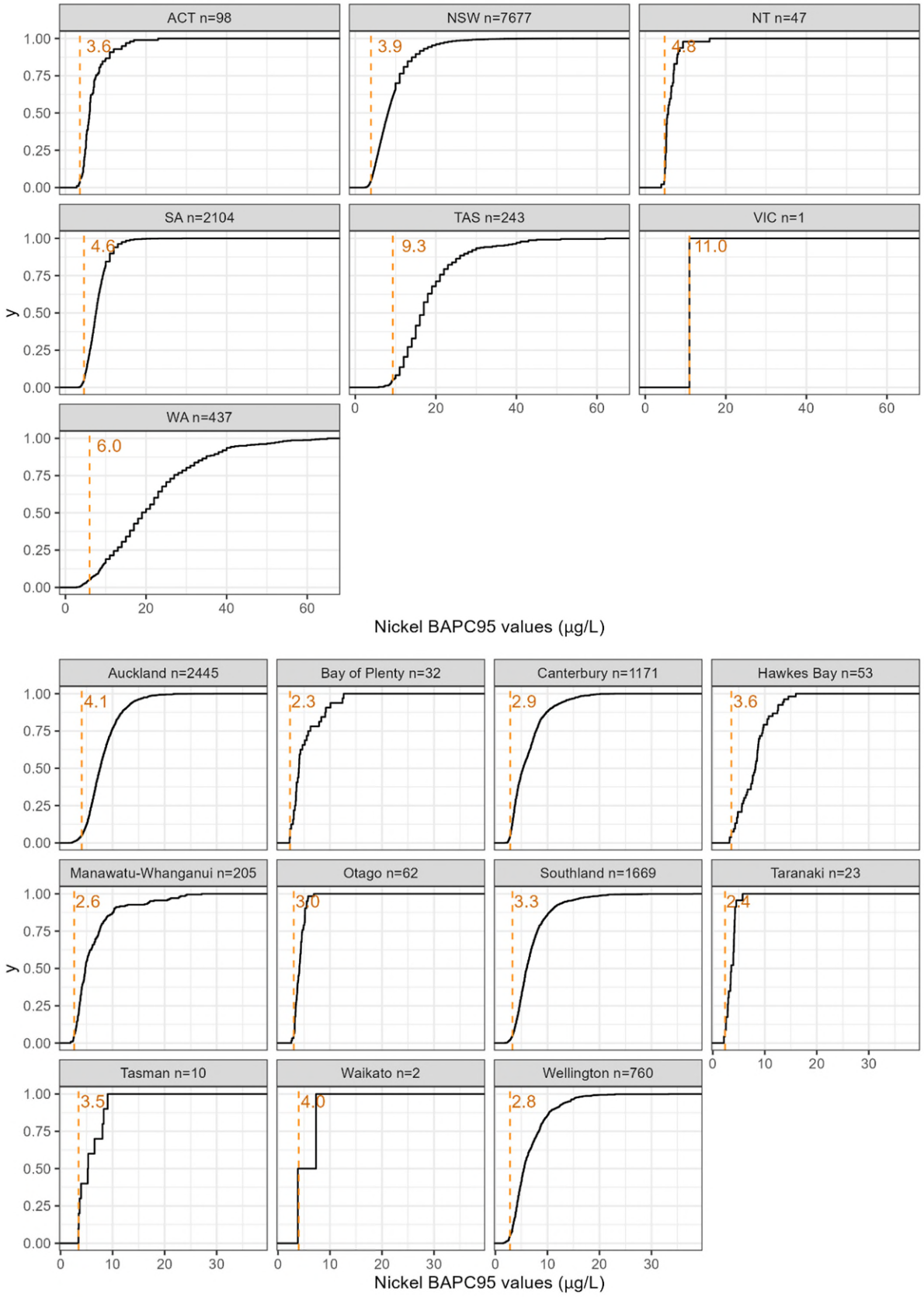


Figure 3.10: Comparisons between states and regions for nickel BAPC values at 95% species protection. The 5th percentile of calculated $BAPC_{95}$ values for each state/region is shown with dashed orange line and in orange text.

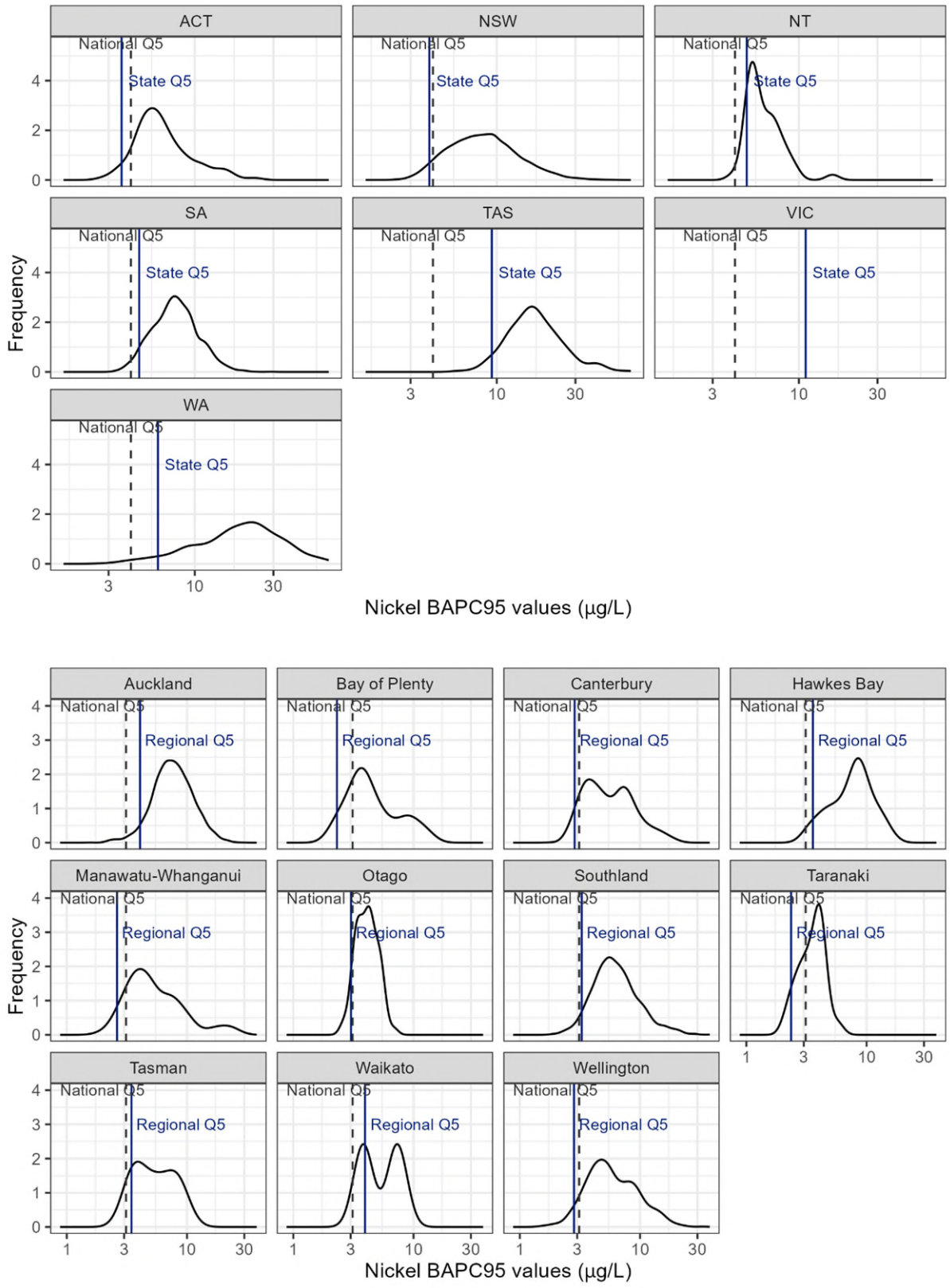


Figure 3.11: Comparisons between states and regions for nickel BAPC values at 95% species protection. The 5th percentile of calculated $BAPC_{95}$ values is shown for each state in blue and for each country in dark grey.

3.4 Zinc

3.4.1 Variation between countries

The zinc BAPCx values were generally lower in New Zealand than in Australia (e.g., Figure 3.12, Table 3.6), which may (as for copper and nickel) reflect the tendency towards lower DOC in New Zealand. The 5th percentile of the zinc BAPC values at the 95% species protection level for Australia (7.0 µg/L) was somewhat higher than the value for New Zealand (5.2 µg/L), although, as with nickel, this difference was much smaller than the difference between countries for copper.

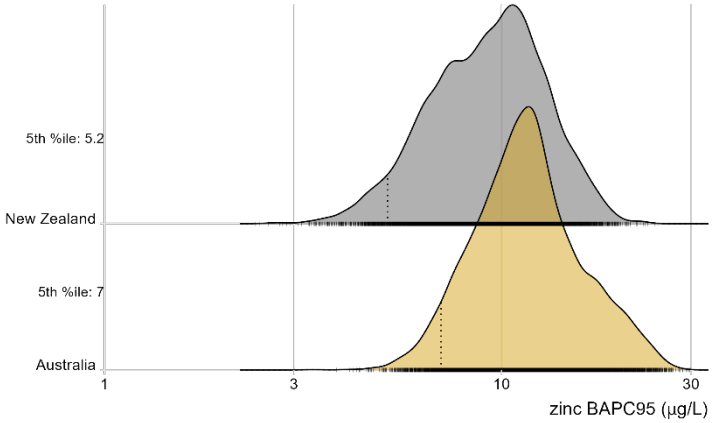


Figure 3.12: Comparison between Australia (gold) and New Zealand (grey) of zinc BAPC values (at 95% species protection). 5th percentile shown with vertical dashed line and is annotated on plot. Note BAPCx values are plotted on a log scale (base 10).

Table 3.6: Comparison of 5th percentile and median **zinc** BAPCx values for each level of species protection.

	5th percentile		Median	
	Australia	**New Zealand**	**Australia**	**New Zealand**
99% protection	2.7	2.0	4.5	3.7
95% protection	7.0	5.2	11.5	9.4
90% protection	10.8	8.0	17.5	14.5
80% protection	18.6	13.8	29.9	24.8
N. data	10104	7730	10104	7730

3.4.2 Variation within Australia and New Zealand

There are some large differences in the zinc BAPC values at the 95% species protection level between states in Australia (Figure 3.13), with highest $BAPC_{95}$ values in Western Australia (WA, median of 18.5 µg/L, Table 3.7) and lowest in Northern Territory (NT, median of 7.7 µg/L). This represents a two to three-fold difference between the lowest median and the highest – much less variation than noted for copper (section 3.2.2). There was only a little over two-fold difference in $BAPC_{95}$ values between regions of New Zealand, with the lowest median of 5.4 µg/L (Waikato) compared to 11.9 µg/L for Hawkes Bay (Table 3.7). However, within many regions, there was a wide range of calculated zinc $BAPC_{95}$ values, presumably reflecting the range in water chemistries within a region.

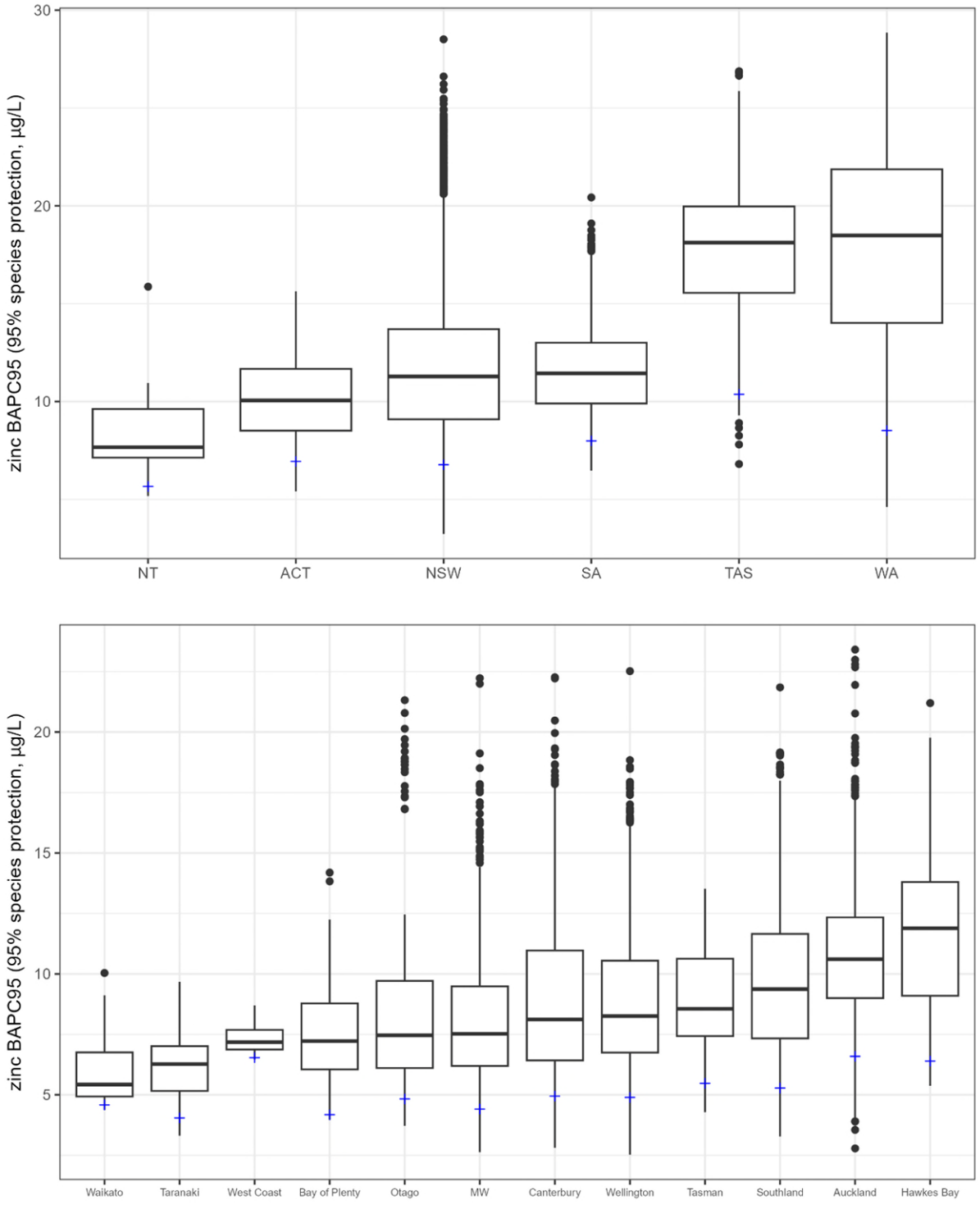


Figure 3.13: Comparisons between states and regions of all in range zinc BAPC values at 95% species protection. Blue line on whisker indicates 5th percentile value for each state or region.

Table 3.7: Variation in **zinc** BAPC values at 95% species protection between states and regions. Data ordered by 5th percentile (Q5).

State / region	Minimum	Q5	Q25	Median	Q75	Q95	Maximum	N
Australia	3.2	7.0	9.4	11.5	13.9	20.2	28.9	10104
NT	5.2	5.7	7.1	7.7	9.6	10.9	15.9	52
NSW	3.2	6.8	9.1	11.3	13.7	19.8	28.5	7021
ACT	5.4	6.9	8.5	10.1	11.7	14.8	15.6	109
SA	6.5	8.0	9.9	11.4	13.0	16.3	20.4	2311
WA	4.6	8.5	14.0	18.5	21.9	25.3	28.9	401
TAS	6.8	10.4	15.6	18.1	20.0	24.0	26.9	210
New Zealand	2.5	5.2	7.3	9.4	11.6	15.4	23.4	7730
Taranaki	3.3	4.0	5.2	6.3	7.0	7.5	9.7	35
Bay of Plenty	4.0	4.2	6.1	7.2	8.8	12.4	14.2	39
Manawatu-Whanganui (MW)	2.6	4.4	6.2	7.5	9.5	15.1	22.2	456
Waikato	4.4	4.6	4.9	5.4	6.8	9.6	10.0	11
Otago	3.7	4.8	6.1	7.5	9.7	18.9	21.3	123
Wellington	2.5	4.9	6.7	8.3	10.6	15.0	22.5	873
Canterbury	2.8	4.9	6.4	8.1	11.0	15.3	22.3	1402
Southland	3.3	5.3	7.3	9.4	11.7	15.7	21.9	2167
Tasman	4.3	5.5	7.4	8.6	10.6	12.2	13.5	16
Hawkes Bay	5.4	6.4	9.1	11.9	13.8	17.6	21.2	97
West Coast	6.5	6.5	6.9	7.2	7.9	8.5	8.7	4
Auckland	2.8	6.6	9.0	10.6	12.3	15.0	23.4	2507

3.4.3 Probability distributions and 5th percentiles

The method to select the DGVs for zinc was as described in Section 3.2.3 for copper. Cumulative frequency plots of zinc $BAPC_{95}$ values for each state and region with the 5th percentile values marked are shown in Figure 3.14, with the 5th percentile values marked. The same data are shown as probability distributions in Figure 3.15.

The plots (Figure 3.15) indicate the states and regions that have waters where zinc would be most toxic (e.g., low DOC, calcium and magnesium waters). In Australia, this was the Northern Territory (NT, 5th percentile = 5.7 µg/L), NSW (6.8 µg/L) and ACT (6.9 µg/L). In six out of the 12 New Zealand regions, the 5th percentile pf $BAPC_{95}$ values was lower than the national 5th percentile, as the latter value is influenced by the many data for Southland and Auckland regions. The lowest 5th percentiles were in Taranaki (4.0 µg/L), Bay of Plenty (4.2 µg/L) and Manawatu-Whanganui (4.4 µg/L).

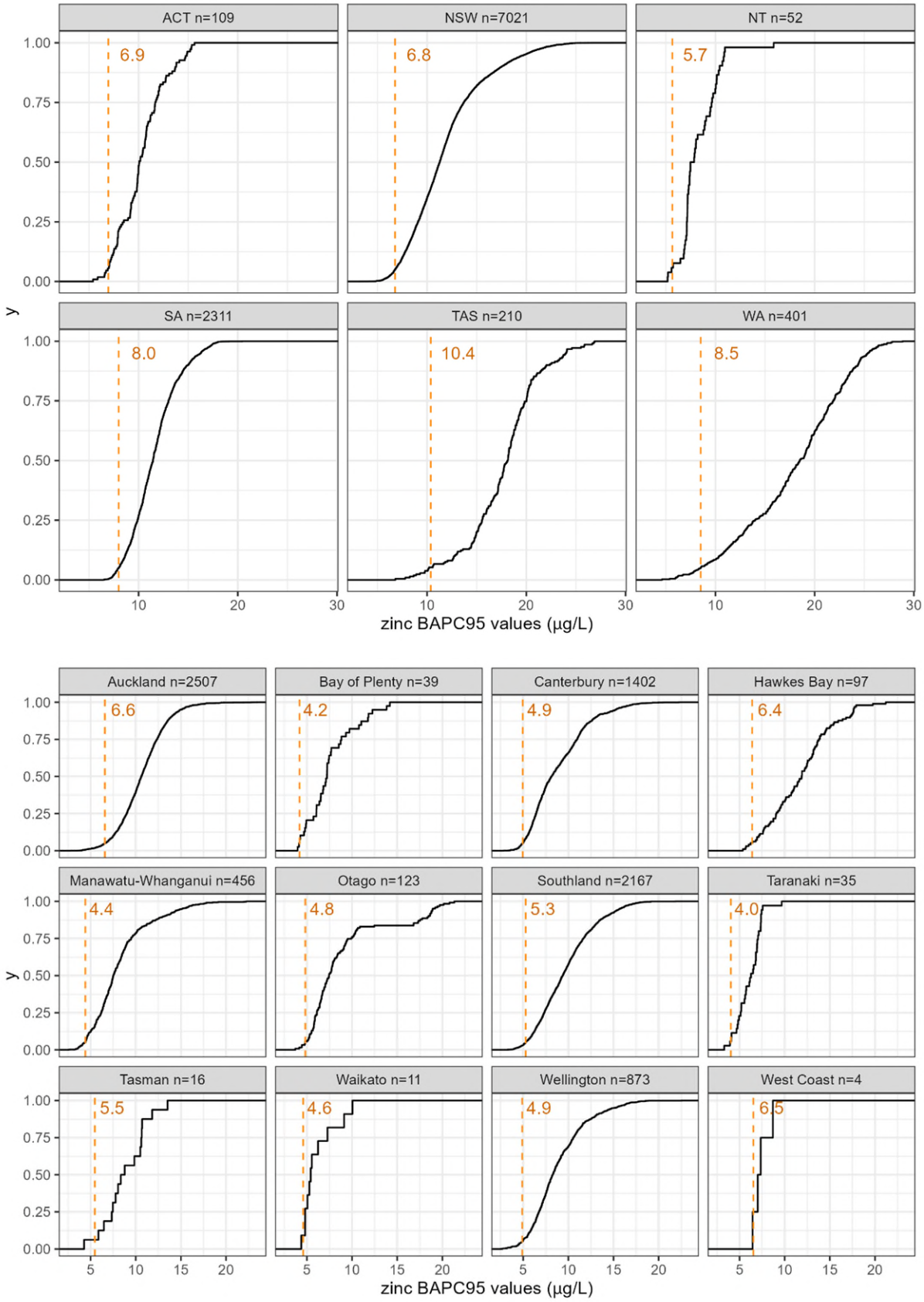


Figure 3.14: Comparisons between states and regions for zinc BAPC values at 95% species protection. The 5th percentile of calculated $BAPC_{95}$ values for each state/region is shown with a dashed orange line and in orange text.

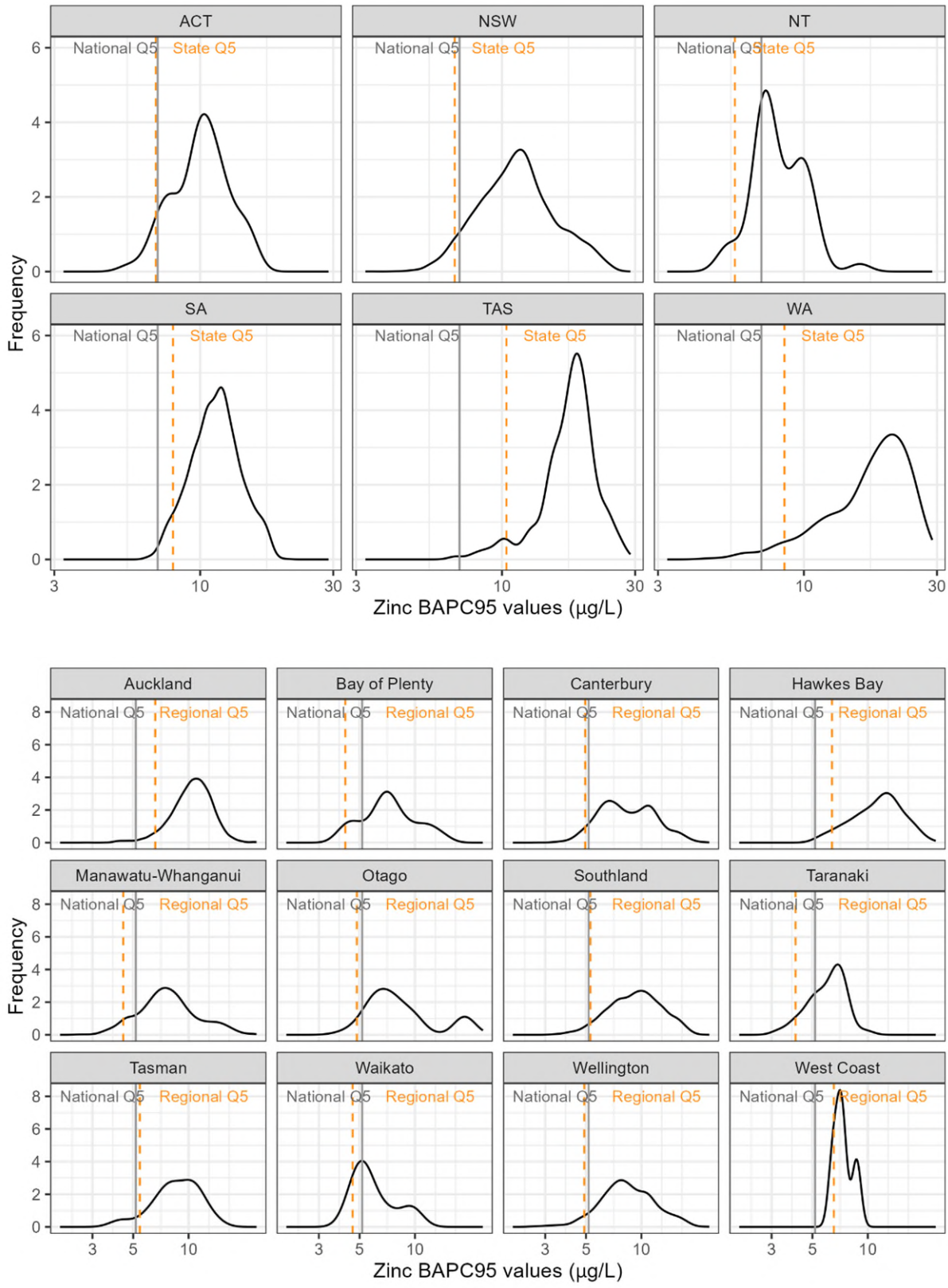


Figure 3.15: Comparisons between states and regions for zinc BAPC values at 95% species protection. The 5th percentile of calculated $BAPC_{95}$ values is shown for each state as a dashed orange line and for each country in dark grey.

4 Selecting freshwater DGVs for copper, nickel and zinc for Australia and New Zealand

The DGVs for copper, nickel and zinc in freshwater are designed to be conservative and to reflect the bioavailability of more than 95% of samples that might be collected across Australia and New Zealand (consistent with the European Commission (2019) approach for bioavailability-based environmental quality standards for metals). **A single DGV for the entire region (i.e., both Australia and New Zealand) is unlikely to achieve the purpose of being protective without being unnecessarily conservative, due to the different water chemistries between both countries** (see section 3 and tables 4.1-4.5). For example, the 5th percentile of $BAPC_{95}$ values for nickel in Australia ranged between 3.4-11 µg/L between states, while in New Zealand regions ranged from 2.3-4.0 µg/L. Given these inter-country differences, different DGVs were derived for each country.

Both the Australian and New Zealand datasets were somewhat limited in terms of their geographic coverage, with little data for some states or regions, particularly for nickel and zinc, where more TMFs are needed to calculate the BAPCx values. In addition, in some locations, many of the samples were outside the model applicability range, especially for the nickel and zinc BAPCx values, and especially for Australian data. Further, for Queensland, although all TMFs were measured at some locations within the state, DOC was measured in different locations to pH, calcium and magnesium. These two issues resulted in the absence of data from Queensland and only a single sample from Victoria (as magnesium was almost always below the applicable range in the data available). It is important to note that having relatively few data for some regions and incomplete applicability of the models for all waters is not unusual at the start of this process. In Europe, when the same approach was adopted, there were very few monitoring data initially, with data only available from just six countries (OECD 2017). Over time, the data coverage has greatly expanded with more than 30 countries now covered, due to the implementation of the approach driving the collection of the required supporting data (G. Merrington, wca, pers. comm). **For this reason, a re-evaluation of the approach some years after implementation, based on the updated dataset, is desirable.**

Further, some Australian sites have been sampled multiple times (e.g., over 200 times for a handful of sites in South Australia, Tasmania and NSW) whereas 30% of Australian sites with DOC data have been sampled only once. Similarly in New Zealand, there are 116 sites with DOC data that have been sampled only once (25% of the dataset), but five sites in Wellington that have been sampled over 100 times each. These factors mean that the water chemistry data collected is not fully representative of the population of samples that might be collected over time across the entirety of each country. Consequently, there is high uncertainty and likely bias in the datasets (McBride 2005). Over time, additional sampling at new locations as a result of implementation of the DGVs should improve the geographical spread of the water chemistry data and reduce the uncertainty and bias.

In the meantime, to reduce the bias from the uneven sampling across the sites, a weighted percentile was used. That is, 5th percentiles from the cumulative probability distributions were calculated after weighting the datasets according to the number of times they had been sampled at each location. For example, where there was only a single sample for a site, this was given a weighting of 1. Where there were three samples, each was given a weighting of 0.33. These weighted percentiles are shown in Table 4.1 and Table 4.2 for copper in Australia and New Zealand, respectively, in Table 4.3 and Table 4.4 for nickel and in Table 4.5 and Table 4.6 for zinc. These values differ from those presented in section 3.2 and 3.3, due to the use of the weighting method.

In New Zealand, there was little difference between the 5th percentiles whether a weighting was used or not. This is because in most regions, all sites had the same, or a similar number of data points, although there were large differences in the number of samples when comparing between regions.

Table 4.1: Australian state, sampling frequency weighted 5th percentile of **copper** BAPCx values for each level of species protection. Values in bold indicate the region with the highest bioavailability water quality conditions, to be adopted as DGVs for copper for Australia. Values in italics would not be considered due to insufficient number of samples.

State	N. data	99% protection	95% protection	90% protection	80% protection
NT	**65**	**0.53**	**0.73**	**0.89**	**1.4**
VIC	379	0.82	1.1	1.4	2.1
QLD	*6*	*0.86*	*1.2*	*1.4*	*2.2*
NSW	14412	0.92	1.3	1.5	2.4
WA	533	1.4	1.9	2.3	3.6
TAS	325	1.4	2.0	2.4	3.8
ACT	138	1.9	2.6	3.1	4.8
SA	2395	1.9	2.6	3.2	4.9

Table 4.2: New Zealand regional, sampling frequency weighted 5th percentile of **copper** BAPCx values for each level of species protection. Values in bold indicate the regions with the highest bioavailability water quality conditions, to be adopted as DGVs for copper for New Zealand.

Region	N. data	99% protection	95% protection	90% protection	80% protection
Bay of Plenty	**169**	**0.53**	**0.73**	**0.89**	**1.4**
Canterbury	**1614**	**0.53**	**0.73**	**0.89**	**1.4**
Otago	**153**	**0.53**	**0.73**	**0.89**	**1.4**
Taranaki	37	0.61	0.83	1.0	1.6
Manawatu-Whanganui	865	0.67	0.93	1.1	1.7
Waikato	24	0.67	0.93	1.1	1.7
Wellington	1167	0.74	1.0	1.2	1.9
Southland	3101	0.8	1.1	1.3	2.1
Hawkes Bay	107	0.85	1.2	1.4	2.2
Auckland	2740	1.0	1.4	1.7	2.7
Tasman	21	1.1	1.5	1.8	2.8
West Coast	44	1.1	1.6	1.9	3.0

Table 4.3: Australian state, sampling frequency weighted 5th percentile of **nickel** BAPCx values for each level of species protection. Values in bold indicate the region with the highest bioavailability water quality conditions, to be adopted as DGVs for nickel for Australia. Values in italics would not be considered due to insufficient number of samples.

State	N. data	99% protection	95% protection	90% protection	80% protection
NSW	**7677**	**0.66**	**3.4**	**6.9**	**14**
NT	47	0.61	4.0	9.5	23
ACT	98	0.82	4.3	8.7	18
SA	2104	0.88	4.6	9.3	20
WA	437	1.1	5.5	11	24
TAS	243	1.4	8.8	20	45
VIC	*1*	*2.3*	*11.1*	*22*	*43*

Table 4.4: New Zealand regional, sampling frequency weighted 5th percentile of **nickel** BAPCx values for each level of species protection. Values in bold indicate the region with the highest bioavailability water quality conditions, to be adopted as DGVs for nickel for New Zealand. alues in italics would not be considered due to insufficient number of samples.

Region	N. data	99% protection	95% protection	90% protection	80% protection
Bay of Plenty	**32**	**0.39**	**2.3**	**5.0**	**11**
Taranaki	23	0.42	2.3	4.8	10
Manawatu-Whanganui	205	0.46	2.6	5.4	11
Wellington	760	0.48	2.7	5.5	12
Southland	1669	0.52	2.9	5.8	12
Canterbury	1171	0.52	3.0	6.1	13
Otago	62	0.54	3.0	6.3	14
Tasman	10	0.65	3.4	6.9	14
Auckland	2445	0.72	3.6	7.2	14.6
Waikato	*2*	*0.77*	*3.8*	*7.5*	*15*
Hawkes Bay	53	0.73	4.0	8.4	18

Table 4.5: Australian state, sampling frequency weighted 5th percentile of **zinc** BAPCx values for each level of species protection. Values in bold indicate the region with the highest bioavailability water quality conditions, to be adopted as DGVs for zinc for Australia.

State	N. data	99% protection	95% protection	90% protection	80% protection
NT	**52**	**1.9**	**5.2**	**8.2**	**15**
NSW	7021	2.4	6.4	9.8	17
ACT	109	2.8	7.3	11	19
SA	2311	3.1	8.2	13	22
WA	401	3.2	8.3	13	22
TAS	210	3.4	9.8	16	29

Table 4.6: New Zealand regional, sampling frequency weighted 5th percentile of **zinc** BAPCx values for each level of species protection. Values in bold indicate the region with the highest bioavailability water quality conditions, to be adopted as DGVs for zinc for New Zealand. Values in italics would not be considered due to insufficient number of samples.

Region	N. data	99% protection	95% protection	90% protection	80% protection
Bay of Plenty	**39**	**1.5**	**4.1**	**6.4**	**11**
Taranaki	35	1.6	4.1	6.4	11
Otago	123	1.5	4.2	6.5	11
Manawatu-Whanganui	456	1.6	4.3	6.6	12
Tasman	16	1.6	4.3	6.7	12
Waikato	*11*	*1.7*	*4.4*	*6.8*	*12*
Wellington	873	1.7	4.4	6.8	12
Southland	2167	1.8	4.8	7.4	13
Canterbury	1402	2.0	5.2	8.1	14
Auckland	2507	2.4	6.1	9.5	16
Hawkes Bay	97	2.3	6.2	9.6	17
West Coast	*4*	*2.5*	*6.5*	*9.9*	*17*

The DGVs for copper do not vary between Australia and New Zealand as there are states and regions in each country with low DOC concentrations (≤0.5 mg/L). In contrast, they do vary for nickel and zinc as the DGVs for these metals also take into account differences in pH, and calcium and magnesium (or hardness for zinc). The water chemistry at these DGVs-termed the reference condition-are also provided in Table 4.7. Note that there can be multiple combinations of water chemistry that result in the same, or very similar BAGVs. Ultimately, all such conditions will represent a high bioavailability condition for the metal in question, for which the DGVs would be sufficiently protective. The reference condition differs for each metal as the relationships between toxicity and water chemistry conditions is different for each metal.

Table 4.7: Recommended DGVs at varying levels of protection, based on sampling frequency weighted 5th percentiles from most sensitive regions or states.

	Copper		**Nickel**		**Zinc**	
Species protection	Australia	New Zealand	Australia	New Zealand	Australia	New Zealand
99% protection	0.53	0.53	0.66	0.39	1.9	1.5
95% protection	0.73	0.73	3.4	2.3	5.2	4.1
90% protection	0.89	0.89	6.9	5.0	8.2	6.4
80% protection	1.4	1.4	14	11	15	11
Reference condition water chemistry						
DOC (mg/L)	0.5	0.5	2.2	0.5	1.0	0.7
pH	Not applicable		7.7	7.6	7.6	7.5
Calcium (mg/L)	Not applicable		4.0	14	Not applicable	
Magnesium (mg/L)	Not applicable		4.0	5	Not applicable	
Hardness (mg $CaCO_3$ /L)	Not applicable		Not applicable		39	28

5 Future work & uncertainties

The spatial distribution of data collated across both countries is incomplete. Some states and regions have relatively poor coverage due to a disconnect in monitoring of some parameters; for example, parameters are measured at the same site but at different times, and/or parameters are just not monitored at all in some areas. Also, there is discrepancy in the amount of data collected from different hydrological systems, with more data available for lowland systems which tend to be more modified than minimally disturbed headwaters. This makes it difficult to determine whether the derived GVs are reflective of water chemistry within these less sampled areas. Although, it is likely that metal exposures in minimally disturbed areas will also be less likely.

To reduce uncertainty in the DGVs, they were only derived from BAPCx values collected from data that fitted within the applicability ranges of the developed models, with only 19%, 51% and 49% of data with available pH, DOC and/or hardness (Ca and Mg concentrations) within the applicability ranges for copper, nickel and zinc, respectively. When copper BAPCs were calculated for water chemistry outside the applicability ranges, the 5th percentile from all Australian data was slightly higher than the 5th percentile from data within the applicability range. For New Zealand the difference was negligible. For both nickel and zinc, the 5th percentile of BAPCx values including data outside the applicability range was lower than if those data were excluded, for both Australia and New Zealand. This suggests that if the applicability range was extended for the same model, the nickel DGVs could be slightly lower than those developed here. These discrepancies suggest that in some instances, especially in low hardness waters (Ca and Mg below the TMF ranges), the DGVs may not be protective. Although, the certainty around this deduction is very limited, as model performance outside of the applicability ranges is also considered to be uncertain.

Below, we have listed areas of future work that would improve certainty around the DGVs when updated in the future.

- Increased data coverage across both countries is recommended. To improve coverage, it is recommended that current monitoring programs within each state and/or region, sample all parameters needed to derive BAPCx values, and these be sampled at the same time. For regions where no data are available, a field campaign may be needed to collect data. This is especially important where data are not available for waters that are likely to be impacted in some way (e.g. by mining, agriculture, urbanisation), and for more sensitive regions such as headwaters (where DOC and hardness may be low), which are currently under-represented.
- More work is needed to extend the TMF ranges of the derived bioavailability models for copper nickel and zinc. More ecotoxicity tests at lower hardness (20 mg/L $CaCO_3$ or Ca and Mg concentrations below 3 and 3.7 mg/L, respectively) and higher hardness (> 400 mg/L $CaCO_3$), at lower pH (< 6) and higher DOC (especially for nickel, above 17 mg/L), are needed. Some of this data may already exist and may need to be incorporated in the future. The models may therefore need revisiting in a few years when more data are available.
- Further validation studies, including ecotoxicity tests with native taxa in natural waters of varying water chemistries (beyond current bioavailability model boundaries and spiked with copper, nickel or zinc) would help ensure that DGVs and BAGVs are sufficiently protective.

Formal publication of the copper, nickel and zinc freshwater DGVs can be found in ANZG (2026a), ANZG (2026b) and ANZG (2026c) DGV technical briefs, respectively. As described in Section 1, the DGVs reported in these technical briefs are intended to be used at Tier 1 of a tiered assessment framework where, if they are exceeded, site- or sample-specific bioavailability will need to be considered, at Tier 2, through the

calculation of BAGVs for the site- or sample-specific water quality. The development and implementation of this approach has been captured in tasks 3 to 5 of the current MERA-funded project, specifically:

- Develop a user-friendly tool to adjust the monitoring data or the DGVs for site-specific bioavailability (task 3);
- Develop the tiered assessment framework and associated user guidance (task 4) (Stauber et al. 2026); and
- Develop appropriate training materials for the whole package (task 5).

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Appendix A Toxicity data for nickel and zinc used in calculating BAPCx values

Table A.1 Species sensitivity coefficients for all species used to derive default guideline values for nickel in freshwater.

Taxonomic group (phylum or clade)	Species	Species sensitivity coefficient[a] (µg/L)
Diatom	*Navicula pelliculosa*	4.5
Green microalga	*Chlorella* sp. (Kakadu isolate)[a]	6.0
	Chlorella sp. 12 (PNG isolate)[a]	3.9
	Monoraphidium arcuatum[c]	5.4
	Nannochloropsis sp.[c]	3.5
	Pediastrum duplex[c]	5.7
	Raphidocelis subcapitata	5.0
Macrophyte (duckweed)	*Lemna aequinoctialis*[c]	12.5
	Lemna minor[c]	13.6
Crustacean (rotifer)	*Brachionus calyciflorus*[c]	7.7
Crustacean (amphipod)	*Hyalella azteca*	5.8
Crustacean (cladoceran)	*Alona affinis*	4.1
	Ceriodaphnia dubia	3.3
	Ceriodaphnia pulchella	5.5
	Ceriodaphnia quadrangula	5.2
	Daphnia longispina	6.5
	Daphnia magna	5.1
	Peracantha truncata	5.7
	Simocephalus serrulatus	6.2
	Simocephalus vetulus	5.5
Gastropod	*Lymnaea stagnalis*	2.0
Cnidarian	*Hydra viridissima*[c]	6.4
Insect (chironomid)	*Chironomus tentans*	7.0
Insect (caddisfly)	*Clistoronia magnifica*	6.4
Fish	*Melanotaenia splendida splendida*[c]	3.4
	Pimephales promelas	5.8

Notes: [a] Species sensitivity coefficient is the difference between the observed (experimental) value and the MLR predicted value for each species at each water chemistry combination tested. The lowest value or the geometric mean of the calculated sensitivity coefficients for an individual species across available tests for that species with the same life stage, duration and endpoint was used as the species-specific sensitivity coefficient for calculating BAPCx values.

Table A.2 Species sensitivity coefficients for all species used to derive default guideline values for zinc in freshwater.

Taxonomic group (phylum or clade)	Species	Species sensitivity coefficient [a] (µg/L)
Chordata (fish)	*Oncorhynchus mykiss*	1.7
	Pimephales promelas	1.5
	Prosopium williamsoni	2.3
	Salmo trutta	2.6
Arthropoda (crustacean)	*Ceriodaphnia dubia*	6.6
	Ceriodaphnia reticulata	6.7
	Daphnia magna	6.7
	Daphnia thomsoni	6.2
	Hyalella azteca	6.9
Arthropoda (insect)	*Neocloeon triangulifer*	5.1
	Rhithrogena hageni	10.5
Mollusca (mollusc)	*Alathyria profuga*	5.3
	Cucumerunio novaehollandiae	4.8
	Echyridella menziesii	
	Hyridella australis	4.8
	Hyridella depressa	5.0
	Hyridella drapeta	5.1
	Lampsilis siliquoidea	6.4
	Lymnaea stagnalis	8.3
	Physa gyrina	8.8
	Velesunio ambiguus	5.4
Rotifera (rotifer)	*Brachionus calyciflorus*	7.6
Chlorophyta (green microalga)	*Chlorella* sp. (Papua New Guinea isolate)	2.0
	Chlorella sp. (Kakadu isolate)	7.0
	Raphidocelis subcapitata	9.6

Notes: [a] Species sensitivity coefficient is the difference between the observed (experimental) value and the MLR predicted value for each species at each water chemistry combination tested. The lowest value or the mean of the calculated sensitivity coefficients for an individual species across available tests for that species with the same life stage, duration and endpoint was used as the species-specific sensitivity coefficient for calculating BAPCx values.