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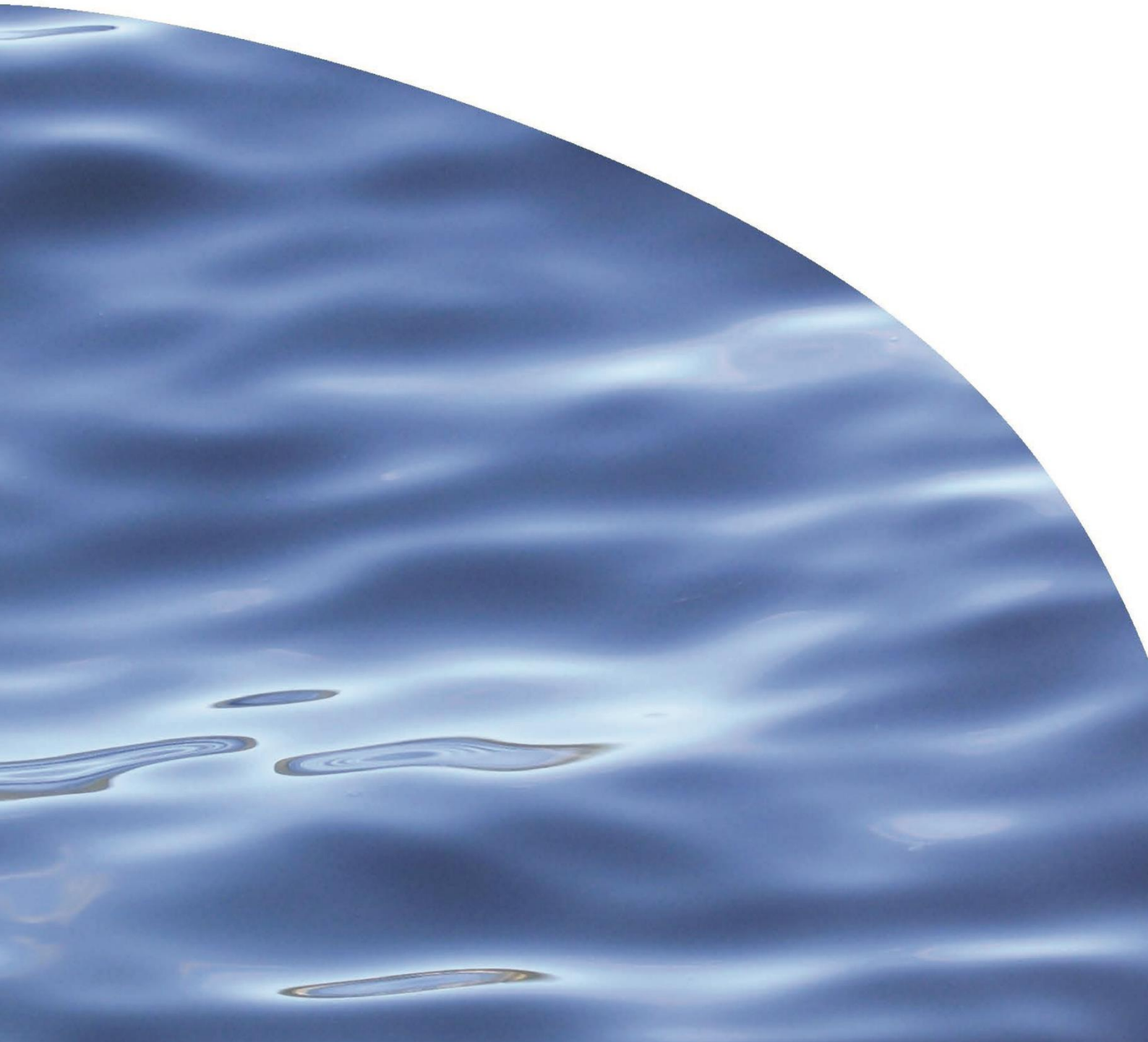
INDICATORS OF FRESHWATER QUALITY BASED ON DEPOSITED SEDIMENT AND RAPID HABITAT ASSESSMENT



INDICATORS OF FRESHWATER QUALITY BASED ON DEPOSITED SEDIMENT AND RAPID HABITAT ASSESSMENT

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Prepared for Ministry for the Environment

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EXECUTIVE SUMMARY

This project collated and analysed regional council river and stream monitoring data, including measures of deposited fine sediment (< 2 mm) and habitat quality at the site scale, to inform the development of environmental indicators for the next national Freshwater Domain report – *Our Fresh Water 2020*. Data were requested from regional councils and unitary authorities that had conducted deposited fine sediment and habitat assessments using standardised protocols developed in the last eight years. As such, data provide a recent and up-to-date summary of these stream attributes.

Not all councils had applied the targeted protocols and for deposited sediment, councils had applied up to six different protocols. The most frequently applied deposited sediment protocol was an instream visual assessment of % fine sediment cover (SAM2) measured at least once at 336 sites spread across six regions. The rapid habitat assessment (RHA) protocol was applied at least once at 901 sites spread across nine regions.

We analysed data using two different levels: Level 1 used all data available and Level 2 used a minimum of three years of data for RHA (≥ 1 sample per year per site used to calculate annual median, the maximum number of years was 6) and a minimum of two years of data for SAM2 (≥ 6 samples per year per site used to calculate an annual median) collected between 2014–2019. However, we recommend the use of the Level 2 dataset for national reporting. The Draft National Policy Statement for Freshwater Management, now out for consultation, would require monthly monitoring of deposited sediment using SAM2, which would meet the Level 2 requirement. Data were grouped by River Environment Classification landcover categories and for deposited sediment by a deposited sediment classification.

The national median RHA value was 63.0. Habitat Quality Scores (i.e. RHA values) were higher in ‘Native’ landcover compared to other landcover categories. Overall, 23.3% of monitoring sites had Habitat Quality Scores indicating Excellent habitat condition, 51.4% were in Good condition, 24% were in Fair condition and no sites were in Poor condition.

The national median deposited fine sediment cover was 4.5%. Deposited fine sediment was higher in ‘Urban’ landcover compared to other landcover categories. When compared to reference condition based on model predictions by Franklin et al. (2019), 85% of sites were below reference values, indicating good stream health. However, modelled reference values were higher than observed deposited fine sediment values at reference sites, and this result suggests there is a need to collect further data to refine and validate deposited fine sediment model predictions to inform robust assessments of the state of deposited fine sediment in rivers and streams.

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1. INTRODUCTION

Freshwater indicators used in national reporting are informed by reliable, accurate, and relevant statistics calculated from national datasets. In *Our Fresh Water 2017*, these included measures that represented three themes: water quality, water quantity and flows, and ecosystems, habitats and species. For ecosystems, habitats and species, findings included (Ministry for the Environment & Statistics NZ 2017):

- Some water bodies have been physically changed, but we do not know the extent or the impact this is having.
- Fine sediment deposited on riverbeds is estimated to have increased, but we don't know the national extent or impact this is having.

The above conclusions for physical habitat were based on the extent of wetlands and inconsistent regional assessments of fish barriers, and for deposited sediment, estimates of freshwater condition informed by predictive models.

Improving our understanding of the extent and impact of habitat modification on freshwater ecosystems requires the development of indicators based on measured data. Regular collection of measured data can inform both state and trends in freshwater condition. The recent adoption of standardised monitoring methods of stream habitat by most regional councils means there are now data to inform measures of freshwater habitat that were not previously available for national level reporting.

This project builds on and improves the suite of indicators that the Ministry for the Environment and Statistics New Zealand use to report on the state of New Zealand's environment under the Environmental Reporting Act 2015. The Ministry currently reports on the state of deposited sediment for a period up to, and including, 2011. This information is based on one-off deposited sediment observations, as well as a national model to estimate streambed sediment cover. The aim of this project is to collect more recent data to update the time period and to move from one-off sediment observations to using regional and unitary councils' deposited sediment monitoring programmes, where most councils now have 2–3 years of monthly deposited sediment monitoring data.

This project will also collate and analyse Rapid Habitat Assessment (RHA) data. The RHA is a protocol for assessing physical habitat condition in New Zealand waterways. The RHA produces a total Habitat Quality Score, which represents the overall state of stream habitat at a site scale.

2. DATA COLLATION

2.1. Survey of regional council and unitary authorities

We conducted a survey to determine whether there were enough new data available to inform an updated national indicator for freshwater habitat. We designed an online survey to find out what, when and where methods to measure deposited sediment and stream habitat are being used by regional councils and unitary authorities (hereafter 'councils'). Councils were asked to complete the survey in June 2019. We used SurveyMonkey software to ask 26 direct questions about monitoring methods and data, as well as requesting supporting information. Focal methods included deposited sediment protocols described in Clapcott et al. (2011) and the Rapid Habitat Assessment protocol described in Clapcott (2015):

- Bankside visual assessment (% cover) – A rapid qualitative visual assessment of the % of fine (< 2 mm) sediment covering the streambed in a run habitat. Also known as SAM1.
- Instream visual assessment (% cover) – The average % cover of fine sediment covering the streambed in a run habitat calculated from a minimum of 20 stratified views using an underwater viewer. Also known as SAM2.
- Wolman count (% fines) – The proportion of particles less than 2 mm in diameter recorded from a Wolman walk, or the measurement of a minimum of 100 particles picked up throughout a run habitat. Also known as SAM3.
- Suspendable inorganic sediment (SIS; g/m^2) – The average amount of inorganic fine sediment entrapped and covering the streambed in a run habitat calculated from a minimum of 5 corers in a run habitat. Also known as SAM4.
- Shuffle score (0-5) – An average qualitative assessment of the size and duration of a sediment plume resuspended when disturbing the streambed at 3 sites within a run habitat. Also known as SAM5.
- Sediment depth (mm) – Quantitative assessment of the depth of sediment in a run habitat. Also known as SAM6.
- Habitat Quality Score (1-100) – a qualitative assessment at the reach scale of 10 habitat components including deposited fine sediment, hydraulic heterogeneity, invertebrate habitat diversity and abundance, fish cover diversity and abundance, bank erosion and vegetation, riparian width and shade. Also known as Rapid Habitat Assessment (RHA).

All councils responded to the survey. A summary of the replies, regarding the suitability of the data to contribute to a national assessment of stream health, is as follows. A summary of responses to key (15) survey questions is provided in Appendix 1.

1. Deposited fine sediment is measured by 13 councils, with SAM 1 (8 councils) and SAM 2 (7 councils) methods being the most commonly applied. Deposited

sediment is measured daily at contact recreation sites through to 3-yearly at state-of-the-environment sites, but most commonly monthly at approximately 560 sites. Sediment is most commonly measured at the same sites where water quality and/or biological monitoring is undertaken. The length of continuous sediment monitoring at a single site ranges from 1–17 years; for example, for SAM 2, there are approximately 385 sites (5 councils) that have been measured monthly for at least 5 years. There appear to be enough data available to inform a national-scale assessment of deposited sediment based on the SAM2 method.

2. The Rapid Habitat Assessment is undertaken by 12 councils. The RHA is measured twice a year through to 3-yearly at water quality or biomonitoring sites, but most commonly annually at approximately 787 sites across 12 councils. The length of continuous annual RHA measurement ranges from 1–9 years, with approximately 500 sites with at least 5 years of data. There appear to be enough data available to inform a national-scale assessment of stream habitat based on the RHA method.
3. Councils use a range of quality control/quality assessment methods to ensure data quality. Data are stored in a wide range of internal databases that are not necessarily externally accessible. Some effort is likely to be necessary to access, collate and quality check the data for a national assessment.

2.2. Combining council data

Based on survey replies a data request was sent to councils to provide all deposited sediment and habitat data collected using the standard protocols, as well as site-specific metadata.

Data were received via email in a range of formats (e.g. Excel spreadsheets, CSV files). The data consisted of sediment and habitat samples labelled by protocol, date and location indexed by geospatial coordinates and/or the NZReach identifier (REC1; Snelder et al. 2004). Note that the number of regions that submitted data on these metrics are different from the number of regions expected from the survey answers (see Section 2.1). For the RHA metric, two regions recently adopted the Clapcott 2015 protocol but did not have data available yet, and one region only used the Clapcott 2015 protocol for special investigations and did not submit data. Additionally, two regions used other methods for habitat assessment, and these were not used in our analyses: either the Stream Ecological Valuation or an adapted EPA method. For deposited sediment, one region recently changed from SAM 1 to SAM 2 and did not have data on SAM 2 available yet. Data were compiled using R software (R Core Team 2019) and organised into a database. This database has two collections (or tables), one containing the RHA data and one containing the sediment data. We did not check or correct the council NZReach assignment. If a council did not provide the

NZReach identifier, we used the REC GIS database and the geospatial coordinates of the sites to obtain it. Data quality assessments did include checking that:

- data were assigned to the correct protocol
- data identified by the council as being collected using a 'modified' protocol were included in the database, but the 'modified' protocol was identified as such
- there were no duplicate sites or data; duplicate data that had the same measurement value and were collected on the same NZReach, council site identifier, date and time (if available) were excluded
    - data missing both NZReach identifier and geospatial coordinates were excluded
    - data missing a year identifier were excluded.

Data were summarised by sample collection protocol to determine the most temporally robust and spatially representative dataset available to inform national indicators. The most widely applied protocols were the RHA metric collected by 9 regions and the SAM 2 protocol collected by 6 regions (Table 1). Therefore, these two metrics were chosen for further analysis.

Next, we explored how many years of metric data were available to inform sediment and habitat indicators. On average, RHA samples were collected annually (i.e. once per summer), whereas SAM2 data were collected monthly (Table 1). Therefore, we grouped RHA data by seasonal year (i.e. July 2018–June 2019) and SAM2 data by calendar year. For RHA, a minimum of 3 years of data was available at 669 sites across 7 regions between 2014 and 2019 (Table 2). For SAM2, we explored how many months of data per year were available per site. Ideally a minimum of 24 replicates (12 replicates per year for 2 years) should be used to obtain a representative site median for % fine sediment cover (SAM2) (Franklin et al. 2019). There were 76 sites across two regions with at least 2 continuous years of 12 replicates per year (Figure 1). There were 165 sites across four regions with 10 replicates per year, 193 sites across four regions with 8 replicates per year, and 211 sites across six regions with a minimum of 6 replicates per year (Figure 1).

Table 1. Summary of all habitat and sediment metric data received from regional council and unitary authorities collected between 2014–2019.

Protocol	Metric	Number of regions with data	Number of samples	Number of unique sites	Average number of replicates per site per year	Number of sites ≥ 2 years (≥ 3)
RHA	Habitat Quality Score (1-100)	9	2594	900	1.1	(459)
SAM1	Bankside visual assessment (% cover)	5	9560	290	4.7	247
SAM2	Instream visual assessment (% cover)	6	19146	335	12.0	320
SAM3	Wolman count (% fine)	3	478	231	1.0	135
SAM4	Suspendable inorganic sediment (SIS; g/m^2)	1	382	100	1.0	86
SAM5	Shuffle score (0–5)	2	2050	155	4.1	112
SAM6	Sediment depth (mm)	1	580	126	1.0	126

Table 2. Summary of all metric data (Level 1) and a subset (Level 2) with a minimum of 3 years of data for RHA (≥ 1 sample per year) and with a minimum of 2 years of data for SAM2 (≥ 6 samples per year) collected between 2014–2019. Data have been grouped by dominant landcover classes using the Land Cover Database version 4.1 used to inform freshwater habitat and sediment indicators.

Protocol	Metric	Level	Number of regions with data	Number of unique sites	Native	Urban area	Exotic forest	Pastoral
RHA	Habitat Quality Score (1-100)	1	9	900	246	41	56	557
RHA	Habitat Quality Score (1-100)	2	7	471	118	25	22	306
SAM2	Instream visual assessment (% cover)	1	6	335	77	17	10	230
SAM2	Instream visual assessment (% cover)	2	6	257	65	14	10	168

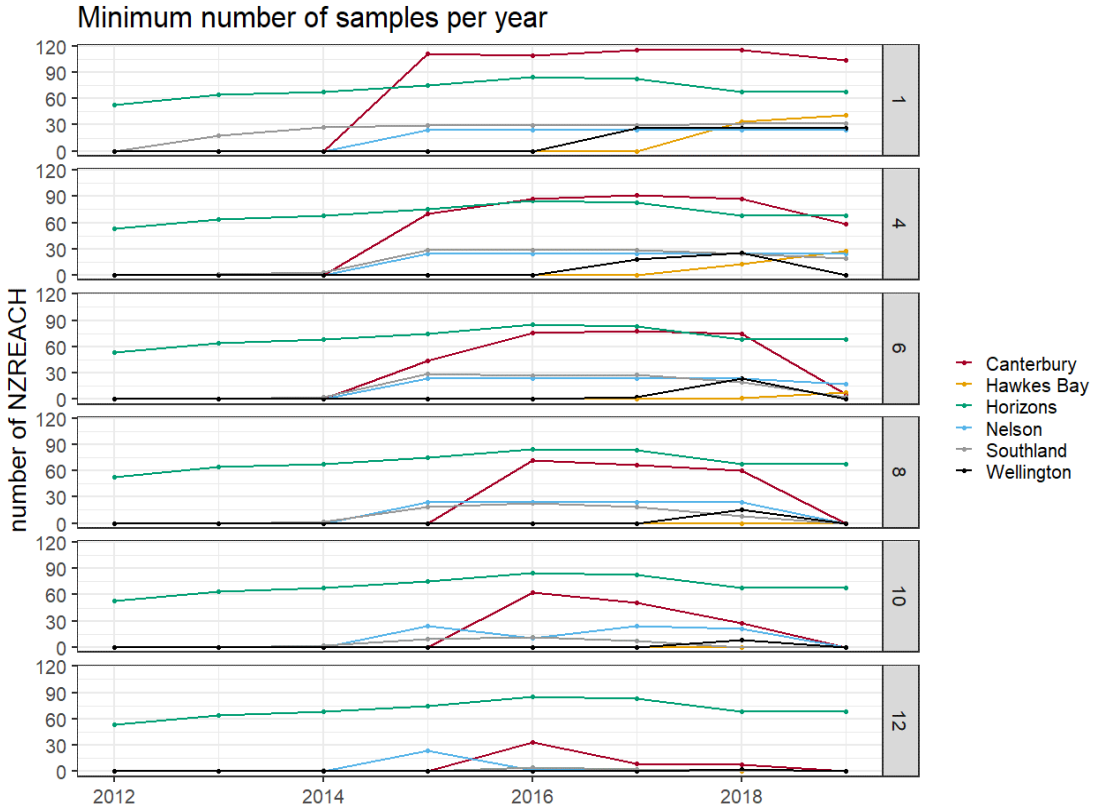

Figure 1. Summary of SAM2 data by region grouped by the number of samples per year from 2012 to 2019.

Missing data need to be accounted for. On LAWA for example, water quality state is calculated when at least 50% of the data are available over a reporting time-period (i.e. at least 2.5 years' worth of data over a five-year period). Therefore, we decided to proceed with the analysis using two levels of data. Level 1 uses all data available and Level 2 uses a minimum of three years of data for RHA (≥ 1 sample per year used to calculate annual median) and a minimum of two years of data for SAM2 (≥ 6 samples per year used to calculate an annual median) collected in the period 2014–2019 (Table 2; Figure 2).

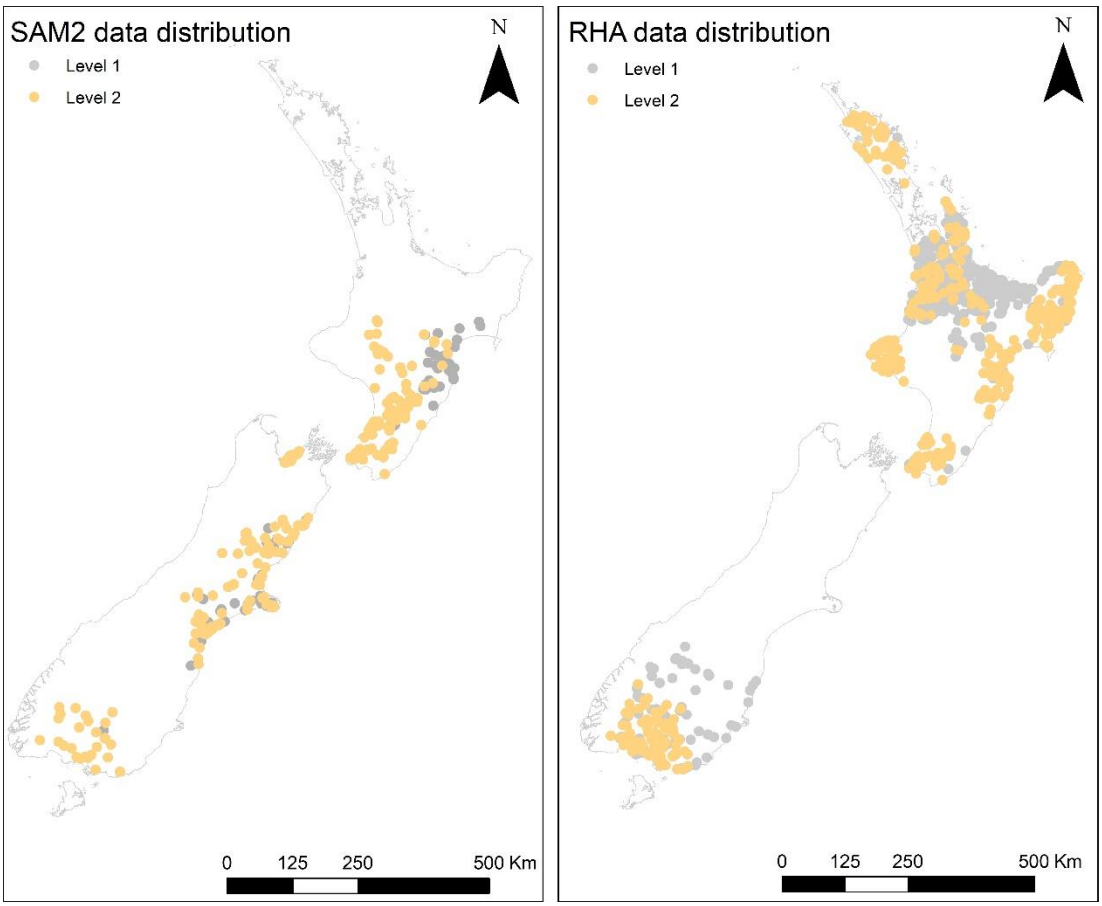

Figure 2. Distribution of SAM2 and RHA data collected by councils for all years and sites (Level 1 – grey dots) and for a minimum of 3 consecutive years for RHA (≥ 1 sample per year) and SAM2 (≥ 6 samples per year) between 2014-2019 (Level 2 – yellow dots).

We further explored the number of sample sites per dominant landcover category to inform the suitability of using the dominant landcover to report on spatial trends in the data. The dominant landcover was calculated using the Land Cover Database version 4.1 detailed classes grouped according to Land, Air, Water Aotearoa's (LAWA) medium land cover classes. Medium classes were aggregated into five dominant land cover categories: Urban area, Pastoral, Exotic forest, Native and Other. Water bodies were excluded from our analyses. When a NZReach was missing from the Land Cover Database, we assigned it the dominant landcover of the geographical nearest NZSegment in the database. For both RHA and SAM2, all landcover classes were represented in both Level 1 and Level 2 datasets with the highest number of sites in Pastoral compared to Native, Exotic Forest and Urban landcover (Table 2). The percentage of stream segments (NZReach) in each of these landcover categories at a national scale is 46.6% for Pastoral, 46.1% for Native, 6.0% for Exotic Forest and 0.8% for Urban area.

3. INDICATOR CALCULATION AND RESULTS

3.1. Rapid habitat assessment

Using the habitat (RHA) metric Level 1 and Level 2 datasets, for each site we calculated the ≥ 3yr mean, median and standard deviations. Next, we grouped sites by dominant landcover, and we performed a Kruskal-Wallis rank sum test to see if there were differences among the landcover classes with respect to the total RHA values. Following this, we performed a Dunn Kruskal-Wallis multiple comparison test, adjusting the p-values with the Holm method. The Dunn test is appropriate for groups with unequal numbers of observations (Zar 2010). We used these non-parametric tests because the residuals of an ANOVA showed metrics to be not normally distributed.

At the national scale, the median total RHA value was 61.7 (mean = 61.6; standard deviation = 16.6) in the Level 1 dataset and 64 (mean = 63; standard deviation =15.7) in the Level 2 dataset.

There was a significant difference among dominant landcover classes in total RHA values in both the Level 1 ($\chi 2 = 184.19$, df = 3, $p < 0.001$) and Level 2 ($\chi 2 = 116.12$, df = 3, p-value < 0.001) datasets. Total RHA scores were significantly higher in Native compared to other landcover classes (Figure 3; Table 3). Subsequently, we explored expressing total RHA scores in two indicator formats:

1. Habitat Quality Scores (HQS) where total RHA scores equal the HQS, and
2. % Habitat Quality Scores (%HQS) where the total RHA score is divided by the 20th percentile values observed in Native landcover multiplied by 100.

The latter indicator is equivalent to an Observed/Expected (O/E) score scaled to 0–100. Resulting scores were assigned habitat condition categories where 0–25 = Poor, 26–50 = Fair, 50–75 = Good, and 76–10 = Excellent.

At the national scale in the Level 1 dataset, 23.3% of sites had Habitat Quality Scores indicating Excellent habitat condition at the site scale, and 84.2% had O/E % Habitat Quality Scores indicating Excellent habitat condition at the site scale. In the Level 2 dataset, 22.4% of sites had Habitat Quality Scores indicating Excellent habitat condition at the site scale, and 80.8% had O/E % Habitat Quality Scores indicating Excellent habitat condition at the site scale.

The proportion of sites in each habitat quality category varied by dominant landcover (Figure 4). On average, Pastoral sites had the highest proportion of sites categorised as being in Poor condition in both Level 1 and Level 2 datasets. Urban areas had the fewest Excellent sites in both Level 1 and Level 2 dataset (Table 4). Median total RHA values (i.e. HQS) for each council grouped by dominant landcover class are provided

in Appendix 2. Median values for each RHA component grouped by dominant landcover class are provided in Appendix 3.

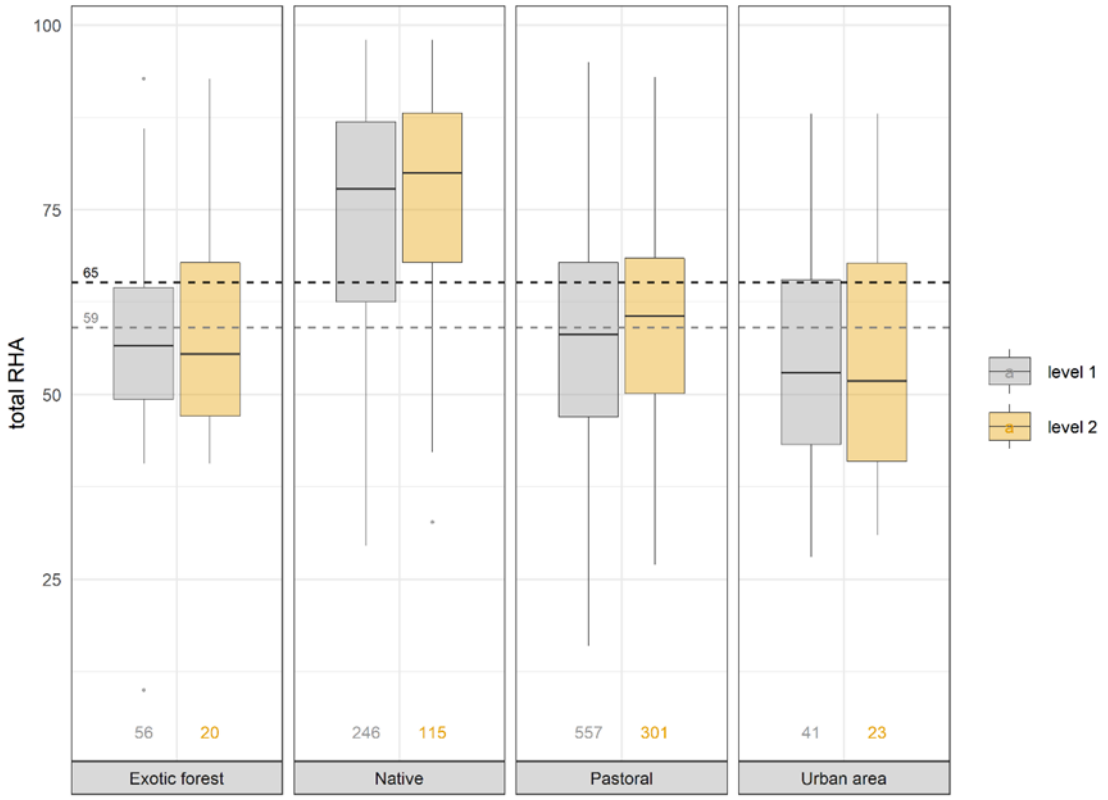

Figure 3. Boxplot showing RHA data grouped by dominant landcover class. The grey dashed line shows the 20th percentile of level 1 Native sites, and the black dashed line shows the 20th percentile of the level 2 Native sites. Numbers indicate the number of NZReach sites in each group.

Table 3. Results of Dunn Kruskal-Wallis multiple comparison test among landcover classes for total RHA values in Level 1 and Level 2 datasets.

Comparison	Z score	Adjusted P value
Level 1		
Exotic Forest - Native	-6.789	< 0.001
Native - Pastoral	13.076	< 0.001
Native - Urban area	6.937	< 0.001
Exotic Forest - Pastoral	-0.030	0.975
Exotic Forest - Urban area	0.802	0.844
Pastoral - Urban area	1.045	0.886
Level 2		
Exotic Forest - Native	-5.030	< 0.001
Native - Pastoral	10.368	< 0.001
Native - Urban area	5.899	< 0.001
Exotic Forest - Pastoral	-0.355	0.721
Exotic Forest - Urban area	0.420	1.000
Pastoral - Urban area	0.974	0.989

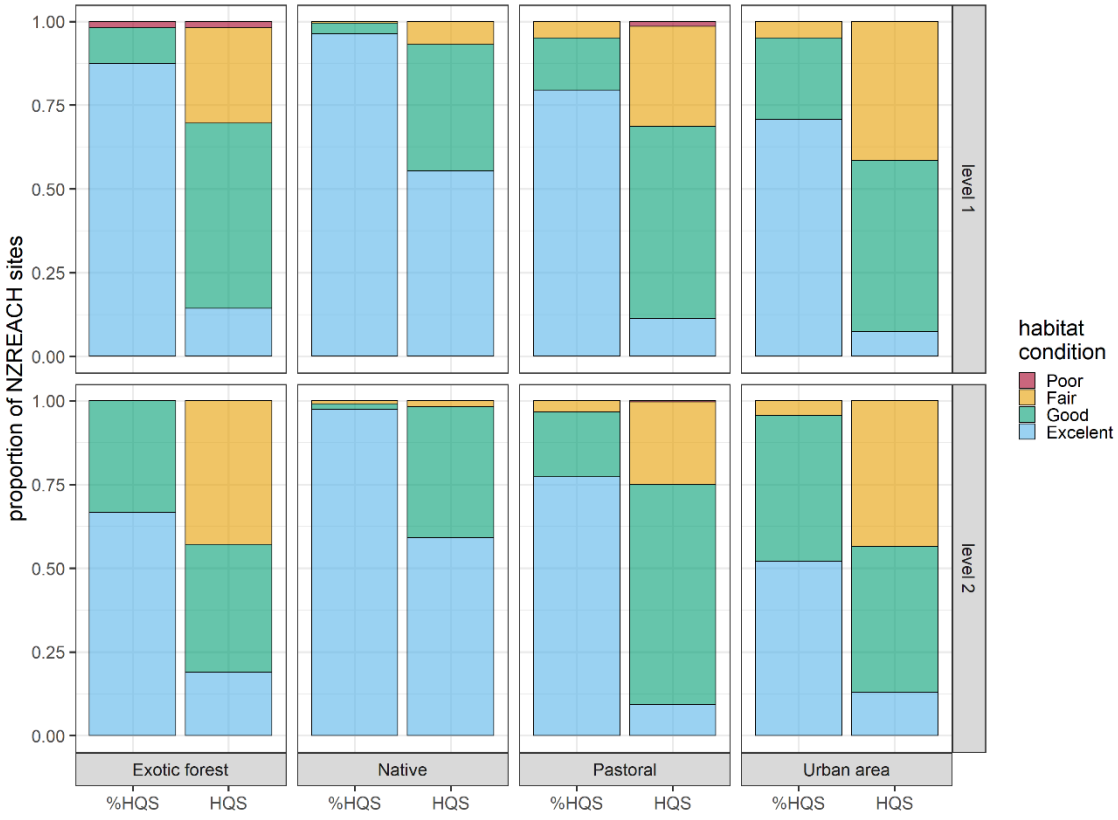

Figure 4. Plot of the proportion of NZReach sites in each habitat condition category grouped by dominant landcover class for the Habitat Quality Score (HQS) and the O/E % Habitat Quality Score (%HQS).

Table 4. Summary of Habitat Quality Scores by dominant landcover class including the relative proportion of sites in each habitat condition category.

Landcover	n	median	mean	standard deviation	% Poor	% Fair	% Good	% Excellent
Level 1								
Urban area	41	53.00	54.61	15.10	0.0	41.5	51.2	7.3
Pastoral	558	58.50	57.01	14.73	1.4	30.0	57.3	11.3
Exotic For.	56	56.62	57.03	13.70	1.8	28.6	55.4	1.4
Native	246	78.00	74.20	14.89	0.0	6.9	37.8	55.3
Level 2								
Urban area	23	51.50	55.03	17.08	0.0	43.5	43.5	13.0
Pastoral	303	60.00	58.70	13.38	0.3	24.9	65.8	9.3
Exotic For.	21	56.50	58.12	14.84	0.0	40.0	40.0	20.0
Native	115	80.00	76.97	13.07	0.0	1.7	39.1	59.1

3.2. Deposited sediment

We calculated site mean, median and standard deviations using the deposited sediment (SAM2) metric Level 1 (all data) and Level 2 (≥ 2 yr) datasets. Next we explored the data with sites grouped by either REC landcover or the deposited sediment classification described in Franklin et al. (2019).

With sites grouped by dominant landcover we calculated O/E scores using two different reference model predictions to inform E:

1. boosted regression tree model built using fine sediment data from the New Zealand Freshwater Fishes Database and reported in Clapcott et al. (2011)
2. boosted regression tree model built using a subset of fine sediment data from reference sites in the New Zealand Freshwater Fishes Database and reported in Depree et al. (2018).

With sites grouped by the deposited sediment classes, we calculated the proportion of sites above reference conditions modelled by Franklin et al. (2019); i.e. 'above' indicates poor stream health. We also explored whether it was possible to calculate the 80th percentile of sites in Native landcover within each deposited sediment class as an alternative reference benchmark.

At the national scale, the median percent deposited fine sediment cover was 5 (mean = 11.3; standard deviation = 17.3) in the Level 1 dataset and 4.5 (mean = 9.2; standard deviation = 13.7) in the Level 2 dataset.

There was a significant difference among dominant landcover classes in SAM2 values in both the Level 1 ($\chi^2 = 34.21$, df = 3, $p < 0.001$) and Level 2 ($\chi^2 = 33.20$, df = 3, p-value < 0.001) datasets. Deposited sediment was significantly higher in Urban

compared to Exotic Forest and in Pastoral compared to Exotic Forest in both datasets (Figure 5; Table 5). The 80th percentile of sites in the Native landcover class was 10% deposited sediment in both datasets and most site averages were below this value, except in Urban landcover (Figure 5). Median deposited sediment values for each council grouped by dominant landcover class are provided in Appendix 4.

Calculated O/E scores showed that most deposited sediment values were below site-specific reference values predicted by the Depree et al. (2018) model (i.e. O/E < 1); 82% below in the Level 1 dataset and 85% below in Level 2 dataset, indicating good stream health. When grouped by dominant landcover, most sites that were above reference predictions were in the Urban landcover (Figure 6).

In contrast, deposited sediment values were mostly above site-specific reference values predicted by the Clapcott et al. (2011) model (i.e. O/E > 1); only 25% were below in the Level 1 dataset and only 24% were below in the Level 2 dataset (Figure 6).

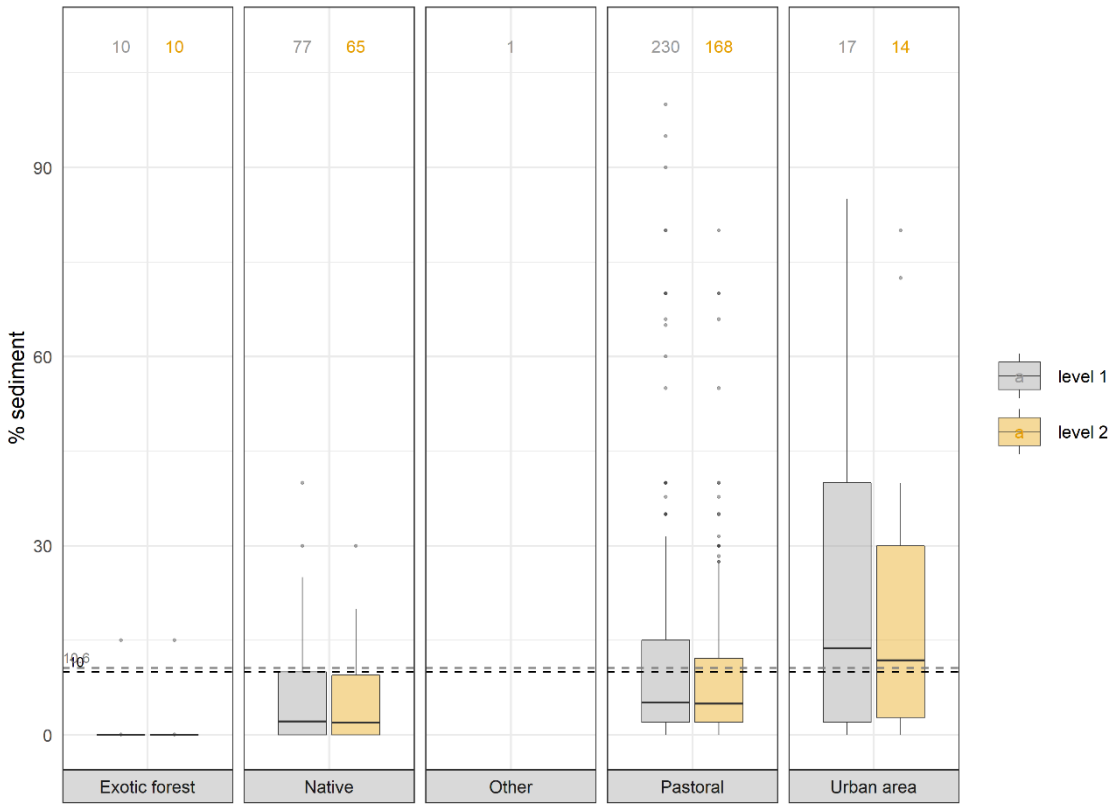

Figure 5. Boxplot showing SAM2 data grouped by dominant landcover class. The dashed line shows the 80th percentile of Level 1 and Level 2 Native sites (the value was the same for both datasets).Numbers indicate the number of NZReach sites in each group.

Table 5. Results of Dunn Kruskal-Wallis multiple comparison test among landcover classes for deposited sediment (SAM2) values in Level 1 and Level 2 datasets.

Comparison	Z score	Adjusted P value
Level 1		
Native - Exotic Forest	-2.542	0.055
Native - Pastoral	-3.643	0.002
Native - Urban	-3.099	0.013
Exotic Forest - Pastoral	-4.130	< 0.001
Exotic Forest - Urban	-4.228	< 0.001
Pastoral - Urban	-1.396	0.325
Level 2		
Native - Exotic Forest	-2.331	0.039
Native - Pastoral	-3.872	< 0.001
Native - Urban	-3.175	0.004
Exotic Forest - Pastoral	-4.170	< 0.001
Exotic Forest - Urban	-4.172	< 0.001
Pastoral - Urban	-1.329	0.183

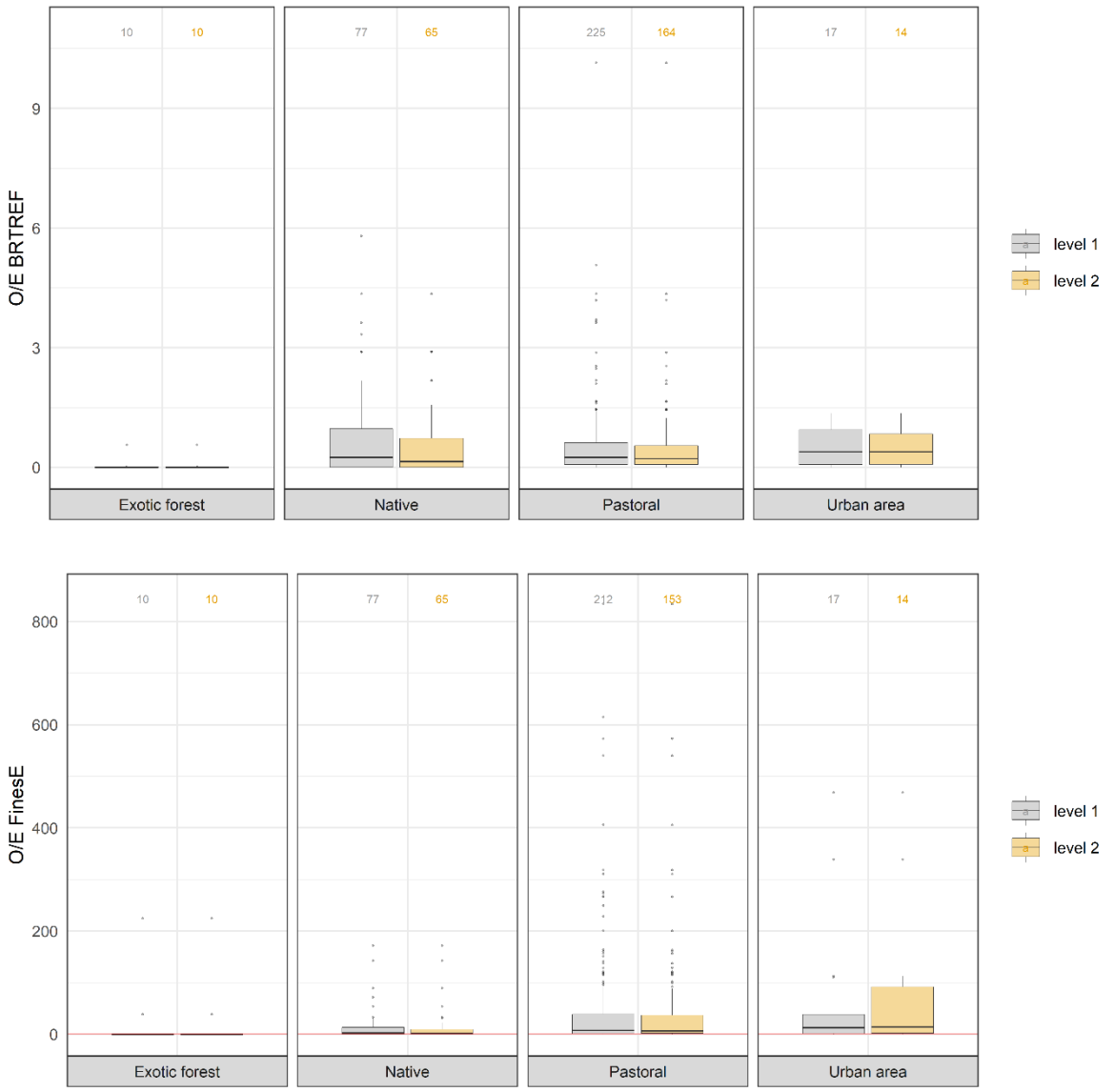

Figure 6. Boxplot showing O/E scores grouped by dominant landcover class based on SAM2 data divided by reference predictions from Depree et al. 2018 (BRTREF, lower) or Clapcott et al. 2011 (FinesE, upper). The red line delineates 1 and O/E scores below 1 indicate good condition. Numbers indicate the number of NZReach sites in each group.

The SAM2 data represented 9 of 12 deposited sediment classes, and for most sites sediment values were below the predicted reference value from Franklin et al. (2019); i.e. 81% below in the Level 1 dataset (Figure 7). In 5 out of 9 sediment classes the proportion of sites within classes that exceeded reference conditions ranged from 12% to 41% depending on the dataset. Median deposited sediment values for each council grouped by deposited sediment class are provided in Appendix 5.

Only three sediment classes (Class 8, 10, and 11) had enough data to calculate the 80th percentile of sites in Native landcover. In all cases, the observed reference condition was below the predicted reference condition (Figure 7). Subsequently, the proportion of sites exceeding the 80th percentile reference condition was greater than the proportion of sites exceeding predicted reference condition.

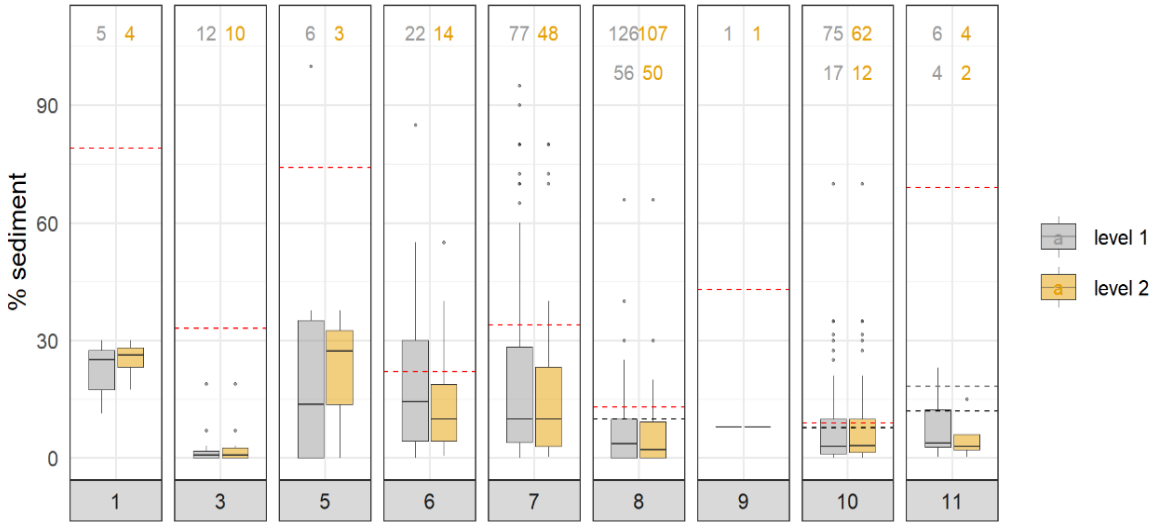

Figure 7. Boxplot of SAM2 data grouped by deposited sediment class. The red dash line indicates the predicted reference from Franklin et al. (2019), the grey dash line indicates the 80th percentile of Native landcover in the Level 1 dataset and the black dash line indicates the 80th percentile of Native landcover in the Level 2 dataset. Numbers indicate the number of NZReach sites in each group.

Comparing SAM2 values benchmarked by the three different predicted reference conditions shows that stream health is predominantly good (i.e. below reference values) when using Franklin et al. (2019) or Depree et al. (2018) models (Figure 8).

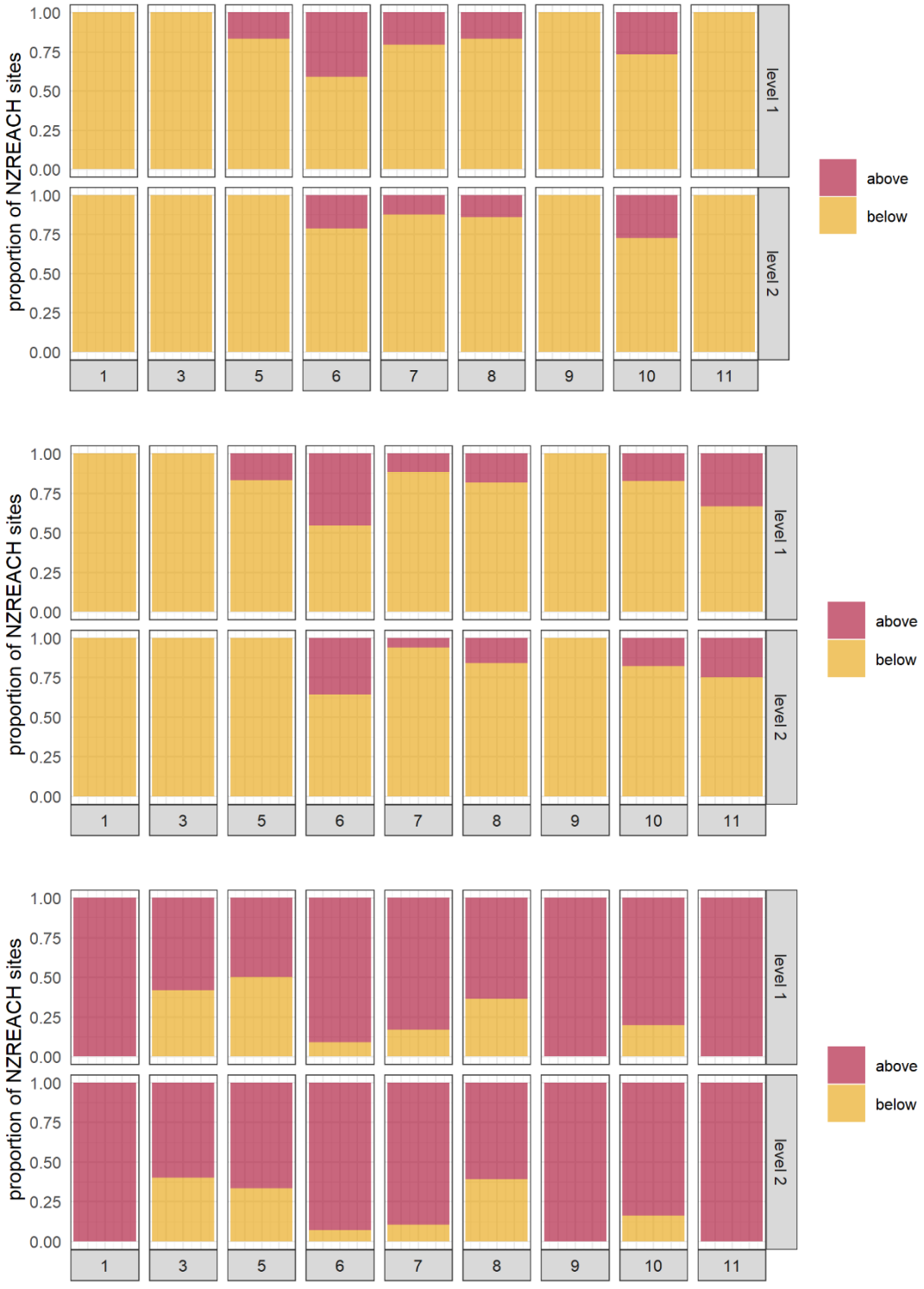

Figure 8. Plot of the proportion of sites above or below predicted reference values grouped by deposited sediment class with a) Franklin et al. 2019, b) Depree et al. 2018, and c) Clapcott et al. 2011.

4. SUMMARY AND RECOMMENDATIONS

4.1. Dataset level

The Level 1 datasets summarise all available data collected between 2014 and 2019. The Level 2 datasets represents a 3-year average calculated from a minimum of 3 annual measurements for RHA and a 2-year average calculated from a minimum of 6 monthly measurements per year for deposited sediment. As such the Level 1 dataset includes more sites and has a greater spatial coverage of New Zealand, whereas the Level 2 dataset is more spatially restricted but provides greater certainty around the accuracy of values.

At a national scale, patterns in indicator results were relatively consistent across Levels. For the RHA data there was no apparent difference in within landcover group variation (i.e. precision) between Level 1 and Level 2 data (e.g. Figure 3) and there were consistent reporting outcomes in terms of median values and the proportion of sites assigned to condition categories (e.g. Figure 4). For deposited sediment, it was evident that there was greater within group variance between Levels (e.g. Figure 5), but when benchmarked to reference conditions indicator patterns became similar across levels (e.g. Figure 8).

We recommend the use of Level 2 data for environmental reporting because of the greater confidence this metric provides in accurately assessing condition. Over time, more sites will meet these data requirements and increase the spatial representation of the dataset.

4.2. Assignment of habitat condition categories

The Rapid Habitat Assessment protocol is described in Clapcott (2015), but this report does not describe how to interpret or report on resulting Habitat Quality Scores. However, the RHA protocol was modelled on the United States Environmental Protection Agency (USEPA) habitat assessment field sheet where each component is scaled from 0 to 20 and component scores are divided into quartiles labelled Optimal, Suboptimal, Marginal and Poor habitat condition (Barbour et al. 1999). RHA components are scaled from 1 to 10 with lowest scores indicating a greatest deviation from expected reference state and highest scores indicating at or close to reference condition. With this in mind, we recommend the use of condition categories assigned to equal quartiles labelled Excellent, Good, Fair and Poor habitat condition to report Habitat Quality Scores. The spread of total RHA values from 10 to 99 supports this application.

We do not support the use of the 20th percentile of Native sites as a generic reference benchmark to calculate %HQS. Despite significantly higher RHA values observed in

Native compared to other landcover classes, scaling to a relevant reference condition is best reserved for correcting natural variation in environmental factors that can influence RHA component values. For example, the deposited sediment component reference condition may be different for soft compared to hard bottomed streams, or the riparian shade component reference condition could be different for large versus small streams. The RHA protocol was designed for application in wadeable hard bottomed streams. Although we note some councils exclude the soft bottom component when applying the protocol to soft bottom streams, the current analysis is based on total RHA scores where all components were assessed.

4.3. Appropriate reference conditions for sediment

Deposited sediment in streams varies temporally in response to natural fluvial processes influenced by spatial patterns in geology, slope, rainfall and stream size. To assess stream condition based on deposited sediment therefore requires knowledge of the reference condition expected across a range of natural variability, and the most suitable indicator is % deviation from reference condition. Previous data collations and explorations have described a lack of reference data for many parts of New Zealand and subsequently several models have been developed to predict the substrate composition, and specifically the proportion of fine sediment, in streams. Models that we are aware of include:

- boosted regression tree model built using 10,026 deposited fine sediment observations (equivalent to SAM1) in the New Zealand Freshwater Fisheries Database (NZFFD), where the influence of land cover was reset to predict fine sediment cover under minimally disturbed condition (FinesE in Clapcott et al. 2011)
- random forest model using substrate composition data from 229 river sites (Haddadchi et al. 2018)
- boosted regression tree model using 15,281 deposited fine sediment observations in the NZFFD (equivalent to SAM1) as well as state of the environment and research data (SAM1 and SAM2) and resetting land use to predict fine sediment under minimally disturbed conditions (BRT ALL model in Depree et al. 2018)
- boosted regression tree model using a subset of the NZFFD observations from sites in minimally disturbed condition (n = 2,022) and extrapolating nationally (BRT REF model in Depree et al. 2018)
- general linear mixed model using state of the environment and research data (SAM2) and macroinvertebrate community composition to quantify the relationship between deposited sediment and macroinvertebrates across 12 different pre-defined sediment classes and predict fine sediment cover at minimal change in macroinvertebrate community composition (Franklin et al. 2019).

In the absence of enough observed fine sediment data in Natural landcover to inform reference conditions, we explored the outcome of using three different reference model predictions. Results clearly show how the choice of reference model can strongly influence the reported state of stream health based on reference condition. We recommend the use of the most recent model (Franklin et al. 2019) to inform reference conditions in the interim and encourage the collection of data from minimally disturbed sites as a priority to refine and validate model predictions in the near future. We reiterate that recent data from three deposited sediment classes suggest the model overpredicts reference values resulting in a better assessment of stream health than may be the case.

5. ACKNOWLEDGEMENTS

We gratefully acknowledge data provided by: Northland Regional 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, Nelson City Council, Canterbury Regional Council, Otago Regional Council, and Southland Regional Council. Auckland Council, West Coast Regional Council, and Marlborough District Council reported no standardised data, yet.

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7. APPENDICES

Appendix 1. A summary of responses to key (15) questions from the survey of regional council and unitary authorities.

1. Do you monitor deposited fine sediment in rivers and streams in your region?

Response	Number of councils
Yes	13
No	3

2. What methods are used to measure deposited sediment?

Methods*	Number of councils
SAM 1 - Bankside visual estimate of % sediment cover	8
SAM 2 - In-stream visual estimate of % sediment cover	7
SAM 3 - Wolman Pebble count	4
SAM 4 - Quorer method	2
SAM 5 - Shuffle Index	2
SAM 6 - Sediment Depth	0

*Variations on methods:
SAM1 - performed only in runs, recording % silt and % sand separately;
SAM2 is carried out as per the protocol note allowing for combined measure over the reach. Use the underwater viewer at 4 or 5 points across each x-section and a number of x-sections up the river;
SAM3 - minimum 50 particles counted;
SAM4 - resuspending sediment using heels of feet inside a barrel rather than with a bucket and stirring rod;
SAM5 - photos only taken if the plume scores 4 or 5.

3. Have you changed or amended the deposited fine sediment methods used since beginning monitoring?

Response	No. of councils	Explanation
No changes	5	
Minor changes	4	SAM3 - minimum number of particles changed from 100 to 50 after deciding that a lower precision result is adequate for characterising larger shifts in particle size distribution, and to save time on site.
		As identified above, we use a modified category list for SAM2 protocols to include a range of substrate categories not just deposited sediment. For monthly monitoring we also only record a single number per site (not all 20 transect/views). For annual monitoring we do include all 20 views.
		SAM1 -We do four transects of 5 views, or 2 transects of 10 views on larger rivers rather than 5 transects of 4. We do this to tie in with our periphyton observations. SAM 2 - the four transects are spread over 150m.

		Prior to June 2015, all estimates were bankside method. Change to mixed (instream and bankside - depending on conditions) post June 2015.
Major changes	2	Changed from SAM 1 to SAM 2 as we found it very difficult to estimate %mud/silt from a bank side assessment, particularly in the riffles.
		Swapping between bankside assessment only, VISPER only and both

4. What design best describes your deposited fine sediment monitoring network?

Network design	No. of councils	Comments
Targeted sites to provide regional representation	9	
Randomly selected sites to provide regional representation	4	
Consent and/or targeted activity sites (e.g., project specific)	2	
Other - I will describe this in the comments below	5	SOE and Contact Recreation sites; Special investigations

5. Does your deposited fine sediment sampling network align with any other sampling networks (e.g., Water Quality, Biomonitoring, etc)??

Response	No. of councils	Comments
Yes - water quality	10	
Yes - biomonitoring network	9	
Both	7	
No	0	
Other	1	Habitat monitoring

6. Does your deposited fine sediment sampling network include soft-bottom and hard-bottom sites, and reference sites?

Response	No. of regional councils	Proportion of sites regionally
Soft-bottom	10	0-54% of all sites
Hard-bottom	13	46-100% of all sites
Reference sites	11	<10% defined by minimal land use impact

7. When do you monitor deposited fine sediment, and at how many sites?

Response	No. of sites	Comments
Monthly	~559	8 RCs
Quarterly	0	~60 sites pre 2016
Twice a year	36	1 RC
Annually	537	6 RC
3-yearly	230	2 RC

8. How long have you been sampling deposited sediment?

Method	Start year	No. of sites
SAM 1	2004-2008	Monthly – 200
	2008-2019	Annually – 200
	2013-2019	3-yearly – 50
	2016-2019	Monthly – 26
	2019	Monthly – 32; Biannual – 36
SAM 2	2002-2019	Monthly – 27
	2008-2018	Monthly – 200
	2009-2019	Monthly – 80
	2012-2019	Annually – 60
	2013-2019	Monthly – 44
	2014-2019	Annually – 64
	2015-2019	Monthly – 34
	2016-2019	Annually - 85
SAM 3	2005-2019	Annually – 85
	2012-2015	Quarterly – 60
	2013-2019	Annually – 130
SAM 4	2012-2015	Quarterly – 60
	2015-2019	Monthly – 85
SAM 5	2012-2015	Quarterly – 60
	2013-2019	Annually – 130
	2016-2019	Monthly – 26

9. Do you monitor habitat in rivers and streams in your region using the Rapid Habitat Assessment (RHA; Clapcott 2015) protocol?

Response	Number of councils
Yes	12*
No	4

* one regional council does not include component 1 of 10 at soft-bottom sites

10. What design best describes your RHA monitoring network?

Network design	No. of councils
Targeted sites to provide regional representation	10
Randomly selected sites to provide regional representation	2
Consent and/or targeted activity sites (e.g., project specific)	
Other - I will describe this in the comments below	

11. Does your RHA sampling network align with any other sampling networks (e.g., Water Quality, Biomonitoring, etc)??

Response	No. of councils	Comments
Yes - water quality	10	
Yes - biomonitoring network	10	
Both	10	
No		
Other	1	Special investigations

12. When do you monitor RHA, and at how many sites?

Response	No. of sites	Comments
Twice a year	59	1 RC
Annually	787	11 RC
3-yearly	230	2 RC

13. When did you start using the RHA protocol?

Year	No. of councils
2010	1
2011	2
2014	2
2015	1
2016	2
2017	1
2018	1
2019	2

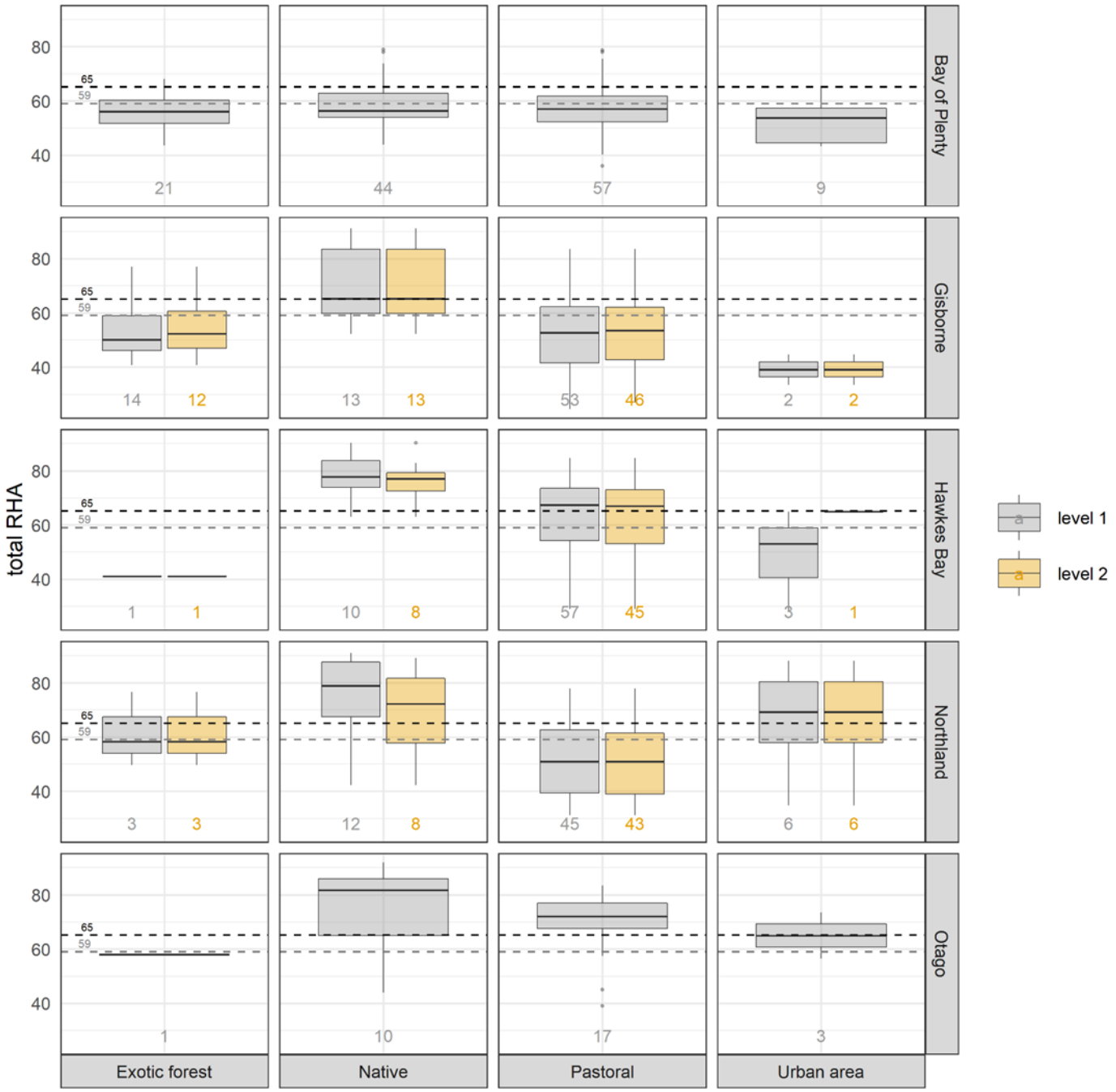
14. What kind of Quality Assurance/Quality Control does your council do to ensure the deposited fine sediment and RHA data are of high standard?

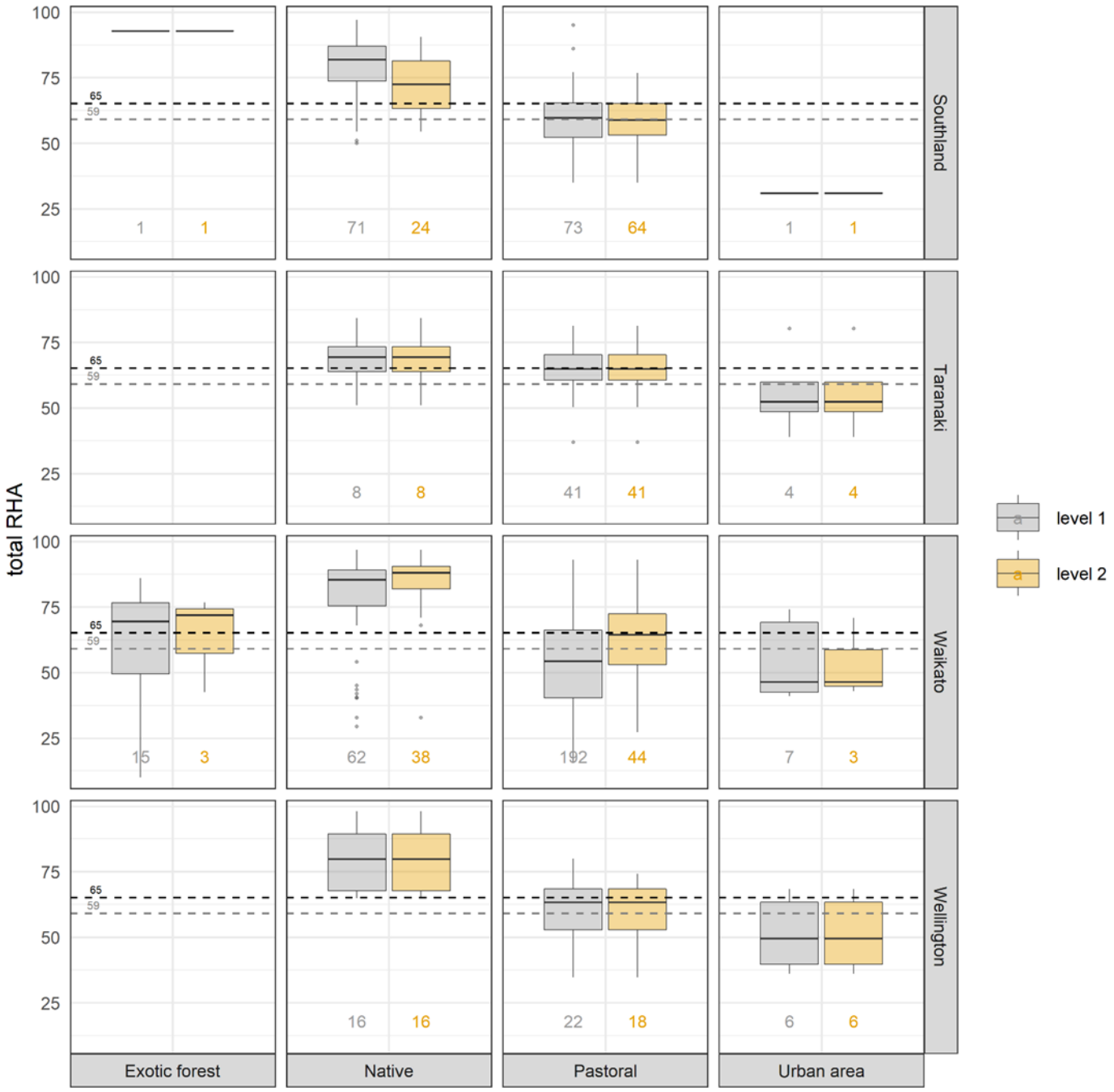
Response	No. of councils
We strictly follow recommended protocols	9
We have council internal QA/QC protocols	4
Highly qualified staff that conduct the sampling and analysis	10
We have peer-review processes during data collection and data entering	7
We do not have any specific QA/QC processes	3

15. Where is your data stored?

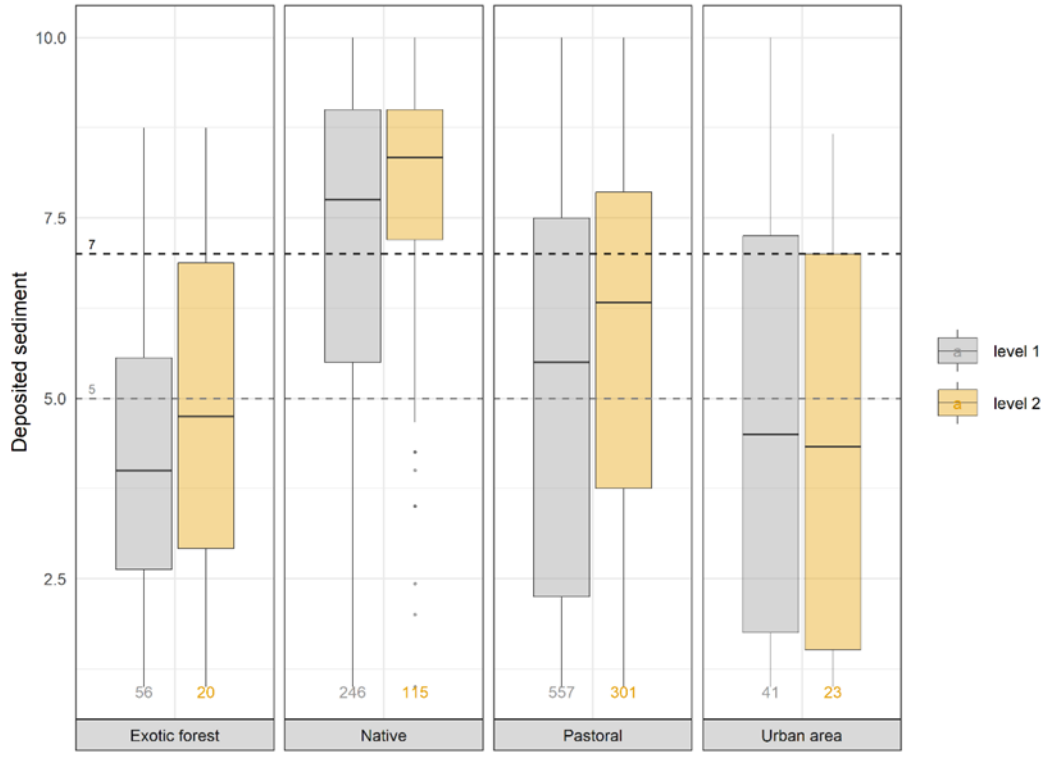
Response	No. of councils
Database (e.g. Hilltop, WISKI, etc)	10
Council internal drive	9
Excel, Access, CADDIS	3

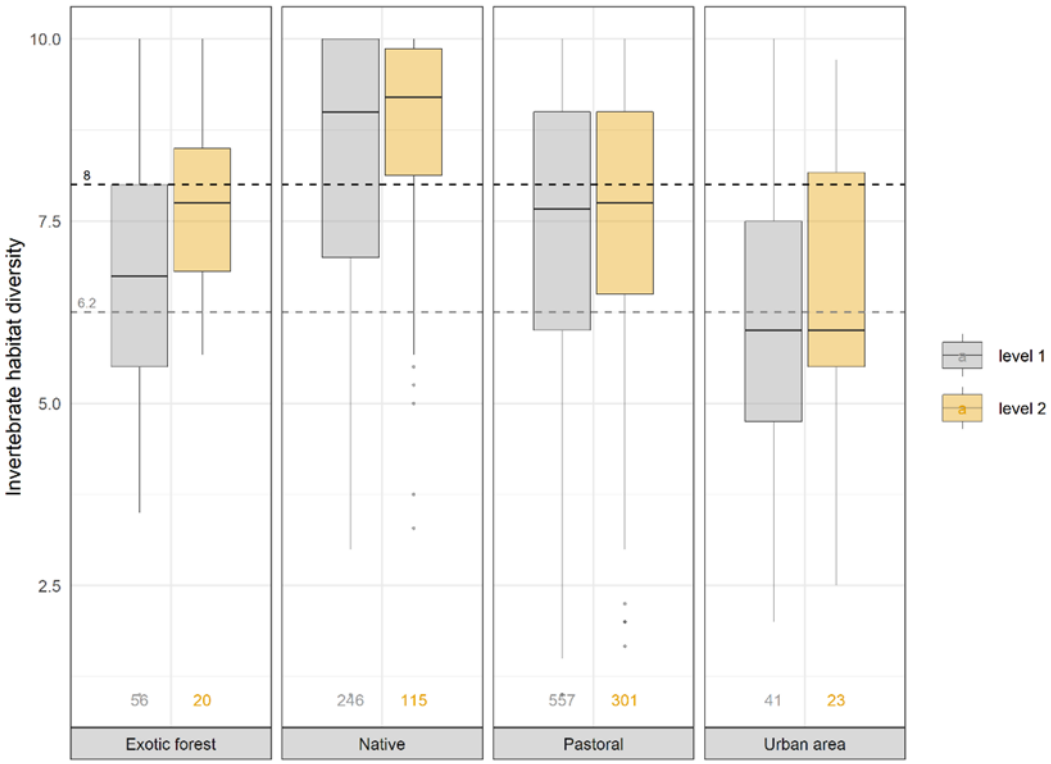
Appendix 2. Boxplot showing total RHA values grouped by dominant landcover class and council. The grey dashed line shows the 20th percentile of Level 1 Native sites and the black dashed line shows the 20th percentile of the Level 2 Native sites. Numbers indicate the number of NZReach sites in each group.

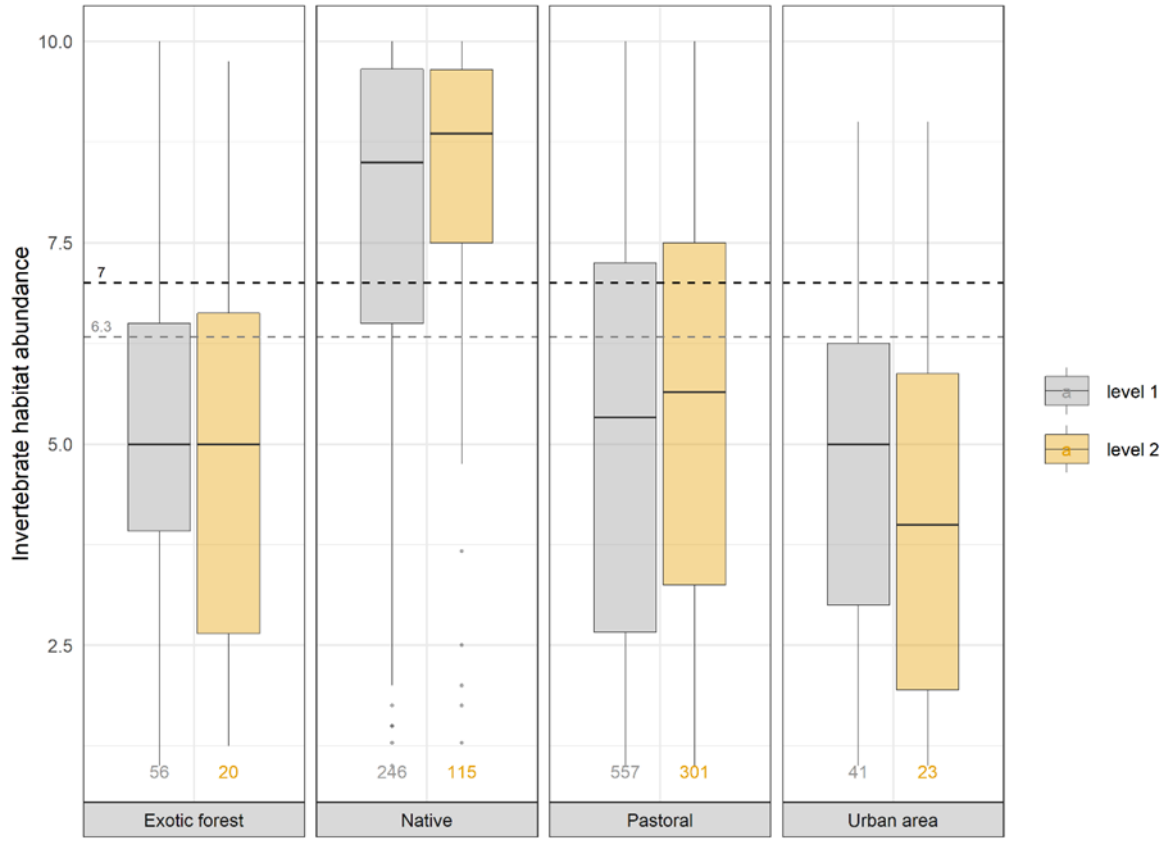


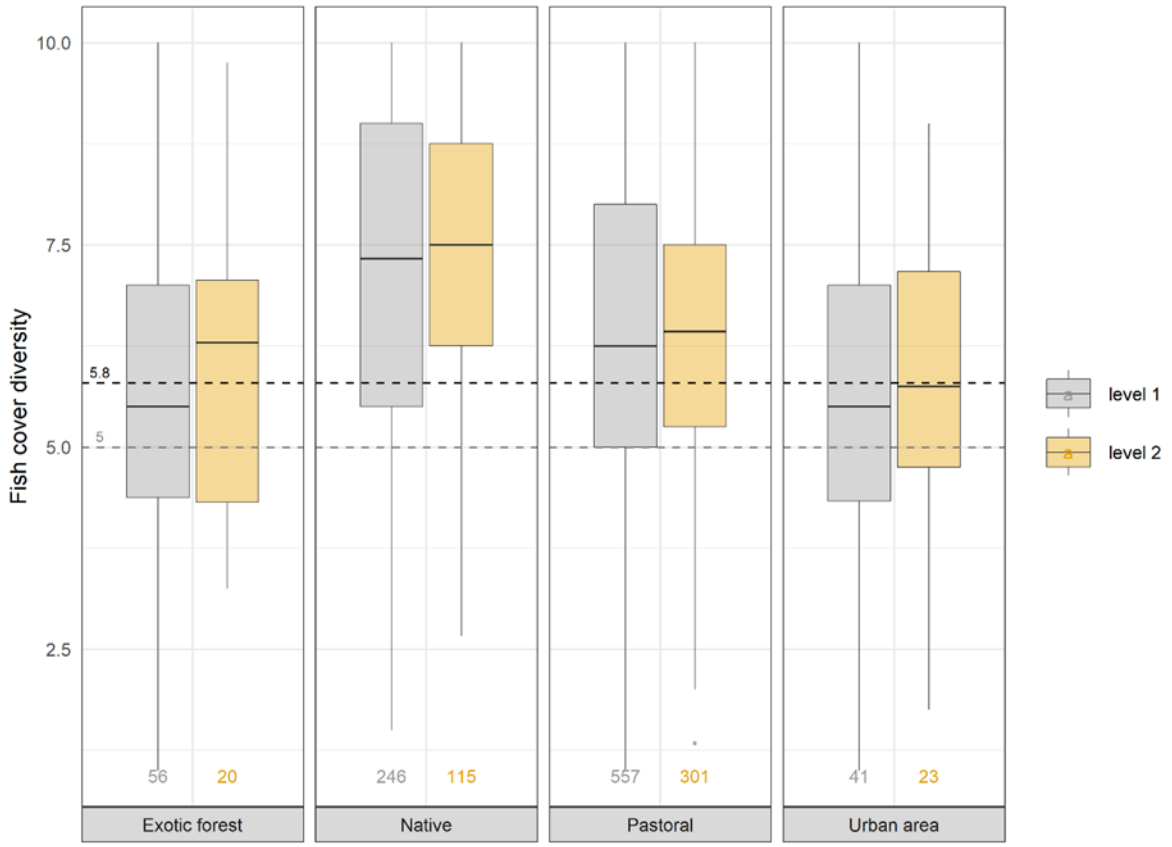

total RHA
100
75
50
25
65
59
Southland
Taranaki
Waikato
Wellington
1 1
71 24
73 64
1 1
8 8
41 41
4 4
15 3
62 38
192 44
7 3
16 16
22 18
6 6
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

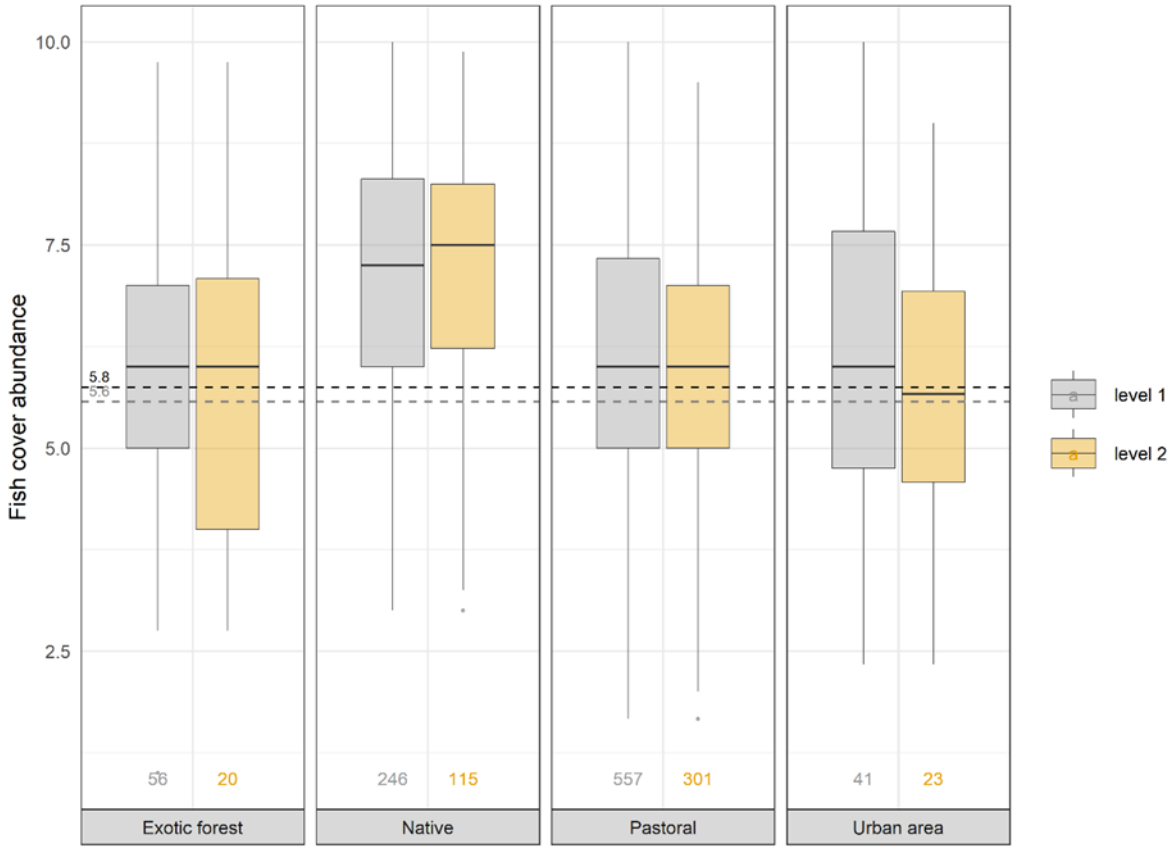
Appendix 3. Boxplots showing individual RHA component values grouped by dominant landcover class. The grey dashed line shows the 20th percentile of Level 1 Native sites and the black dashed line shows the 20th percentile of the Level 2 Native sites. Numbers indicate the number of NZReach sites in each group.

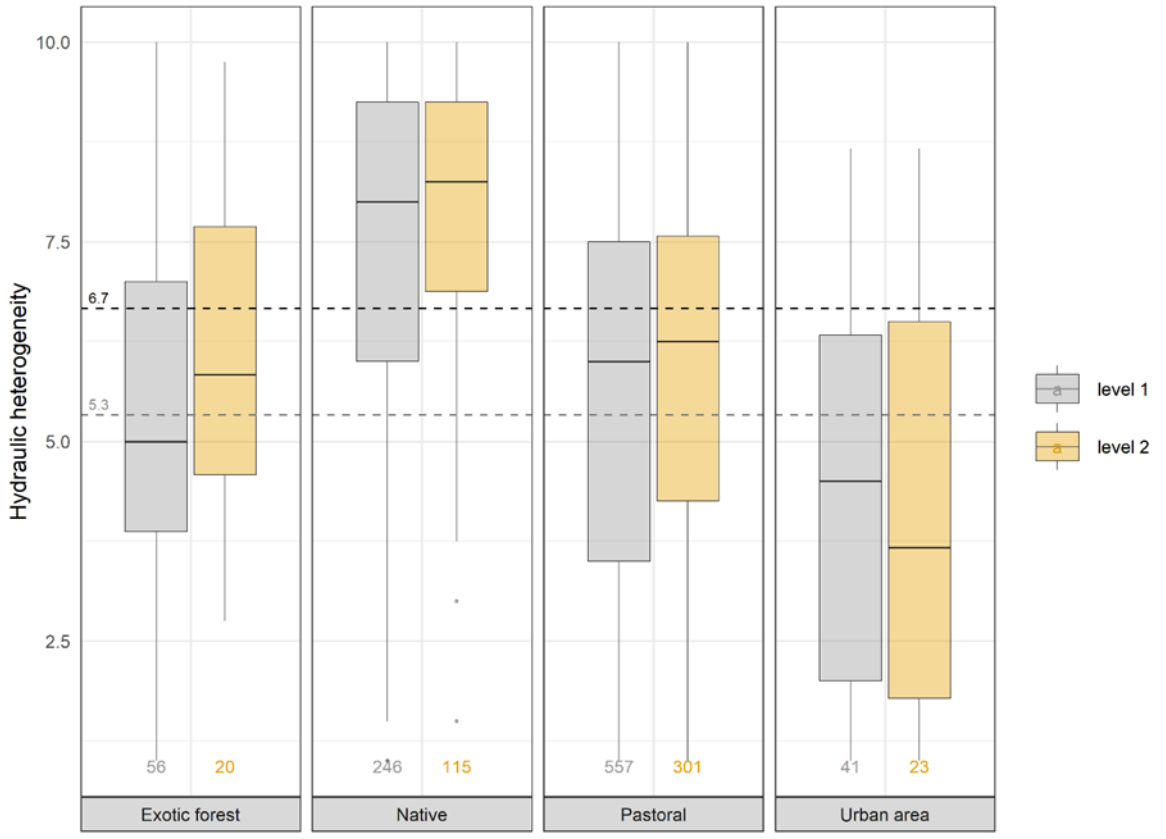


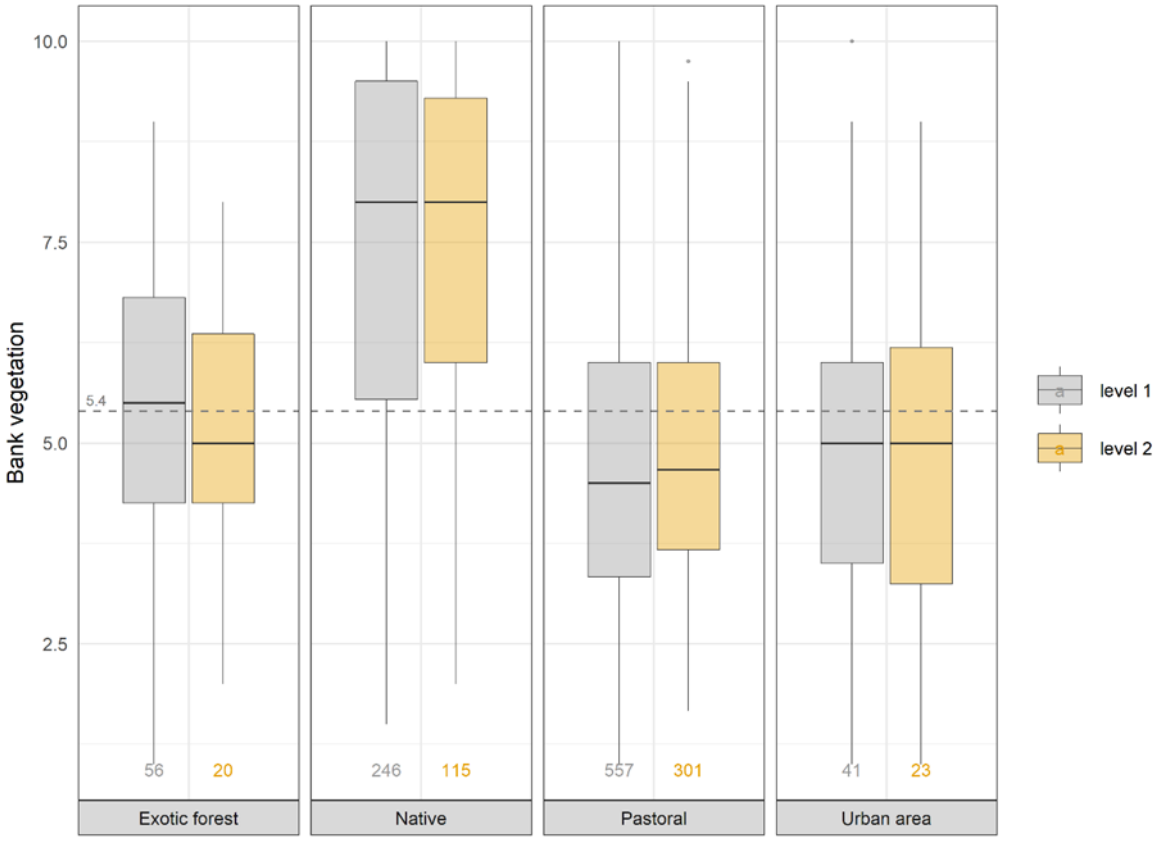


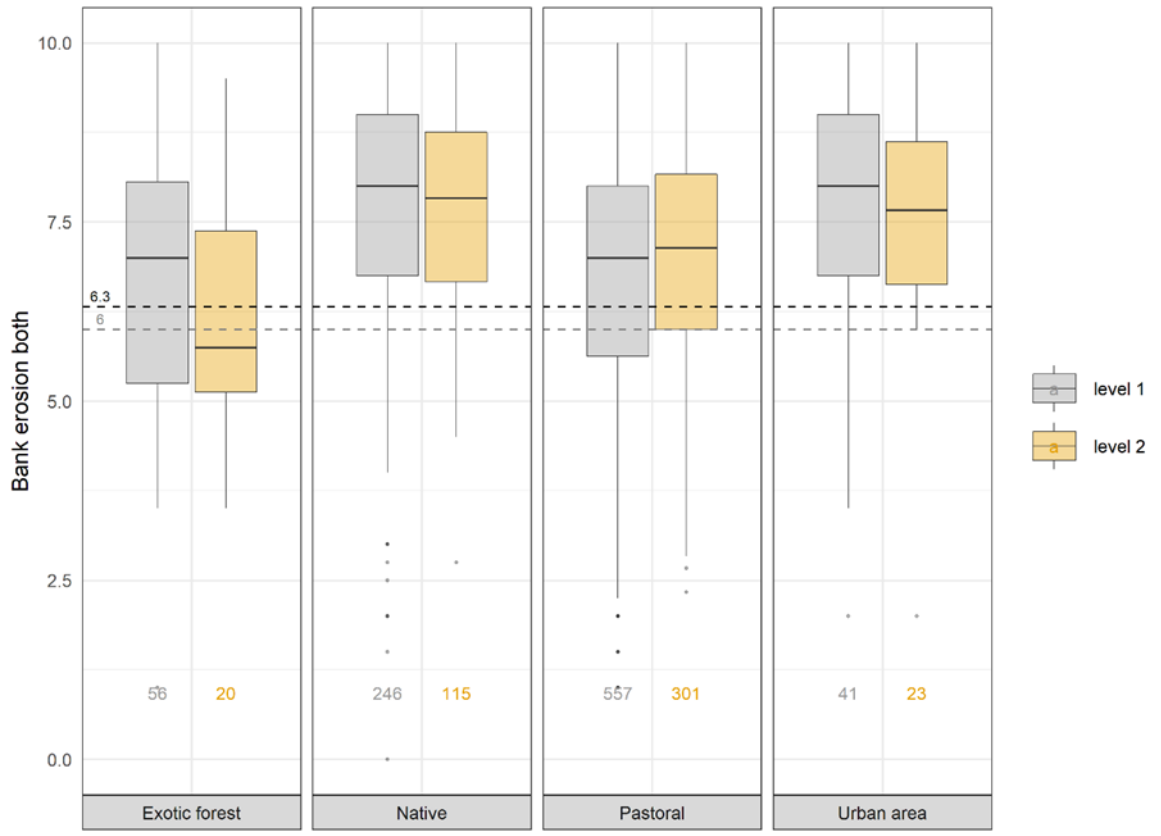

Invertebrate habitat abundance
10.0
7.5
5.0
2.5
7
6.3
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

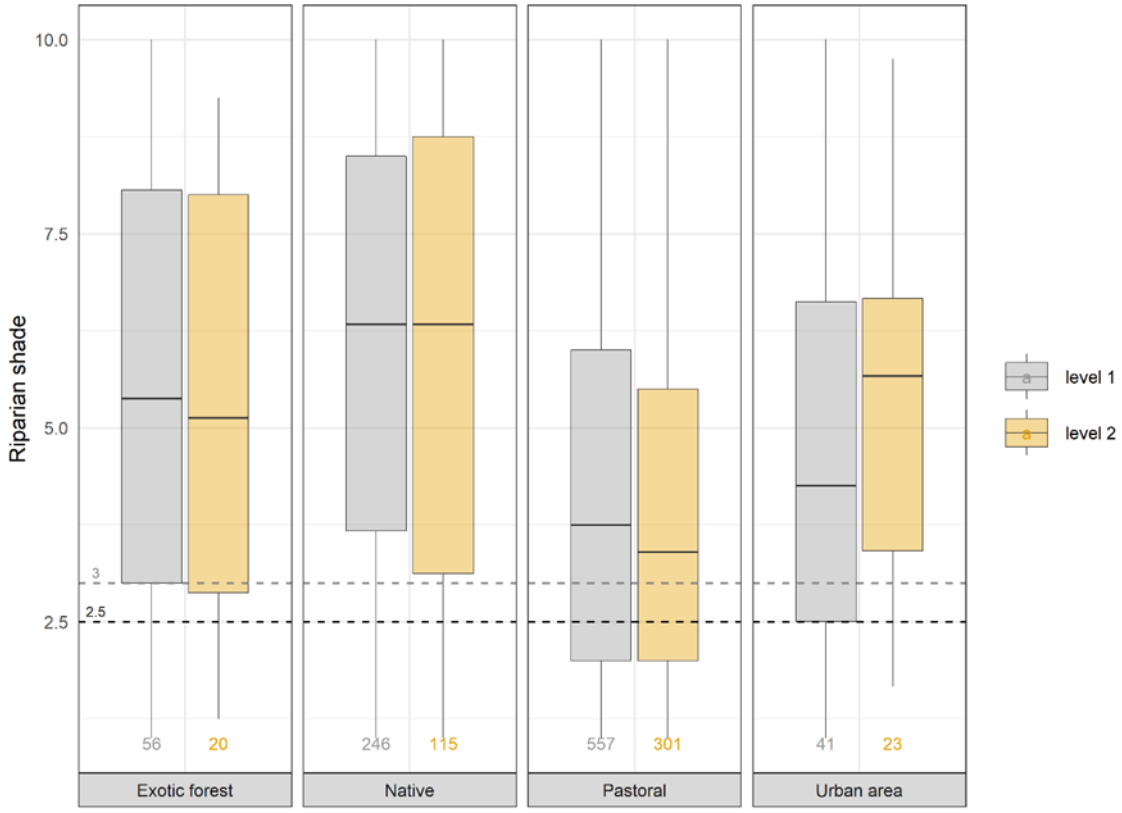

Fish cover diversity
10.0
7.5
5.0
2.5
5.8
5
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

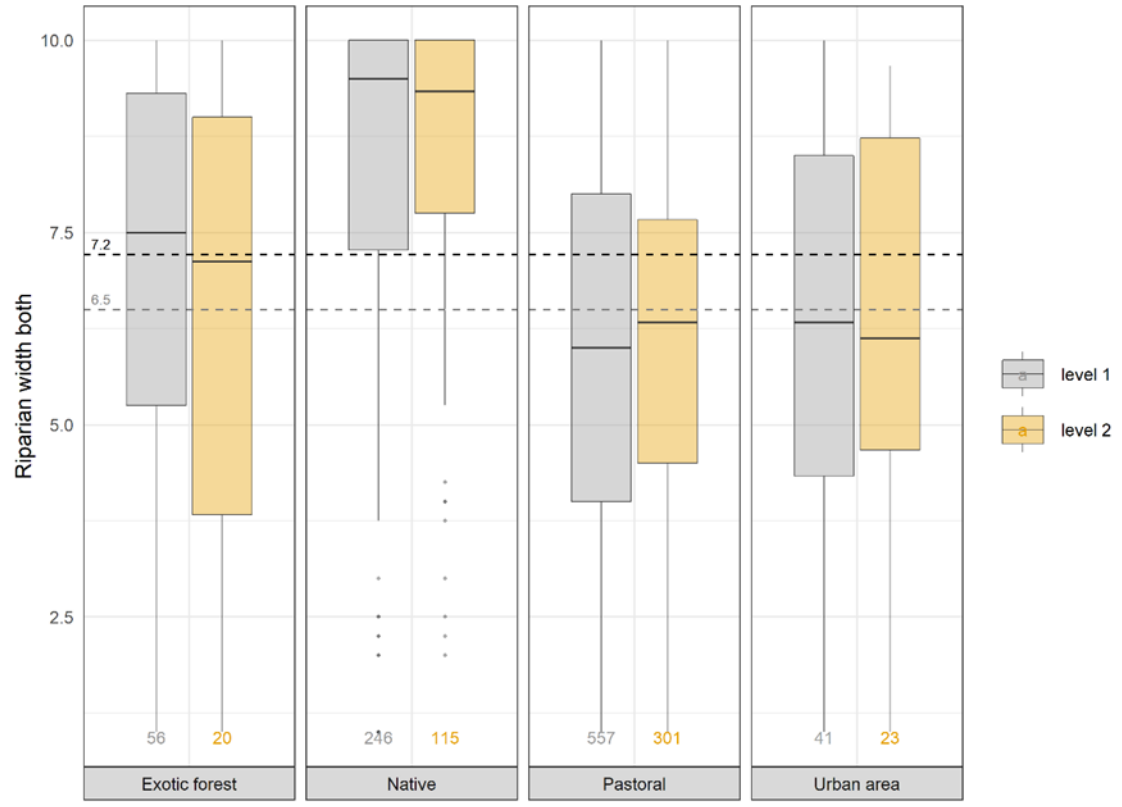

Fish cover abundance
10.0
7.5
5.0
2.5
5.8
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2


Hydraulic heterogeneity
10.0
7.5
5.0
2.5
6.7
5.3
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

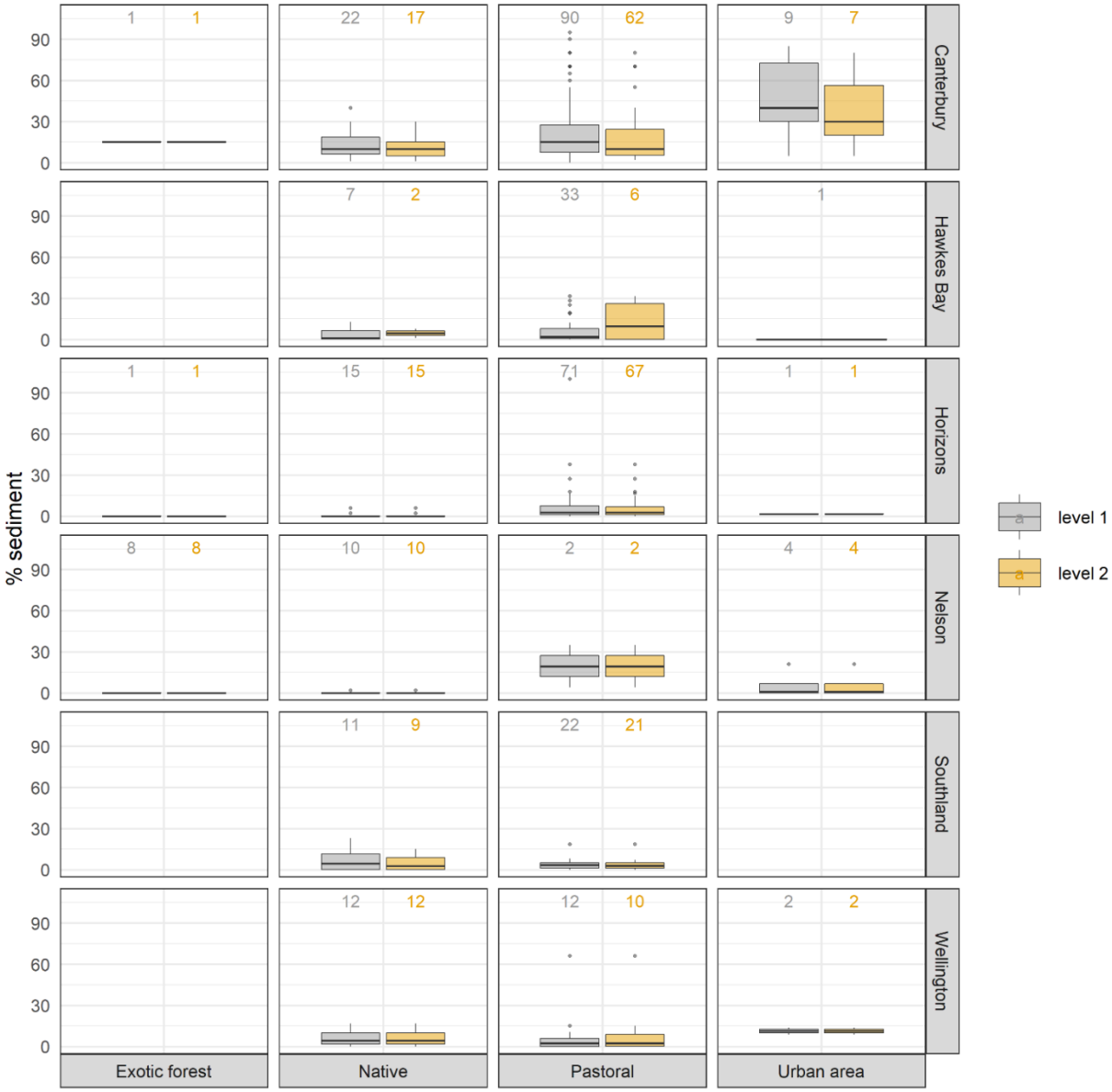

Bank vegetation
10.0
7.5
5.4
5.0
2.5
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2


Bank erosion both
10.0
7.5
6.3
6
5.0
2.5
0.0
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

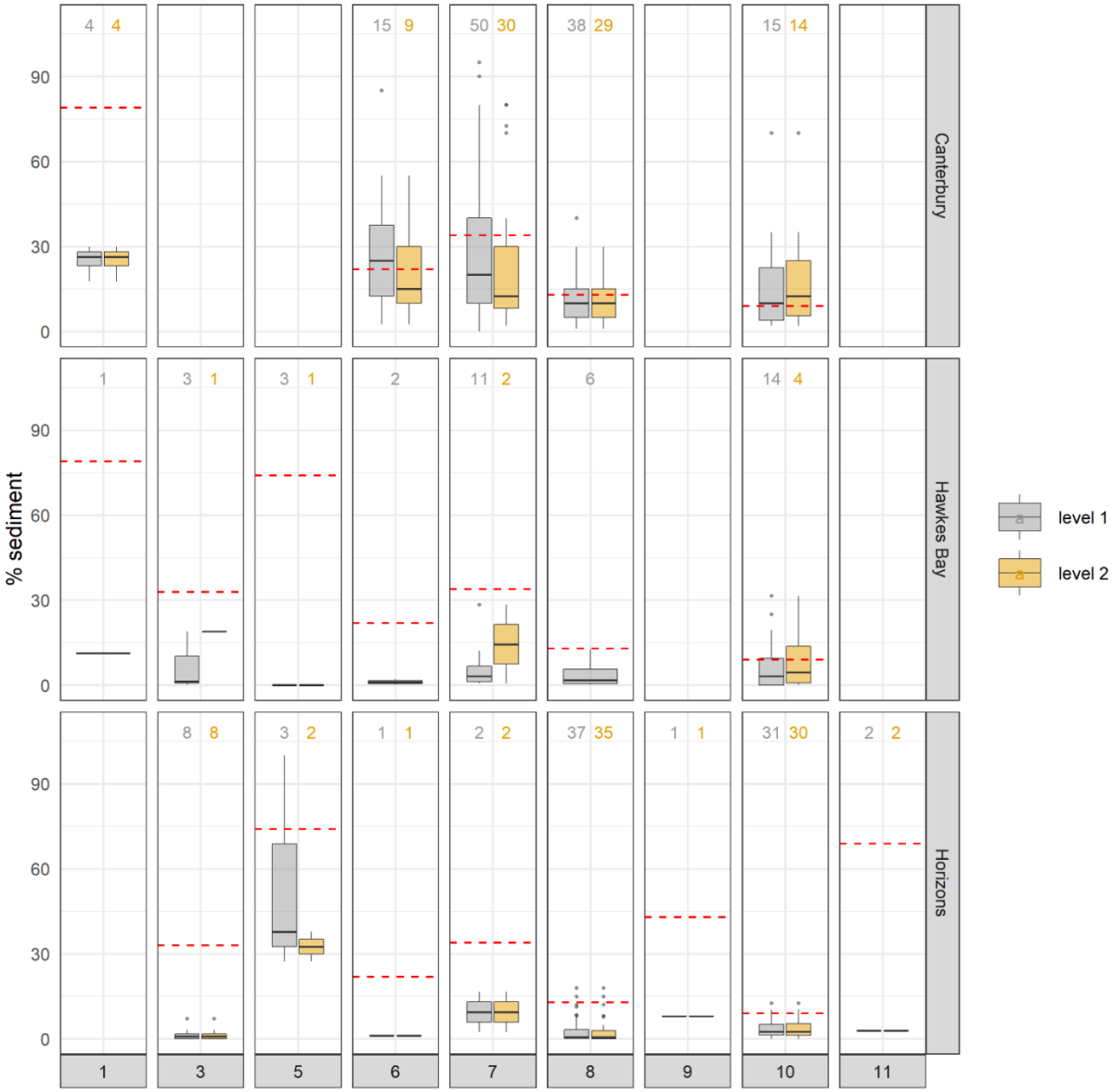

Riparian shade
10.0
7.5
5.0
2.5
3
2.5
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

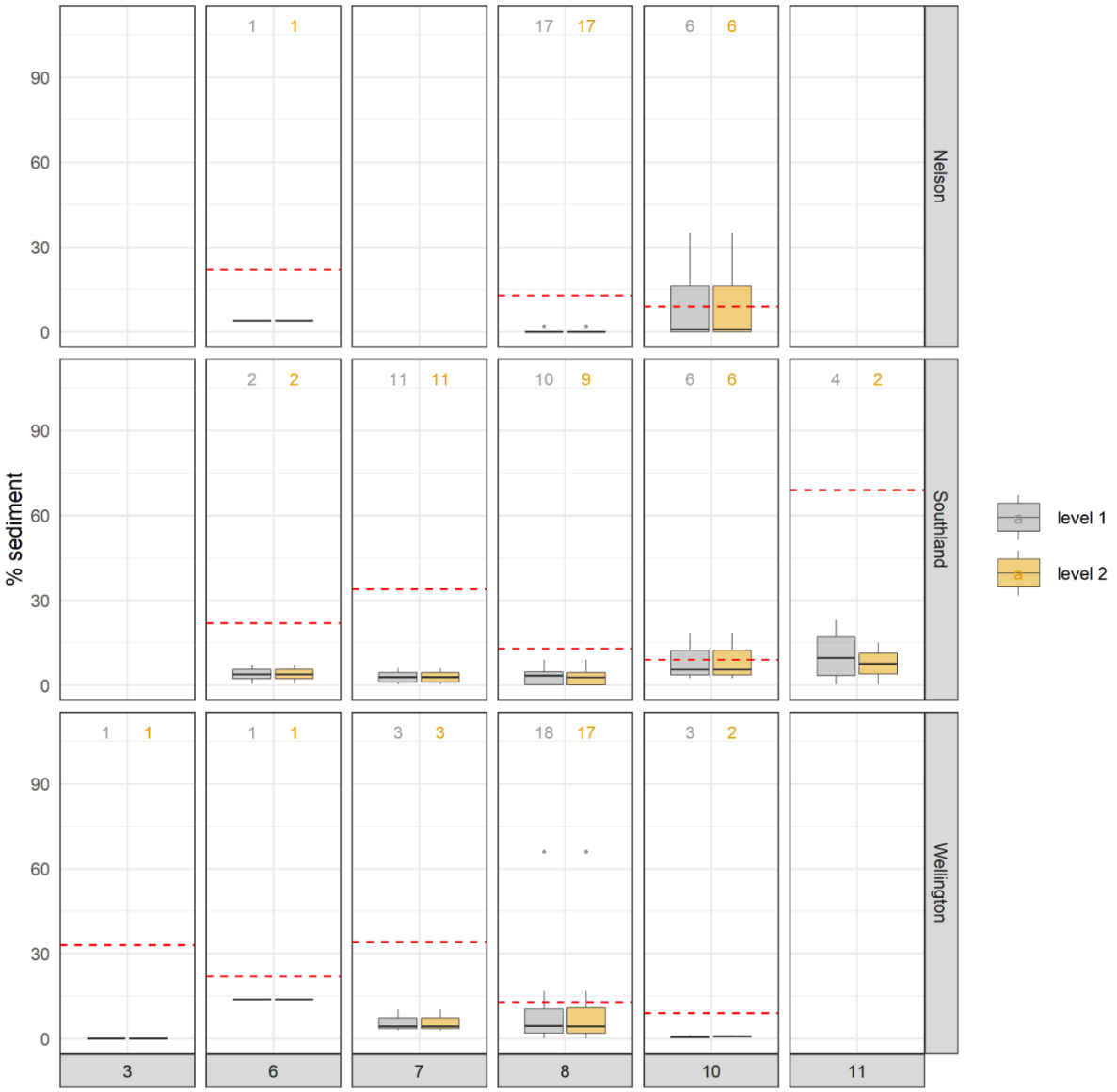

Riparian width both
10.0
7.5
5.0
2.5
7.2
6.5
56
20
246
115
557
301
41
23
Exotic forest
Native
Pastoral
Urban area
level 1
level 2

Appendix 4. Boxplot showing deposited sediment (SAM2) values grouped by dominant landcover class and council. Numbers indicate the number of NZReach sites in each group.



Appendix 5. Boxplot showing deposited sediment (SAM2) values grouped by deposited sediment class and council. Numbers indicate the number of NZReach sites in each group. The red dashed line shows the reference value for each sediment class.




% sediment
0
30
60
90
1 1
17 17
6 6
2 2
11 11
10 9
6 6
4 2
1 1
1 1
3 3
18 17
3 2
Nelson
Southland
Wellington
3
6
7
8
10
11
level 1
level 2