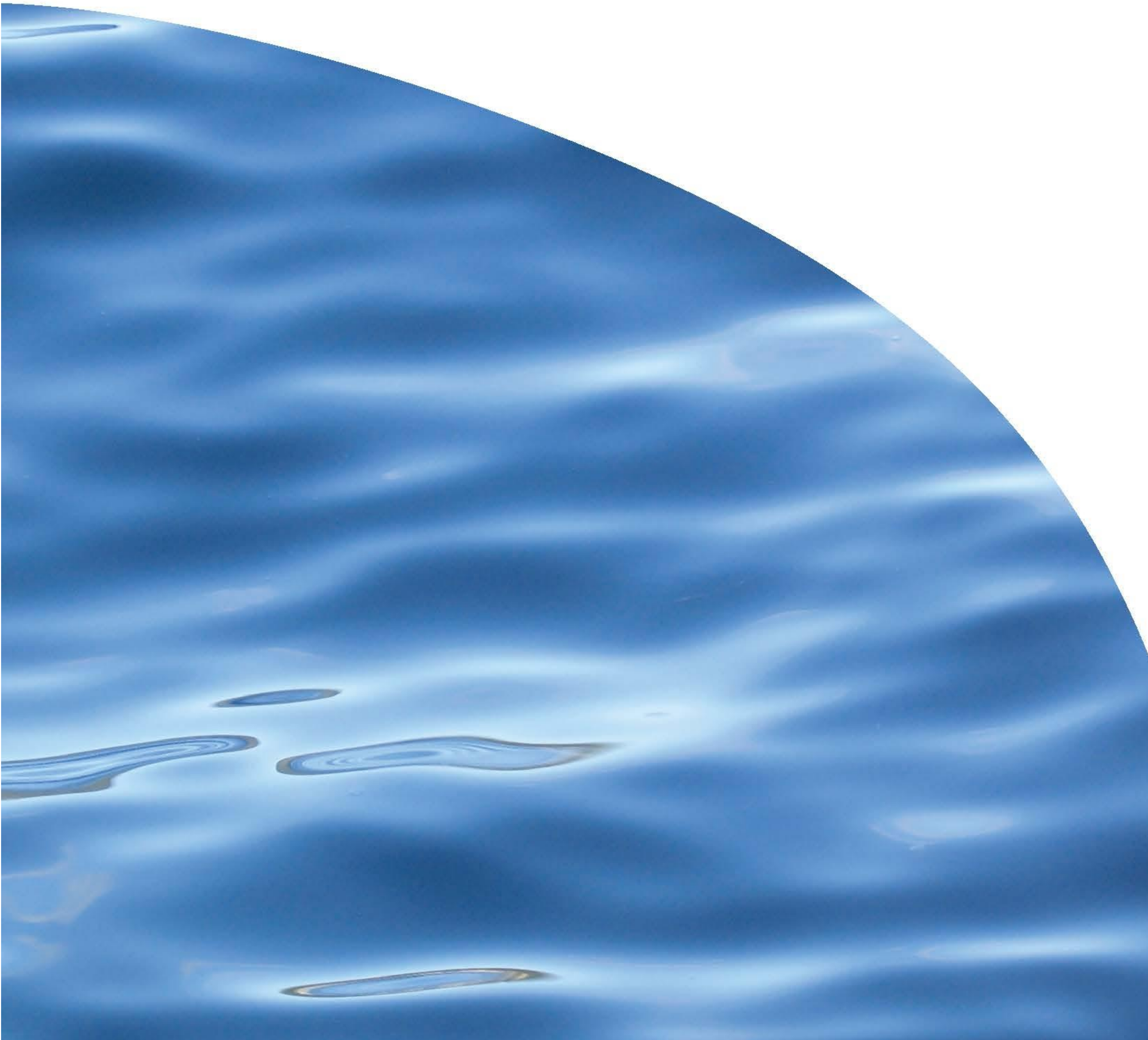
CAWTHRON INSTITUTE

REPORT NO. 2649

NATIONAL RAPID HABITAT ASSESSMENT PROTOCOL DEVELOPMENT FOR STREAMS AND RIVERS



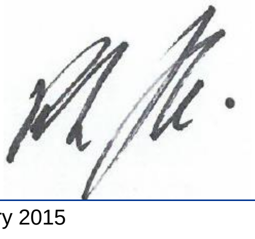
NATIONAL RAPID HABITAT ASSESSMENT PROTOCOL DEVELOPMENT FOR STREAMS AND RIVERS

JOANNE CLAPCOTT

Prepared for Northland Regional Council

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Robin Holmes



APPROVED FOR RELEASE BY:
Roger Young

ISSUE DATE: 30 January 2015

RECOMMENDED CITATION: Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council. Cawthron Report No. 2649. 29 p. plus appendices.

EXECUTIVE SUMMARY

This report aims to advance the development of a standardised national rapid habitat assessment protocol for rivers and streams. It summarises the analysis of trial data collected by Regional Council and Department of Conservation staff during routine monitoring in 2013 / 2014. The report was funded by Envirolink medium advice grant 1519.

A draft protocol containing nine parameters was trialled at 560 sites throughout New Zealand. Correlation analysis showed strong relationships between some parameter scores and measured visual or modelled estimates of stream habitat characteristics. For example, shade scores were validated by site measures of shade (r_s = 0.84, n = 64), and invertebrate habitat scores were validated by invertebrate community metrics (MCI: r_s = 0.52, n = 494). There was insufficient data to validate some parameters. Total scores were strongly related to catchment-scale measures of percent native vegetation cover (r_s = 0.46, n =553), percent impervious cover (r_s = -0.35, n = 553) and land-use intensification (r_s = -0.52, n = 553). Total scores were also related to descriptors of environmental variability supporting the use of a comparison to reference approach for reporting final scores as a percentage of reference scores. Overall, correlation results suggest that the draft protocol likely includes a good range of parameters that together provide a representative assessment of stream habitat quality.

Inter-user variability was investigated at 17 sites and results showed general consistency among users but highlighted that some parameter assessments were subject to high variability. Total scores were on average within 15% of each other.

User feedback was incorporated into an amendment of the draft protocol. Specifically, feedback on the scoring and wording of habitat parameters was considered and these changes to the protocol resulted.

1. Focus on numerical assessments of parameters to inform parameter scores, which minimises subjectivity.
2. Change the range of scores from 1–20 to 1–10. User feedback and literature review suggests that seven (or more) categories are sufficient.
3. Reinstate invertebrate and fish abundance and diversity as distinct parameters to allow the separate assessment of components. This approach was suggested by the initial working group and supported by data analysis.
4. Exclude human effects, such as channel alteration or the presence of fencing to ensure the stream habitat quality score can be robustly related to causes, rather than incorporating them.

The resulting protocol provides a ‘habitat quality score’ (HQS) and the future development of a separate habitat modification assessment is recommended, as is the case with comparable river assessment protocols overseas.

The recommended HQS is informed by the following 10 parameters scored 1–10. The total maximum score is 100. However, the total score could be scaled to a reference score to provide a % HQS for reporting.

- Deposited sediment
- Invertebrate habitat diversity
- Invertebrate habitat abundance
- Fish cover diversity
- Fish cover abundance
- Hydraulic heterogeneity
- Bank erosion
- Bank vegetation
- Riparian width
- Riparian shade

The habitat quality score protocol:

Habitat parameter	Condition category										SCORE
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulance, backwater. Presence of deep pools score higher.*										
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										
Left bank AND Right bank	*Mature native trees with diverse and intact understorey*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. RAPID HABITAT ASSESSMENT DEVELOPMENT

1.1. Background

The Stream Habitat Assessment Protocols (SHAP; Harding *et al.* 2009) provide a set of standardised protocols for the assessment of physical habitat in New Zealand waterways. The provision of a 'scoring' system to rank sites based on the degradation of physical habitat was not part of the SHAP development.

In the absence of a standardised protocol, regional councils continued to use a wide range of rapid habitat assessment (RHA) protocols providing a habitat 'score'. A review identified that eight differing RHAs were in use throughout the country with varying temporal consistency (Clapcott 2012).

A workshop was convened in September 2013 to address the lack of RHA protocol standardisation. The output of the workshop was the development of a draft national RHA protocol to be tested nationally in the summer of 2013 / 2014 (Clapcott 2013). The draft protocol contained nine distinct parameters that were chosen by the working group.

In August 2014, Northland Regional Council secured Envirolink funding to collate and analyse the RHA test data and associated feedback as part of the further development of a national RHA protocol.

1.2. Scope

This project includes:

1. Collation of data from all councils who trialled the draft national rapid assessment protocol during summer 2013 / 2014.
2. Analysis of trial data to identify strengths and redundancies among parameters with an aim to refine the draft protocol.
3. Refinement of the protocol taking into account both results from data analysis and suggestions / comments from all parties involved in the trial.

2. NATIONAL DATA SET

2.1. Collation of data

The draft RHA was trialled by staff from eight regional councils as well as the Department of Conservation at 560 sites during the 2013 / 2014 summer monitoring period. Of those sites, 553 had spatial identifiers that located sites throughout New Zealand (Figure 1).

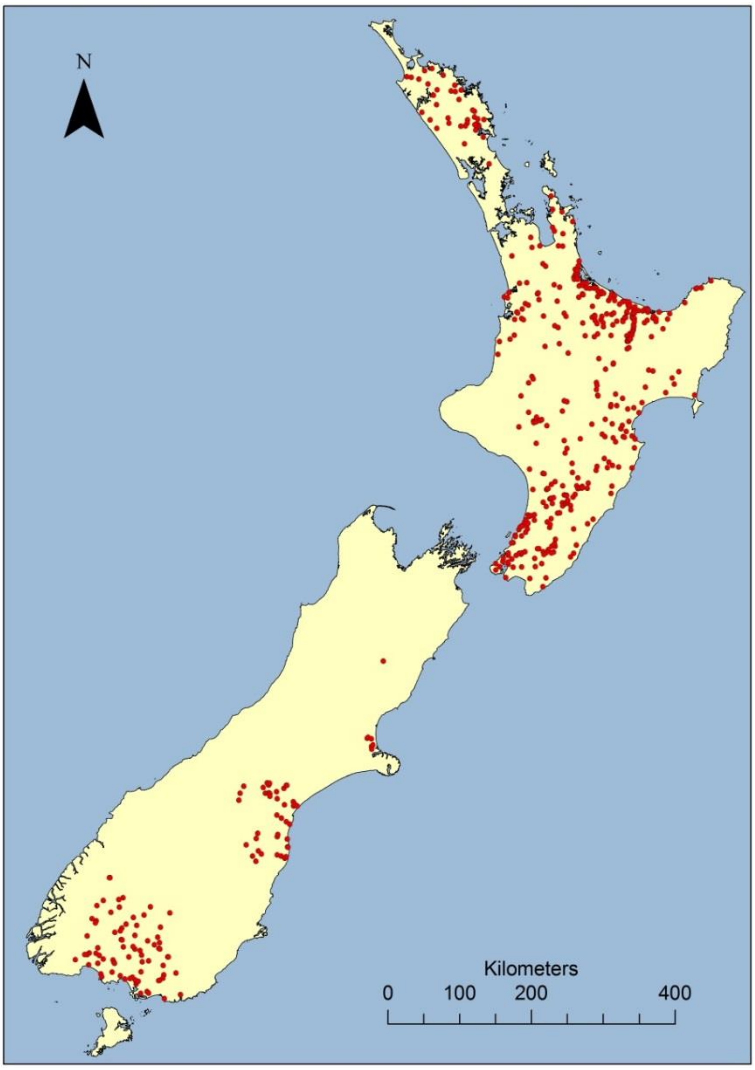


Figure 1. Location of rapid habitat assessment (RHA) trial sites.

2.2. Analysis of data

This investigation involved looking at relationships between the draft RHA parameter scores, environmental descriptors and other measures of stream health as a means to 'validate' subjective scores.

2.2.1. Data distribution

Firstly, the distribution of RHA scores was examined to determine the suitability of linear methods for comparison. The distribution of parameter scores illustrates the bounded nature of index scores (*i.e.* between 0 and 20) and the tendency of some scores to trend towards one end of the range (*i.e.* log-normal distribution). Total scores were all normally distributed (Figure 2), including:

- Total RHA as an average of all nine parameter scores (min = 19, 25th % = 89.5, median = 115, 75th % = 137, max = 180)
- Total RHA weighted as an average of all nine scores with parameters 2 and 3 weighted by *2 (min = 25, 25th % = 108.5, median = 142, 75th % = 168.5, max = 220)
- Total RHA % as a percentage of the maximum score (min = 1, 25th % = 50, median = 64, 75th % = 75, max = 100)

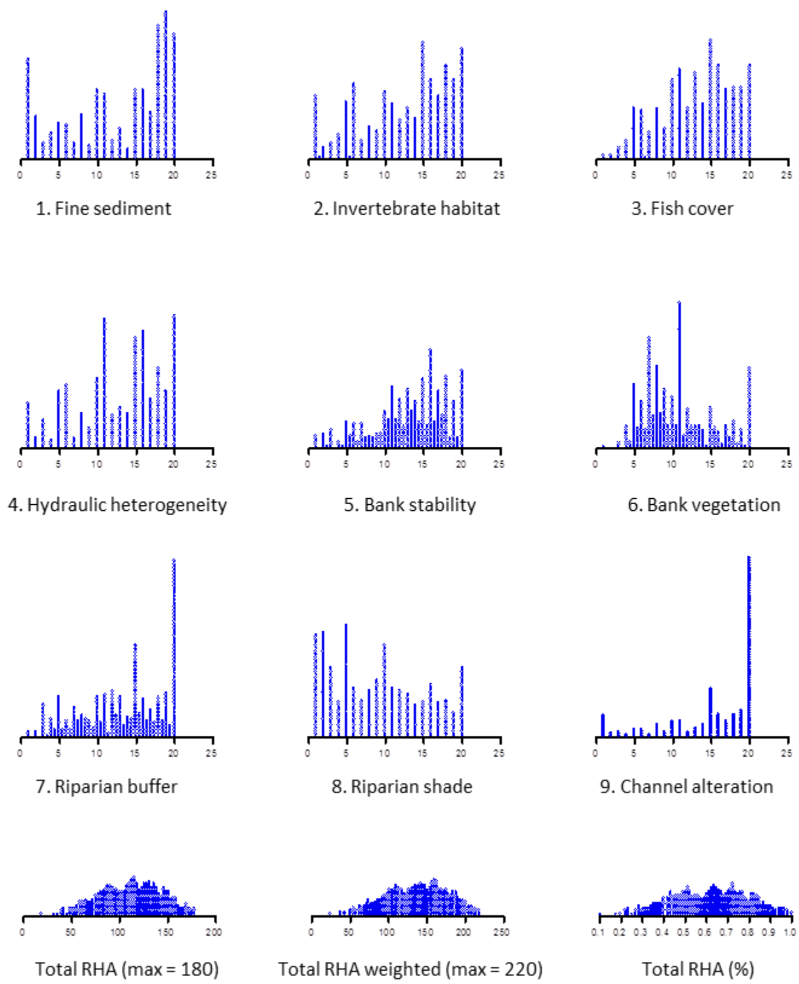


Figure 2. Distribution of data for nine parameter scores and total rapid habitat assessment (RHA) scores. N = 553.

Parameter scores were halved to simulate the use of a 1–10 instead of a 1–20 range. Numbers were truncated to whole numbers (*e.g.* 6.75 randomly assigned 6 or 7) and numbers less than 1 rounded up to 1. The distribution of data for a 1–10 range mirrors that seen previously for a 1–20 range (Figure 3).

Because distributions were either normal or log-normal, Spearman rank correlations were used to examine the relationships among parameter scores and environmental descriptors and other stream health indicators. Analyses were repeated using 1–10 scores and results are included in Appendices 1–3.

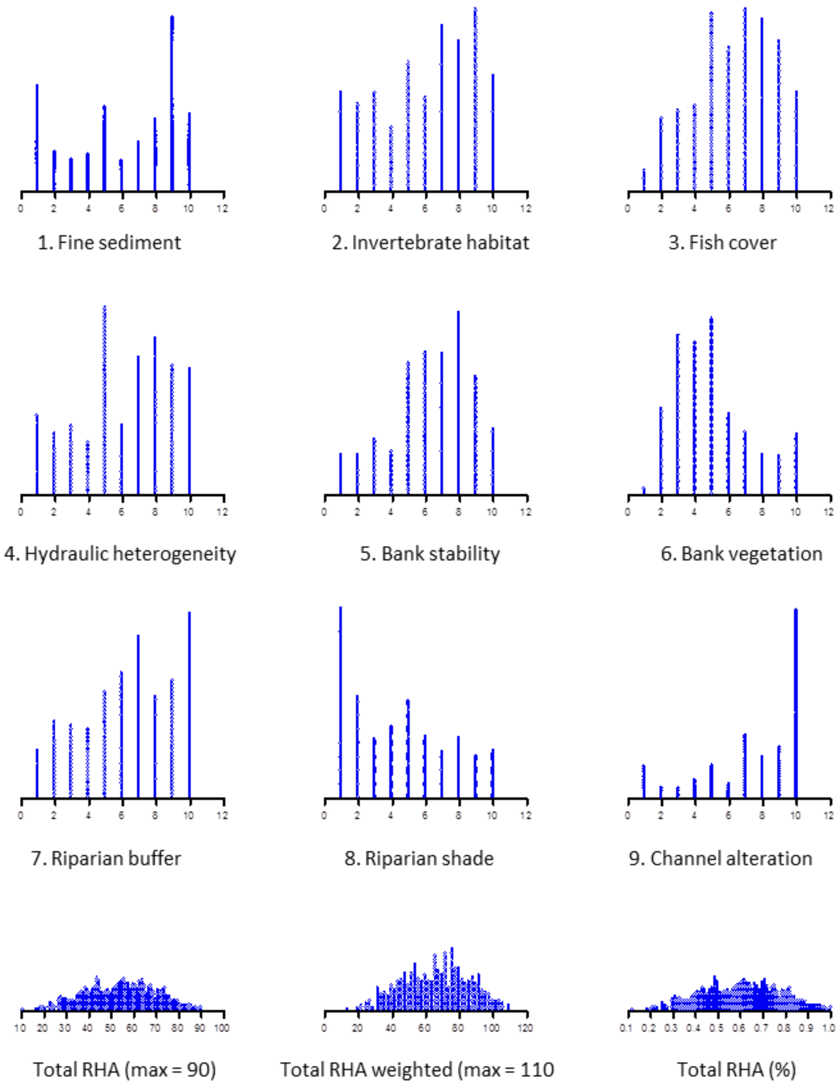


Figure 3. Distribution of data for nine parameter scores and total rapid habitat assessment (RHA) scores assuming a 1–10 ordinal scale. N = 553.

2.2.2. Correlations among parameters

The draft RHA parameters were chosen to represent distinct structural and functional aspects of a stream environment (Clapcott 2013). However, some parameters were predicted to be more closely related than others. For example, hydraulic heterogeneity scores were predicted to correlate well with fish cover. Likewise, riparian buffer width was expected to correlate well with riparian shade.

Scatterplots illustrate the relationships among parameters (Figure 4). The highest correlation coefficients were observed between bank vegetation and riparian buffer width (P6:P7, r_s = 0.72), Fine sediment and invertebrate habitat (P1:P2, r_s = 0.64) and invertebrate habitat and hydraulic heterogeneity (P2:P4, r_s = 0.58). With the number of sites (N) greater than 500, the critical value for significant relationships between parameters is r_s = 0.15 (p< 0.001). As such, all pairings were statistically significant, except fine sediment and riparian shade (P1:P8, r_s = -0.04) and hydraulic heterogeneity and riparian shade (P4:P8, r_s = 0.14).

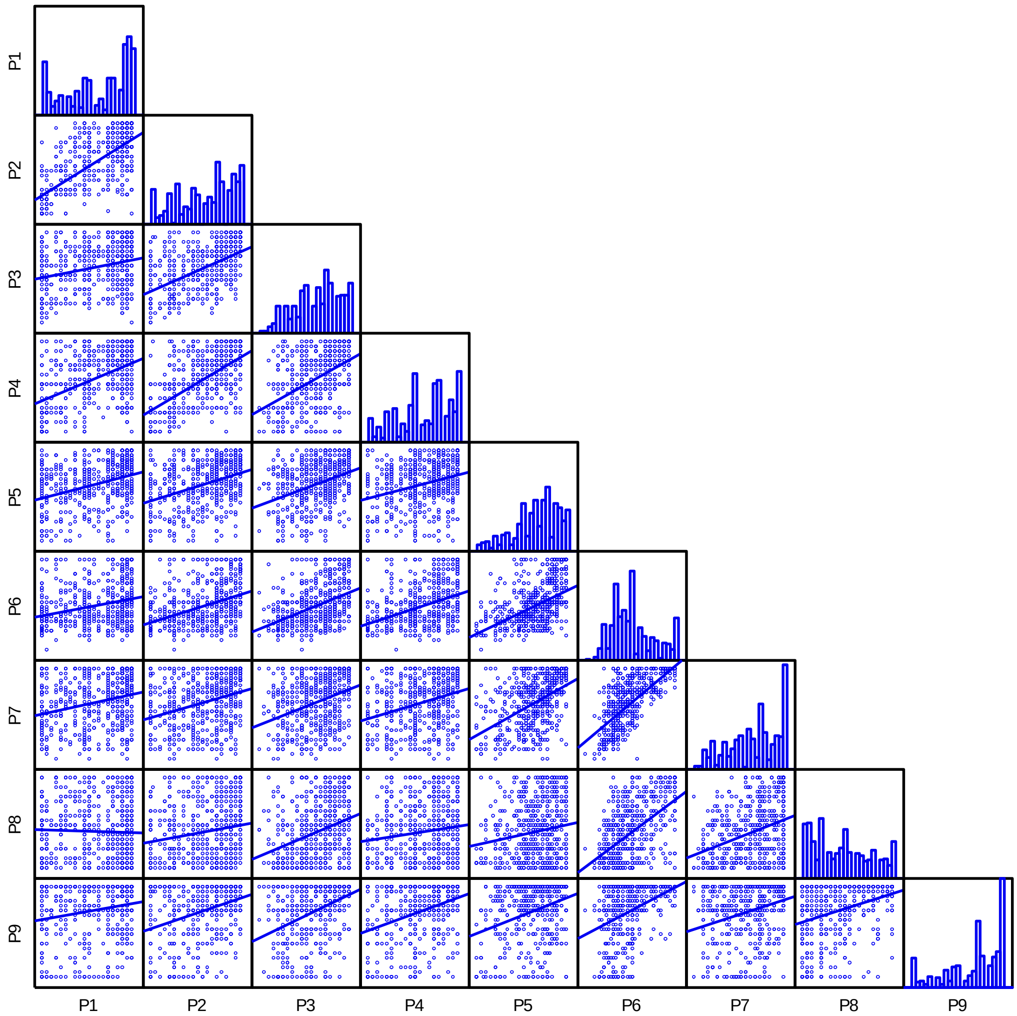


Figure 4. Correlations among rapid habitat assessment (RHA) parameters including a linear line of best fit.

All parameters were also significantly correlated with the Total RHA score with coefficients ranging from r_s = 0.50 (P8) to r_s = 0.78 (P6).

2.2.3. Correlations with other stream variables

Regional council environmental monitoring data was collated for sites where the RHA was trialled. Data included measures of invertebrate and fish communities and physical habitat variables (Table 1). Additionally, geographic information for each site from the FENZ (Freshwater Ecosystems of New Zealand) database (Leathwick *et al.* 2010) was compiled including measures of catchment land use and estimates of physical stream habitat. Rapid habitat assessment parameter scores were compared to relevant variables measured at the same site.

Table 1. Number of sites where draft rapid habitat assessment (RHA) was trialled and additional measures of stream health and physical stream habitat were collected in 2013 / 2014.

	Site no.	Fine sediment	Invertebrates	Fish	Habitat heterogeneity	Bank undercut	Fenced	Shade
Department of Conservation	13	13		12				12
Environment Bay of Plenty	131	69	122		104	128	103	
Environment Canterbury	50	1	49					
Environment Southland	80	72	73				69	
Greater Wellington	55	55	55		54			
Hawkes Bay	49		30					
Horizons	81	80	72					
Northland	39	33	39	9				
Waikato Regional Council	55	55	54	22	55		55	52
Total	553	378	494	43	213	128	227	64

1. Fine sediment deposition

Fine sediment cover of the streambed was measured by regional councils using either a bankside visual estimate (SAM1) or in-stream visual estimate (SAM2) (Clapcott *et al.* 2011). There was a strong correlation between RHA sediment scores (P1) (range 1–20) and sediment cover estimates (range = 0–100) (Figure 5). There was a weaker, yet significant, correlation between P1 scores and modelled predictions of segment-scale substrate size (range = 1.0-5.1) and modelled predictions of segment-scale average percentage of fine sediment cover (range 1 = 99; predictions of less than 1 were rounded to 1) from the FENZ database (Clapcott *et al.* 2011; Figure 5).

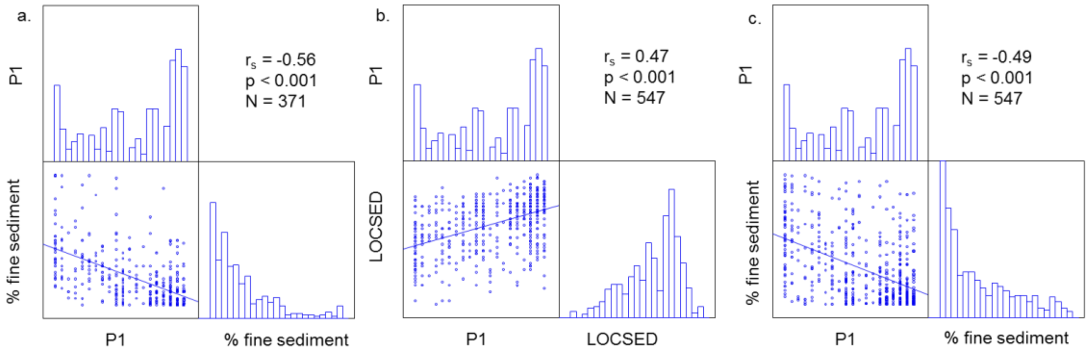


Figure 5. Relationship between P1 scores and a. field estimates of fine sediment cover, b. modelled estimates of average segment-scale substrate size (LOCSED) and c. modelled estimates of average segment-scale percentage of fine sediment cover

2. Invertebrate habitat

Invertebrate community data was collected by regional councils using standard methods (Stark *et al.* 2001) from 495 sites where the RHA was trialled. Calculated community indices included:

- Number of macroinvertebrate taxa (no.taxa)
- Percentage of taxa belonging to the orders Ephemeroptera, Plecoptera and Trichoptera (% EPT taxa)
- Macroinvertebrate community index (MCI) score

All correlations between the RHA invertebrate community scores (P2) (range = 1–20) and invertebrate indices were positive (Figure 6); the strongest relationship observed was between P2 and MCI (range = 49-151), then no. of taxa (range = 4-37), then % EPT taxa (range = 0-80).

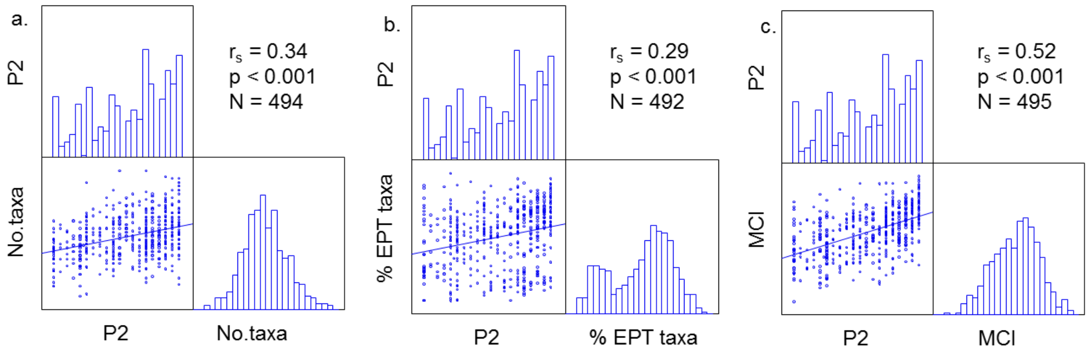


Figure 6. Relationship between P2 scores and measures of a. number of taxa, b. % EPT (% taxa of the orders, Ephemeroptera, Plecoptera and Trichoptera), and c. macroinvertebrate community index (MCI) score.

3. Fish cover

Fish community data was collected by regional councils and Department of Conservation staff at 61 sites in the Northland, Waikato and Southland regions. Sampling methods included a combination of electrofishing and netting. Calculated community indices included the number of fish taxa (no. of taxa; range 0–9), the percentage of fish taxa being exotic (% exotic; range 0–100), and c. estimates of fish abundance (range 0–198)[1]. There were no significant correlations between the RHA parameter assessing fish cover (range 1–20) and indices of fish communities (Figure 7).

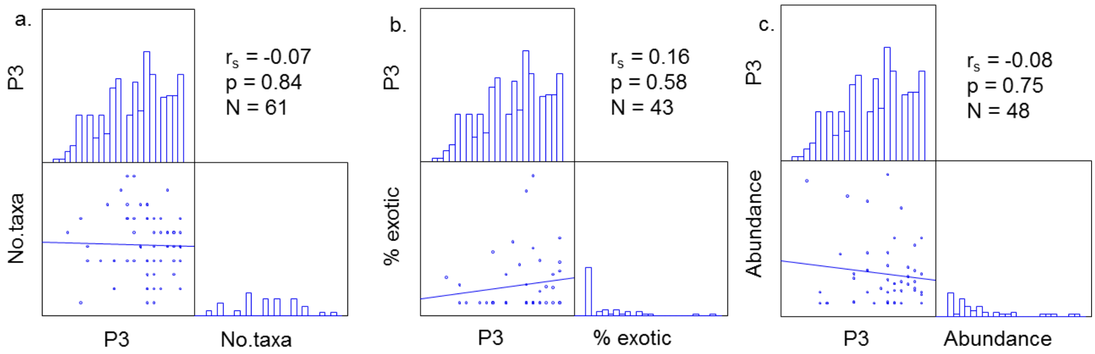


Figure 7. Relationship between P3 scores and measures of a. number of fish taxa, b. % exotic fish taxa, and c. estimates of fish abundance.

4. Hydraulic heterogeneity

The number of differing hydraulic habitats was counted at 213 sites by regional council staff following the P2b protocol (Harding *et al.* 2009). There was no relationship between counts (range 1–6) and the RHA parameter scoring hydraulic heterogeneity (P4) (range 1–20) (Figure 8). However, there was a significant correlation between P4 scores and modelled estimates of segment-scale average flow habitat score (where higher scores reflect faster flowing water; range 2.3–4.6) from the FENZ database (Leathwick *et al.* 2010).

[1] Estimates of fish abundance were scaled to the highest number when recorded as ‘greater than’ in data files and only data from single pass electrofishing was included.

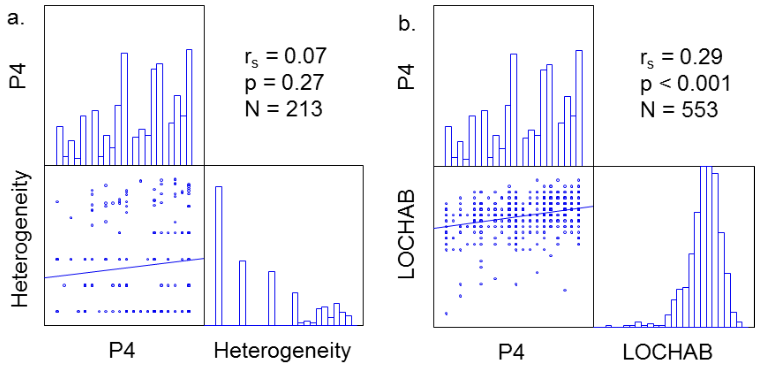


Figure 8. Relationship between P4 scores and a. counts of hydraulic habitats, and b. modelled estimates of segment-scale average habitat variability.

5. Bank stability

The data available to validate the RHA parameter assessing bank stability (P5) was a measure of bank undercutting in metres recorded at 128 sites in the Bay of Plenty region. There was no significant correlation between P5 (range 3–20) and bank undercutting (range 0–2) at those sites (Figure 17).

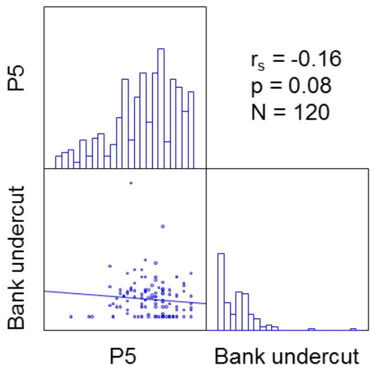


Figure 9. Relationship between P5 scores and measures of bank undercut.

6. Bank vegetation

There was no data available to validate the RHA bank vegetation parameter score.

7. Bank buffer (width)

The presence of streamside fencing was scored by regional council staff at 227 sites; 1 = not fenced, 2 = partially fenced, 3 = fully fenced. This score was related to the RHA parameter assessing the riparian buffer (P7) (range 1–20) with a significant positive correlation (Figure 10).

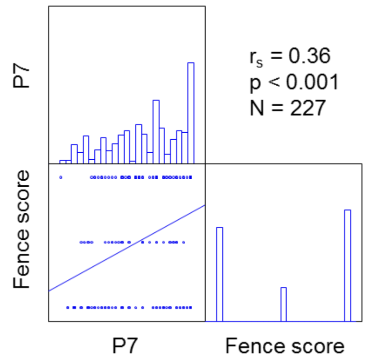


Figure 10. Relationship between P7 scores and 1–3 scoring of site fencing status.

8. Riparian shade

Visual estimates of percentage cover of shade were made at 64 Northland or Waikato sites. There was a strong positive correlation between estimated shade cover (range 0–96) and the RHA parameter (P8) scoring shade within the wetted stream width (range 1–20) (Figure 11). The RHA parameter P8 was also correlated to modelled estimates of segment-scale riparian shade (range) from the FENZ database (Leathwick *et al.* 2010).

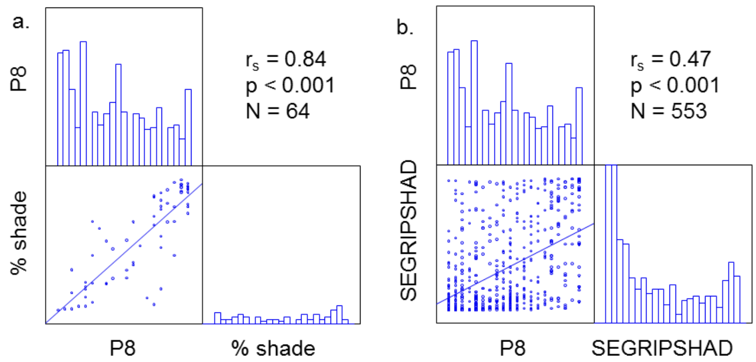


Figure 11. Relationship between P8 scores and a. field estimates of shade cover, and b. modelled estimates of segment-scale average riparian shade cover.

9. Channel alteration

There was no data available to validate the RHA channel alteration parameter score.

2.2.4. Total rapid habitat assessment scores and catchment land use and natural descriptors

A RHA total score is the sum of the nine RHA component scores. This score represents the overall state of stream habitat at a site. The physical characteristics of a stream are determined by land use and its interaction with a range of natural factors, such as geology, topography and climate. A useful measure of stream health should respond well to land use and be less sensitive to natural variation. We expected to see a strong relationship between RHA scores and measures of catchment land use but weaker relationships between RHA scores and natural factors (for example: geology or slope). These potential relationships were examined using the draft RHA dataset.

Total RHA scores (range 19–180) were significantly correlated to three catchment-scale land-use measures from the FENZ database (Leathwick *et al.* 2010; Figure 12), including:

- percentage of native vegetation cover (range 0–100)
- percentage of impervious surfaces (Log+1) as an indication of urban impacts (range 0–91)
- modelled nitrogen concentration (Log) as an indication of land use intensification (range 0.1–20.6).

The same relationships were observed for total RHA weighted and total RHA (%) scores.

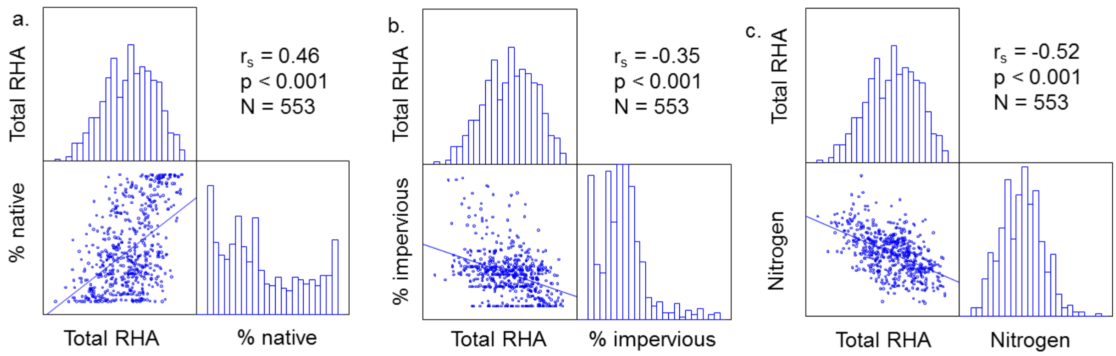


Figure 12. Relationship between total rapid habitat assessment (RHA) scores and a. catchment-scale native vegetation cover, b. log-transformed catchment-scale impervious land cover, and c. log-transformed estimated nitrogen concentration.

The total RHA score was also related to measures of natural environmental variability from the FENZ database including positive correlations with segment-scale average slope (range 0–8.3), upstream average slope (range 0.1–30.2) and downstream maximum slope (range 0–30.3) (Figure 12). This suggests that steeper streams have higher RHA scores, but that the position in the stream network is important, *i.e.* segments sufficiently upstream to accommodate steep drops such as waterfalls or rapids downstream as indicated by downstream maximum slope. Total RHA scores were also positively correlated with the number of days with high rainfall (> 25 mm) upstream (range 2.4–44.0) and negatively correlated with upstream winter temperature normalised by upstream summer temperature (negative values are typically rivers with montane headwaters; range -4.8–1.6), but not related to segment summer temperature (range 12.6–19.7) (Figure 18). These correlations suggest that wetter streams will have higher RHA scores, but again the position in the stream network is important with rivers with cooler headwaters having higher scores.

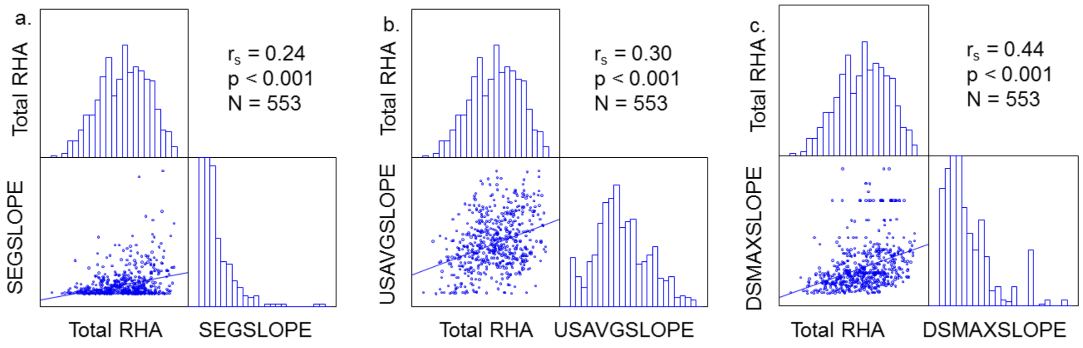


Figure 13. Relationship between total rapid habitat assessment (RHA) scores and a. segment-scale average slope, b. upstream average slope, and c. downstream maximum slope.

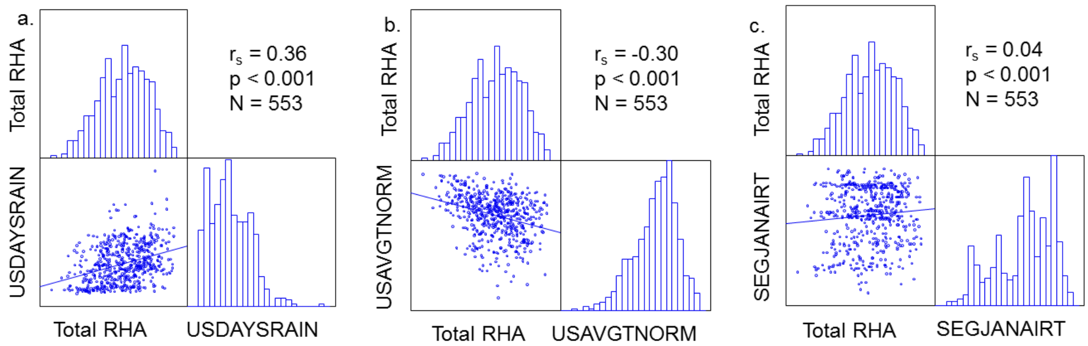


Figure 14. Relationship between total rapid habitat assessment (RHA) scores and modelled estimates of a. upstream rain days, b. upstream normalised winter temperature, and c. segment-scale summer temperature.

Total RHA scores were not correlated to estimates of mean annual flow or 7-day mean annual low flow (MALF; not shown), but were positively correlated to flow stability (the ratio of low flow to average flow, range 0.01–0.58). Total RHA scores were also correlated to segment-scale descriptors of substrate size (range 1-5.2) and flow habitat heterogeneity (range 2.3–4.6) (Figure 15). Finally, total RHA scores were also correlated to catchment-scale variables that describe the physical and chemical properties of the underlying geology, including calcium (range 0.73–2.86), phosphorus (range 0.97–4.0), and hardness (range 1–4.55) (Figure 16). These results suggest that geological setting may influence RHA scores with harder geologies with less phosphorus and/or calcium concentrations having higher scores.

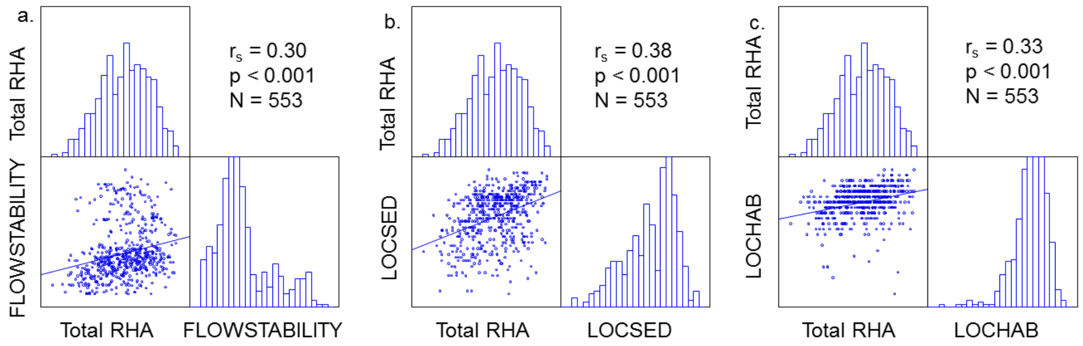


Figure 15. Relationship between total rapid habitat assessment (RHA) scores and modelled estimates of a. flow stability, b. segment-scale average substrate size, and c. segment-scale average habitat heterogeneity.

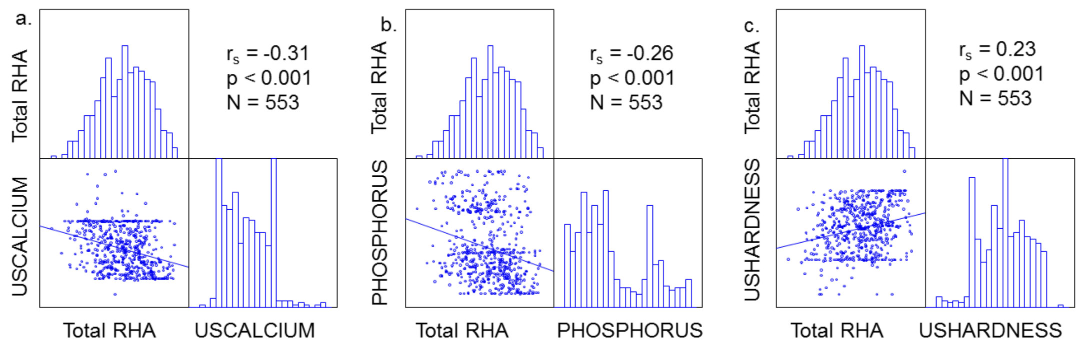


Figure 16. Relationship between total rapid habitat assessment (RHA) scores and catchment-scale descriptors of geological a. calcium, b. phosphorus, and c. hardness.

2.3. Summary of findings

The distribution of some parameter scores were skewed indicating the possibility of bimodal distributions. Most notably, 41% of all sites had no channel alteration (that was visible at the site scale) resulting in a channel alteration parameter 9 score of 20. It may be that a large proportion of surveyed sites were unaffected, or that channel alteration was difficult to assess at the site scale. Either way, results do not support the inclusion of this parameter in a total RHA score. Similarly,

- 17% of sites were fully fenced with > 15 m riparian buffers, resulting in a riparian outlier parameter score of 20
- 18% of sites had less than 5% shade resulting in a riparian shade parameter score of 1 or 2
- 9% of sites had > 75% fine sediment cover resulting in a fine sediment parameter score of 1.

However, these smaller proportions seem acceptable.

Fine sediment parameter cover scores were validated by visual sediment assessments and invertebrate parameter scores were validated by measured invertebrate metrics; suggesting both these qualitative assessments are well worded and should be retained.

The fish cover parameter scores were not correlated to measured fish metrics. This may reflect the limited fish dataset available for validating scores (n = 61). Alternatively, broader catchment-scale habitat characteristics, which are not accounted for in the RHA, may have an overriding influence on stream fish populations (*e.g.* Roni *et al.* 2008). Nevertheless, studies where fish populations are correlated to local habitat characteristics have demonstrated the importance of spatial complexity (McEwan & Joy 2013), suggesting that this should be the focus of the fish cover parameter.

Hydraulic habitat parameter scores were not validated by visual counts of flow types suggesting this parameter could benefit from further refinement. Not surprisingly, the bank stability parameter score did not correlate to measures of bank undercutting because the bank stability parameter focuses on proportions of erosion rather than scalar measures of bank undercutting. [Proportions could be recorded and translated to scalar measures if the survey reach length was recorded.]

Riparian buffer width parameter scores were higher at sites that were fenced and riparian shade parameter scores were validated by visual assessments of shade cover, supporting the inclusion of these two parameters. There was no data to validate bank vegetation or channel alteration.

The inclusion of nine parameters resulted in a total RHA score that was correlated to land use, but also related to environmental descriptors that vary naturally, such as slope, climate and geology. These later relationships support the comparison to a reference condition for specific stream types, *e.g.* low gradient streams compared to a lower gradient reference site and the % score reported.

3. INTER-USER VARIABILITY

3.1. Data analysis

The RHA protocol was trialled at 17 sites in the Southland region by different users. Each site was visited by two or three users completing an assessment on different days between February and July 2014. Parameter and total scores were compared among users (all data distributions appeared relatively normal and so were examined without transformation).

Total scores (by un-weighted sum where the maximum = 180) ranged from 19 to 168 at the surveyed sites (Figure 17) suggesting a wide range in stream habitat quality. Inter-site variability in total scores ranged from 2 (site 9) to 86.5 (site 11). On average, inter-user variability resulted in a 24.5 point difference in site scores. There was no trend to suggest sites with higher or lower total scores were subject to more or less inter-user variability. Results suggest that total scores would need to differ by more than 15% to be detectable by varying users.

Figure 17. Ranges in the total rapid habitat assessment (RHA) score observed at 17 surveyed sites in the Southland region. Boxes represent the range between two users (rectangles without tails) or three users (rectangles with tails) at each site.

At sites with greatest inter-user variability in total scores (*e.g.* sites 3, 10, 11), there was greatest disparity in parameter scores for fish cover, riparian buffer/shade and channel alteration (Figure 18); parameters that are unlikely to be affected by the temporal disparity between surveys.

Across all sites, some parameter scores had greater inter-user variability than others. For example, users were most consistent in their appraisal of invertebrate habitat and bank vegetation and least consistent for hydraulic heterogeneity and bank stability (Figure 18, Table 2). It may also indicate that the wording of some parameters may be ambiguous leading to wider interpretation. This was taken into consideration when rewording the protocol.

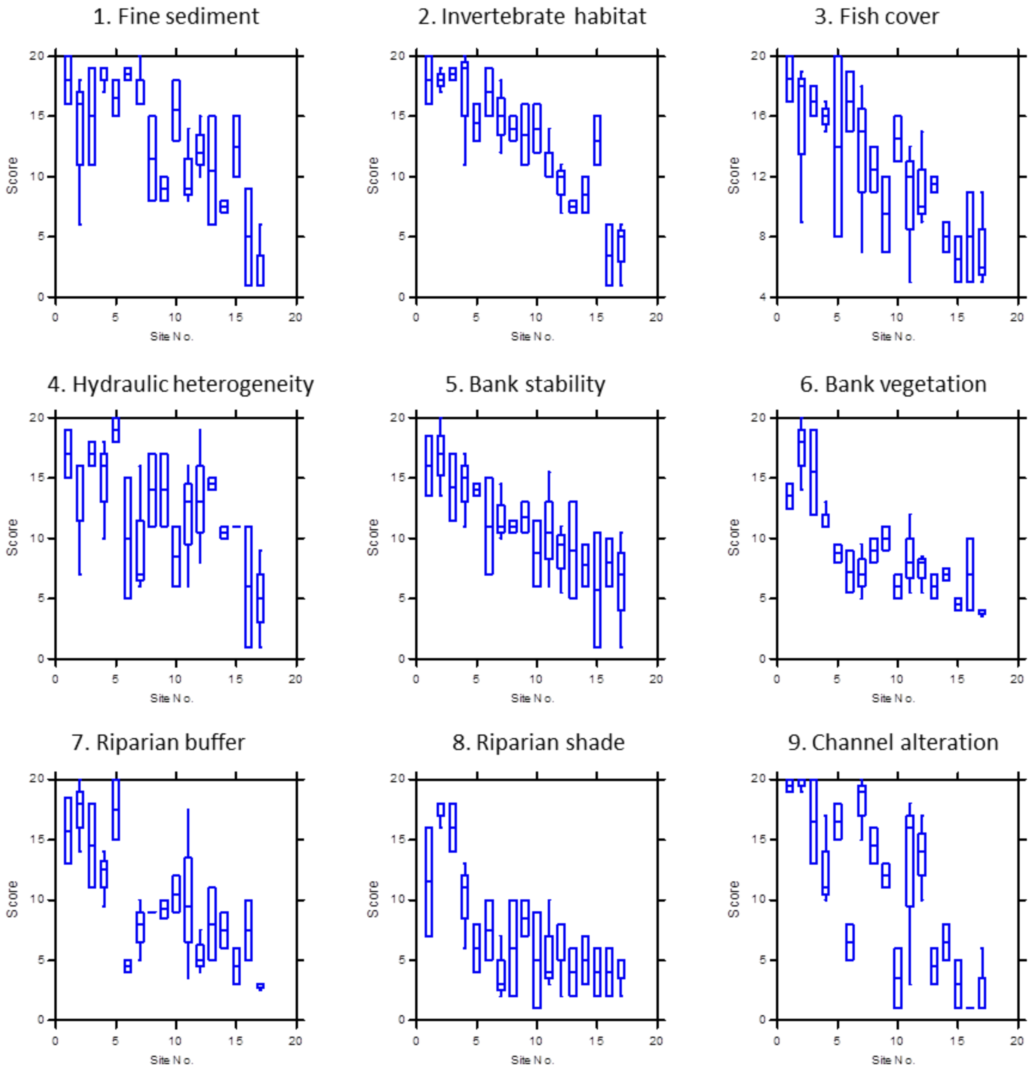


Figure 18. Ranges in scores of rapid habitat assessment (RHA) parameters observed at 17 surveyed sites in the Southland region. Boxes represent the range between two users (rectangles without tails) or three users (rectangles with tails) at each site.

Table 2. Average range in rapid habitat assessment (RHA) parameter scores observed among users at 17 sites in the Southland region. See Figure 18 for parameter descriptors.

		Parameter									
Site	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
1	3	4.0	4.0	3.0	4.0	5.0	2.0	5.5	9.0	1.0	13.5
2	3	12.0	2.0	10.0	9.0	6.5	6.0	6.0	2.0	1.0	38.0
3	2	8.0	1.0	2.0	2.0	5.5	7.0	7.0	4.0	7.0	41.5
4	3	2.0	9.0	2.0	8.0	6.0	2.0	4.5	7.0	7.0	22.5
5	3	3.0	3.0	12.0	2.0	1.0	1.5	5.0	4.0	3.0	20.5
6	2	1.0	4.0	4.0	10.0	8.0	3.5	1.0	5.0	3.0	21.5
7	2	4.0	6.0	11.0	10.0	4.5	4.5	5.0	5.0	5.0	30.0
8	2	7.0	2.0	3.0	6.0	1.0	2.0	0.0	8.0	3.0	8.0
9	2	2.0	5.0	5.0	6.0	2.5	2.0	1.5	3.0	2.0	2.0
10	2	5.0	4.0	3.0	5.0	5.5	2.0	3.0	8.0	5.0	34.5
11	3	6.0	4.0	9.0	10.0	9.5	6.5	14.0	7.0	15.0	73.5
12	3	5.0	4.0	6.0	11.0	5.5	3.0	3.5	6.0	7.0	20.0
13	2	9.0	1.0	1.0	1.0	8.0	2.0	6.0	4.0	3.0	13.0
14	2	1.0	3.0	2.0	1.0	3.5	1.0	3.0	4.0	3.0	17.5
15	2	5.0	4.0	3.0	0.0	9.5	1.0	3.0	4.0	4.0	15.5
16	2	8.0	5.0	6.0	10.0	4.0	6.0	5.0	4.0	0.0	14.0
17	2	5.0	5.0	6.0	8.0	9.5	0.5	0.5	3.0	5.0	30.5
Mean		5.1	3.9	5.2	6.1	5.6	3.1	4.3	5.1	4.4	24.5

3.2. Summary of findings

Without training, inter-user variability resulted in scores having to be 15% different to detect a real difference. Training and experience should reduce this amount. Likewise, the use of a more prescriptive way to assign scores rather than subjective interpretation of terminology could also reduce inter-user variability.

Inter-user variability was least for invertebrate habitat and bank vegetation and greatest for the parameters hydraulic heterogeneity and bank stability. This suggests the later parameters would benefit from further refinement.

4. USER FEEDBACK

Comments were collated to identify potential improvements to the draft protocol. Comments generally grouped into three categories: those concerning training and field application; those concerning wording of attributes; and, those concerning the scoring of attributes and overall site assessments.

4.1. Application and training

Examples of feedback:

"*our only problem is that it does not deal with soft bottom streams*"

"*I feel there needs to be some sort of process/guidance to establish what the natural state is: upland/lowland, hard/soft bottom, pristine/intense landuse, periphyton/macrophyte dominant*.'

"*I think it is very important to have two separate protocols for lowland / hill country (soft / hard bottomed…), it seems impossible to combine them: it leads to endless discussions in the field.*"

"*I'd prefer the scaling compared to reference / minimum human influence condition, as it is a stable baseline to judge against that doesn't change with changing values / perceptions / perspectives / knowledge*."

"*The sheet itself is very busy to look at and maybe I simply missed sections by mistake, make it clearer or defining sections so that the users can easily see where they are up to.*"

"*() thought an app would be a good thing … especially if it scrolled through each section with a next button so you didn't miss stuff*"

It is apparent from the feedback that the scope of the habitat assessment needs to be clearly defined. As previously outlined, a comparison to reference approach is preferred. However, the reference condition will vary for different stream types. An observed *vs*. expected (O / E) approach can be achieved by grading resulting scores by comparing to reference scores. For example, the score at a relevant reference site may be 88 and therefore the observed score at a test site (*e.g.* 70) would be divided by the expected score at the reference site to provide a O / E score: 70 / 88 = 0.8 or 80%.

4.2. Wording of attributes

"*Suggest a photo guide for better estimate of categories*"

"*some of the questions seemed to have a very narrow focus meaning they were only relevant to specific types of river*"

"*macrophyte growth is always weighted negatively, whereas it often provides a good and different habitat type for both inverts and fish*"

"*Similarly, the ultra clean streams without any periphyton growth will have a low abundance of grazing inverts (i.e. a lot EPT taxa), so a little bit of periphyton is not always a bad thing either*."

"*Fine sediment deposition: Fine, although it is sometimes hard to estimate looking from the surface*"

"*Bank stability: what do we do if there is artificial bank stabilisation or bedrock?*"

"Question 8 ... I think this question should be left out of the rapid assessment and perhaps just use the riparian buffer question to infer the information regarding bankside shade."

"keywords differentiating between categories would reduce risk that people focus on different words when differentiating between categories"

The draft protocol included additional sections to aid the allocation of scores in the absence of a training manual. This may have made the worksheet appear overly busy. Ideally a training manual would be compiled providing photos to further inform score allocation. Remaining feedback focuses largely on the applicability of parameters to specific steam types, which is taken into consideration when amending the protocol.

4.3. Scoring

"*Deciding on a value between 1 and 20 chews up a fair bit of time*"

"*if each question was scored out of 10 as opposed to 20 there would be less variation between the scores given by different individuals and people would feel more confident in awarding specific scores*"

"*I prefer ranking in 20 scores, as they give flexibility in considering higher or lower quality scores within a category*"

"*My main concerns with the questionnaire is the potential for different boxes to be selected ... Especially for Q's 2, 3, 4 and 7 … should we use the first question to determine which box then the next 2 questions to help determine where in that box (high or low) to put it?"*

"I also found myself trying to keep scoring relative for the streams we did which may have compromised my objectivity depending on order we did them and how pristine they were."

"*hard bottomed streams in 100% native bush were "easy", as rightly or wrongly I just scored them as maximum*."

The 1–20 scoring range per parameter was questioned. Practitioners working with community groups have also noted that a 1–20 range hinders application and hence tools such as the Waicare field manual use a range of 0–8 per parameter[2]. Using a range of 1–10 instead of 1–20 does not affect the data distribution and if anything, reduces the apparent 'noise' associated with user error (see Figure 3.). However, the error around a central tendency has been shown to be consistent regardless of the number of categories when numbers vary between 7 and 100 (Cicchetti *et al.* 1985). Previous studies have suggested that ordinal scales with less than four categories tend to be poor in terms of validity and reliability. However, both validity and reliability increase up until seven categories, beyond which there is no material increase (Preston & Colman 2000; Lozano *et al.* 2008). Furthermore, a higher number of categories can result in binomial distributions making data difficult to analyse.

A range of 1–20 was used in the draft RHA because it was most familiar to users based on the field sheets currently in use, including the United States Environmental Protection Agency (USEPA) method. But there is no evidence to suggest anything is gained by using a 1–20 range in parameter scores instead of a 1–10 range. It may be advantageous to use a 1–10 range if it minimises confusion and expedites field application. This was taken into consideration when amending the protocol.

[2] https://www.waicare.org.nz/Files/3%20-%20Field%20Manual.pdf

5. AMENDING THE PROTOCOL

Based on the findings of data validation, inter-user variability and user feedback the draft protocol was amended. Changes address parameter and total scores, the number of parameters and parameter wording.

5.1. Parameter and total scores

1. Change in scoring range:
   Literature review and the balance of feedback suggest a 1–10 range is most appropriate for a subjective scoring protocol. Data analysis confirms there is no advantage in a 1–20 range over a 1–10 range.
2. Total score as a sum of all parameters:
   Data analysis suggests there is no advantage to weighting parameters 2 (invertebrate habitat) and 3 (fish cover) in the calculation of a total score. A non-weighted score results in less confusion and errors in spreadsheet based calculations.
3. Total score as a whole number:
   The total RHA score can be expressed as a total score being the sum of parameter scores (*e.g.* RHA score = 64) or expressed as a percentage of the total possible (*e.g.* 64/100*100 = 64%). However, it makes sense to reserve the later for normalisation to a measured reference site (*e.g.* 64/71 = 90%) to avoid confusion over whether the denominator was theoretical (*i.e.* the maximum RHA score) or measured (the average RHA score measured at a relevant reference site/s).

5.2. Number of parameters

Nine parameters were included in the draft protocol. These parameters were chosen to assess physical stream attributes including the provision of 'habitat' for biota and associated functions such as the delivery/retention of sediment, nutrients, and organic matter (*e.g.* assessments of bank stability, vegetation and shade). The majority of attributes assess the state of physical stream habitat. However, parameters 7 (riparian buffer) and 9 (channel alteration) also assess human management actions. The inclusion of such in a habitat assessment score creates circularity in any analysis between cause and effect. For this reason the River Habitat Survey approach used in the United Kingdom partitions attributes into those that describe the state or 'naturalness' from those that describe human modifications. These attribute groups are used to calculate two distinct habitat scores—habitat quality assessment, and habitat modification score (Raven *et al.* 1998). It is important to quantify the presence of human pressures that shape stream habitat, but the rapid habitat assessment trialed in New Zealand seeks to describe the state of habitat, not what is causing that state. The parameter for assessing channel alterations was excluded from the protocol for the above reason. The same reasoning led to the removal of the specific assessment of the presence of fencing from the buffer width parameter.

At the workshop to select draft parameters, 11 original parameters were identified (Clapcott 2013). Invertebrate habitat diversity and abundance were combined into a single invertebrate habitat parameter in the draft protocol because it was considered difficult to subjectively assess these components separately. Likewise, fish habitat diversity and abundance were combined in a single parameter scoring fish cover, recognising that a range of fish species may utilise any / all wetted area during their lifecycle. It was suggested that these two inclusive parameters should be given extra weight to ensure the importance of invertebrate / fish habitat diversity and abundance was not diluted in the total RHA score. Analysis of data shows that the weighting of these two parameters does not significantly affect patterns in total scores. As such, given the right wording (see next section), there is no statistical reason to separate or combine these attributes. The amended protocol keeps them separate resulting in a total of 10 parameters.

5.3. Wording of parameters

Example scores were included in the draft protocol field sheet to aid users in the absence of a field manual (*e.g.* Figure 19). Feedback from users suggested these were very useful and helped clarify ambiguity with terms such as 'moderate'. However, users also gave feedback that the draft version was 'too wordy'. So numerical guidelines, rather than example scores, were included for all parameters except bank vegetation (*e.g.* Figure 20). An advantage of this approach is that if numerical estimates are recorded in addition to scores, these estimates could be used later, for example, in a suitability assessment for specific species (Holmes *et al.* 2012).

3. Fish cover	Abundant and diverse >70% fish cover in reach *and* Wide variety (≥4) of persistent fish cover providing spatial complexity such as woody debris, root mats, undercut banks, overhanging/ encroaching vegetation, macrophytes, boulders, cobbles	Common and adequate 40-70% fish cover *and* Moderate variety (3) of fish cover types providing spatial complexity; woody debris and overhanging vegetation or undercut banks score higher if persistent	Patchy and limited 10-40% fish cover *and* Limited variety (2) of fish cover types, woody debris, overhanging vegetation or undercut banks are rare; only larger cover elements are persistent	Rare or absent <10% fish cover *and* Fish cover rare or absent; few hiding places or interstitial spaces
Example score	*20 = 95% of habitat favoured by expected fish community, lots instream and bank complexity* *19 = 90%, 18 = 85%, 17 =80%, 16 = 75%*	*15 = 70% of habitat favoured by expected fish community, o/hanging veg/banks stable* *11 = 40%*	*10 = 40%, fish cover is boulders and logs in water* *6 = 10%*	*5 = 8%, fish cover is a few seasonal macrophytes instream* *1 = 0% fish cover, uniform substrate*
SCORE ___ x 2	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Figure 19. Extract from the draft rapid habitat assessment (RHA) field sheet.

4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	

Figure 20. Extract from the recommended rapid habitat quality assessment field sheet.

5.4. Amended protocol

The amended protocol is included here (Figure 21), as well as an example of a completed field sheet (Figure 22). Use of this assessment provides a habitat quality score (HQS). A Microsoft Excel ® version can be requested from the author.

It is recommended that the following protocol be applied:

Where	At state of environment monitoring sites
When	On completion of a site visit for other biological monitoring, *e.g.* invertebrate monitoring. If the protocol was applied independently of other monitoring then the field officer should walk the full length of the site prior to scoring. If site length is not previously defined then use 20 × wetted width or a minimum of 50 metres
What	All parameters
Score	Sum of 10 parameters provides a habitat quality score. This observed score can be compared to the average score from reference site(s) to provide a HQS % assessment

Habitat parameter	Condition category										SCORE
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulance, backwater. Presence of deep pools score higher.*										
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										
Left bank AND Right bank	*Mature native trees with diverse and intact understorey*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										

Figure 21. Recommended rapid habitat quality assessment field sheet.

Habitat parameter	Condition category										SCORE
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										9
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										7
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										9
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										3
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										9
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulance, backwater. Presence of deep pools score higher.*										7
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										8
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										4
Left bank AND Right bank	*Mature native trees with diverse and intact understorey*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										3
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										1
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										60

Figure 22. Example of a completed rapid habitat quality assessment field sheet.

5.5. Recommendations for future development

1. Development of a standardised habitat modification scoring protocol. This could include measures of:
    - Channel modification (*e.g.* straightening, widening, deepening)
    - Riparian management practices (*e.g.* fences, stop banks)
    - In-stream structures (*e.g.* gabions, weirs, concrete)
    - Human litter (*e.g.* quantity and quality)
2. Further validation of HQS parameter scores. There was insufficient measured data to validate all parameters.
3. Analysis of temporal variability. Most parameters should not change over time unless a site is subject to major physical natural or anthropogenic disturbance. However, replicate temporal samples are needed to confirm this. If the user varies each time, it is likely that resulting scores will reflect inter-user variability rather than temporal variability.
4. Field training guide and/or workshops. Images are valuable in helping untrained users select appropriate parameter scores. Drawings and photo examples of the range in parameter attributes would be highly advantageous. Several users also expressed the helpfulness of the scoring examples included in the draft protocol. These could be included for different stream types within a comprehensive field guide.
5. Technology to support data collection and reporting. A software application that can be used in the field could include training images as well as prompts to ensure accurate data collection.
6. Current draft protocol data could be used to estimate a HQS using the following equation: $HQS = sum(p1, p2x2, p3x2, p4{:}p8)/2$. This results in a normal distribution of data for the 560 surveyed sites (min = 12, 25^{th} % = 47, median = 63, 75^{th} % = 75, max = 100)

6. REFERENCES

Cicchetti DV, Shoinralter D, Tyrer PJ 1985. The Effect of Number of Rating Scale Categories on Levels of Interrater Reliability: A Monte Carlo Investigation. Applied Psychological Measurement 9 (1): 31-36.

Clapcott JE, Young RG, Harding JS, Matthaei CD, Quinn JM, Death RG 2011. Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson, New Zealand.

Clapcott JE 2012. Review of Rapid Habitat Assessment Protocols. Prepared for Hawke's Bay Regional Council. Cawthron Report No. 2267. 33 p.

Clapcott JE 2013. Rapid habitat assessment workshop. Prepared for Hawkes Bay Regional Council. Cawthron Report No. 2445. 7 p.

Harding JS, Clapcott JE, Quinn JM, Hayes JW, Joy MK, Storey RG, Greig HS, Hay J, James T, Beech MA, Ozane R, Meredith AS, Boothroyd IKD 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. University of Canterbury Press.

Holmes R, Hayes J, Williams M 2012. Broad-Scale Trout Habitat Mapping in a Best Practice Dairy Catchment. Cawthron Report No. 2230. 25 p.

Leathwick JR, West D, Gerbeaux P, Kelly D, Robertson H, Brown D, Chadderton WL, Ausseil A-G 2010. Freshwater Ecosystems of New Zealand (FENZ) Geodatabase. www.doc.govt.nz/conservation/land-and-freshwater/freshwater/freshwater-ecosystems-of-new-zealand/

Lozano LM, García-Cueto E, Muñiz J 2008. Effect of the number of response categories on the reliability and validity of rating scales. Methodology: European Journal of Research Methods for the Behavioral and Social Sciences 4 (2): 73-79.

McEwan AJ, Joy MK 2013. Diel habitat use of two sympatric galaxiid stream fishes at two spatial scales a small upland stream in Manawatu, New Zealand. Environmental Biology of Fishes 97: 897-907.

Preston CC, Colman AM 2000. Optimal number of response categories in rating scales: Reliability, validity, discriminating power, and respondent preferences. Acta Psychologica 104: 1-15.

Raven PJ, Holmes NTH, Dawson FH, Everard M 1998. Quality assessment using River Habitat Survey data. Aquatic Conservation: Marine and Freshwater Ecosystems 8: 477-499.

Roni P, Hanson K, Beechie T 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management 28 (3): 856-890.

Stark JD, Boothroyd IKG, Harding JS, Maxted JR, Scarsbrook MR 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Working Group Report No.1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57 p.

7. APPENDICES

Appendix 1. Spearman rank correlation coefficients for relationships between parameters and total rapid habitat assessment (RHA) scores. N = 547. A. parameters scored 1–20. B. parameters scored 1–10.

A.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**Total**
P1	1.00									
P2	0.64	1.00								
P3	0.27	0.56	1.00							
P4	0.46	0.58	0.49	1.00						
P5	0.38	0.38	0.38	0.32	1.00					
P6	0.29	0.43	0.44	0.41	0.53	1.00				
P7	0.29	0.35	0.38	0.34	0.51	0.72	1.00			
P8	-0.04	0.20	0.35	0.14	0.15	0.53	0.33	1.00		
P9	0.21	0.34	0.41	0.34	0.32	0.44	0.40	0.33	1.00	
Total	0.60	0.77	0.69	0.68	0.63	0.78	0.69	0.50	0.60	1.00

B.

	Pb1	**Pb2**	**Pb3**	**Pb4**	**Pb5**	**Pb6**	**Pb7**	**Pb8**	**Pb9**	**Total**
Pb1	1.00									
Pb2	0.64	1.00								
Pb3	0.28	0.55	1.00							
Pb4	0.47	0.59	0.48	1.00						
Pb5	0.38	0.37	0.37	0.30	1.00					
Pb6	0.30	0.43	0.43	0.42	0.50	1.00				
Pb7	0.29	0.33	0.36	0.33	0.48	0.71	1.00			
Pb8	-0.03	0.20	0.34	0.13	0.15	0.52	0.33	1.00		
Pb9	0.21	0.35	0.41	0.34	0.32	0.44	0.39	0.33	1.00	
Total	0.61	0.76	0.69	0.68	0.62	0.78	0.68	0.49	0.61	1.00

Appendix 2. Spearman rank correlation coefficients for relationships between rapid habitat assessment (RHA) parameters scored 1–10 and other stream measures.

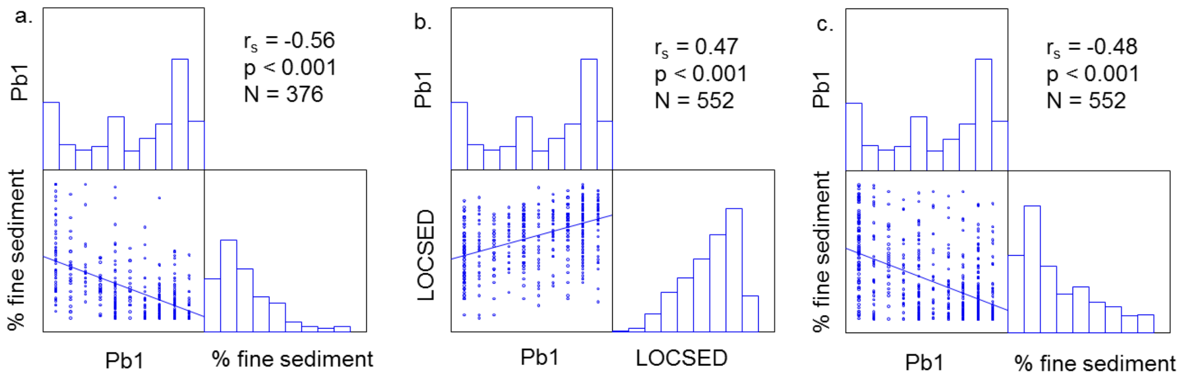


Figure A2.1. Fine sediment deposition in naturally hard-bottomed streams scored 1–10 (Pb1) and a. field estimates of fine sediment cover, b. modelled segment-scale average substrate size (LOCSED) and c. modelled segment-scale average percentage of fine sediment cover.

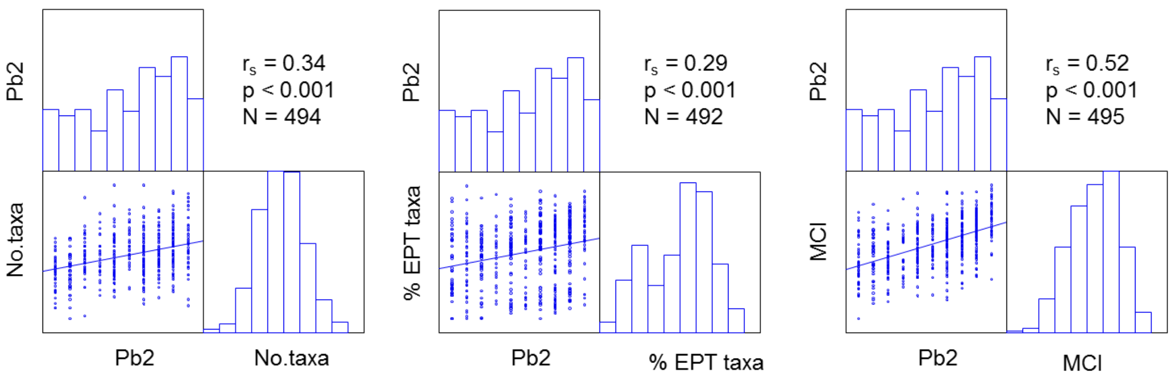


Figure A2.2. Invertebrate habitat scored 1–10 and a. number of taxa, b. % EPT taxa (% taxa of the orders, Ephemeroptera, Plecoptera and Trichoptera), and c. macroinvertebrate community index (MCI) score.

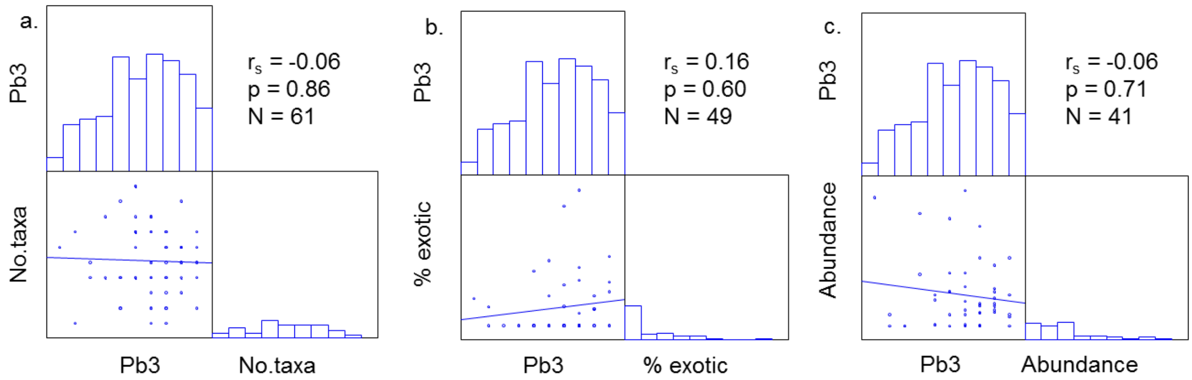


Figure A2.3. Fish cover scored 1–10 and a. number of fish taxa, b. % exotic fish taxa, and c. estimates of fish abundance.

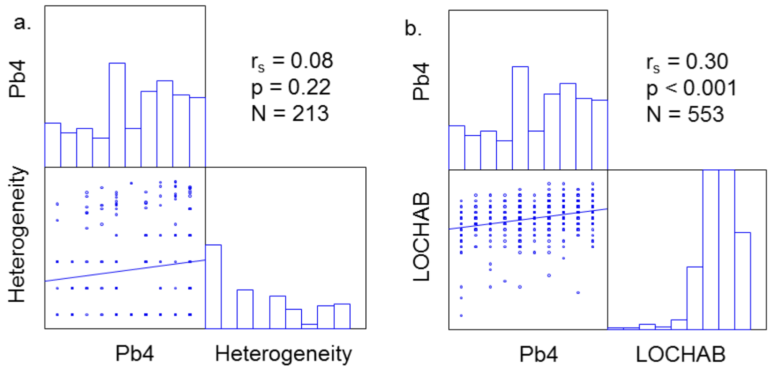


Figure A2.4. Hydraulic heterogeneity scored 1–10 and a. counts of hydraulic habitats, and b. modelled estimates of segment-scale average habitat variability.

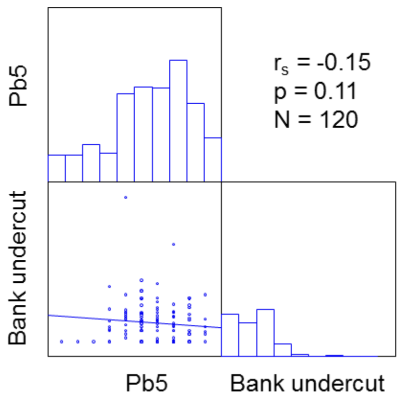


Figure A2.5. Bank stability scored 1–10 and measures of bank undercut.

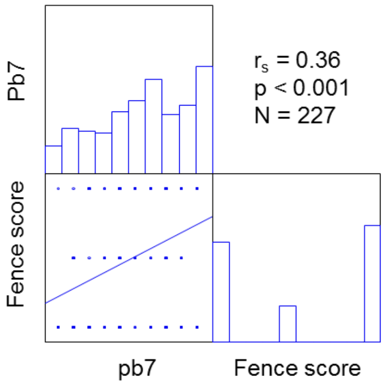


Figure A2.6. Riparian buffer (width) scored 1–10 and 1-3 scoring of site fencing status.

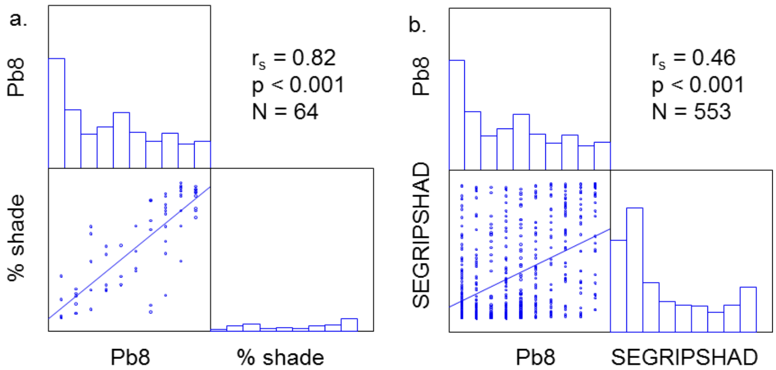


Figure A2.7. Riparian shade scored 1–10 and a. field estimates of shade cover, and b. modelled estimates of segment-scale average riparian shade cover.

Appendix 3. Spearman rank correlation coefficients for relationships between total rapid habitat assessment (RHA) scores as a sum of parameters scored 1–10 and measures of land use and environmental variability.

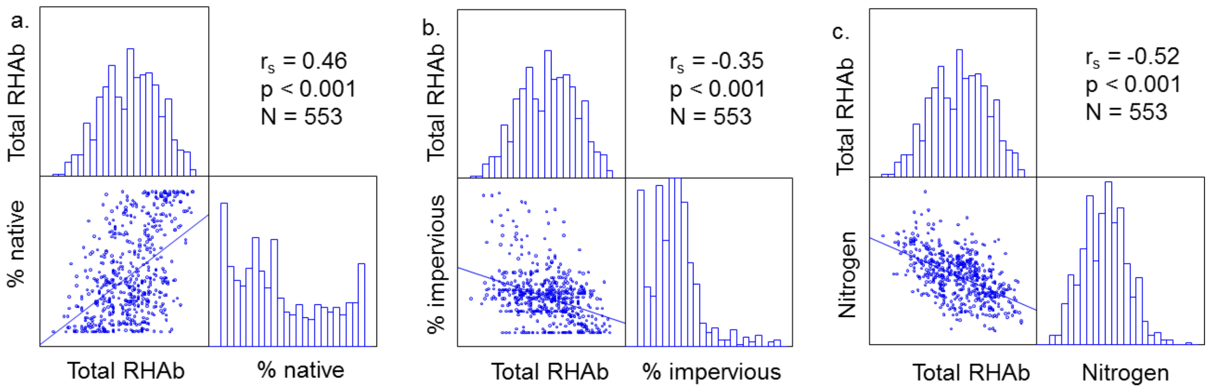


Figure A3.1. Total rapid habitat assessment (RHA) scores from parameters scored 1–10 and a. catchment-scale native vegetation cover, b. log-transformed catchment-scale impervious land cover, and c. log-transformed estimated nitrogen concentration.

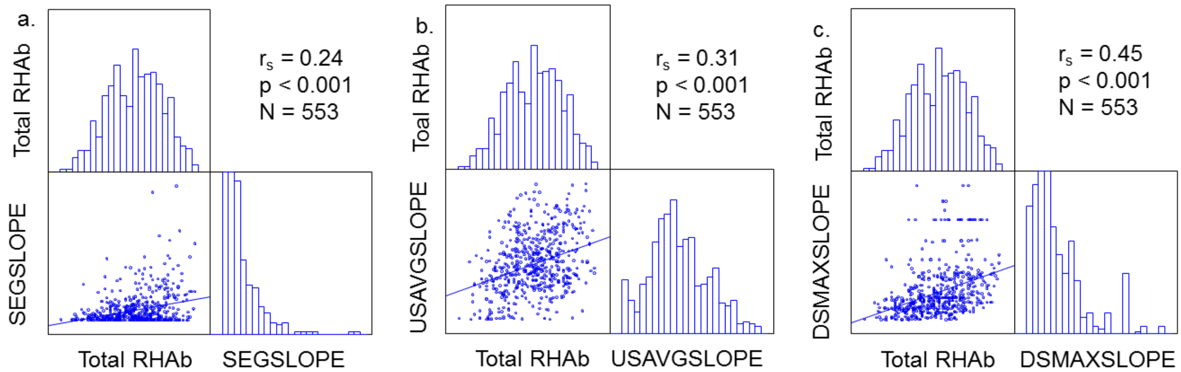


Figure A3.2. Total rapid habitat assessment (RHA) scores from parameters scored 1–10 and a. segment-scale average slope, b. upstream average slope, and c. downstream maximum slope.

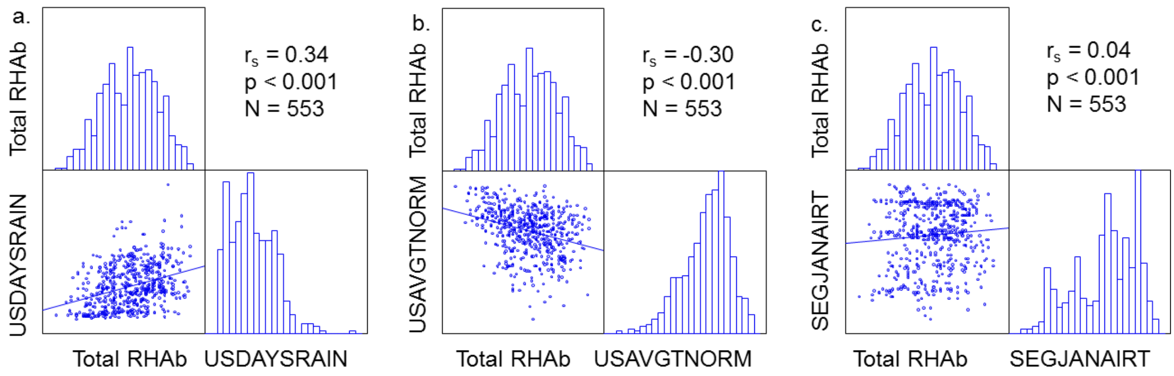


Figure A3.3. Total rapid habitat assessment (RHA) scores from parameters scored 1–10 and modelled estimates of a. upstream rain days, b. upstream normalised winter temperature, and c. segment-scale summer temperature.

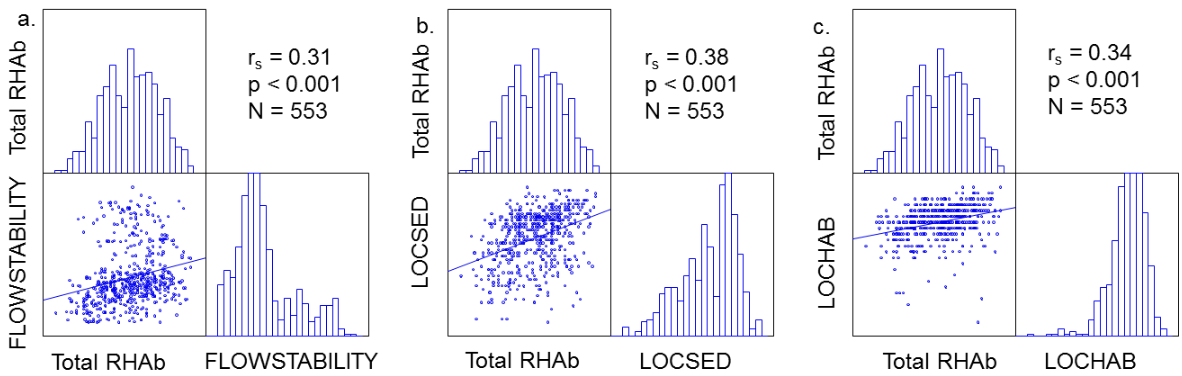


Figure A3.4. Total rapid habitat assessment (RHA) scores from parameters scored 1–10 and modelled estimates of a. flow stability, b. segment-scale average substrate size, and c. segment-scale average habitat heterogeneity.

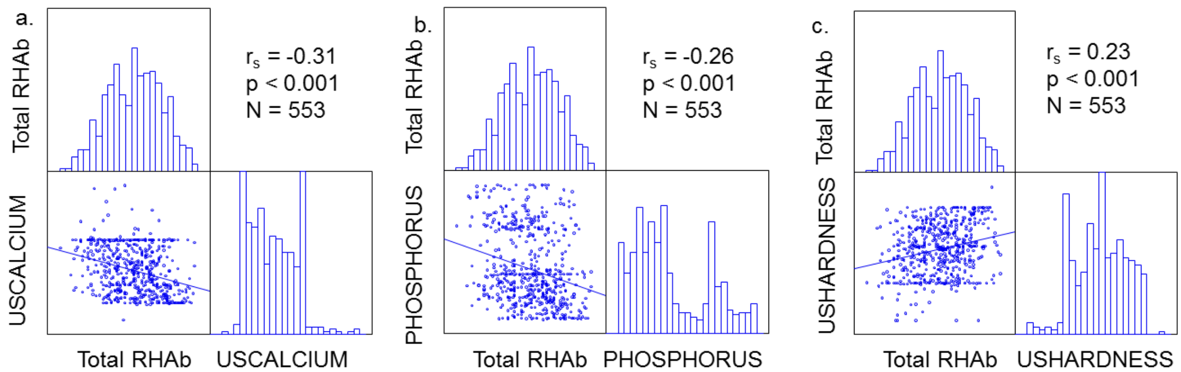


Figure A3.5. Total RHA scores from parameters scored 1–10 and catchment-scale descriptors of geological a. calcium, b. phosphorus, and c. hardness.