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Update to freshwater physical habitat statistics for environmental reporting

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Update to freshwater physical habitat statistics for environmental reporting

Roland Eveleens, Finnbar Lee, Laura Kelly, Joanne Clapcott

Prepared for Ministry for the Environment

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Executive summary

This report documents an update of the national dataset of Rapid Habitat Assessment (RHA) results to support environmental reporting on freshwater physical habitat in Aotearoa New Zealand. The Ministry for the Environment (MfE) engaged Cawthron Institute to compile and analyse RHA data collected by regional and unitary councils between 2013 and 2024. This update builds on earlier work by Clapcott et al. (2020). We provide an updated national dataset of habitat quality scores (HQS) derived from RHA data, assess the suitability of the data for calculating state and trend statistics, and recommend approaches for reporting on freshwater habitat quality and change.

Key findings

Data were compiled for 1,619 unique sites nationwide, with good coverage across most regions but gaps in the Auckland and Tasman Regions and Fiordland. Record lengths ranged from 1 year to 9 years per site.

Nationally, the median HQS was 65 out of a maximum of 100 for sites with at least 3 years of data collected between 2020 and 2024, with sites distributed across all habitat quality classes: 17% excellent, 60% good, 22% fair, and < 1% poor. Our analyses suggest that 3 years of data are sufficient for reporting state while balancing accounting for interannual variability with spatial coverage. Requiring at least 3 years of data within the last 5 years reduced the number of sites eligible for calculating a current state for HQS from 1,619 to 814, and three regions were excluded.

Habitat quality differed by dominant upstream land cover. 'Urban' sites had the lowest median HQS (52.0), while 'Native' (76.5) sites had the highest. 'Pastoral' catchments were the only class to include a site rated as 'poor', while 'Native' had the highest proportion of sites rated as 'excellent', followed by 'Other'.

Power analyses showed that due to high variability, at least 12 years of data are required to detect ecologically meaningful national trends with confidence. While some sites displayed apparent trends, 79% of Sen's slope confidence intervals spanned zero, confirming that the dataset is too variable for robust short-term trend analysis. State–state comparisons using 3-year medians provide a more practical option for assessing change, requiring a minimum of 6 years of data per site.

State–state comparisons between 2020–2024 and earlier reporting (2017–2019) (Clapcott et al. 2020) provided an indication of temporal change for 432 sites spanning seven regions. These comparisons showed HQS increased at 221 sites, declined at 199 and was unchanged at 12. Thirty-five sites shifted to a higher habitat quality class, 349 remained within the same class and 48 declined. No individual RHA parameter appeared to consistently drive changes in HQS.

Recommendations

- Use 3-year medians of HQS and habitat classes to report state, to account for variability while maximising spatial coverage.
- Encourage long-term monitoring of sites (≥ 12 years) to provide sufficient data to enable calculation of robust national trends.
- Distinguish between long-term state of the environment monitoring sites and sites monitored for targeted investigations to minimise the potential for bias in national reporting of habitat state.

1. Introduction

Freshwater indicators used in national reporting are informed by reliable, accurate and relevant statistics calculated from national datasets. 'Our freshwater 2023' (MfE and Stats NZ 2023) presented 24 separate indicators covering different aspects of Aotearoa New Zealand's freshwater ecosystems. Freshwater physical habitat is a fundamental component of these indicators, as it underpins the structure and function of aquatic communities. Understanding changes in habitat condition is therefore critical to assessing the extent and impact of human activities on freshwater ecosystems.

Most regional councils and unitary authorities assess physical habitat in rivers and streams using the Rapid Habitat Assessment (RHA), a standardised qualitative protocol developed by Clapcott (2012, 2013, 2015). The Ministry for the Environment (MfE) and Statistics New Zealand (Stats NZ) have a joint legislative responsibility under the Environmental Reporting Act 2015 to report on the state of Aotearoa New Zealand's environment. To help fulfil this responsibility, MfE engaged Cawthron Institute (Cawthron) to collate and analyse RHA data to update the 'freshwater physical habitat' indicator based on all data available up to 2024. The freshwater physical habitat indicator was last updated in 2020. This project builds on earlier work by Clapcott et al. (2020), which first established a national dataset of RHA observations for environmental reporting.

1.1 Purpose and scope

The purpose of this project is to provide an updated national dataset of RHA results and to calculate habitat quality scores (HQS) suitable for environmental reporting. Specifically, this work involves:

1. Calculating HQS for each RHA site using collated, processed and mapped data.
2. Testing the data for interannual temporal and spatial variability to assess whether the statistical requirements of MfE and Stats NZ for trend analysis are met. Where appropriate, trends in habitat quality will be calculated and reported. Where the dataset does not meet requirements for trend analysis, assess whether comparisons between current and previous (pre-2020) habitat state are suitable for reporting on change, and provide these state–state comparisons if appropriate.
3. Delivering the following data outputs:
    a) a tabular dataset of HQS and the 10 RHA parameter scores by site and monitoring periods
    b) a tabular dataset of trends, or other measures of change, where possible
    c) full metadata consistent with environmental reporting specifications, including data dictionaries and annotated code documenting data cleaning, analysis, transformation, modelling, visualisation and export.

1.2 Report structure

The remainder of this report is organised as follows: **Section 2** provides a description of the RHA protocol and parameters; **Section 3** outlines the methods used to collate, process and analyse the RHA data; **Section 4** presents the results of the data collation and statistical testing; **Section 5** discusses implications for environmental reporting and provides recommendations on the use of RHA data for reporting habitat quality and change; **Appendix 1** provides supplemental information supporting the data analyses; and **Appendix 2** details the R scripts and datasets that will be provided alongside the report.

2. Rapid Habitat Assessment protocol

The RHA provides a semi-quantitative standardised assessment of the physical habitat condition of wadeable streams at the reach scale (Clapcott 2015). The protocol was designed to provide a broad picture of habitat state while still being applicable at a site within about 20 minutes, making it suitable for use alongside other indicators typically assessed at state of the environment (SOE) monitoring sites. Field assessment involves scoring 10 habitat parameters: deposited sediment, invertebrate habitat diversity, invertebrate habitat abundance, fish cover abundance, fish cover diversity, hydraulic heterogeneity, bank erosion, bank vegetation, riparian width and riparian shade. Each parameter is scored on a scale from 1 to 10 using defined criteria that translate qualitative observations into numerical values. Scores are then summed to produce a total HQS (10–100), representing the overall state of stream habitat at the site; note that a higher score indicates higher habitat quality.

RHA data are typically collected by regional and unitary council staff, contractors or researchers trained in the method, with the aim of consistent application across sites and regions. This efficient, cost-effective approach allows for national-scale collation and comparison of habitat condition. However, as the method is based on observer judgement within defined scoring criteria, it may be subject to variability in field application. Moreover, it does not provide the same level of precision as fully quantitative physical habitat measurements. Finally, because RHA is applied mainly at wadeable SOE sites, national estimates of river habitat condition derived from collated RHA data are likely to under-represent very small and very large native-forest rivers and over-represent degraded lowland / pastoral systems (cf. Whitehead et al. 2022).

While some councils have previously collected (e.g. Greater Wellington, Horizons and Otago Regional Councils) or continue to collect (e.g. Bay of Plenty Regional Council) habitat data using a draft version of the RHA (Clapcott 2013), the scope of this project was restricted to data collected using the finalised protocol. The final RHA method was published in January 2015, meaning there is no nationally standardised dataset available prior to this date. From 2015 onward, however, the consistent application of the RHA across most regions provides a robust basis for national reporting and strengthens the potential for reliable state and trend analyses of stream habitat condition.

2.1 Rapid Habitat Assessment parameters

To aid interpretation of the analyses presented in this report, the 10 habitat parameters are described below. Additional information on the field assessment methods is available through resources developed by Cawthron.[1]

Deposited sediment: visual estimate of the extent of fine sediment (sand and silt < 2 mm in size) covering the streambed. Excessive fine sediment can smother habitat, reduce oxygen availability and

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[1] https://www.cawthron.org.nz/research/our-projects/rapid-habitat-assessment-protocol/

degrade conditions for invertebrates and fish; therefore, areas with less fine sediment cover are given a higher score.

Invertebrate habitat diversity: the range of available microhabitats for aquatic invertebrates (e.g. cobbles, gravels, macrophytes, woody debris). Greater diversity supports higher species richness; therefore, areas with more microhabitats – including the presence of interstitial spaces – are given a higher score.

Invertebrate habitat abundance: quantity and extent of instream habitats favourable for sensitive aquatic invertebrates such as stonefly, mayfly and caddisfly; for example, flowing water over gravel-cobbles clear of filamentous algae / macrophytes. Higher abundance increases opportunities for colonisation and productivity; therefore, a greater proportion of favourable substrate is given a higher score.

Fish cover density: the number of different substrate types with the potential to provide instream cover for fish; substrate types include woody debris, root mats, undercut banks, overhanging / encroaching vegetation, macrophytes, boulders and cobbles. A diverse array of cover supports different life stages and species with varying habitat preferences; therefore, areas with more substrate types and the presence of substrates providing spatial complexity are given a higher score.

Fish cover abundance: the amount of instream cover available for fish. Adequate cover is critical for shelter, feeding and predator avoidance; therefore, areas with more cover are given a higher score.

Hydraulic heterogeneity: variation in flow types (e.g. riffles, runs, pools, backwaters) within a reach. Greater heterogeneity provides habitat mosaics that sustain ecological complexity; therefore, areas with more hydraulic components and the presence of deep pools are given a higher score.

Bank erosion: extent and severity of streambank instability or active erosion due to scouring at the waterline, slumping of the bank or stock pugging. High erosion can contribute sediment loads and indicate loss of riparian or geomorphic integrity; therefore, areas with less erosion are given a higher score.

Bank vegetation: condition and type of vegetation stabilising streambanks. Healthy, well-vegetated banks reduce erosion, filter run-off and provide habitat. More established vegetation and a greater diversity of species scores higher.

Riparian width: width of vegetated riparian buffer alongside the stream constrained by vegetation, fences or other structures. Wider buffers enhance habitat quality, regulate microclimate and intercept pollutants; therefore, areas with a wider riparian buffer are given a higher score.

Riparian shade: degree of shading of the stream channel throughout the day provided by riparian vegetation, banks or other structures. Adequate shading helps regulate water temperature, control nuisance plant growth and maintain habitat quality; therefore, areas with more shade are given a higher score.

2.2 Interpretation

The 10 habitat parameters are summed to produce an HQS between 10 and 100, where higher scores indicate better quality habitat. These scores can be compared over time, between sites or with local reference sites. Guideline values for interpreting HQS are defined in Clapcott et al. (2020) and provided in Table 1.

Table 1. Habitat quality classes and descriptions for interpreting Rapid Habitat Assessment score (Clapcott et al. 2020).

Habitat condition	Score range
Excellent	>75
Good	>50 and ≤75
Fair	>25 and ≤50
Poor	≤25

3. Data collation

RHA data were sourced from all regional and unitary councils in April 2025 by emailing contacts from their science and environmental data teams. The emails requested any RHA data held for the period 2013–24, together with associated metadata. All councils responded: 15 of the 16 supplied data as CSV files or Excel spreadsheets, while Auckland Council advised that they do not collect habitat data using the RHA protocol.

All data received from councils were compiled using R statistical software (R Core Team 2024), with all processing steps documented in the Quarto markdown file *Data_collation.qmd* (see Appendix 1 for details of scripts used for compilation and analyses). The main steps were:

1. Joining site metadata to RHA records.
2. Rearranging columns and standardising formats across datasets.
3. Merging the 15 datasets into a single national dataset.

The compiled dataset was quality-checked to ensure completeness and validity. Metadata were checked for presence and consistency, and RHA parameters (sub-metrics) were verified to fall within the expected range of 1–10. Where gaps were identified, additional requests were made to councils to supply missing metadata, and minor corrections were applied where appropriate. Records with missing sub-metrics, or values recorded as zero or greater than 10, were excluded. Records collected in the 2024/25 hydrological year were also excluded to remain within the specified reporting period. The reporting period used for current state throughout this report is 2020–24 (inclusive), while the periods for state–state comparisons are 2015–19 (inclusive) and 2020–24 (inclusive). The final RHA protocol was not available prior to January 2015; therefore, no comparable data were available before this time period.

In total, data were compiled for 1,619 unique sites across Aotearoa New Zealand, with distinct spatial gaps in the Auckland and Tasman Regions and the lower West Coast / Fiordland (Figure 1). Sites included both long-term monitoring sites within SOE programmes and sites monitored as part of short-term targeted investigations. Overall, 1,332 sites were classed as 'hard-bottomed' and 262 sites were classed as 'soft-bottomed' by the councils that provided the data.[2] There were 25 sites where no substrate information was provided. Most sites were sampled annually, although some – particularly in the Taranaki and Hawke's Bay Regions – were monitored multiple times per year. The length of sample records ranged from 1 year to 9 years per site (Figure 2).

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[2] The classification of site substrate mainly relates to benthic macroinvertebrate sampling, but aids in interpreting RHA data. 'Hard-bottomed' sites are naturally dominated by cobble or gravel substrates, while 'soft-bottomed' sites are naturally dominated by fine sediments such as mud or pumice.

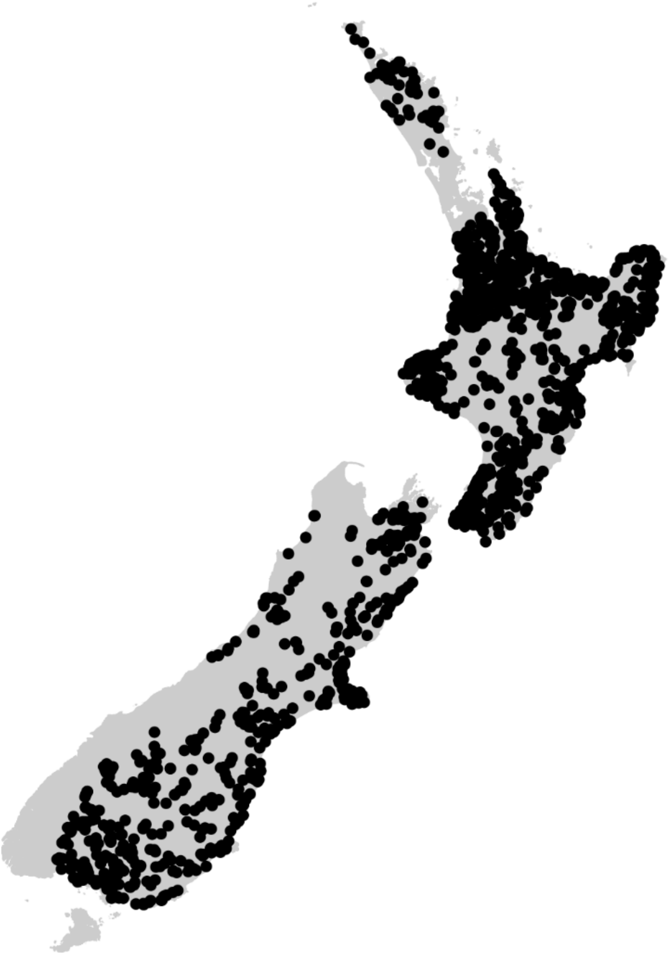

Figure 1. Distribution of Rapid Habitat Assessment data collected by councils between 2013 and 2024.

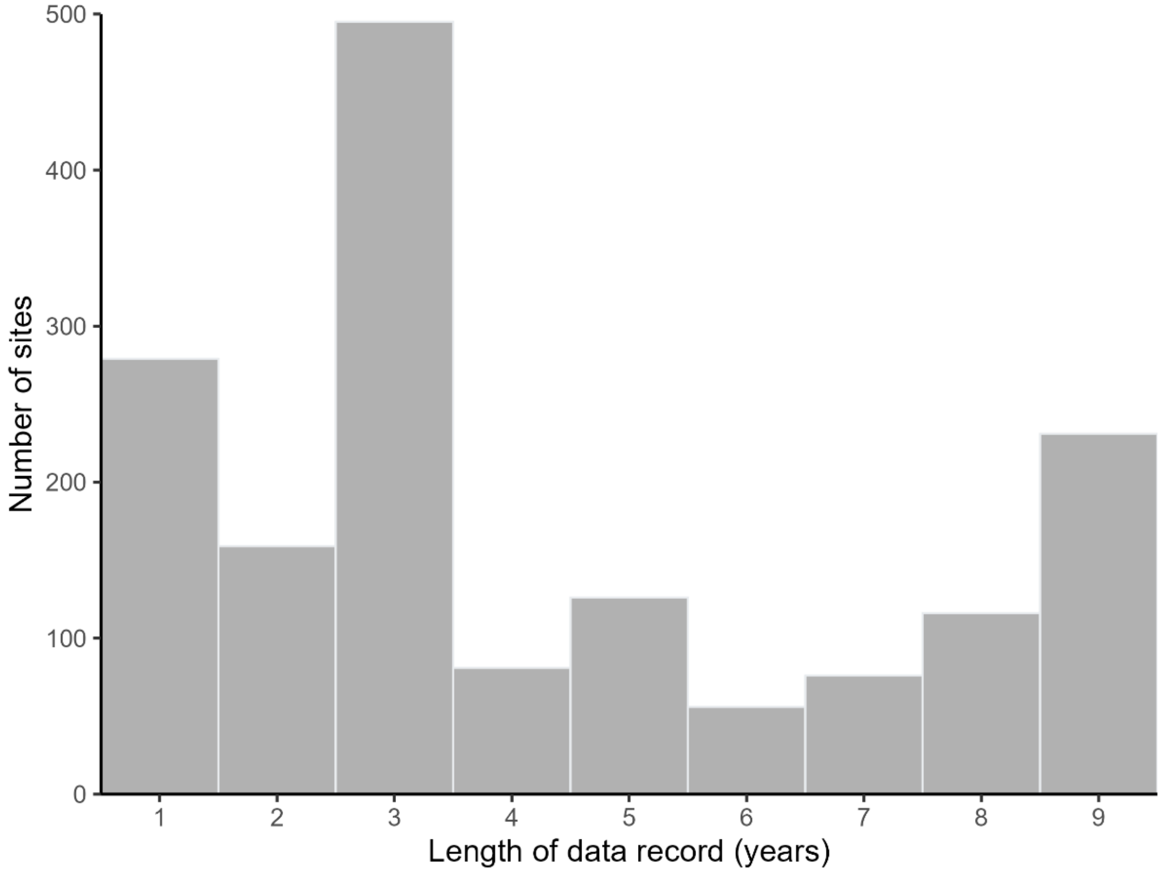

Figure 2. Number of years data were collected from each site included within the combined dataset for the period 2013–24. See Appendix 1 for a breakdown of number of sites sampled per year for each council.

To assess spatial patterns, upstream land-cover information was extracted from the Land Cover Database version 6.0 (LCDB6) for all sites with spatial information. The supplied NZReach or NZSegment numbers were matched to the River Environment Classification (REC2) river network and cross-checked against site locations to reveal and correct georeferencing errors, such as instances where NZReach and NZSegment had been accidentally transposed or were incorrect. Using Model Builder in ArcGIS Pro (version 3.4), the following process was then implemented for each site: (1) the trace tool was used to select all upstream REC river lines; (2) intersecting REC watershed polygons were selected and merged to form a catchment polygon; (3) LCDB6 was clipped to the catchment boundary; and (4) the area of each land-cover class present was summarised to provide percentages of total area for each class.

The LCDB6 classifies land cover into one of 33 land-cover classes. These classes were simplified following the Land, Air, Water Aotearoa (LAWA) 'medium' cover classes.[3] Land-cover classes describing waterbodies ('Lake or Pond', Rivers', and `Estuarine Open Water`) were excluded from our analyses. Medium classes were aggregated into five land-cover categories as outlined in Clapcott et al. (2020; see Table 2): Urban area, Pastoral, Exotic Forest, Native and Other. Following Fraser and Snelder (2021), the

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[3] https://www.lawa.org.nz/learn/factsheets/land/land-cover-and-why-it-is-important

dominant upstream land-cover class was assigned based on the most common upstream land cover, unless:

- Pastoral cover exceeded 25%, in which case the category was set to Pastoral; or
- Urban cover exceeded 15%, in which case the category was set to Urban.
- If both Pastoral and Urban exceeded their respective thresholds, then Urban was given precedence.

Table 2. Land-cover classes in the Land Cover Database (LCDB), and the Land, Air, Water Aotearoa (LAWA) 'medium' classes and simplified Rapid Habitat Assessment (RHA) classes used in this report.

LCDB class	LCDB identifier	LAWA medium class	RHA class
Exotic Forest	71	Exotic Forest	Exotic Forest
Forest – Harvested	64	Exotic Forest	Exotic Forest
Deciduous Hardwoods	68	Exotic Forest	Exotic Forest
Indigenous Forest	69	Indigenous Forest	Native
Broadleaved Indigenous Hardwoods	54	Indigenous Forest	Native
Fernland	50	Indigenous Scrub	Native
Manuka and / or Kanuka	52	Indigenous Scrub	Native
Sub Alpine Shrubland	55	Indigenous Scrub	Native
Matagouri or Grey Scrub	58	Indigenous Scrub	Native
Mangrove	70	Indigenous Scrub	Native
Gorse and / or Broom	51	Exotic Scrub	Other
Mixed Exotic Shrubland	56	Exotic Scrub	Other
Landslide	12	Natural Bare	Other
Permanent Snow and Ice	14	Natural Bare	Other
Alpine Grass / Herbfield	15	Natural Bare	Other
Gravel or Rock	16	Natural Bare	Other
Sand or Gravel	10	Natural Bare	Other
Herbaceous Freshwater Vegetation	45	Other Herbaceous Vegetation	Other
Flaxland	47	Other Herbaceous Vegetation	Other
Herbaceous Saline Vegetation	46	Other Herbaceous Vegetation	Other
Tall Tussock Grassland	43	Tussock Grassland	Other
Short-rotation Cropland	30	Cropping	Pastoral
Orchards, Vineyards or Other Perennial Crops	33	Cropping	Pastoral
Depleted Grassland	44	Exotic Grassland	Pastoral
High Producing Exotic Grassland	40	Exotic Grassland	Pastoral
Low Producing Grassland	41	Exotic Grassland	Pastoral
Transport Infrastructure	5	Artificial Bare Surfaces	Urban
Surface Mine or Dump	6	Artificial Bare Surfaces	Urban
Built-up Area (settlement)	1	Urban Area	Urban
Urban Parkland / Open Space	2	Urban Area	Urban

4. Habitat Quality Score calculation and results

To ensure consistency across all compiled datasets and avoid systematic errors, HQS was calculated for all records by summing sub-metric scores. The HQS values were then used to investigate appropriate data requirements for reporting, calculate current habitat state for sites with sufficient data, investigate the suitability of the dataset to calculate trends, and explore relationships between habitat quality and land cover.

4.1 Investigating data requirements for reporting

As with all environmental reporting, setting appropriate data requirements to account for natural variability is an important consideration for assessing the state of freshwater physical habitat. Clapcott et al. (2020) recommended that at least 3 years of data should be used to calculate state. We compared the use of 3 years versus 5 years of data to calculate state, as a 5-year period aligns with current policy reporting requirements for other annually monitored freshwater metrics, such as the Macroinvertebrate Community Index (MCI; MfE 2024). However, restricting the datasets to only sites with at least 5 years of data halved the number of sites that could be included (Table 3).

Table 3. Number of sites with council-provided Rapid Habitat Assessment data for 2015 to 2024; data are presented by the record length requirements investigated to inform data requirements for calculating freshwater physical habitat state. See Table 4 for a breakdown of the number of sites for which current state was calculated.

Council	Total number of sites	Sites with 3 or more years of data	Sites with 5 or more years of data
Bay of Plenty Regional Council	130	116	–
Environment Canterbury	195	165	–
Environment Southland	160	103	101
Gisborne District Council	87	83	74
Greater Wellington Regional Council	179	52	45
Hawke’s Bay Regional Council	100	90	73
Horizons Regional Council	100	85	67
Marlborough District Council	58	–	–
Nelson City Council	7	7	7
Northland Regional Council	88	69	52
Otago Regional Council	118	60	33
Tasman District Council	2	–	–
Taranaki Regional Council	74	69	64
West Coast Regional Council	32	31	–
Waikato Regional Council	289	251	89
Total	**1,609**	**1,181**	**605**

For each site, we considered the most recent data available when investigating how many years of data to include in assessments of habitat state The relevant data included: the most recent year, the most recent 3 years and the most recent 5 years.[4] The most recent 3- and 5-year periods were used because some councils rotate the sites being monitored using the RHA each year; this means that a requirement to use data from consecutive years would unnecessarily remove sites. The site mean and median were calculated for all periods, with standard deviation also calculated for the 3- and 5-year periods (Figure 3).

From this comparison, the median HQS was 63 (mean = 61.7) for the most recent year of data, 63 (mean = 61.8, standard deviation = 16.1) for the most recent 3 years, and 65.5 (mean = 64.6, standard deviation = 14.9) for the most recent 5 years (Figure 3). There was no significant difference between median HQS when data were summarised by time periods of 1 year, 3 years or 5 years of the most recent data (Repeated measures ANOVA, $F_{2, 1208} = 1.246$, $p = 0.288$).

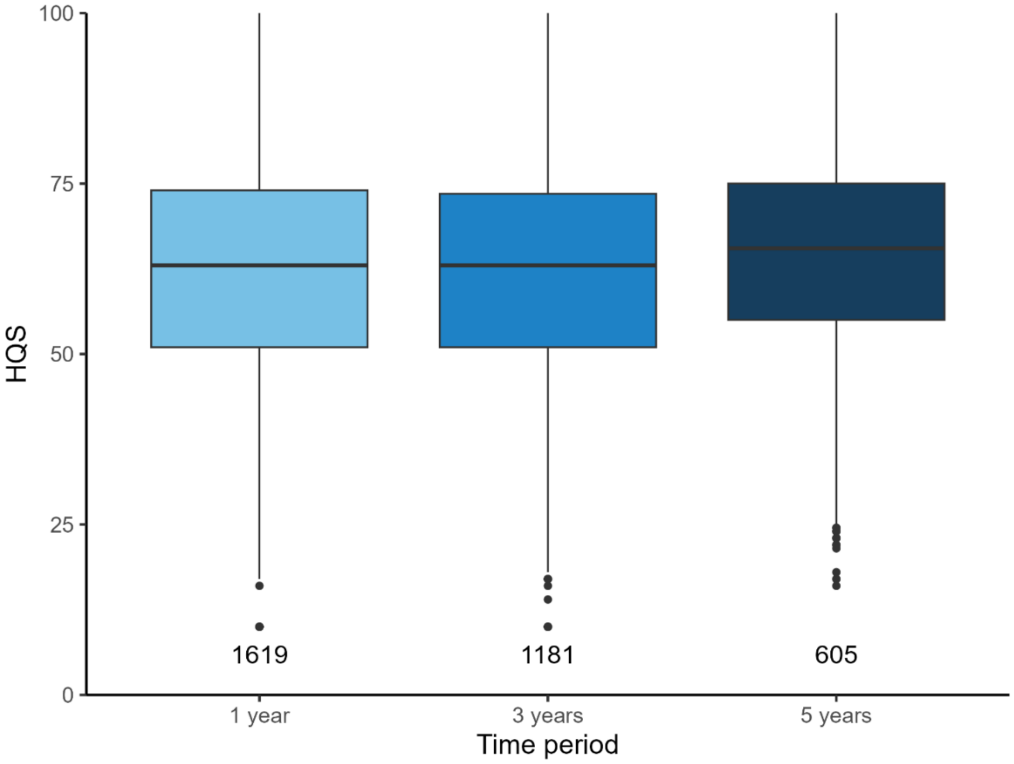

Figure 3. Raw habitat quality scores (HQS) for each time period, representing the most recent year, 3 years and 5 years of data available for each site. Numbers indicate the sites included for each period. The thick centre lines indicate the median, and the lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 × IQR from the hinge (where IQR is the interquartile range or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 × IQR of the hinge.

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[4] Where multiple data points were available for the same year, all data points were used for analyses.

We calculated rolling means to further investigate how mean HQS varied with the number of years of data included for each site. We noted that 3-year medians for HQS were strongly correlated with 5-year medians ($R^2 = 0.946$, $p < 0.001$, df = 603; Figure 4), suggesting that including additional years of data would not alter conclusions about the state of freshwater physical habitat. Therefore, we recommend that 3 years of data is sufficient for reporting habitat state for RHA data as it adequately accounts for temporal variation and increases the spatial coverage of reporting compared to more stringent requirements.

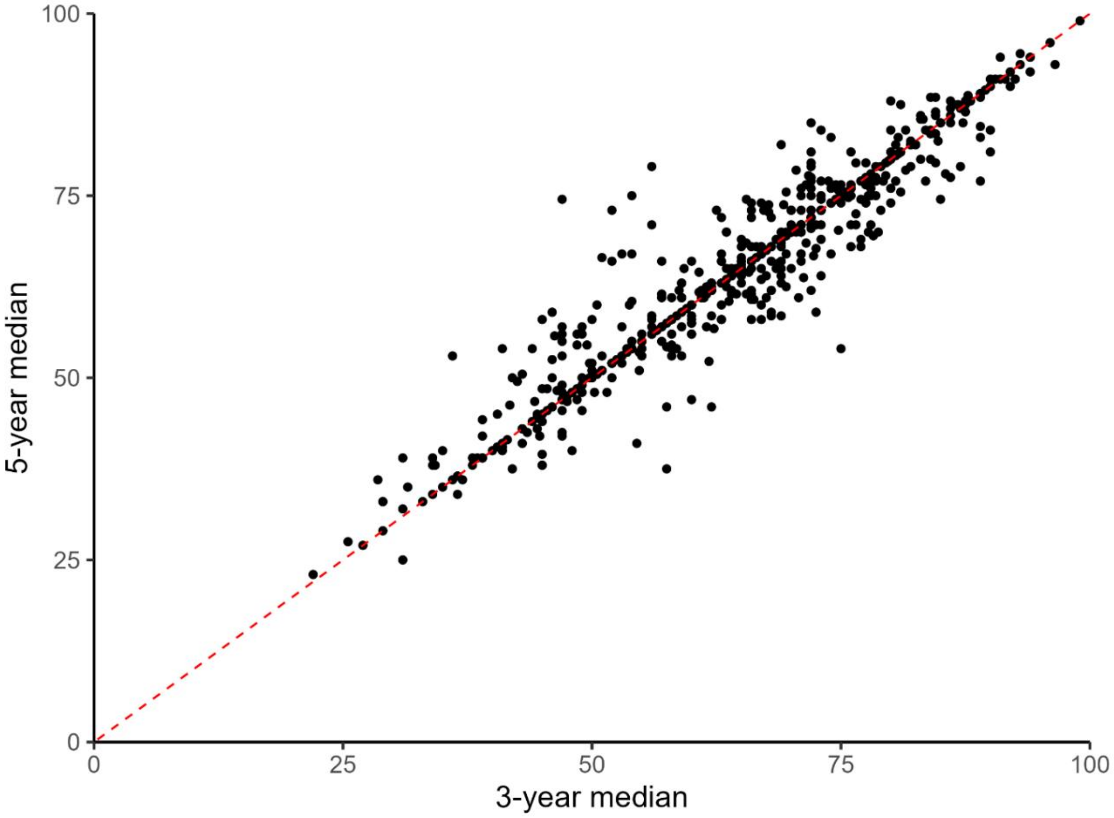

Figure 4. Comparison of 3- and 5-year medians of habitat quality scores for all sites with 5 or more years of data. Medians presented are calculated from the most recent records for each site, with the dashed red line representing x = y.

4.2 Current habitat state

To determine the current state of freshwater physical habitat, we calculated median HQS for each site that had at least one observation for at least 3 years between 2020 and 2024. While this decreased the number of sites analysed (n = 814), it reduced statistical bias and allowed consistent comparisons between sites by ensuring the same period was considered. Setting the data requirement at a minimum of 3 years within the last 5 years was based on our analysis of the conditions for reporting RHA data. There was also a need to align with the data requirements for reporting current state for other environmental indicators (e.g. Moreau et al. 2025). This allowed current state to be calculated for sites in 12 of the 15 regions that supplied data. No sites in the Bay of Plenty, Marlborough or Tasman Regions had sufficient data to calculate current state (Figure 5).

Table 4. Number of sites per council for which current habitat state could be calculated. To calculate current state, sites required at least one observation per year for at least 3 years between 2020 and 2024. All data available from 2020 to 2024 were used in the assessment.

Council	Sites with sufficient data to calculate current state
Bay of Plenty Regional Council	–
Environment Canterbury	164
Environment Southland	101
Gisborne District Council	71
Greater Wellington Regional Council	50
Hawke's Bay Regional Council	72
Horizons Regional Council	85
Marlborough District Council	–
Nelson City Council	7
Northland Regional Council	32
Otago Regional Council	46
Tasman District Council	–
Taranaki Regional Council	68
West Coast Regional Council	31
Waikato Regional Council	87
Total	**814**

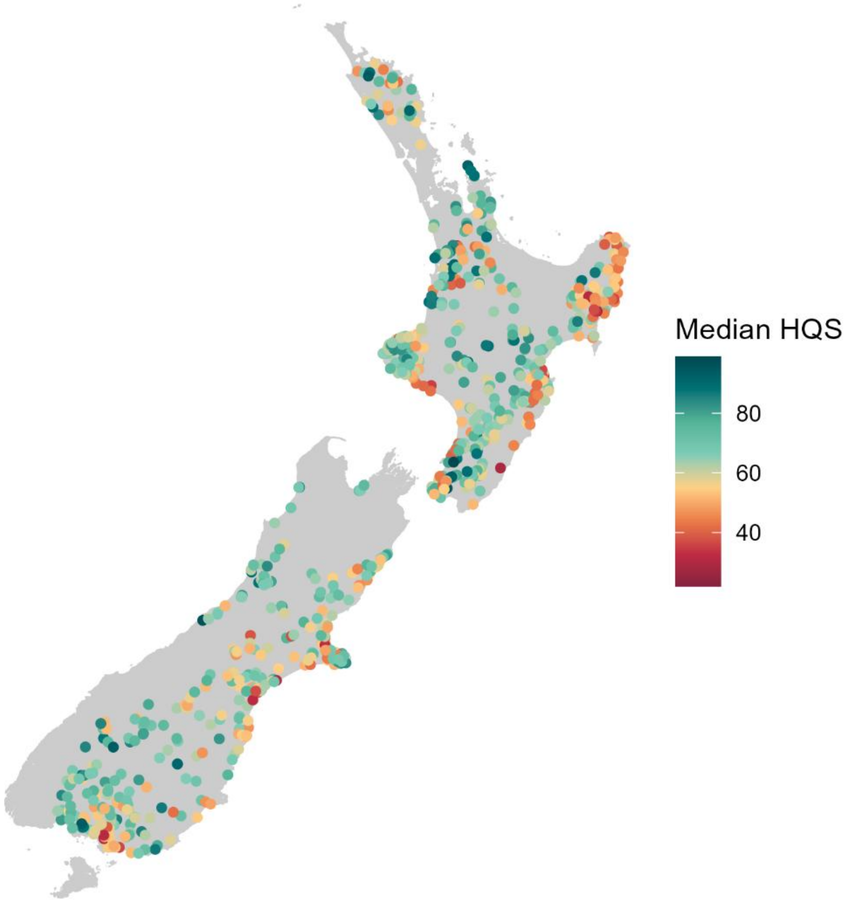

Figure 5. Median habitat quality scores (HQS) for sites with sufficient data to calculate current state for freshwater physical habitat. The minimum requirement for site inclusion was one observation per year for at least 3 years between 2020 and 2024. All data available from 2020 to 2024 was used in the assessment.

Nationally, the median HQS was 65, with individual site medians ranging from 22 to 99. When we assigned sites to habitat quality classes using the median HQS for each site (Table 1), 166 sites were classed as excellent, 527 were good, 120 were fair and one was poor. In general, hard-bottomed sites had a higher habitat quality than soft-bottomed sites (Figure 6). Variation in individual RHA parameters are shown in Appendix 2.

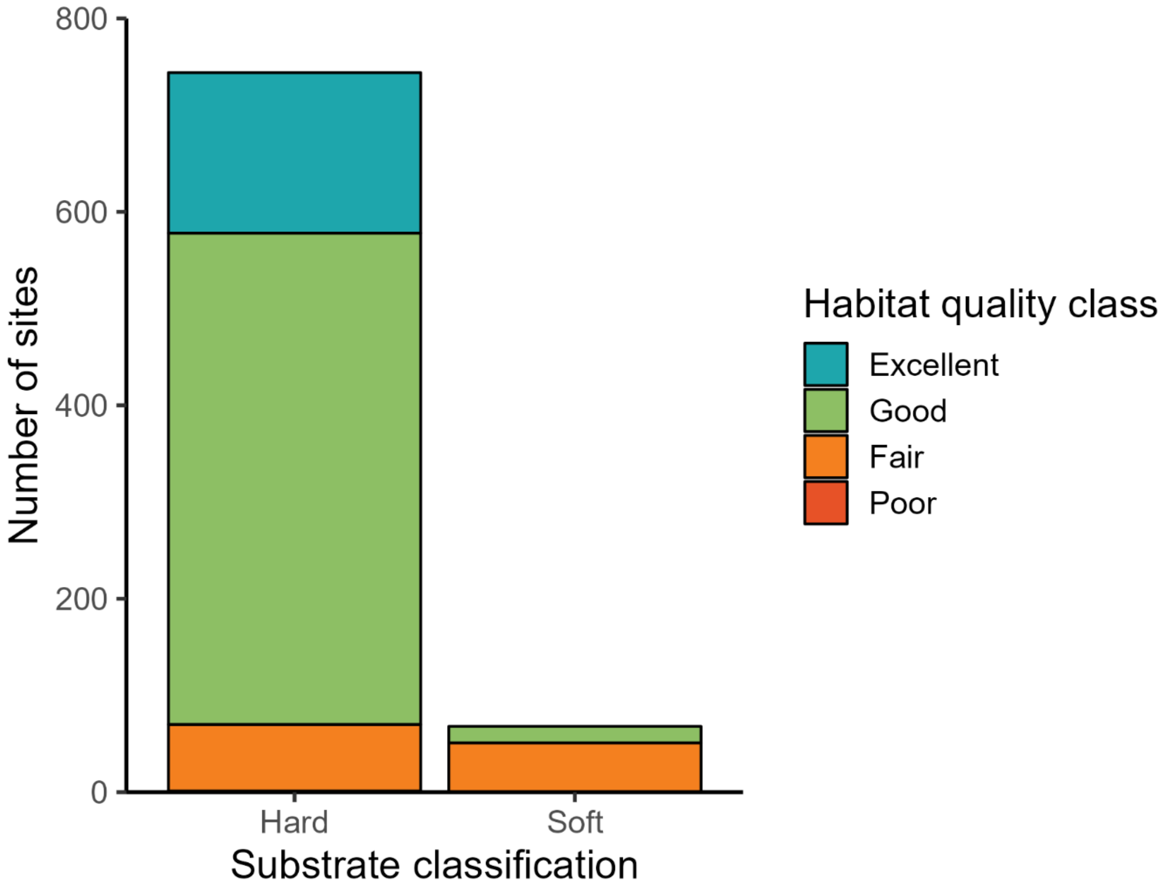

Figure 6. Habitat quality classes for hard- and soft-bottomed sites based on site medians.

4.3 Spatial patterns

For sites with sufficient data to calculate current state (at least one observation per year for at least three years between 2020 and 2024, see Section 4.2), the difference in median HQS between different dominant land covers was investigated. Of the 814 sites that current state was calculated for, six sites did not have sufficient spatial information to extract land cover, meaning that 808 sites were included in this analysis.

Land cover

The number of monitored sites varied substantially across the five land-cover classes, ranging from 26 sites in the 'Exotic forest' category to 537 sites in the 'Pastoral' category (Table 5). Median HQS values differed between land-cover classes (Figure 7, Table 5). Sites in 'Urban' catchments had the lowest median score (52.0), followed by 'Exotic Forest' (58.5), 'Pastoral' (62.0), 'Other' (65.5) and 'Native' (76.5).

The proportion of sites in each habitat quality class also varied by land cover (Figure 8). 'Pastoral' sites were the only land-cover group to include a site in 'poor' condition, while all classes had sites in the 'fair', 'good' and 'excellent' categories. The 'Native' class had the highest proportion of sites with 'excellent' habitat quality. Uneven distribution of monitoring sites across land-cover classes may have contributed to the patterns observed.

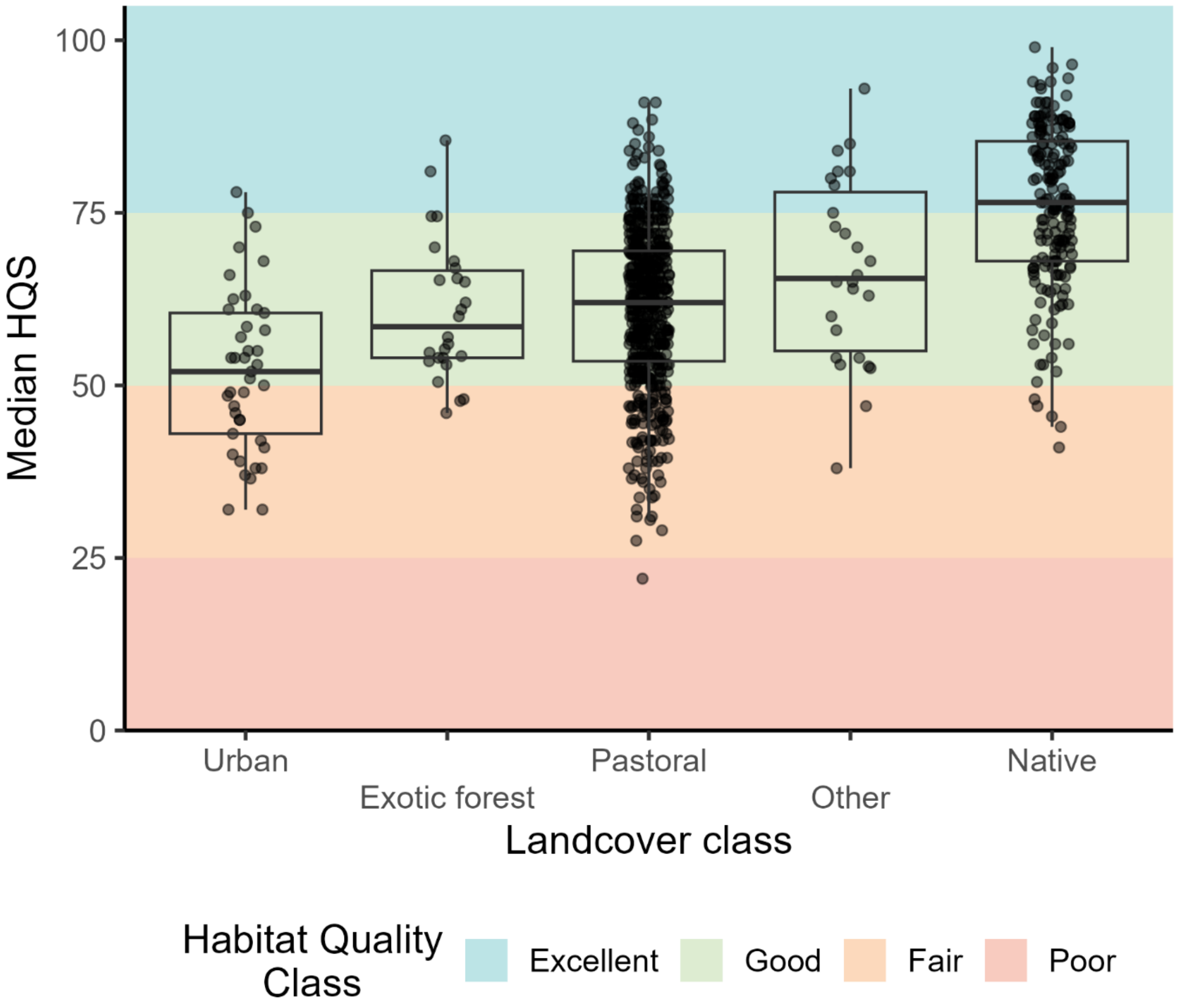

Figure 7. Comparison of habitat quality scores (HQS) split by dominant upstream land cover. Median HQS was calculated for sites with at least one observation per year for at least 3 years between 2020 and 2024. Points represent individual sites.

Table 5. Summary of habitat quality scores by dominant upstream land-cover class including the proportion of sites in each habitat condition category. n = the total number of sites in the given land-cover class. SD = the standard deviation.

Land-cover class	n	Median	Mean	SD	% Poor	% Fair	% Good	% Excellent
Exotic forest	26	58.5	60.89	10.28	0	11.54	80.77	7.69
Native	178	76.5	75.93	11.72	0	2.81	41.01	56.18
Other	26	65.5	66.66	13.38	0	7.69	65.38	26.92
Pastoral	537	62	61.2	11.64	0.19	16.76	73	10.06
Urban	41	52	52.13	11.71	0	46.34	51.22	2.44

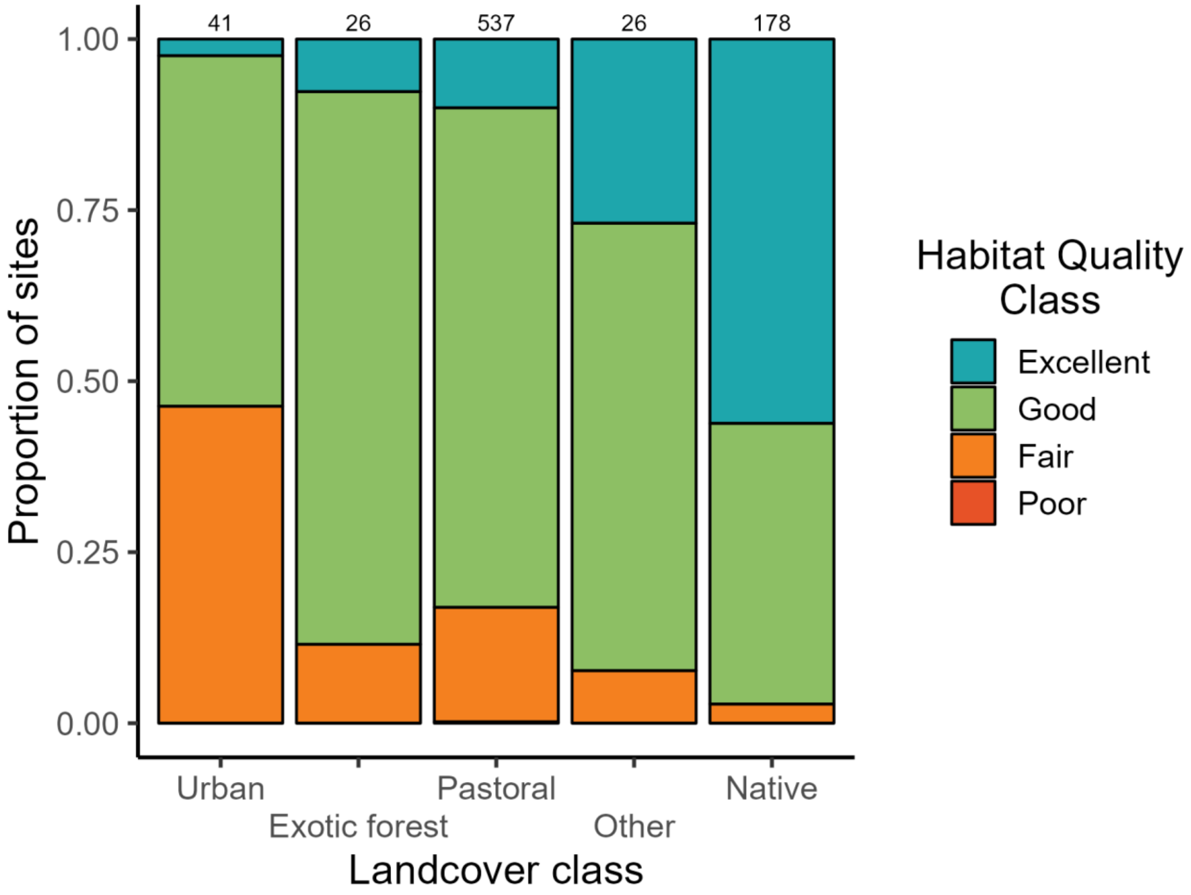

Figure 8. Comparison of habitat quality scores (HQS) split by dominant upstream land cover. Median HQS was calculated for sites with at least one observation per year for 3 years between 2020 and 2024. Numbers above the bars are the total number of sites for the given land-cover class.

4.4 Temporal patterns

Assessing changes in freshwater physical habitat over time provides information on shifts in environmental state. Importantly, it also facilitates the evaluation of management actions and policies, providing insights into the relationships between environmental conditions and drivers, and potentially providing early warning of environmental problems. The current established statistical process for calculating trends for environmental monitoring data in Aotearoa New Zealand uses Mann–Kendall correlation assessment and Sen's slope regression (Snelder et al. 2021).

Calculating trends relevant to environmental reporting requires both sufficient data points and statistical power to detect whether an ecologically meaningful trend is present. Initial data requirements for the RHA dataset included at least 5 years of data for a site. While this is less restrictive than those set for LAWA's annually monitored metrics,[5] the extended time period allowed investigation of variability. Statistical power was assessed using a Monte Carlo simulation approach, with an ecologically meaningful trend defined as an increase or decrease in HQS of 25. This threshold was set to represent an average change of at least one point for each parameter beyond the 15% inter-user variability identified during the development of the RHA protocol (Clapcott 2015).

Investigating variability

To evaluate whether temporal trends could be reliably detected in the RHA dataset, we first assessed variability across sites with at least 5 years of data. Trend detection was carried out using Mann–Kendall correlation and Sen's slope regression. We also tested whether the variability of the dataset provided sufficient statistical power to detect ecologically meaningful changes. We conducted power analyses using Monte Carlo simulations (n = 1,000) following Yue et al. (2002). The simulations estimated the probability of detecting a true trend at a site, given the observed variability in the compiled dataset. Both linear and exponential trend shapes were tested to represent alternative trajectories of change over time.

For data generation, two distributions were used to reflect the bounded, discrete nature of the HQS data. Simulated datasets based on: (1) a randomised normal distribution was scaled to match the observed distribution and standard deviation of the compiled dataset (Figure 9), with values rounded to integers and truncated at zero; and (2) a Poisson distribution provided a direct analogue to count-based, bounded data. These approaches ensured that the simulated datasets captured the statistical properties of the observed HQS data while also ensuring the power analyses was robust by allowing comparison of multiple data distributions.

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[5] https://www.lawa.org.nz/learn/factsheets/calculating-water-quality-trends-in-rivers-and-lake

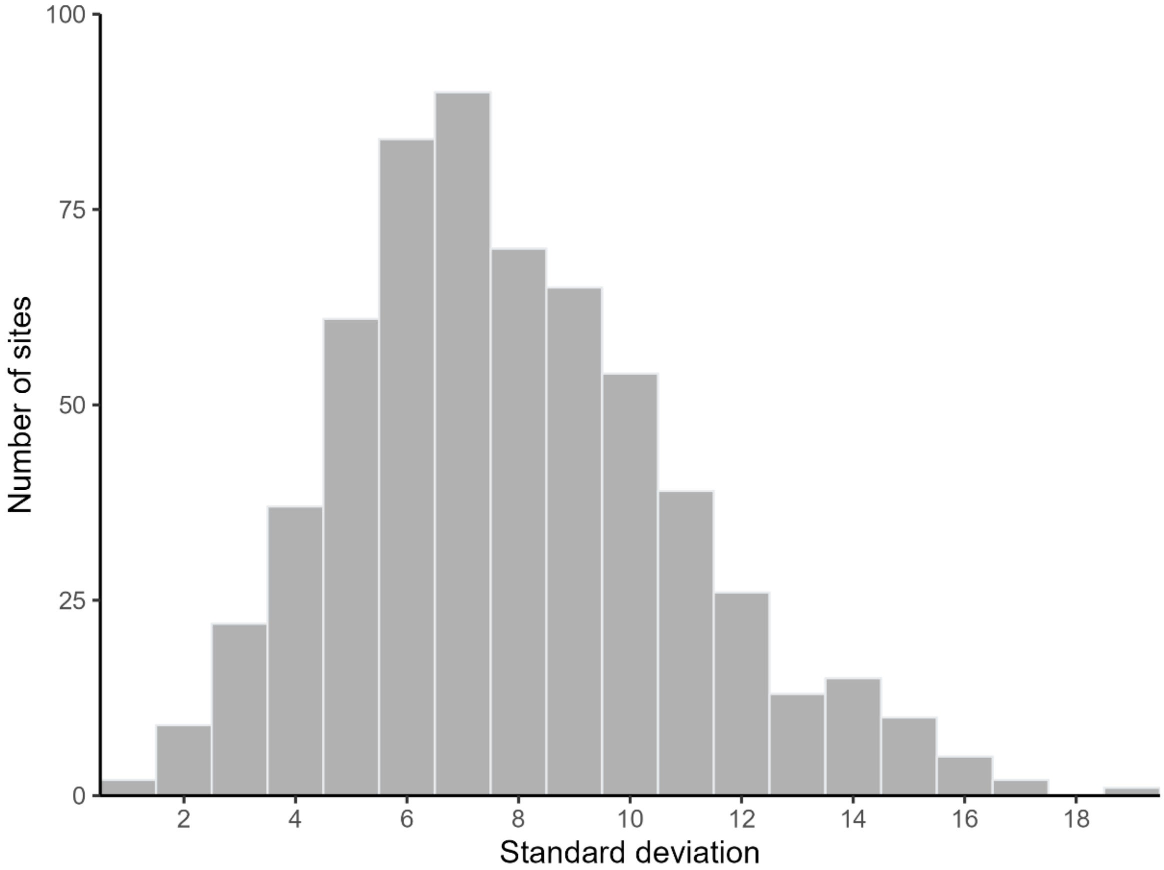

Figure 9. Standard deviation of habitat quality scores for all sites with at least 5 years of Rapid Habitat Assessment data.

Trends of a given effect size (k) were simulated and tested for detectability using the Mann–Kendall test under the assumed data distribution and sample size. For each scenario, the probability of rejecting the null hypothesis of no trend when a true trend was present (i.e. test power) was estimated using Monte Carlo simulations with alpha set at 0.05. A target power of 0.8 was used, reflecting the conventional balance between Type II error (failing to detect a true trend) and Type I error (detecting a false trend); this was consistent with power analyses in freshwater environmental studies (e.g. Larned and Unwin 2012). The simulations iterated across combinations of sample size, effect size and data variability to identify conditions under which statistical power exceeded 0.8. This process was repeated for each trend type (linear and exponential) and underlying distribution (normal and Poisson).

The power analyses indicated that only some sites had statistical power to detect ecologically meaningful trends, reflecting the high variability in the dataset and limiting its suitability for national reporting (Appendix 2). Under the assumption of normally distributed data, a linear 2.5% annual change (equivalent to a shift in habitat quality class over 10 years) could be detected for 37% of sites with 9 years of data (SD ≤ 6). Detecting this trend at all sites would require at least 17 years of data. A stronger linear change of 5% per year (equivalent to a shift in habitat quality class over 5 years) was detectable at 97% of sites (SD ≤ 14.5) with 10 years of data, and 11 years were sufficient for full site coverage. For exponential trends with normally distributed data, a shift in habitat quality class over

10 years (k = 0.03) was detectable at only 52% of sites. Results under a Poisson distribution were similar: a 5% annual linear change was detected with 8 years of data, while 12 years were required to detect either linear or exponential changes of 2.5% per year. Overall, these results suggest that a longer data record than currently available is required to calculate robust trends for HQS data. Based on the simulated data used for the power analyses, a minimum of 12 years of data would enable trend detection at many sites, while 15 years would provide greater robustness across the network.

To validate the power analyses, we conducted a trend assessment using a Mann–Kendall correlation assessment and Sen's slope regression following the approach used by LAWA (Snelder and Fraser 2018). Although several sites showed ecologically meaningful change (greater than 2.5% per year), 79% of Sen's slope confidence intervals included 0, indicating that trends could not be confidently classified as increasing or decreasing. These findings are consistent with the power analyses, confirming that the compiled HQS dataset is too variable, given the number of data points available, to support robust trend detection.

State–state comparisons

To examine changes in freshwater physical habitat over time, we compared current HQS data with the most recent national reporting by Clapcott et al. (2020), which covered monitoring up to the 2018/19 hydrological year. Following the same approach used to calculated habitat state, medians were calculated for each period, including all sites with at least one observation per year for 3 years. For the seven regions with sufficient data (compared to the 12 regions represented in the analysis of current state), changes between medians were assessed at each site. Sufficient data were available for 432 sites. Of these, HQS increased at 221 sites, declined at 199 sites and showed no change at 12 sites (Figure 10). The largest observed decline in HQS was 23.5, while the largest increase was 20.75. For sites where HQS improved, most individual RHA parameters showed small increases. No single parameter appeared to play a greater role in influencing the increase in overall condition. For sites that displayed a decline in HQS, individual parameters were variable, but deposited sediment and invertebrate habitat abundance appeared to decline more than other parameters (Figure 11). When classified using the habitat quality classes, 35 sites moved to a higher class, 349 remained in the same class and 48 shifted to a lower class (Figure 12). Patterns were consistent between hard- and soft-bottomed sites, although no soft-bottomed sites achieved the 'excellent' habitat quality class (Figure 13).

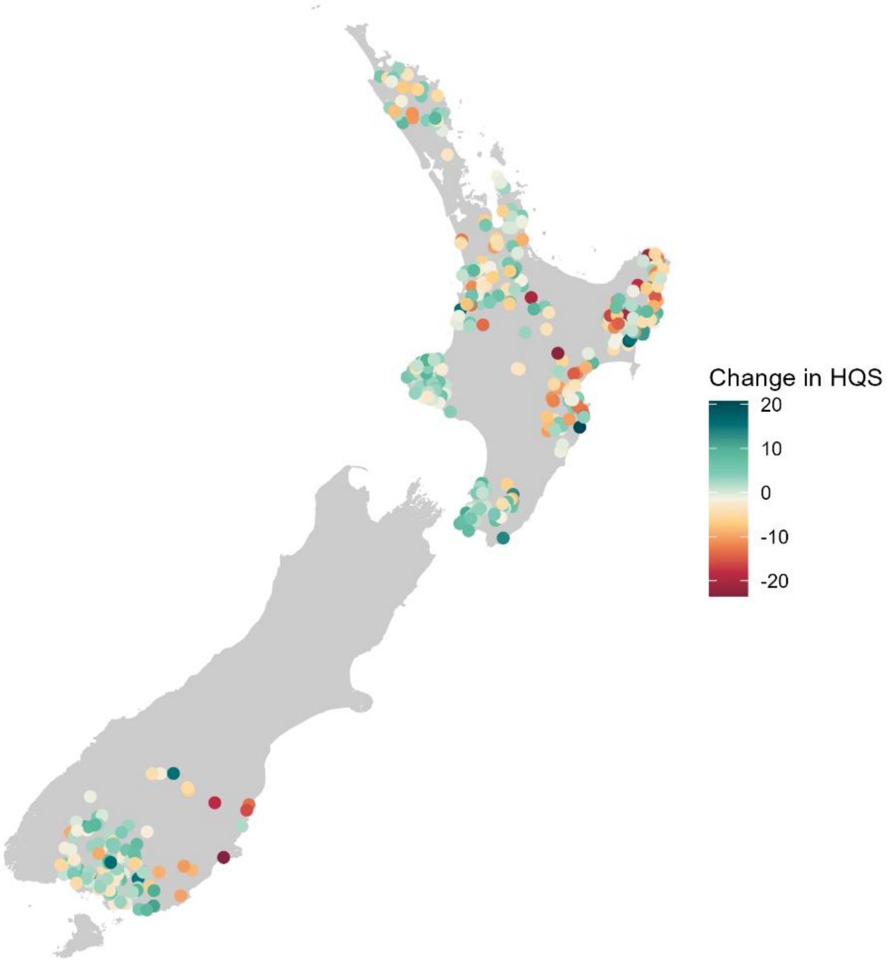

Figure 10. State–state comparison of habitat quality scores (HQS) showing the change in median HQS between 2015–19 and 2020–24 periods.

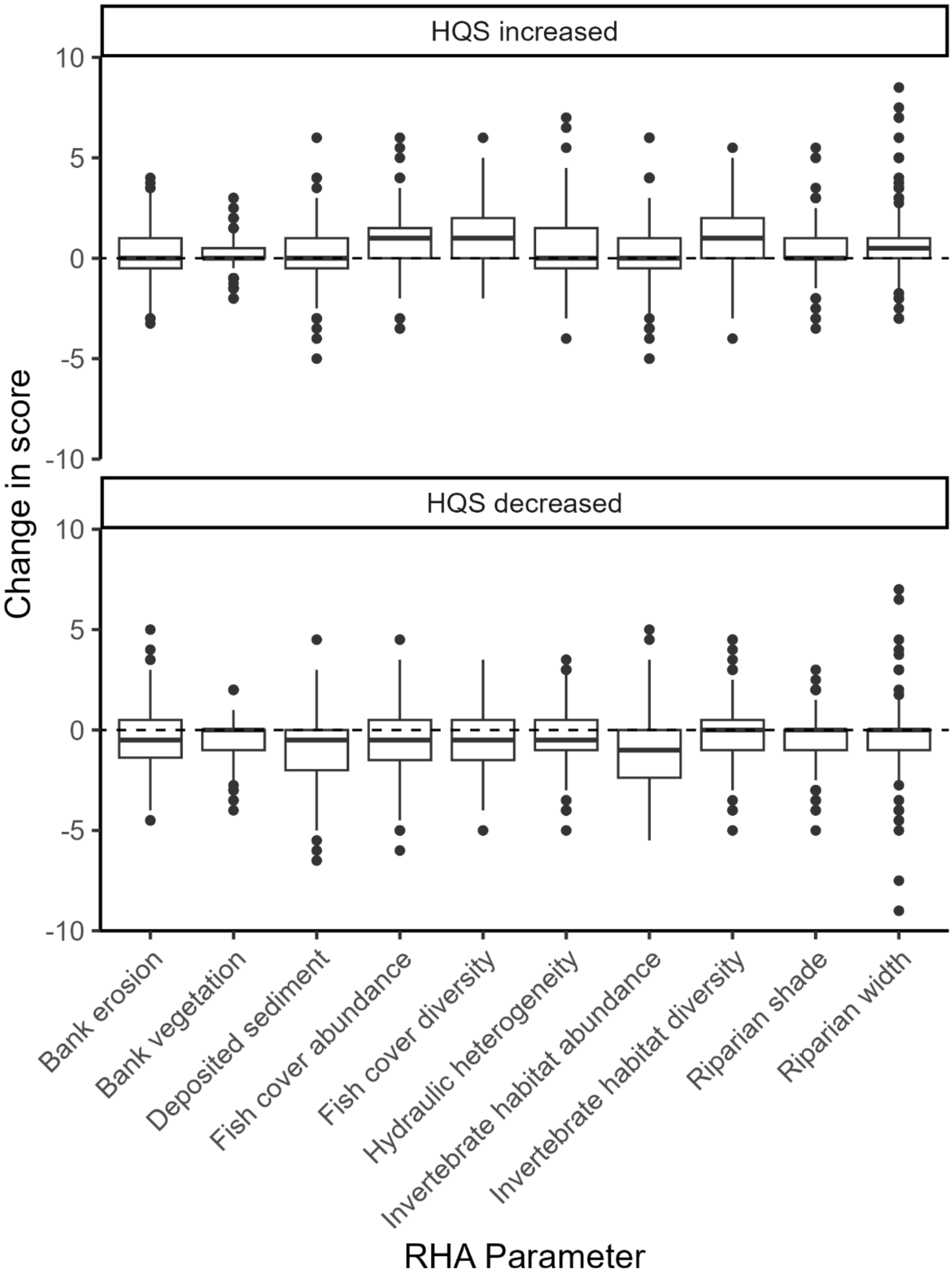

Figure 11. Changes in individual Rapid Habitat Assessment (RHA) parameters for sites that displayed an increase or decrease in habitat quality scores (HQS).

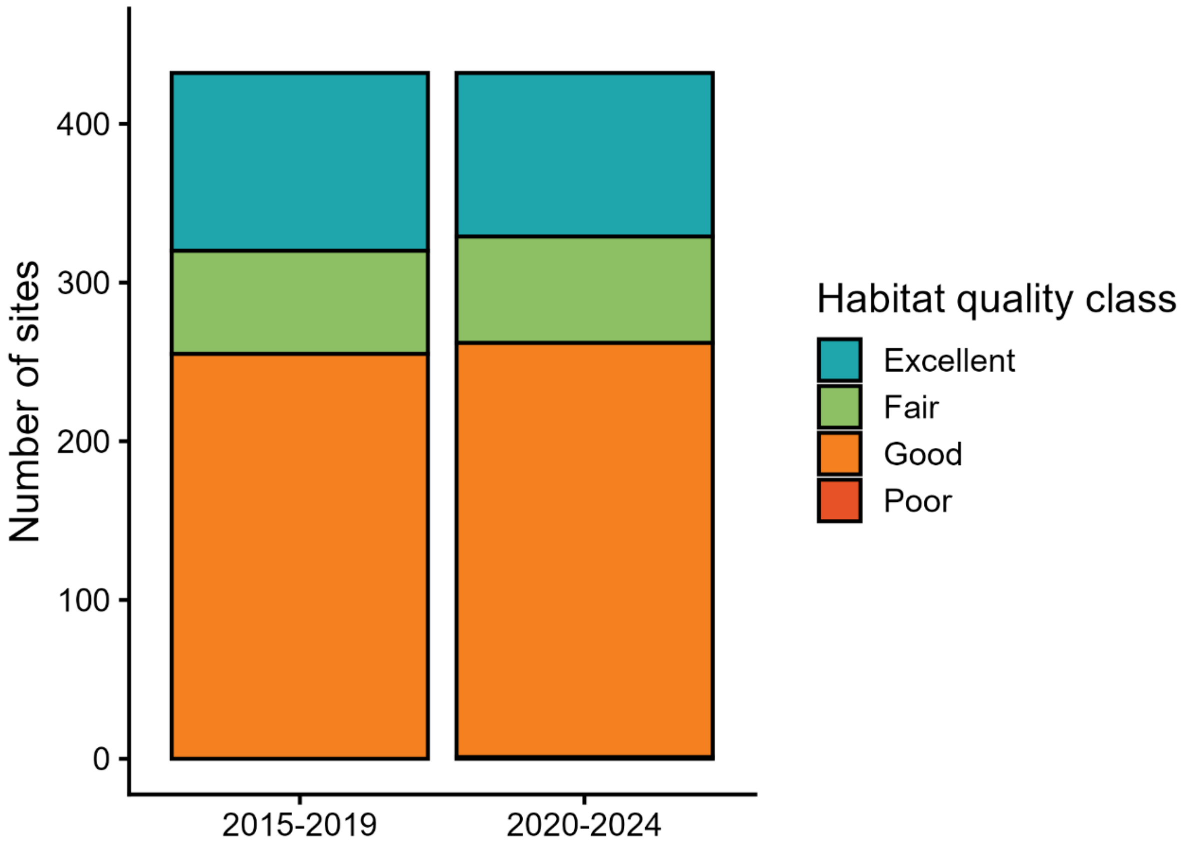

Figure 12. The number of sites assigned to each habitat quality class in 2015–19 and 2020–24. Note that for 2020–24, one site is classed as ‘poor’, but is not easily visible on the graph.

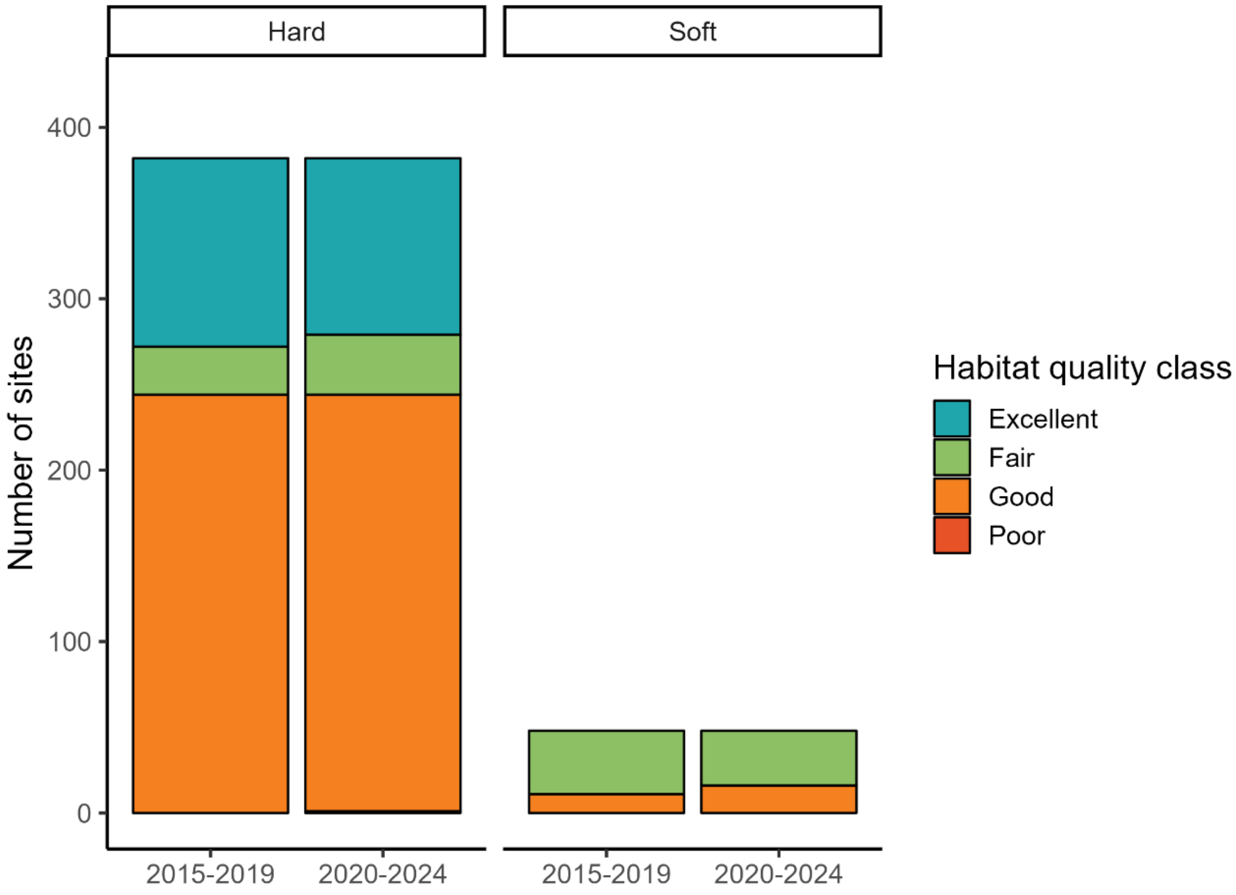

Figure 13. State–state comparison of median habitat quality scores split by substrate type to show the change in habitat quality classes for data collected between 2015–19 and 2020–24 data for hard- and soft-bottomed sites. Note that post-2019, one hard-bottomed site is classed as 'poor', but it is not easily visible on the graph.

5. Discussion

The process of compiling and analysing RHA data to update physical habitat indicators for freshwater ecosystems raised important considerations for its use in environmental reporting. Our findings provide recommendations on how RHA data – and the resulting HQS – can be best applied to reporting habitat quality and change, highlighting both useful approaches and some challenges.

Reporting habitat state. Analysis of the compiled dataset indicates that 3 years of RHA data is sufficient for reporting physical habitat state. This period strikes a practical balance between accounting for interannual variation and maximising spatial coverage. Although RHA data were variable, extending the reporting period to 5 years did not meaningfully alter estimates of current state, but it did halve the number of sites available and exclude multiple regions. Including the most recent non-consecutive years of data also enabled greater inclusion of sites monitored on a rotating basis.

State was reported as both 3-year medians of HQS and by assigning sites to habitat classes. Given the qualitative nature of the RHA data and the high variability observed in HQS at individual sites, small differences in scores may not be ecologically meaningful. We therefore recommend reporting both 3-year medians and habitat classes, as this provides context and helps interpret changes in HQS.

Assessing changes over time. Our analysis showed that the RHA data are highly variable, limiting their use for detecting trends over short time frames. Power analyses indicated that 12 years of data are likely required to robustly assess national trends, with 15 years providing greater confidence. Such a timescale likely matches the period required for instream processes to change habitat (e.g. riparian plant growth, shifts in sediment regime or reach-scale channel geomorphology change). This finding also underscores the importance of maintaining long-term monitoring of physical habitat to enable reliable trend detection. At the national scale, state–state comparisons using 3-year medians provide an indication of temporal change, but require at least 6 years of data per site over a 10-year period.

Addressing potential bias. Another key consideration is the potential for bias in the compiled dataset. Much of the council-supplied data came from long-term SOE monitoring, but some records originated from investigations into specific pressures or management issues. These investigation sites are often selected for targeted purposes, rather than being part of a representative river network, and the monitoring is typically short term. While such data may meet requirements for assessing state, they are unlikely to provide the temporal depth needed to assess change over time. Where possible, distinguishing between long-term SOE monitoring and targeted investigations will improve the robustness of national-level reporting.

6. Acknowledgements

We thank Bay of Plenty Regional Council, Environment Canterbury, Environment Southland, Gisborne District Council, Greater Wellington Regional Council, Hawke's Bay Regional Council, Horizons Regional Council, Marlborough District Council, Nelson City Council, Northland Regional Council, Otago Regional Council, Tasman District Council, West Coast Regional Council and Waikato Regional Council for providing RHA data. We also thank Alba Cervantes-Loreto (Cawthron) for providing assistance with power analyses as well as Lisa Floerl and Alison Brownlee (Cawthron) for assistance with extracting spatial data.

7. Appendices

Appendix 1. Accompanying materials

As an additional deliverable, the R scripts used for all analyses and the output datasets are provided alongside this report. All datasets are accompanied by a data dictionary briefly describing the variables included.

A1.1 Scripts

Table A1.1. R scripts used to complete all analyses included in this report.

File name	Description
Data_collation.qmd	Script for compiling the Rapid Habitat Assessment (RHA) data received from individual councils into one compiled dataset.
Data_analysis.qmd	Main analysis script. Includes data checks, initial exploration, state calculation, state–state comparisons, exploratory calculation of trends and joining of spatial information with state.
Landcover_analysis.qmd	Analysis of land-cover data, including determining dominant upstream land cover.
mann_kendall_power.R	Power analysis used to investigate the statistical power of trend analyses.

A1.2 Datasets

Table A1.2. Output datasets generated by the analysis included in this report. Accompanying data dictionary files are labelled *[dataset name]_data_dictionary.csv*.

File name	Description
compiledRHAdata.csv	Compiled dataset of all Rapid Habitat Assessment (RHA) data received from individual councils. This is the output from *Data_collation.qmd*
HQS_current_state.csv	Dataset of current habitat state based on median habitat quality scores (HQS) as reported in Section 4.2.
HQS_upstream _landcover.csv	Summary dataset of upstream land cover for each site for which current state could be calculated.
HQS_landcover_summary.csv	Dominant upstream land cover for each site for which current state could be calculated, as reported in Section 4.3.
HQS_state_comparison.csv	Dataset of state–state comparison of median HQS as reported in Section 4.4.

Appendix 2. Supplementary results from data analyses

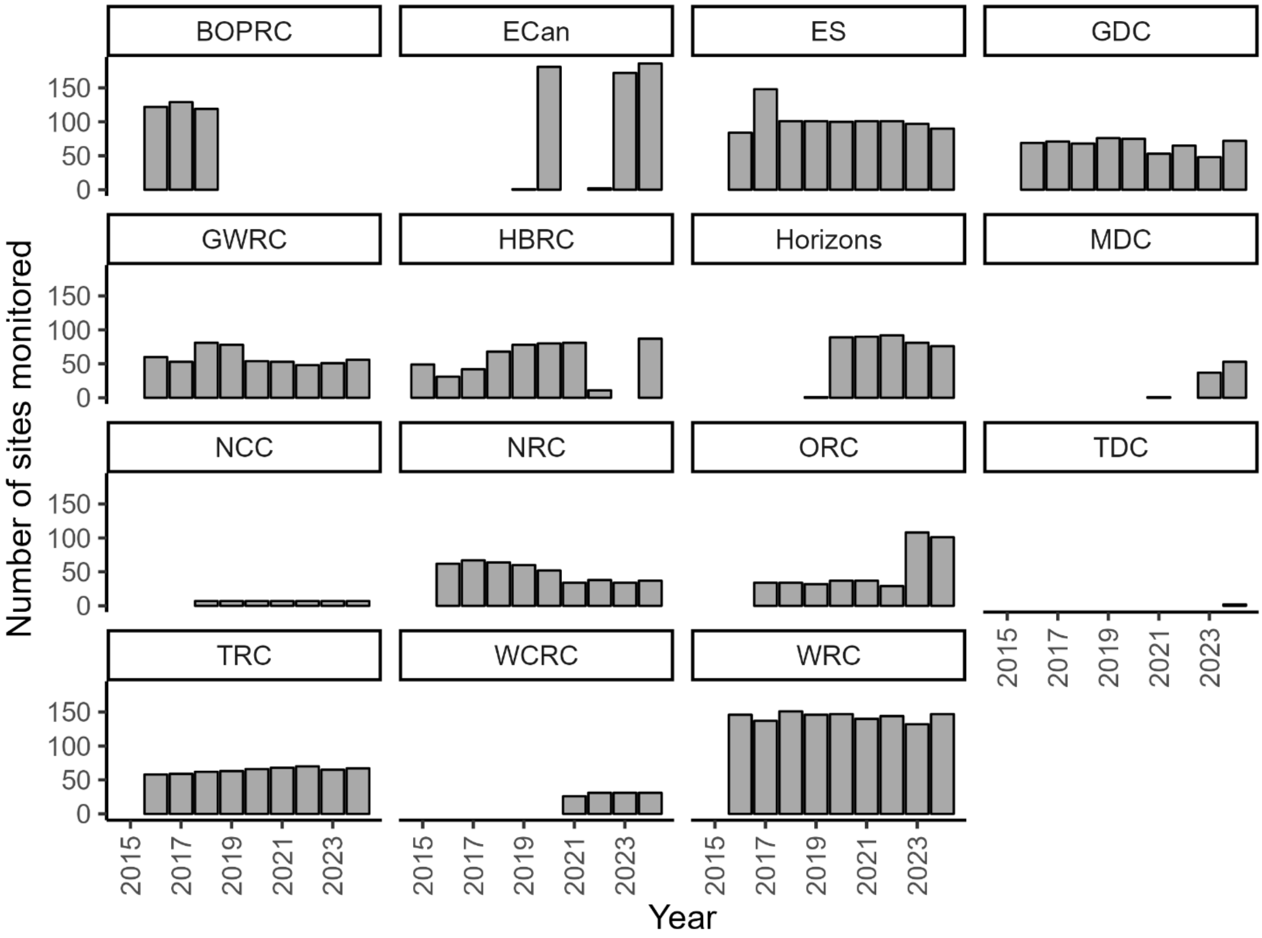

Figure A2.1. Number of sites monitored by each council per year.

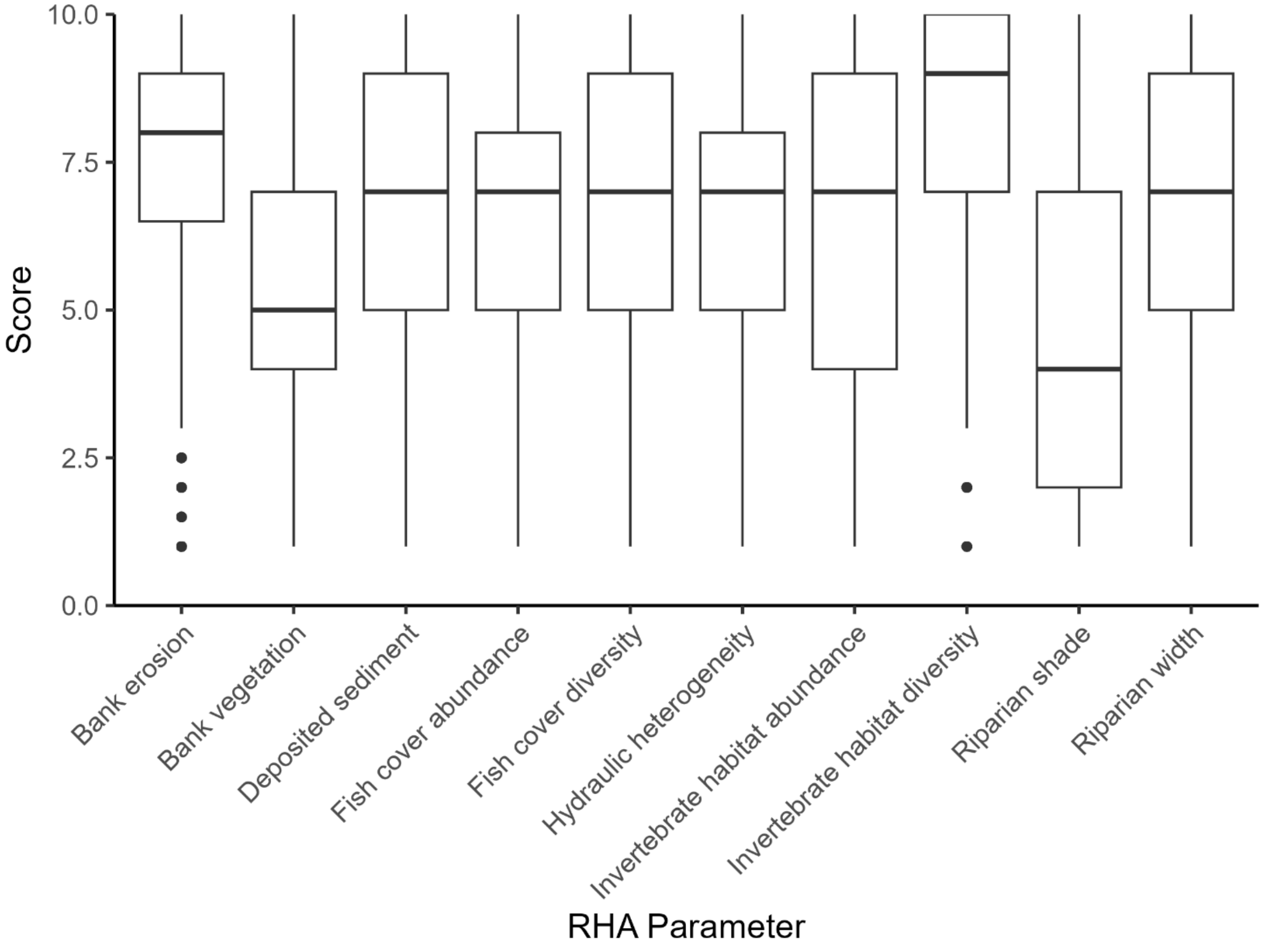

Figure A2.2. Individual Rapid Habitat Assessment (RHA) parameter scores for sites where current state could be calculated for the period between 2020 and 2024 (see Section 4.2 for data requirements).

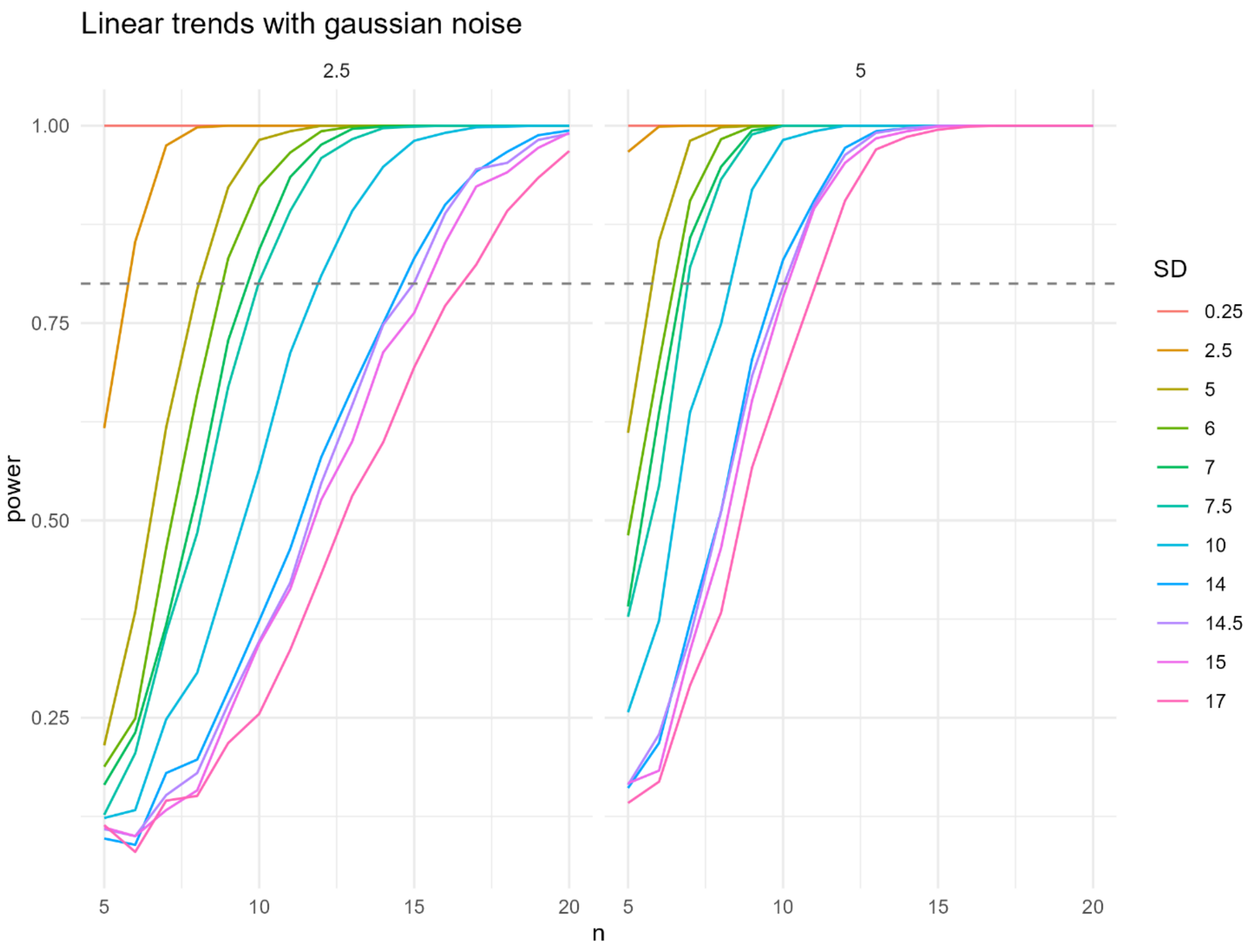

Figure A2.3. Power analyses output for a linear trend assuming data is normally distributed. The output shows the results of Monte Carlo simulations (n = 1,000) for two different effect sizes using a simulated dataset (see Section 4.2 for a description of the power analyses). An effect size (k) of 2.5 is equivalent to a change in habitat class over 10 years, while an effect size of 5 is equivalent to a change in habitat class over 5 years. Power is the probability of rejecting the null hypothesis of no trend when a true trend was present, with the dashed horizontal line representing the 0.8 threshold required to detect trends. n is the number of data points available, and SD is the standard deviation of the simulated datasets based on the variability of the compiled Rapid Habitat Assessment dataset.

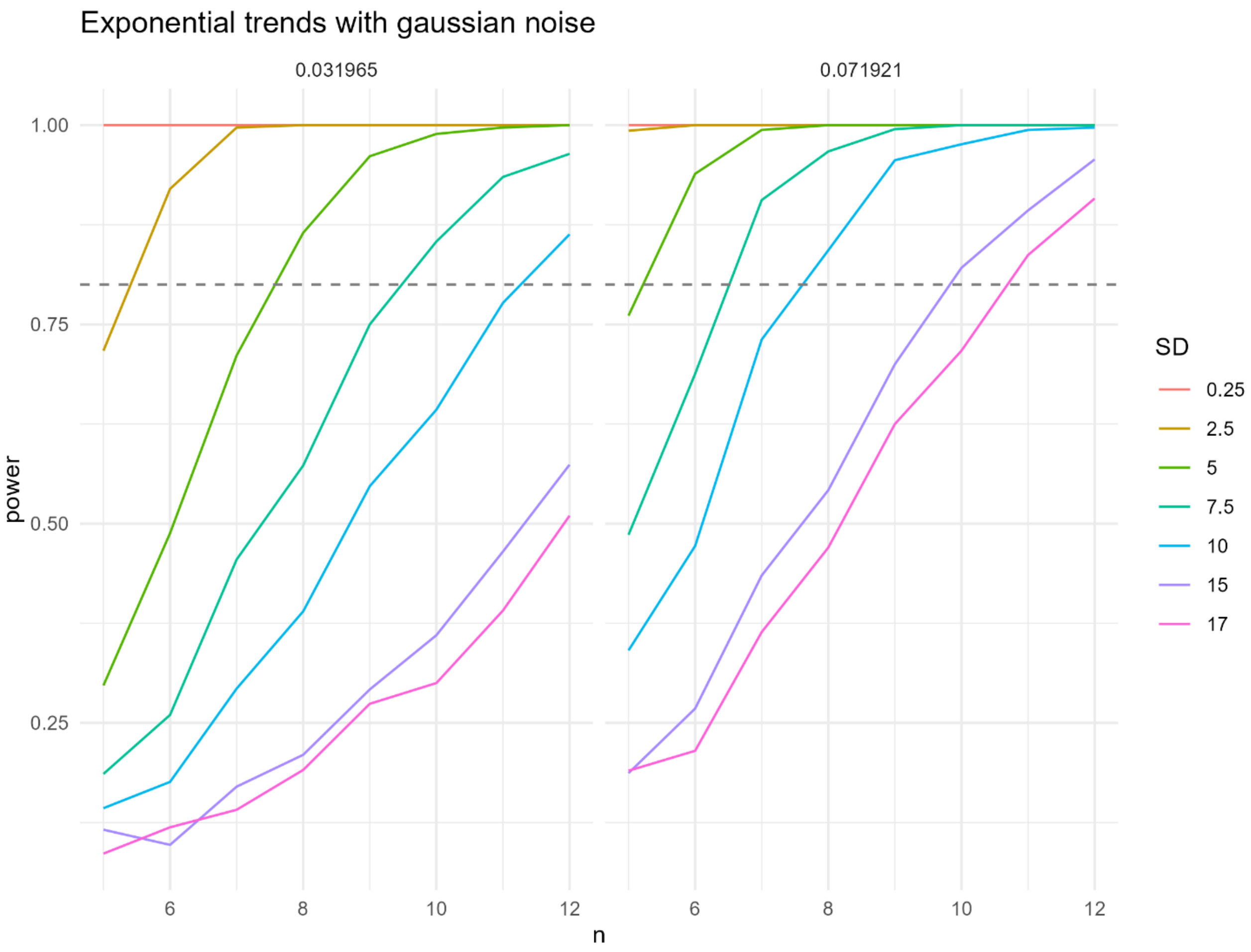

Figure A2.4. Power analyses output for an exponential trend assuming data is normally distributed. The output shows the results of Monte Carlo simulations (n = 1,000) for two different effect sizes using a simulated dataset (see Section 4.2 for a description of the power analyses). An effect size (k) of 0.031965 is equivalent to a change in habitat class over 10 years, while an effect size of 0.071921 is equivalent to a change in habitat class over 5 years. Power is the probability of rejecting the null hypothesis of no trend when a true trend was present, with the dashed horizontal line representing the 0.8 threshold required to detect a significant trend. n is the number of data points available, and SD is the standard deviation of the simulated datasets based on the variability of the compiled Rapid Habitat Assessment dataset.

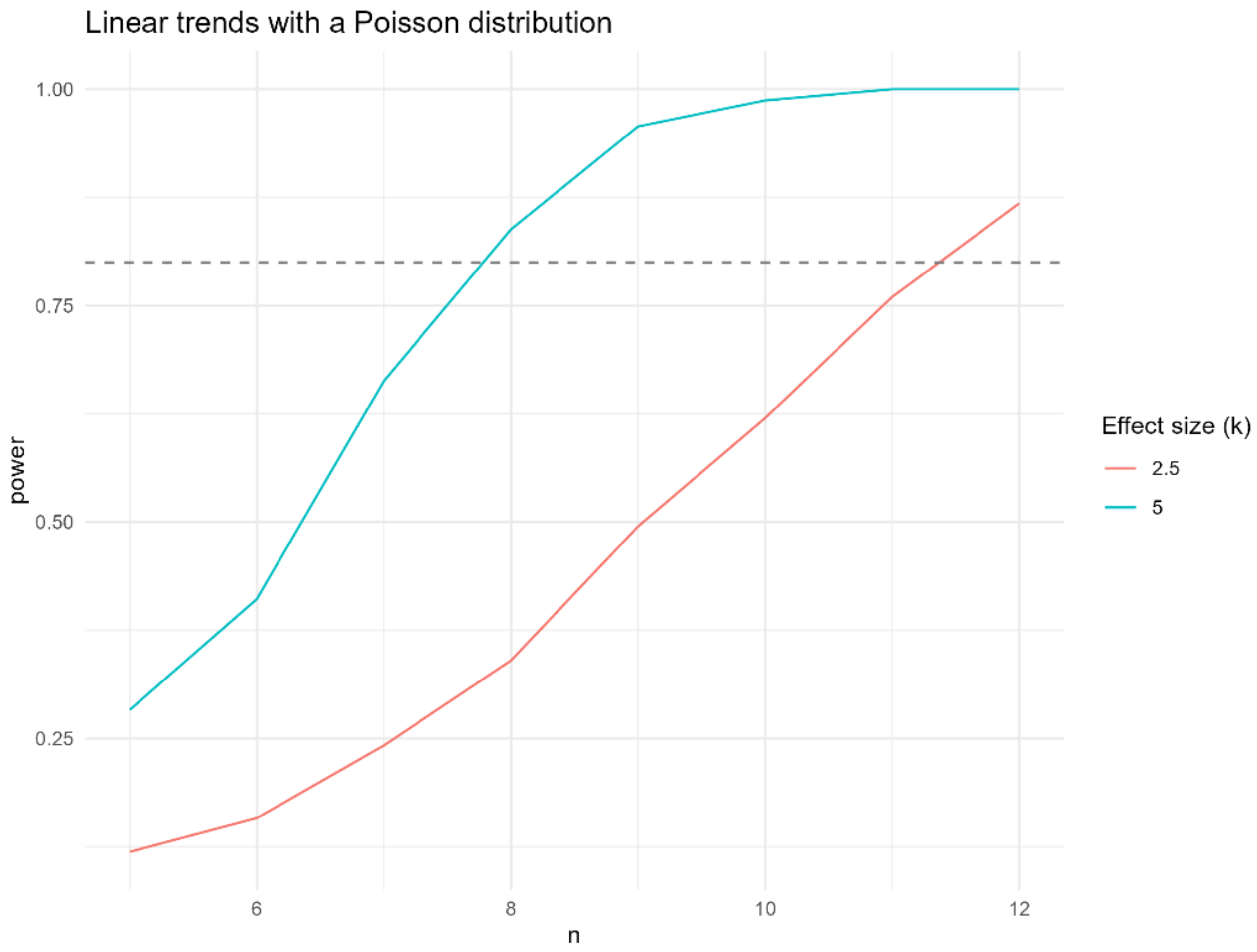

Figure A2.5. Power analyses output for a linear trend assuming data follows a Poisson distribution, The output shows the results of Monte Carlo simulations (n = 1,000) for two different effect sizes using a simulated dataset (see Section 4.2 for a description of the power analyses). An effect size (k) of 2.5 is equivalent to a change in habitat class over 10 years, while an effect size of 5 is equivalent to a change in habitat class over 5 years. Power is the probability of rejecting the null hypothesis of no trend when a true trend was present, with the dashed horizontal line representing the 0.8 threshold required to detect a significant trend. n is the number of data points available.

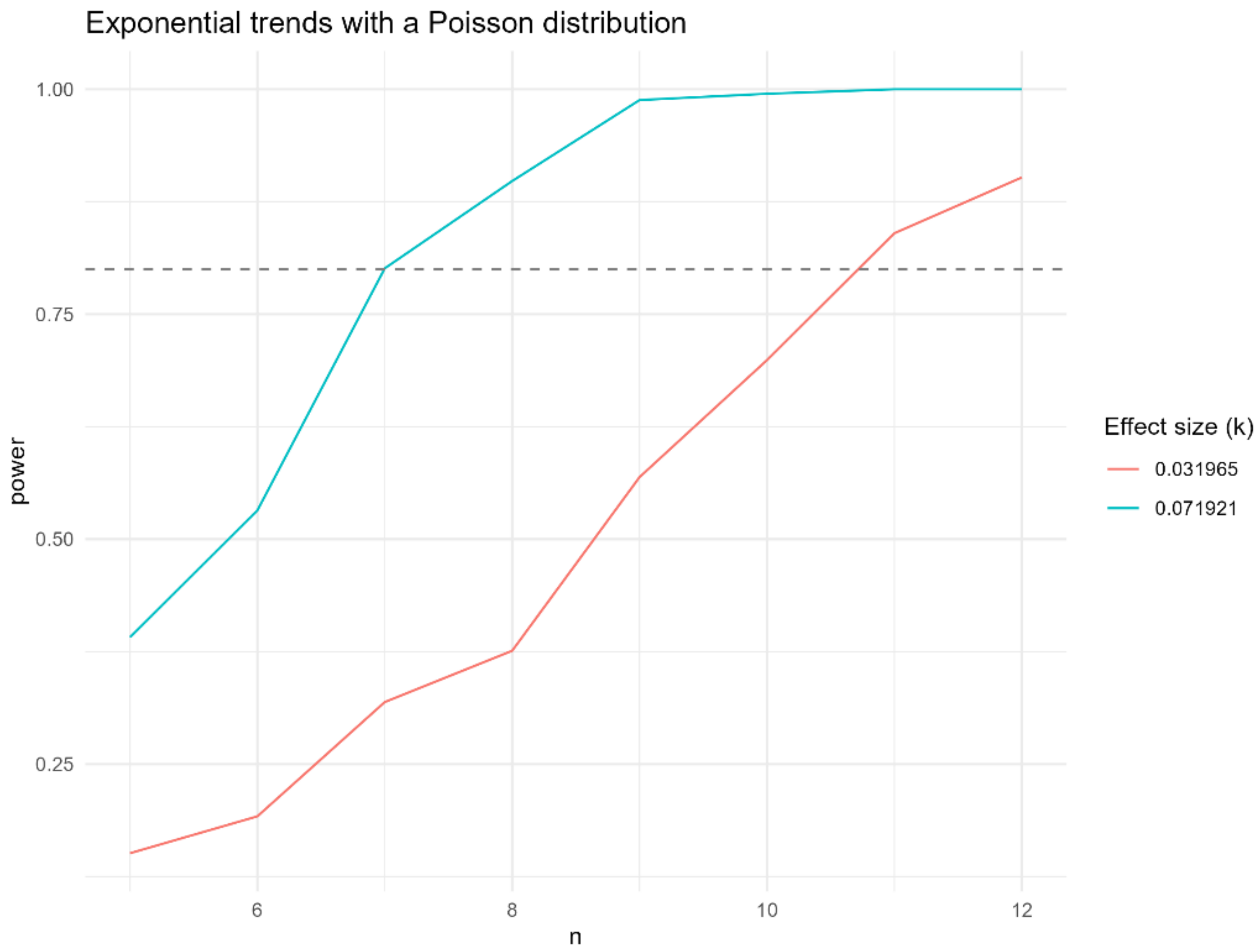

Figure A2.6. Power analyses output for an exponential trend assuming data follows a Poisson distribution. The output shows the results of Monte Carlo simulations (n = 1,000) for two different effect sizes using a simulated dataset (see Section 4.2 for a description of the power analyses). An effect size (k) of 0.031965 is equivalent to a change in habitat class over 10 years, while an effect size of 0.071921 is equivalent to a change in habitat class over 5 years. Power is the probability of rejecting the null hypothesis of no trend when a true trend was present, with the dashed horizontal line representing the 0.8 threshold required to detect a significant trend. n is the number of data points available.

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