A Fish Index of Biotic Integrity (IBI) For Horizons Regional Council

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A FISH INDEX OF BIOTIC INTEGRITY (IBI) FOR HORIZONS REGIONAL COUNCIL

Report and user guide for use with the Horizons Fish IBI excel macro

Report by Mike Joy and excel macros by Ian Henderson

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JUNE 2015

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INTRODUCTION

BACKGROUND

The Index of Biotic Integrity (IBI) was originally developed using fish in the USA by James Karr during the early 1980s (Karr, Fausch et al. 1986). The original version had 12 metrics that reflected fish species richness and composition, the number and abundance of indicator species, trophic organization and function, reproductive behavior, fish abundance, and condition of individual fish. This process has been repeated and IBIs developed on many continents. The fish fauna of New Zealand is however, radically different from the continental faunas, thus the IBI developed for New Zealand has a number of changes (Joy and Death 2004). The basic concept of applying a number of metrics to assess fish assemblage condition and the use of a large number of sites to give a regional background level of biological integrity, then comparing a site of interest with that dataset to assess the status of the test site, has been retained in the New Zealand IBI. The IBI described in this report is novel in that it has abundance metrics not included in the Joy and Death (2004) IBI.

NEW ZEALAND IBI

New Zealand's freshwater fish fauna has only a single adult trophic level, and disease in wild fish populations is virtually absent, so many of the metrics used overseas could not be included here. The 20 metrics that are used in this new IBI measure taxonomic richness over habitat guilds, as well as using indicator species by measuring the number of species and abundance of individuals listed as intolerance to degraded conditions and the ratio of native to exotic species.

Many studies have shown that New Zealand's fish fauna is largely structured by elevation and distance from the coast (McDowall 1988, McDowall 1990, Joy and Death 2001), and this is obvious in the Horizons region (Fig. 1).

DERIVATION OF IBI SCORING LINES

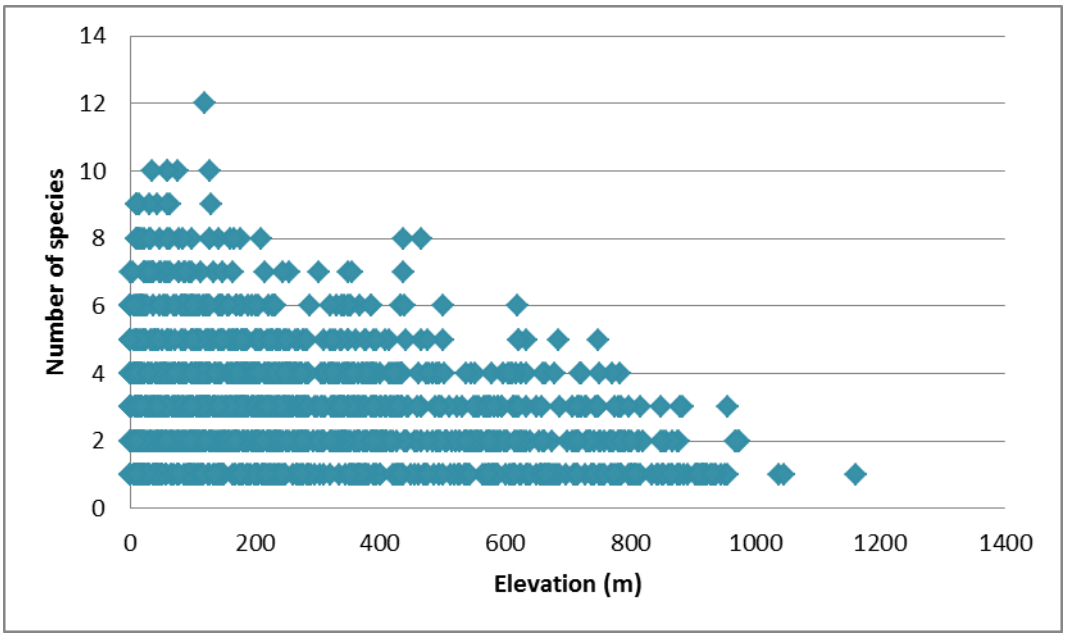

Figure 1. Number of native species from 1619 sites in the Horizons region plotted against elevation

Because elevation and distance from the coast are the overriding controllers of native fish species distribution they were used to structure expectations of fish assemblages. The first 10 metrics were assessed for both elevation and distance from the coast and added to the other 10 metrics then summed to give the final score.

The scoring process for each of the first 10 metrics is summarized using the example of native species richness (metric 1 & 2). The sites are plotted against elevation as in Fig. 1 and an upper line is drawn by eye from the highest elevation to include approximately 95% of the sites (Fig. 2).

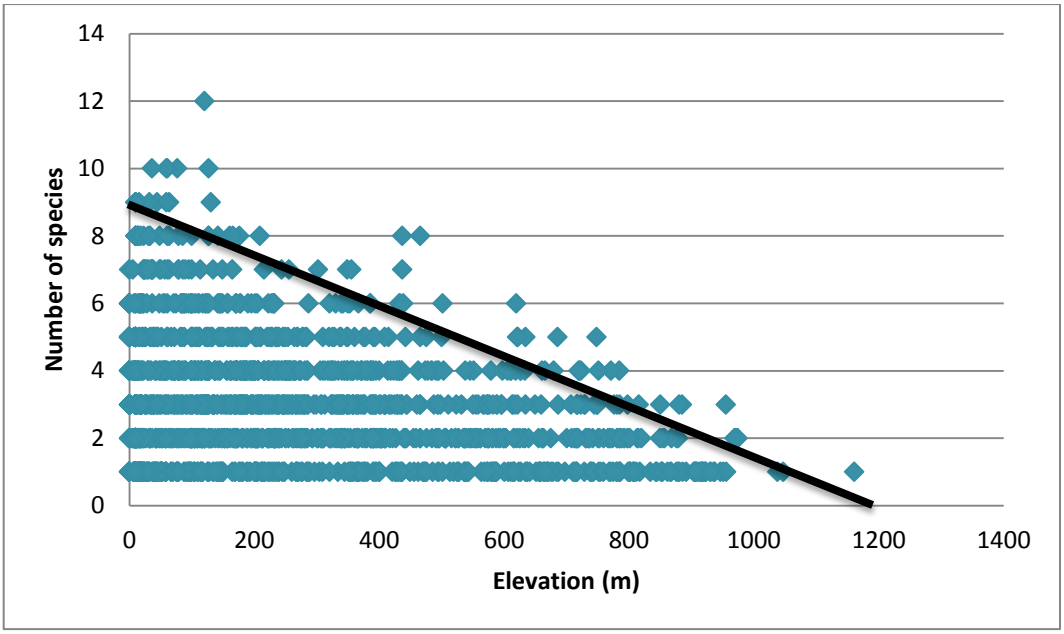

Figure 2. Fitting of upper species richness line by eye to include 95% of sites below line.

This line was named by James Karr as the maximum species richness line (MSRL) and shows the upper bound for species richness. It is only used for the following step. The area under the line was then trisected to score sites (Fig. 3). The lower two lines then became the scoring lines: if a site is below the lower line it scores 1 (no score for 0 species), between the lower two lines scores 3, and above the second line it scores 5. So in the example for a site at 100m elevation, one or two species would score 1, three, four or five species would score 3, and six or more species would score a 5 for the native fish metric.

The process outlined above is repeated for the 10 metrics (5 guilds each measured by elevation and distance, described in detail in next section).

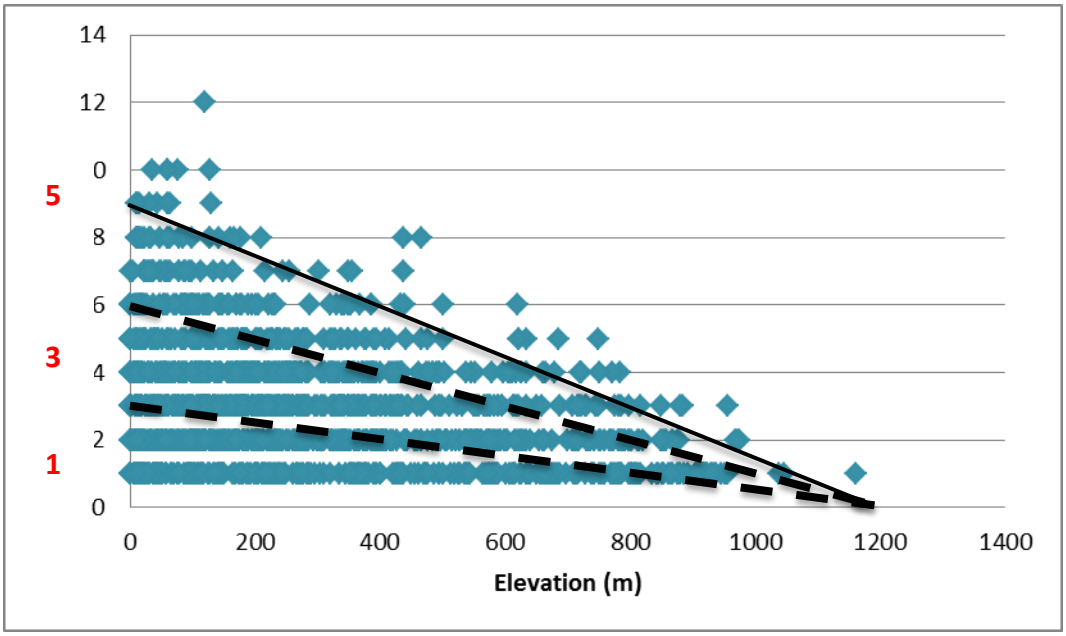

Figure 3. The area below the MSRL was trisected to give the scoring lines (dashed) and an example of site scoring from the lines below the MSRL. For example at 30 m elevation, 2 species would score 1, 4 or 5 species would score 3, and 6 or more species would score 5. Note the upper SR line is not used again for scoring; it is just there to set the position of the lower two lines.

HORIZONS FISH IBI METRICS

TAXONOMIC RICHNESS

Metrics 1, 2, 11 & 16 are based on the number and abundance of native species. Native species richness is an attribute of freshwater biotas commonly used in biological assessment. Native species richness and abundance was used as opposed to total species richness, as non-native species generally prefer degraded habitats and thus increase species richness. The exception to this is trout, as their presence is indicative of relatively good ecosystem health, so they were added as 'honorary' natives in this report. The assumptions underpinning the use of the species richness metric are: 1) that environmental degradation will change diverse communities containing many species to simple assemblages dominated by a few species, and 2) that most of the non-native species thrive in degraded conditions. Fish communities with a high proportion of non-native fish will give a low score.

HABITAT GUILDS

Metrics 3, 4, 12 & 17 use the native benthic riffle species guild as an indicator of the condition of riffle zones in rivers. These habitats are crucial for many native species and absence of the species requiring these areas indicates degradation of riffle habitats.

Metrics 5, 6, 13 & 18 use the native benthic pool species guild and **Metrics 7,8,14 & 19** use the native pelagic pool species guild. These metrics were used to make the index sensitive to changes in stream geomorphology resulting from the effects of channelisation and dams on habitats required by fish in these guilds. As with the other metrics, only native pelagic pool species were included because many of the alien species indicative of degradation found in New Zealand are pelagic.

TOLERANT SPECIES

Metrics 9, 10, 15 & 20 make use of the native fish species known to be intolerant of ecosystem health degradation. These species in this group come from the relatively limited information on the tolerance of New Zealand freshwater fish to different environmental variables (Joy and Death 2004). Species were selected based on their tolerance to impacts such as migration barriers and water quality variables such as dissolved oxygen fluctuation, temperature, sediment and ammonia.

CLASSIFICATION OF FISH INTO METRICS

The fish were classed into the 20 IBI metrics based on the 5 guilds (Table 1). The metrics are non-exclusive and are based on information from the literature and from personal experience (Joy and Death 2004).

Table 1. The classification of fish species that could be found in the Horizons region into the different metrics (note: most of the non-native species have not been found to date).

Scientific name	*Common name*	*Native*	*Benthic-riffle*	*Benthic-pool*	*Pelagic-pool*	*Intolerant*	*Non-native*
Aldrichetta forsteri	Yelloweye mullet	1			1		
Ameiurus nebulosus	Catfish						1
Anguilla australis	Shortfin eel	1		1			
Anguilla dieffenbachii	Longfin eel	1	1	1		1	
Anguilla spp.	Eel	1	1				
Carassius auratus	Goldfish						1
Cheimarrichthys fosteri	Torrentfish	1	1				
Cyprinus carpio	Koi carp						
Galaxias argenteus	Giant kokopu	1		1		1	
Galaxias diversus	Dwarf galaxiid	1	1			1	
Galaxias brevipinnis	Koaro	1	1	1		1	
Galaxias fasciatus	Banded kokopu	1		1	1	1	
Galaxias maculatus	Inanga	1			1	1	
Galaxias postvectis	Shortjaw kokopu	1		1	1	1	
Galaxias spp.	Unknown galaxiid	1					
Gambusia affinis	Mosquitofish						1
Geotria australis	Lamprey	1	1			1	
Gobiomorphus basalis	Crans bully	1		1			
Gobiomorphus breviceps	Upland bully	1		1			
Gobiomorphus cotidianus	Common bully	1		1			
Gobiomorphus gobioides	Giant bully	1		1		1	
Gobiomorphus hubbsi	Bluegill bully	1	1			1	
Gobiomorphus huttoni	Redfin bully	1	1			1	
Gobiomorphus spp.	Bully	1		1			
Tripterygiidae	Triplefin						1
Hypophthalmichthys molitrix	Silver carp						1
Leuciscus idus	Golden orfe						1
Mugil spp.	Mullet	1			1		
Neochanna apoda	Brown mudfish	1		1		1	
Oncorhynchus mykiss	Rainbow trout				1	1	
Perca fluviatilis	Perch						1
Retropinna retropinna	Common smelt	1			1	1	
Rhombosolea retiaria	Black flounder	1		1		1	
Salmo trutta	Brown trout				1	1	
Scardinius erythrophthalmus	Rudd						1
Tinca tinca	Tench						1

The five different guilds and how they are scored are shown below in tables 1 & 2. The individual metrics are described in the next section.

Table 2. The 20 metrics and their scoring methods for the Horizons fish IBI. The scoring lines referred to for the first 10 metrics are the dashed lines in Figure 3.

Metric #	*Metric name*	*Score*		
		5	3	1
	Elevation and distance to coast species richness lines			
1 & 2	Number of indigenous species	Above upper line	Between lines	Below lower line
3 & 4	Number of benthic riffle species	Above upper line	Between lines	Below lower line
5 & 6	Number of benthic pool species	Above upper line	Between lines	Below lower line
7 & 8	Number of pelagic pool species	Above upper line	Between lines	Below lower line
9 & 10	Number of intolerant species	Above upper line	Between lines	Below lower line
	Proportional metrics			
11	Proportion of indigenous species	>66%	33-66%	<33%
12	Proportion benthic riffle species	>66%	33-66%	<33%
13	Proportion of benthic pool species	>66%	33-66%	<33%
14	Proportion of pelagic pool species	>66%	33-66%	<33%
15	Proportion of intolerant species	>66%	33-66%	<33%
16	Relative abundance of indigenous species	>66%	33-66%	<33%
17	Relative abundance of benthic riffle species	>66%	33-66%	<33%
18	Relative abundance of benthic pool species	>66%	33-66%	<33%
19	Relative abundance of pelagic pool species	>66%	33-66%	<33%
20	Relative abundance of intolerant species	>66%	33-66%	<33%

Table 3. The species richness lines for each of the guilds used in the first 10 metrics of the IBI. The intercept is the point where the middle scoring line (upper dashed line in Figure 3) meets the x and y axes.

Guilds	*Scale*	*X intercept*	*Y intercept*
Native	Elevation	1200	6
Native	Distance	350	7
Benthic riffle	Elevation	1200	3
Benthic riffle	Distance	350	4

Benthic pool	Elevation	1200	3
Benthic pool	Distance	350	4
Pelagic pool	Elevation	1200	2
Pelagic pool	Distance	350	3
Intolerant	Elevation	1200	3
Intolerant	Distance	350	4

CALCULATION OF TOTAL IBI SCORE

To calculate the total IBI, the scores for the 20 metrics are summed to give the IBI score for each sampling site. There are 10 metrics calculated over elevation and distance from the coast separately, each one giving a maximum of 5, and 10 metrics based on proportions, so the total IBI possible maximum score is 100 and the minimum is 0 for no native fish.

INTERPRETATION OF RESULTS

All 1619 sites were run through the Horizons IBI model and the IBI scores calculated. The mean score for the region was 48.9, the mode 54, median 52, and the maximum was 88. The distribution of IBI scores shows that most sites are around the mid to late sixties (Fig. 4).

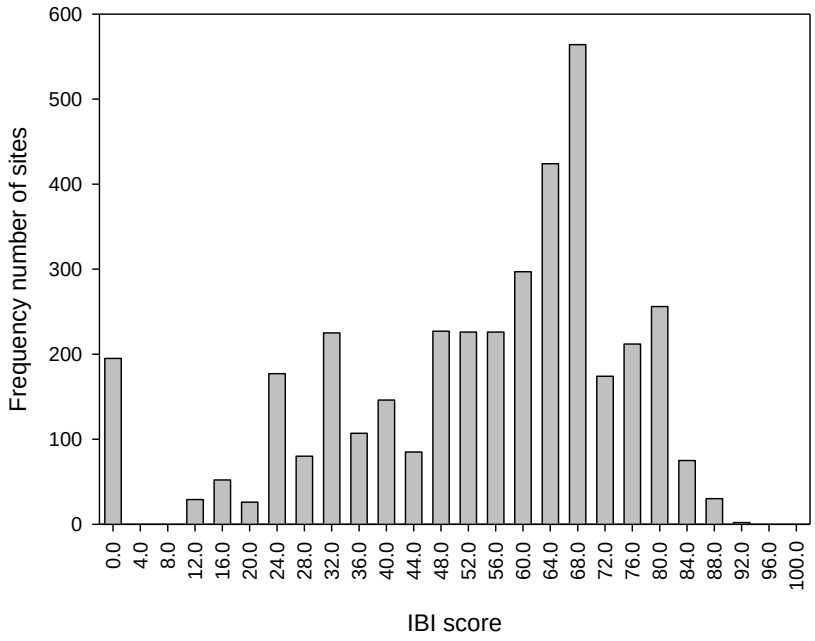

Figure 4 Histogram of IBI scores for all sites

The attributes and integrity classes were applied to the Horizons IBI scores to help with assessment of site scores. The distribution of scores was used to get these classes; the percentiles of the distribution were used to define the thresholds similar to Karr et al. (1986). Table 4 shows these classes, the sites above the 80th percentile are excellent, good for those above the 60th percentile, moderate above the 40th percentile, poor above the 20th percentile, and very poor below the 20th percentile. (As a further guide the excel macro produces a distribution histogram to give an indication for how the site you are interested in compares with the 1619 sites in the region used to build the model).

Table 1. Attributes and suggested integrity class thresholds for the Horizons IBI calculated from the distribution of scores.

Total IBI score	**Integrity class**	***Attributes***

68 – 100	Excellent	*Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 80th percentile of Horizons sites*
58 – 67	Good	*Site is above the 60th percentile of all Horizons sites, species richness is slightly less than best for the region*
46 – 57	Moderate	*Site is above the 40th percentile of Horizons sites but species richness and habitat or migratory access reduced, some signs of stress*
36 – 45	Poor	*Site is less than average for Horizons region IBI scores, less than the 40th percentile, thus species richness and or habitat are severely impacted*
1 – 35	Very poor	*Site is below the 20th percentile meaning site is impacted or migratory access almost non existent*
0	No native fish	*Site is grossly impacted or access non existent*

THE RELATIONSHIP BETWEEN LAND-USE AND FISH ASSEMBLAGE INTEGRITY

The IBI scores for 1619 sites were classified using the River Environment Classification (REC)[1] to see the relationship between land-cover and fish assemblage integrity measured by the IBI (33 sites were in miscellaneous and wetland classes so were not included in this analysis). The distribution of sites was strongly biased towards REC high intensity pasture sites, and very low numbers of low intensity pasture, urban and tussock sites (Fig. 5).

[1] http://www.mfe.govt.nz/environmental-reporting/about/tools-guidelines/classifications/freshwater/

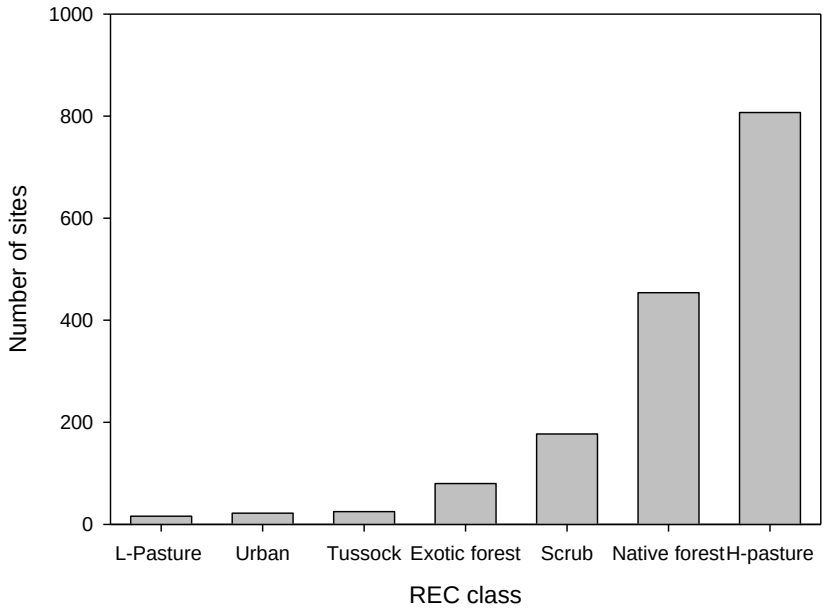

Figure 4. The number of fish sites from the Horizons region in each REC class

There were clear differences in average IBI scores revealed between land-cover types (Fig. 6, Table 5). The average score was highest at low intensity pasture (note very few sites in this REC class), native forest and scrub sites and lowest at urban, exotic forest, tussock and pasture sites. An analysis of variance confirmed the differences between REC classes; $F_7 = 31.5$, $P = 0.0000$.

Table 2. Statistics for IBI scores for main REC land-cover classes

	Urban	*Exotic forest*	*Tussock*	*H-pasture*	*Scrub*	*Native forest*	*L-pasture*
Mean	28.73	41.30	42.48	45.35	53.82	58.13	63.25
Standard Error	5.31	2.38	3.68	0.70	1.59	0.91	5.67
Median	24	34	34	50	60	64	70
Mode	0	34	34	0	34	64	34
Minimum	0	0	0	0	0	0	24
Maximum	72	88	78	88	88	88	88
Count	22	80	25	807	177	454	16

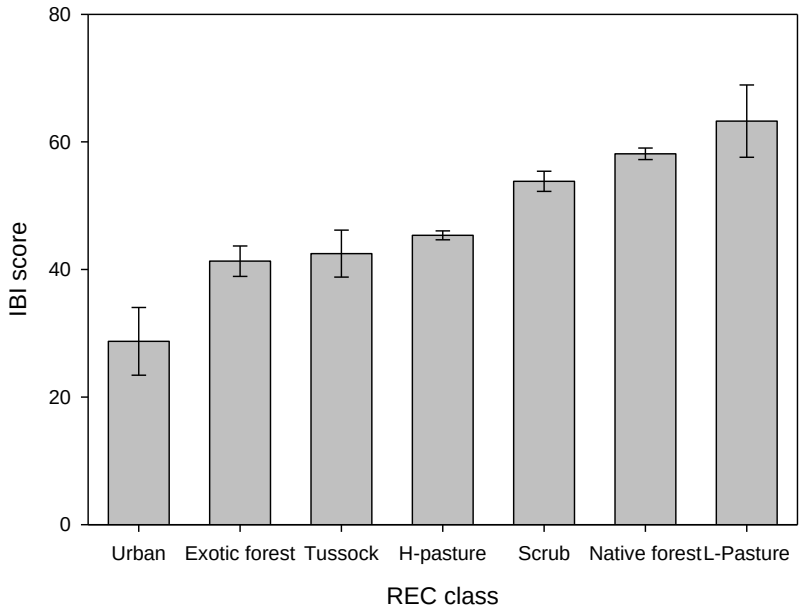

Figure 5. Distribution of IBI scores across the main REC land-cover classes

The *post hoc* Tukey tests revealed the pairwise differences in IBI scores between the REC classes (Table 6). The average IBI score at indigenous forest sites was higher than all other land-cover classes, while urban and pasture IBI scores were lower than all the others.

Table 3. Significant differences between IBI scores at different land-use classes from Tukey Post hoc test

REC Land-cover type pairing		*p-value*
Native forest	Exotic forest	0.000000
Native forest	H-pasture	0.000000
Urban	Native forest	0.000000
Urban	Scrub	0.000002
Urban	L-pasture	0.000008
Scrub	H-pasture	0.000018
Scrub	Exotic forest	0.000165
L-pasture	Exotic forest	0.002671
Urban	H-pasture	0.005011
Tussock	Native forest	0.005803

High proportions of the 'poor' and 'very poor' scores were found in the urban and pasture REC class catchments, while the very good and excellent scores were more

prevalent in indigenous forest and scrub classes (Table 7 and Fig. 7). Exotic forest had a mixture of integrity classes possibly related to different harvesting times.

Table 4. Numbers of the 1619 Horizons region sites within each REC land cover type in each IBI integrity class

IBI Class	*River environment classification class*						
	L-Pasture	Native forest	Scrub	Tussock	Urban	Exotic forest	H-pasture
Very poor	5	93	53	17	14	49	257
Poor	0	21	10	0	2	2	100
Moderate	0	64	21	2	2	8	219
Good	3	128	45	2	1	13	162
Excellent	8	148	48	4	3	8	69
Totals	16	454	177	25	22	80	807

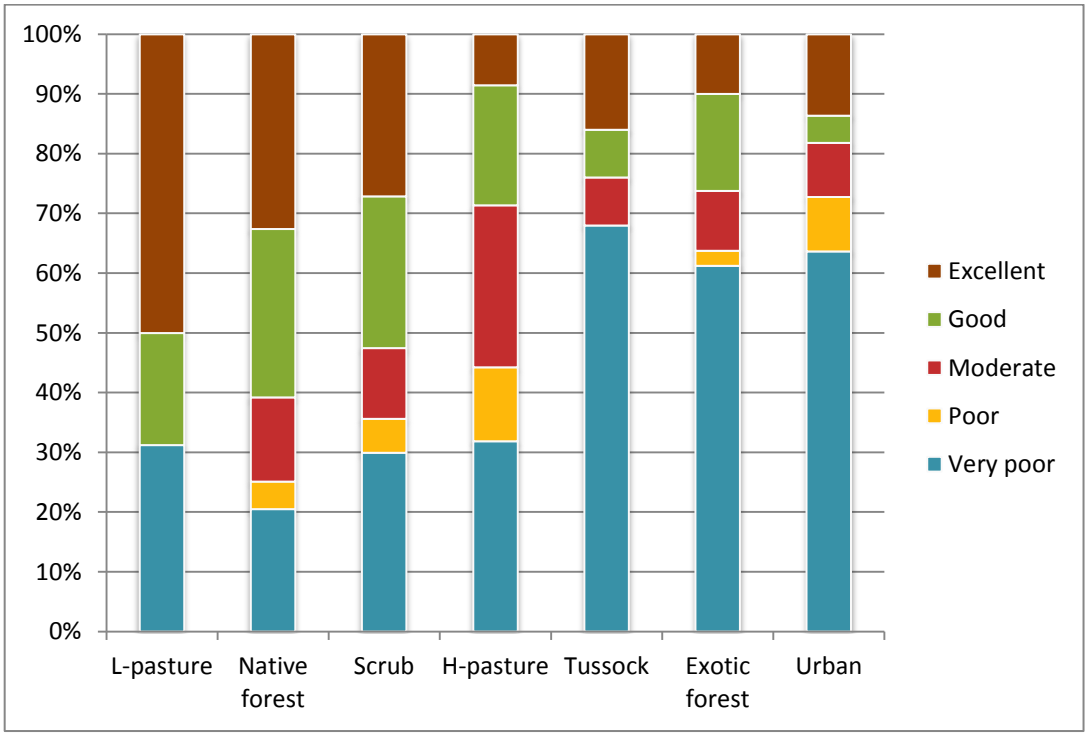

Figure 6. Percentages of the IBI classes for each of the REC classes

DISCUSSION

Assessing river health using a fish Index of biotic integrity in New Zealand differs from other bioassessment measures in that it is more holistic; because the fish species are mostly migratory it characterises the whole waterway, upstream and downstream of the site (Joy and Death 2004). This assessment contrasts with an invertebrate index assessment that is more site-specific and affected more by proximal habitat factors. This difference in the scale of assessment is an important distinction. For example, a low fish IBI score can at a lowland site be indicative of upstream land-use as the land-use impacts can cause a chemical barrier to upstream migration, or build-up in sediment and loss of habitat heterogeneity. Conversely at an upstream site in natural landscape, a low score could be because of a physical barrier like a culvert or waterfall downstream.

The data used in the construction of the model spans a few decades so some of the scores may reflect previous land-use and thus may no longer be applicable; therefore caution is required when looking at maps of the distribution of scores in areas of recent landuse change. The aim of this exercise was to produce a working IBI model and the more fish data the better for this, but analysis of results of historical data must take temporal changes into account.

REGIONAL COMPARISONS

The regional nature of the fish IBI application means that the scoring is regional and not applicable at a national scale. For national scale comparison a national model must be employed. A national IBI has been produced based on 27000 sites (Joy 2013), which uses different scoring lines based on the national data and numbers can be drawn from this for comparisons if required.

RUNNING A SET OF SITES THROUGH THE HORIZONS_FISH_IBI SOFTWARE TO CALCULATE SCORES: AN EXAMPLE:

1. Open the excel file **Horizons_fish_IBI**

2. Enter details in the Batch notes cell - any information you want to appear on the output file

3. The fish presence data can be pasted in from another file or entered by hand, the first row is for the site name or number, the second row is for the height above sea level in meters of the site, the third is the distance (as the fish swims) of the site from the coast.

4. In the column below the site details, the fish captured at the site are entered. You can enter the numbers caught but the model is based on presence/absence only so anything greater than zero will be counted as a presence and zero or no data will be counted as an absence.

5. To test a single site click on a cell in the column containing the site of interest then click on “test one site” button in IBI toolbar. The IBI score is calculated and the score with its Integrity class are shown above the graph. The graph gives the position of site in relation to all the sites from the region as a red bar.

6. To remove the graph click on the remove graphs button on the IBI toolbar and start again for another site.

7. To run a group of sites through you can paste a set of sites in following the format of the example sites. To run them all, click on the test all sites button. This will take you to the output sheet where the results are summarized. This page can then be printed.

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