A FISH INDEX OF BIOTIC INTEGRITY (IBI) FOR THE NORTHLAND REGION

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

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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, 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 has been retained that is 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 and then comparing a site of interest with that dataset to assess the status of the test site.

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 these metrics could not be included. The six metrics that are used in the New Zealand IBI measure taxonomic richness over a number of habitat guilds, and as well use indicator species by measuring the number of species showing 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 Northland region (Fig. 1).

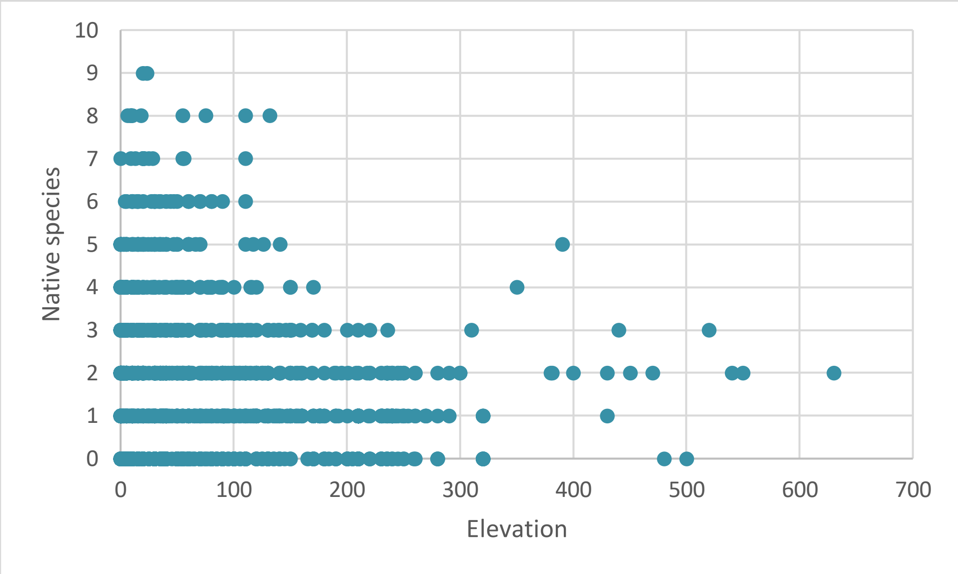

Figure 1 Number of native species from 1602 sites in the Northland region plotted against elevation

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 six metrics were assessed for both elevation and distance from the coast to give 12 metrics overall and these were summed to give the final score.

The scoring process for each metric is summarized using the example of native species richness (metric 1). 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).

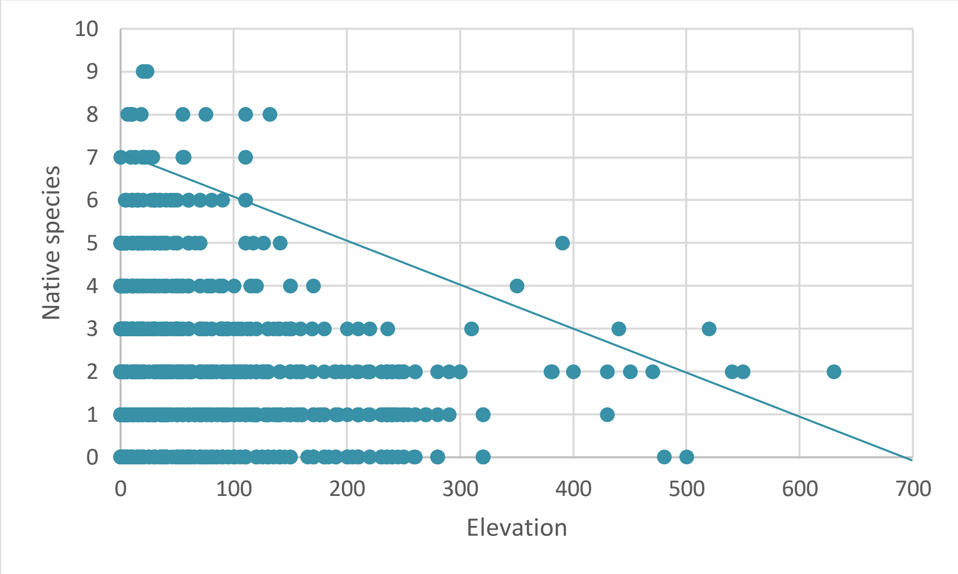

Figure 2. Fitting of line by eye upper species richness line to include 95% of sites below line.

This line was named by James Karr as the maximum species richness line (MSRL) and shows the upper bound for species richness and is only used for the following step. The area under the line was then trisected to score sites (Fig. 3). The 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 200m elevation one species would score 1, two species would score 3 and four or more species would score a 5 for the native fish metric.

The process outlined above is repeated for the 6 metrics (described in detail in next section) and repeated for distance from the sea for the same 6 metrics.

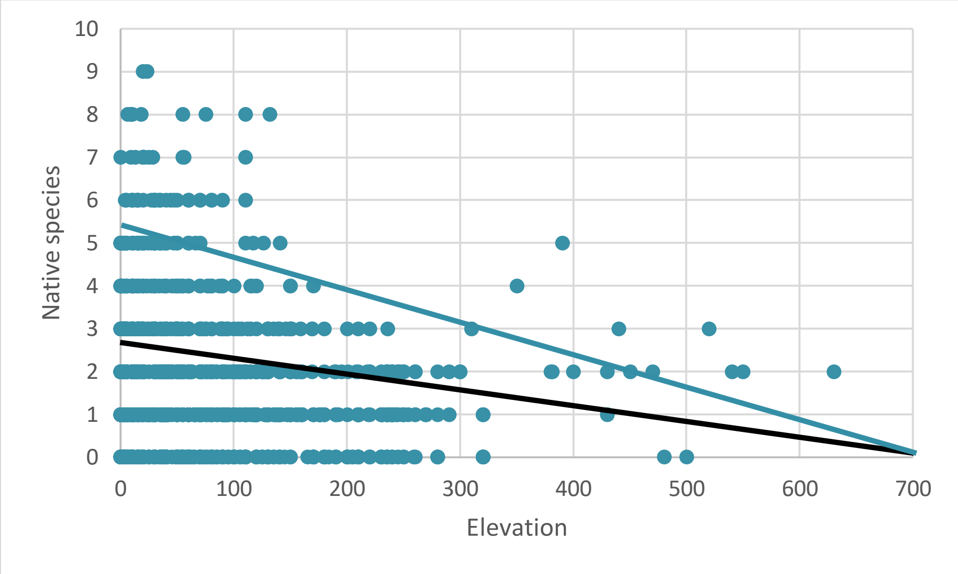

Figure 3. The area below the MSRL was trisected to give the scoring lines and an example of site scoring from the lines below the MSRL. For example, at 30 m elevation 2 species would score 1, 4 would score 3 and 6 or more species would score 5.

NORTHLAND FISH IBI METRICS

TAXONOMIC RICHNESS

Metric 1 is the number of native species, an attribute of freshwater biotas commonly used in biological assessment. We used native species richness (but including trout), as opposed to total species richness as non-native species may prefer degraded habitats and thus increase species richness. The exception to this is trout so they were added as 'honorary' natives in this report. The assumption underpinning the use of the species richness metric is that environmental degradation will change diverse communities containing many species to simple assemblages dominated by a few species.

HABITAT GUILDS

Metric 2, the number of native benthic riffle species is used as an indicator of degradation in riffle zones in rivers. **Metric 3** is the number of native benthic pool species and metric 4 is the number of native pelagic pool species. 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. Only native pelagic pool species were included because many of the alien species indicative of degradation found in New Zealand are pelagic.

TOLERANT SPECIES

Metric 5 is the number of stream-degradation-intolerant species and makes use of limited information on the tolerance of New Zealand freshwater fish to different environmental variables. 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.

INVASIVE SPECIES

Metric 6 is the proportion of native to alien species and measures the extent to which the fish assemblage has been invaded by introduced species. The presence of non-native species reflects biological pollution, and generally, these species in New Zealand are more tolerant of degradation of habitat and water quality than the native species and thus, they may indicate degraded conditions (Note only Gambusia have been found in the region to date).

CLASSIFICATION OF FISH INTO METRICS

The fish were classed into the six IBI metrics (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 Northland 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
Aldrichetta forsteri	Yelloweye mullet	1			1	
Ameiurus nebulosus	Catfish					
Anguilla australis	Shortfin eel	1		1		
Anguilla dieffenbachia	Longfin eel	1	1	1		
Carassius auratus	Goldfish					
Cheimarrichthys fosteri	Torrentfish	1	1			
Cyprinus carpio	Koi carp					
Galaxias argenteus	Giant kokopu	1		1		1
Galaxias unknown	Unknown galaxiid	1			1	
Galaxias brevipinnis	Koaro	1	1	1		1
Galaxias fasciatus	Banded kokopu	1		1	1	1
Galaxias gracalis	Dwarf inanga	1	1			1
Galaxias maculatus	Inanga	1			1	1
Galaxias postvectis	Shortjaw kokopu	1		1	1	1
Gambusia affinis	Mosquitofish					
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 inidentified	Bully unidentified	1		1		
Mugil spp.	Mullet	1			1	
Neochanna diversus	Black mudfish	1		1		1
Neochanna heleios	Northland mudfish	1		1		1
Oncorhynchus mykiss	Rainbow trout				1	1
Parioglossus marginalis	Guppy	1				1
Perca fluviatilis	Perch					

Retropinna retropinna	Common smelt	1			1	1
Rhombosolea retiarii	Black flounder	1		1		1
Salmo trutta	Brown trout				1	1
Scardinius erythrophthalmus	Rudd					
Tinca tinca	Tench					

CALCULATION OF TOTAL IBI SCORE

To calculate the total IBI, the scores for the six metrics are summed to give the IBI score for each sampling site. There are six metrics calculated over elevation and distance from the coast separately each one giving a maximum of 10 so the total IBI maximum score possible is 60 and the minimum 0.

INTERPRETATION OF RESULTS

All 1602 available sites were run through the Northland IBI model and IBI scores calculated, the mean score was 19.6 and the median was 20. The distribution of IBI scores shows the highest number of sites at the lower end of the integrity scores and reducing with the higher scores (Fig. 4).

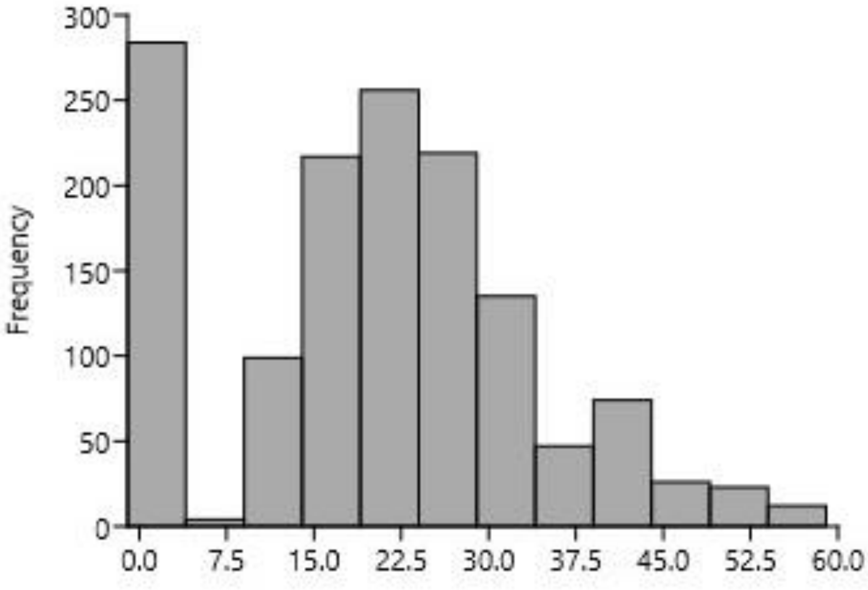

Figure 4. The distribution of IBI scores across the 1602 sites in the Northland region used to calibrate the IBI

INTEGRITY CLASSES

As a guide to interpreting the final scores (Karr, Fausch et al. 1986) gave the following ranges of qualitative assessments based on the distribution of IBI scores: excellent (58 – 60), good (48 – 52), fair (40 – 44), poor (28 – 34), and very poor (0 – 22) (the IBI is 0 at sites where no native fish are caught). The attributes and integrity classes adapted from the Karr groups were applied to the Northland IBI scores to help with assessment of site scores. The distribution of scores was used to get the classes, the percentiles of the distribution were used to define the thresholds and they differ slightly from Karr et al. (1986) classes (Table 2). (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 1602 sites in the region used to build the model). The graphs used to calculate the MSRLs can be seen in Appendix 1.

Table 2. Attributes and suggested integrity class thresholds for the Northland IBI calculated from the distribution of scores.

Total IBI score	**Integrity class**	***Attributes***
41 – 60	Excellent	*Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 90th percentile of Northland sites*
33 – 40	Very good	*Site is above the 80th percentile of all Northland sites species richness is slightly less than best for the region*
25 – 32	Good	*Site is above the 60th percentile of Northland sites but species richness and habitat or migratory access reduced some signs of stress*
21 – 24	Fair	*Score is just above average, but species richness is significantly reduced habitat and or access impaired*
16 – 20	Poor	*Site is less than average for Northland region IBI scores, less than the 50th percentile, thus species richness and or habitat are severely impacted*
8 – 15	Very poor	*Site is impacted or migratory access almost non existent*
0	No fish	*Site is grossly impacted or access non existent*

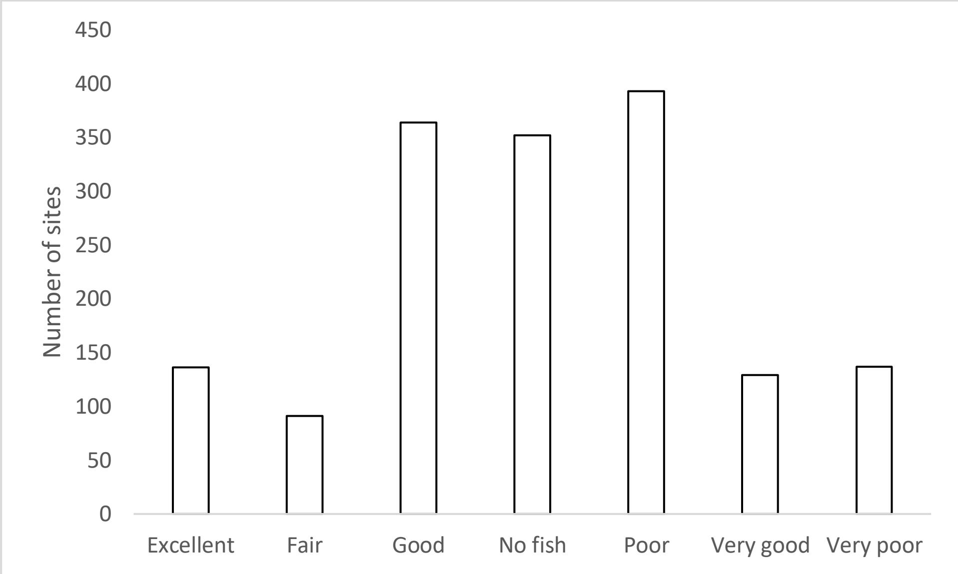

Figure 5. The number of fish sites from the Northland district in each integrity class

THE RELATIONSHIP BETWEEN LAND-USE AND FISH ASSEMBLAGE INTEGRITY

The IBI scores for 1602 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 (15 sites were in miscellaneous and wetland classes so were not included in this analysis). The average score was highest at indigenous forest and urban sites and lowest at exotic forest and scrub sites (Figure 6 and Table 3).

Table 3. Statistics for IBI scores for main REC land-cover classes

	EX-FOREST	IND-FOREST	PASTORAL	SCRUB	URBAN
N.	163	290	844	74	25
MIN.	0	0	0	0	0
MAX.	58	60	58	46	54
MEAN	16.1	26.7	19.4	19.1	21.2
STD. ERROR	0.93	0.94	0.43	1.44	3.48
STAND. DEV	11.9	16.1	12.4	12.3	17.4
MEDIAN	16	28	20	18	20

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

There were clear differences in average IBI scores revealed between land-cover types (Figure 5, Table 4). An analysis of variance showed that some of differences between REC classes were statistically significant ($F_{5,1596} = 27.77$, $P < 0.000$).

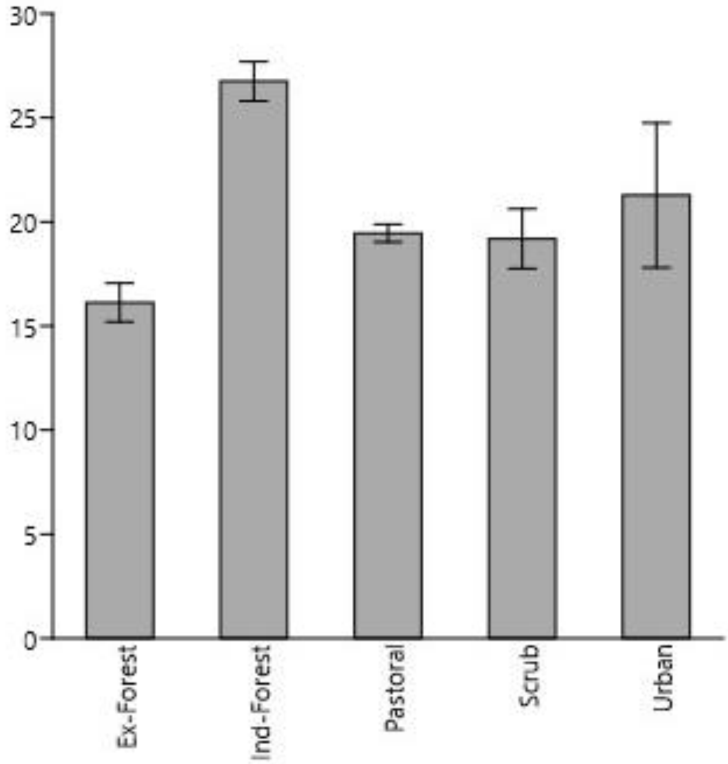

Figure 6. Distribution of IBI scores across the main REC land-cover classes the number of sites in each class is shown in the bars.

The *post hoc* Tukey tests revealed the pairwise differences in IBI scores between the REC classes (Table 4). The average IBI score at indigenous forest sites was significantly higher than all other land-cover classes, while exotic forest scores were lower than all the others. Pasture, scrub and urban scores were lower than indigenous forest and higher than exotic forest but not significantly different from each other (table 4).

Table 4. Dunn's post-hoc *p*-values for differences between IBI scores at different land-use classes (the lower the P-value the stronger the evidence for a difference)

	EX-FOREST	IND-FOREST	PASTORAL	SCRUB
EX-FOREST				

IND-FOREST	0.0000			
PASTORAL	0.0011	0.0000		
SCRUB	0.1230	0.0000	0.6046	
URBAN	0.1224	0.0409	0.7945	0.6172

High proportions of the 'poor' and 'very poor' scores were found in the urban, pasture, scrub and exotic forest REC class catchments, while the very good and excellent scores were more prevalent in indigenous forest classes (Table 5 & Fig 7). Exotic forest had a mixture of integrity classes possibly related to different harvesting times, and the 'no fish' sites were spread across all classes. Indigenous forest class had mostly excellent, very good and good scores (Table 5 & Fig 7).

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Table 5. Percentages of the 1602 Northland region sites within each REC land cover type in each IBI integrity class

	EXOTIC FOREST	INDIGENOUS FOREST	PASTURE	SCRUB	URBAN
EXCELLENT	2%	26%	5%	7%	25%
VERY GOOD	6%	17%	6%	11%	14%
GOOD	17%	19%	27%	18%	7%
FAIR	9%	5%	6%	8%	0%
POOR	33%	14%	22%	23%	25%
VERY POOR	5%	3%	14%	15%	4%
NO NATIVE FISH	27%	17%	19%	19%	25%

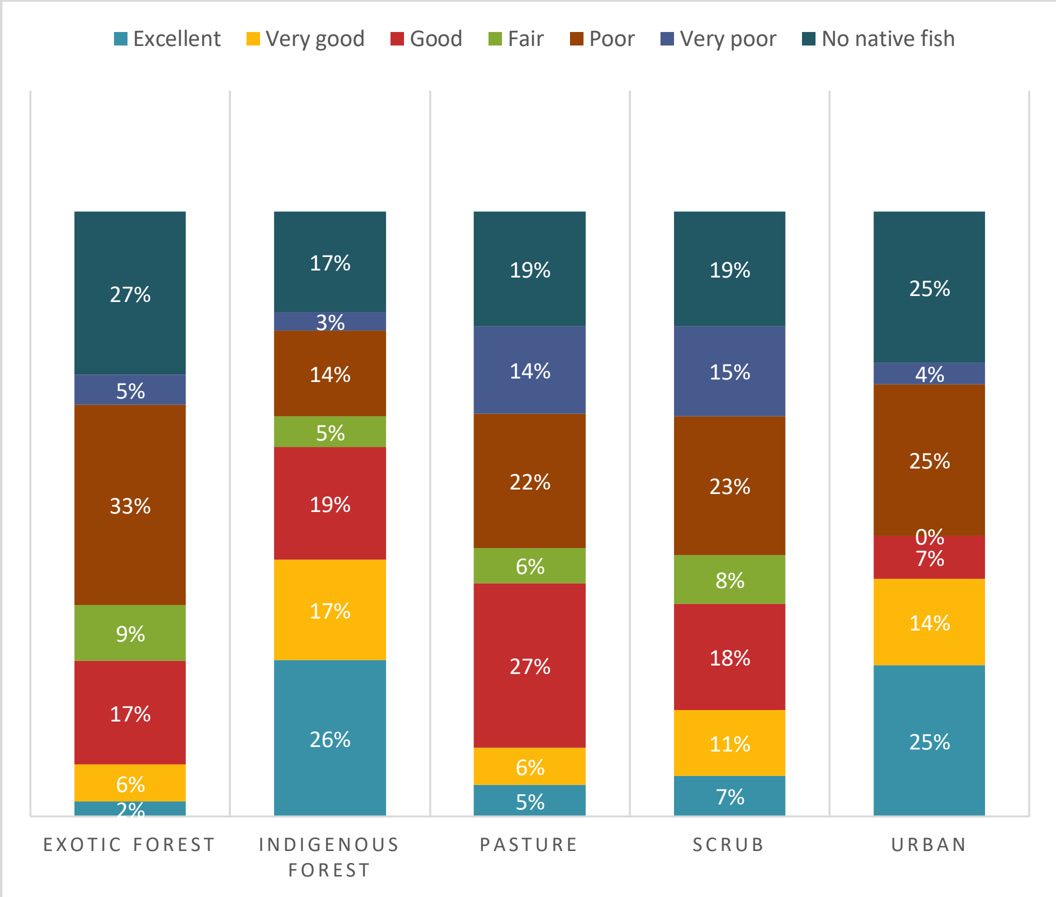


Figure 7. Distribution of IBI classes within REC river classes.

MAPPING SITES AND IBI INTEGRITY CLASSES

The 1602 sites were mapped over the region coded by their IBI integrity class to illustrate the spatial variability in fish biotic integrity (Figure 8). While there are exceptions in general the lower integrity sites can be seen associated with pasture, scrub and forestry REC classes, and high scores in native vegetation scrub and indigenous forest. The other obvious pattern is the high integrity sites are associated with the small areas of remaining indigenous vegetation cover in the region especially at the seaward ends. The IBI will be lower above migration barriers and sometimes these are natural barriers like waterfalls so when a low score is found this must be taken into account.

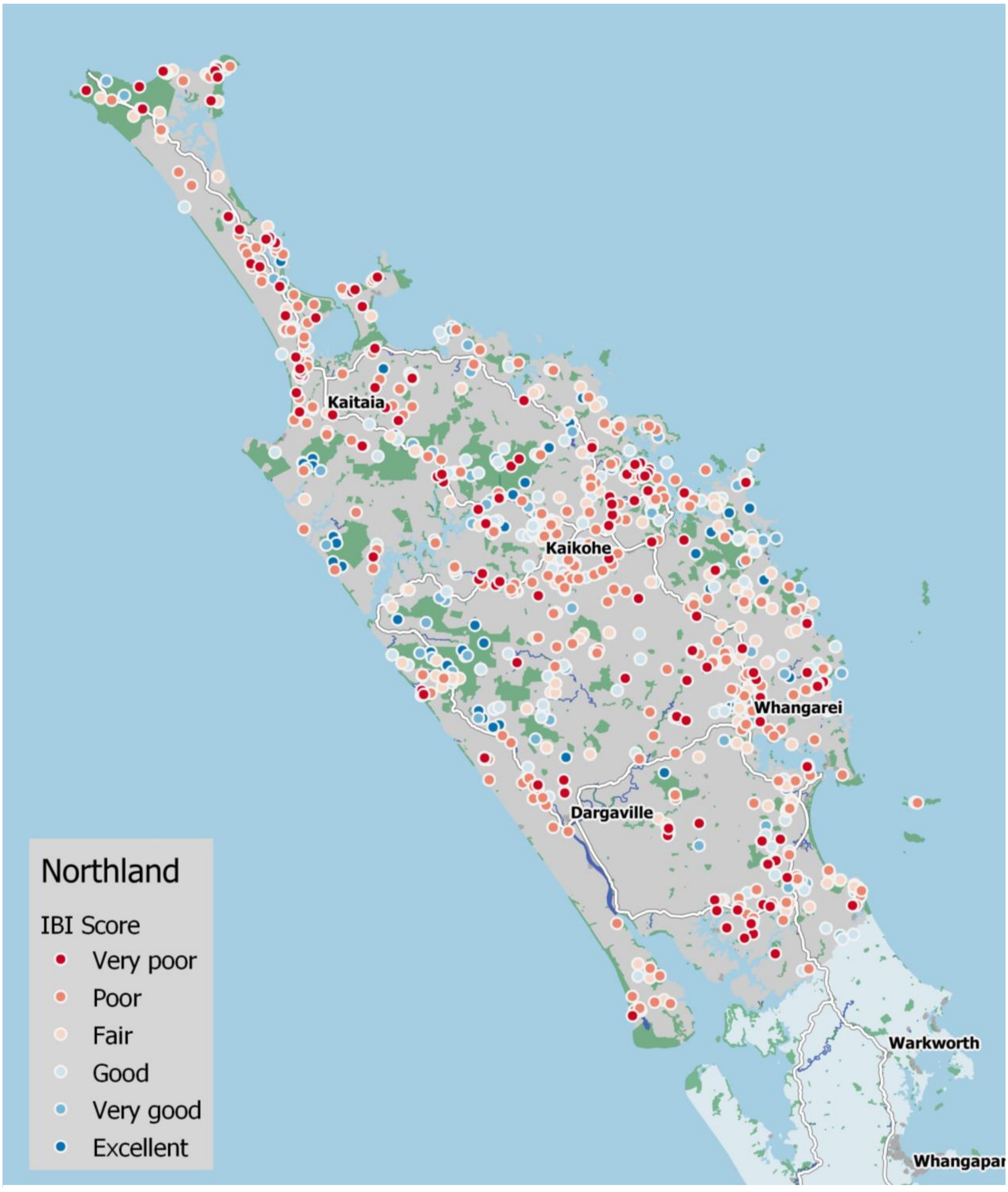


Figure 8. The fish data sites in the Northland region color coded by IBI classes (sites with no native fish classes excluded).

DISCUSSION

The assessment of river health using a fish Index of biotic integrity differs from other measures in that it is more holistic; because the fish species are mostly migratory it characterizes 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 at a lowland site can be indicative of upstream land-use as the land-use impacts can cause a chemical barrier to upstream migration, 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 more than four decades since 1980 so some of the scores will reflect previous land-use and thus may no longer be applicable so caution is required when looking at maps of the distribution of scores. 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. The targets are set by the current situation for the region, showing that they are achievable within the region. But for national scale comparison a single 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. The regional scores drawn from this for comparisons shows Northland has one of the lowest average IBI scores nationally (Fig. 9).

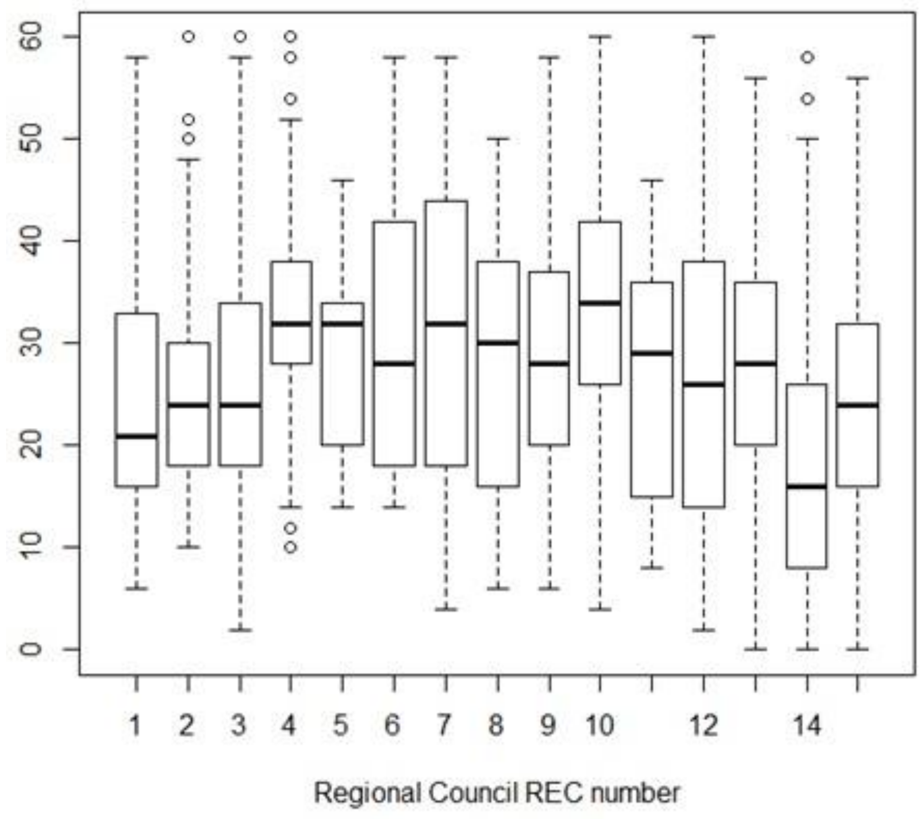
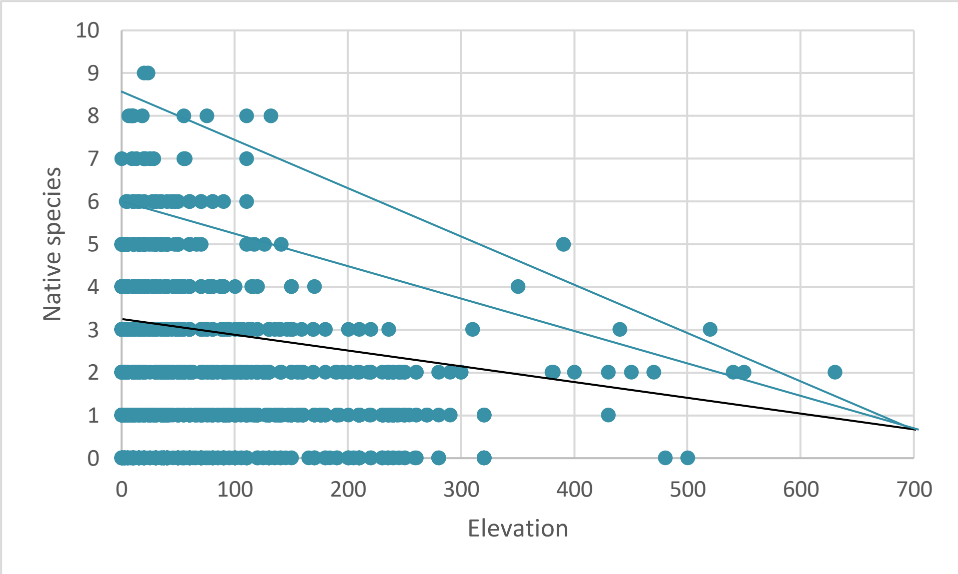


Figure 9. Regional comparison using a national IBI (number 1 is Northland)

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

1. Open the excel file **Northland 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 is shown 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.

GRAPHS USED TO CALCULATE SCORING LEVELS



Native species
Elevation
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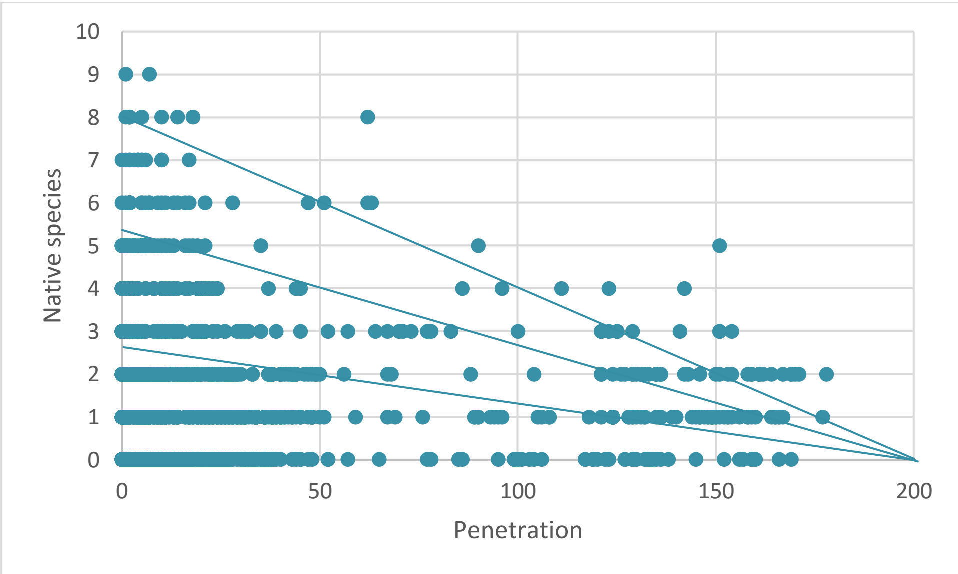

Native species
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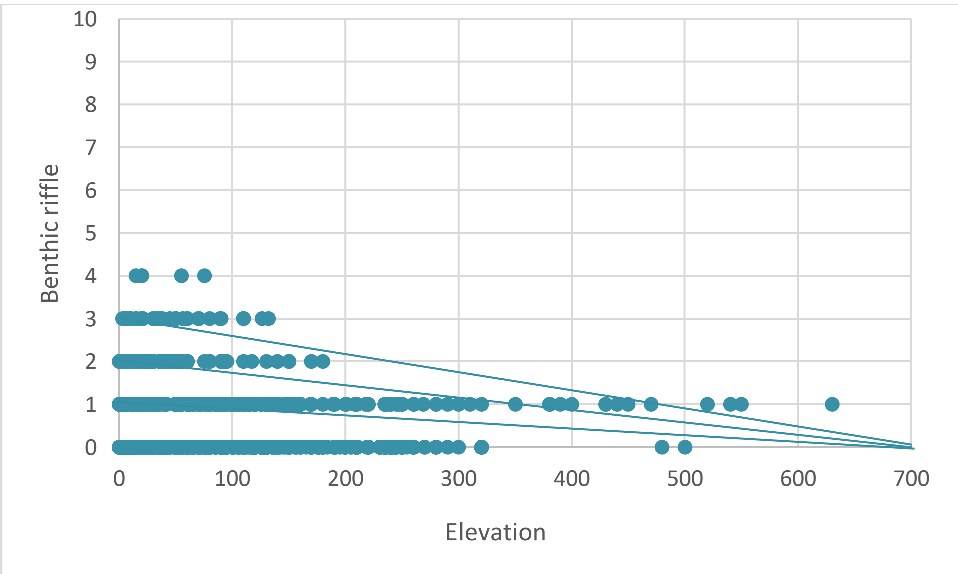

Benthic riffle
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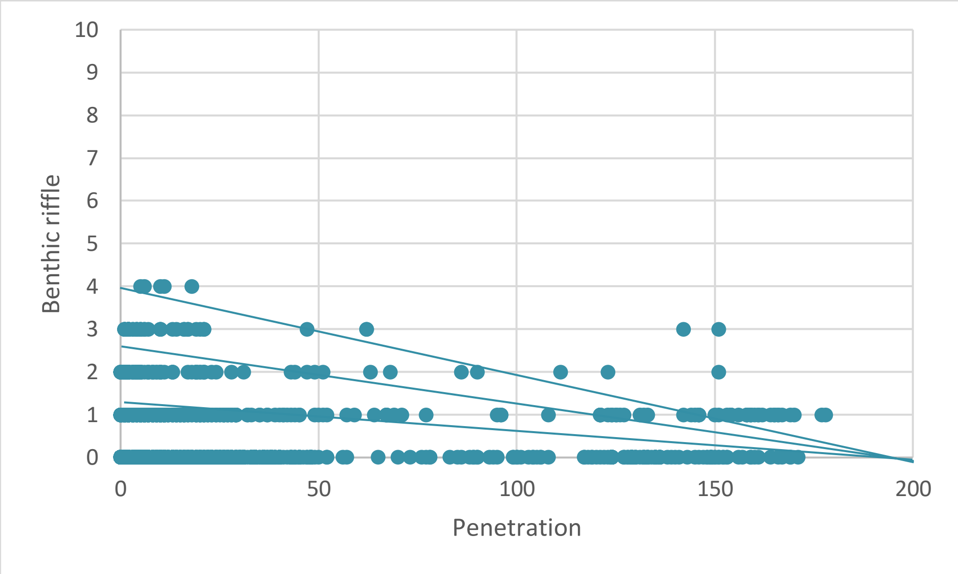
Benthic riffle
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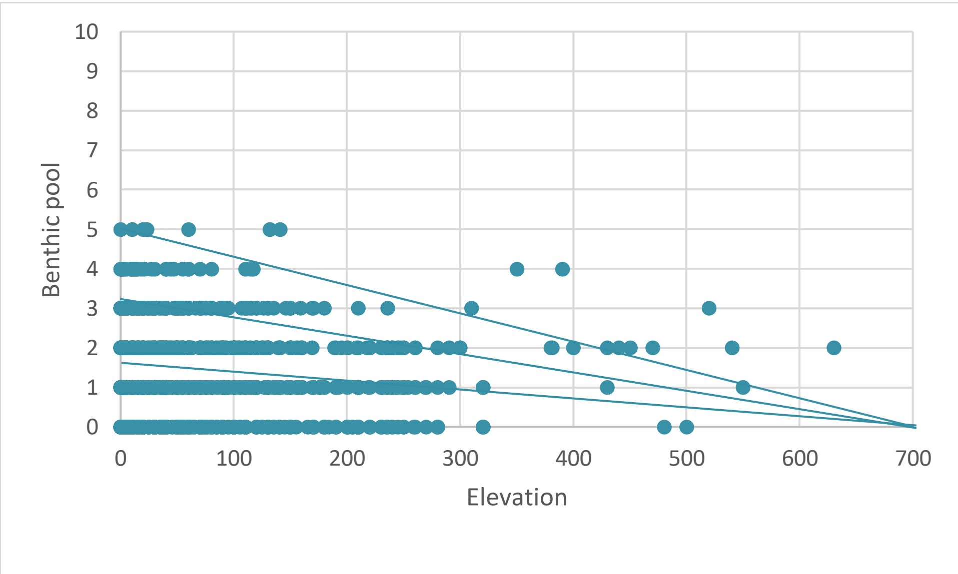
Benthic pool
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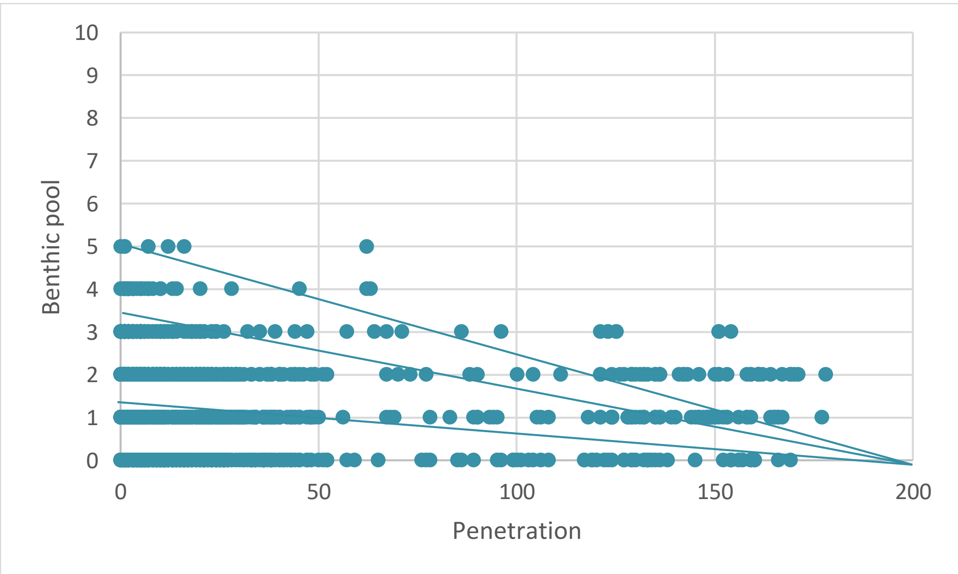
Benthic pool
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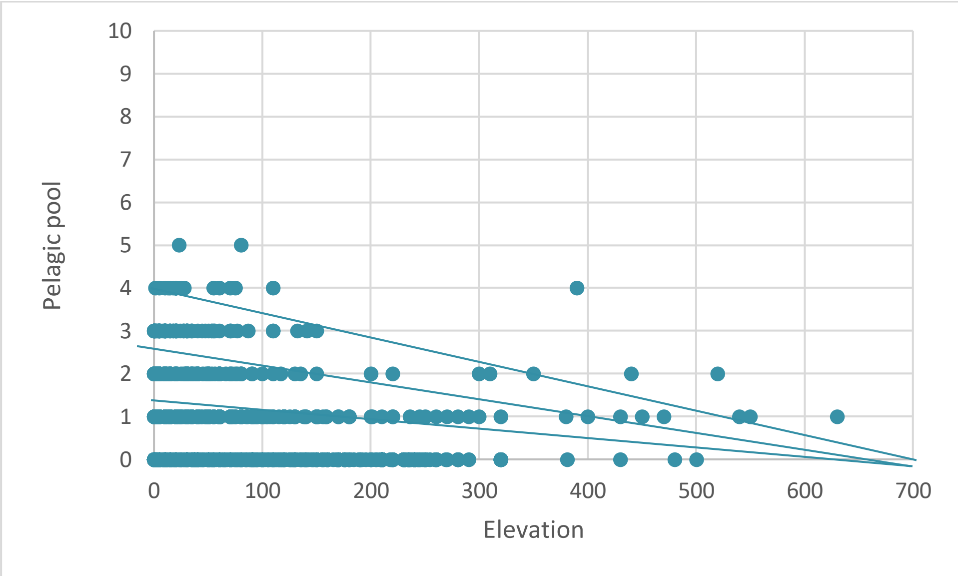
Pelagic pool
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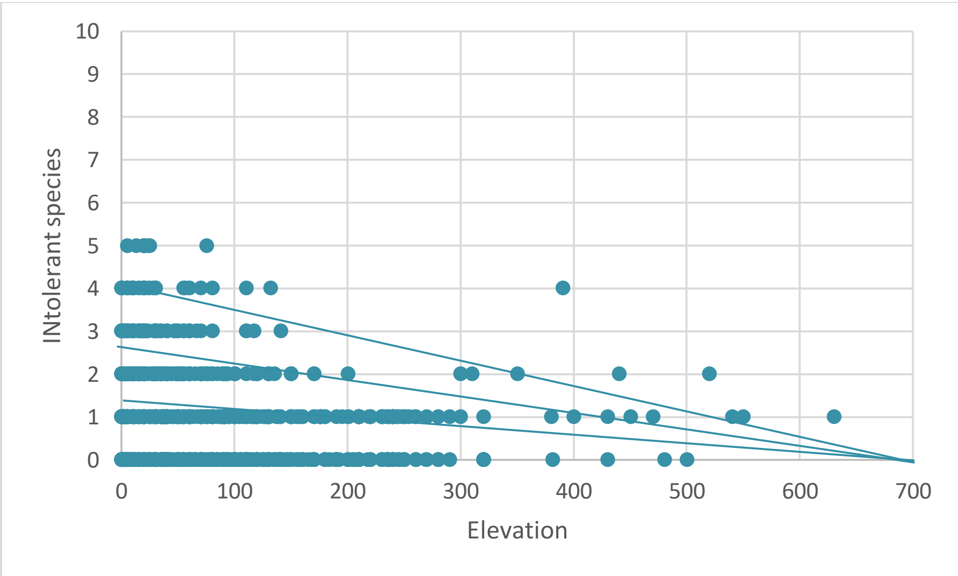
INtolerant species
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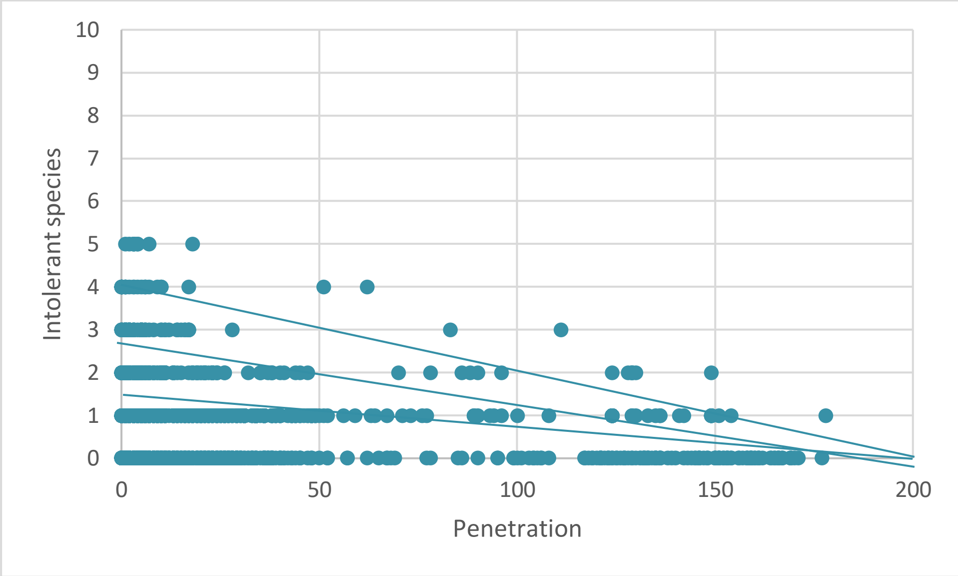
Intolerant species
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Penetration

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