Environment Waikato Technical Report 2007/23

A New Fish Index of Biotic Integrity using Quantile Regressions: the Fish QIBI for the Waikato Region

www.ew.govt.nz
ISSN 1172-4005 (Print)
ISSN 1177-9284 (Online)

Prepared by:
Mike Joy, Institute of Natural Resources, Massey University

Software by Ian Henderson,
Centre for Freshwater Ecosystem Modeling and Management, Massey University

For:
Environment Waikato
PO Box 4010
HAMILTON EAST

June 2007

ISSN: 1172-4005

Document #: 1187949

Peer reviewed by:
Mark Hamer Date Jun 2007

Approved for release by:
Dr Vivienne Smith Date Jun 2007

Disclaimer

This technical report has been prepared for the use of Waikato Regional Council as a reference document and as such does not constitute Council's policy.

Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved, and is accurately reflected and referenced in any subsequent spoken or written communication.

While Waikato Regional Council has exercised all reasonable skill and care in controlling the contents of this report, Council accepts no liability in contract, tort or otherwise, for any loss, damage, injury or expense (whether direct, indirect or consequential) arising out of the provision of this information or its use by you or any other party.

Acknowledgement

We thank John Leathwick (NIWA) for his suggestion to use quantile regression and bringing quantile regression to our notice.

Table of Contents

List of Figures

List of Tables

Introduction

The index of biotic integrity (IBI) was originally developed using fish in the USA by James Karr during the early 1980s. The original version had 12 metrics that reflected fish species richness and composition, number and abundance of indicator species, trophic organization and function, reproductive behaviour, 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 radically different from the continental faunas the IBI was originally developed on. To apply the IBI here a number of changes have been made. The basic concept has been retained; applying metrics to fish assemblages and the use of a large number of sites to give a background level of biological condition and then comparing a site of interest with that dataset to assess the status of the test site. Details on metrics and calculations are given below, for more details see: Joy, M.K. & Death, R.G. (2004) Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. *Environmental Management*, **34**, 415-428.

New Zealand's freshwater fish fauna has only a single trophic level and disease in wild fish populations is virtually absent, thus, those metrics could not be used here. The six metrics decided on measure taxonomic richness over a number of habitat types. Some indicator species are used by measuring the number of species showing tolerance to degraded conditions and finally 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 and this is obvious in the Waikato region (Fig. 1).

Because elevation and distance from the coast are the overriding controllers of 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.

Since the development of the first New Zealand IBI[1] and the Waikato IBI[2] there have been developments in the statistical tools available to get an accurate measure of regressions. This new approach - quantile regression enables a more accurate allocation of IBI scores from the data used in this approach and is described later in this report.

1 The conventional IBI scoring approach

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

This line was named by James Karr[3,4] as the maximum species richness line (MSRL). It shows the upper bound for species richness and is only used for partitioning the rest of the plot. The area under the line was then trisected to score sites (Fig. 3). The three 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 (Fig. 4).

[1] Joy, M. K., and R. G. Death. 2004. Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. Environmental Management **34**:415-428.

[2] Joy, M. K. 2006. A predictive Model of Fish Distribution and Index of Biotic Integrity (IBI) for Wadeable Streams in the Waikato region. Environment Waikato Technical Report 2006/07 Ecology Group and Centre for Freshwater Ecosystem Modelling and Management.

[3] Karr, J. R. 1981. Assessments of biotic integrity using fish communities. Fisheries **6**:21-27.

[4] Karr, J. R. 1987. Biological integrity and environmental assessment: a conceptual framework. Environmental Management **11**:249-256.

The process outlined above is repeated for the 6 metrics (described below) and for distance from the sea for the same 6 metrics.

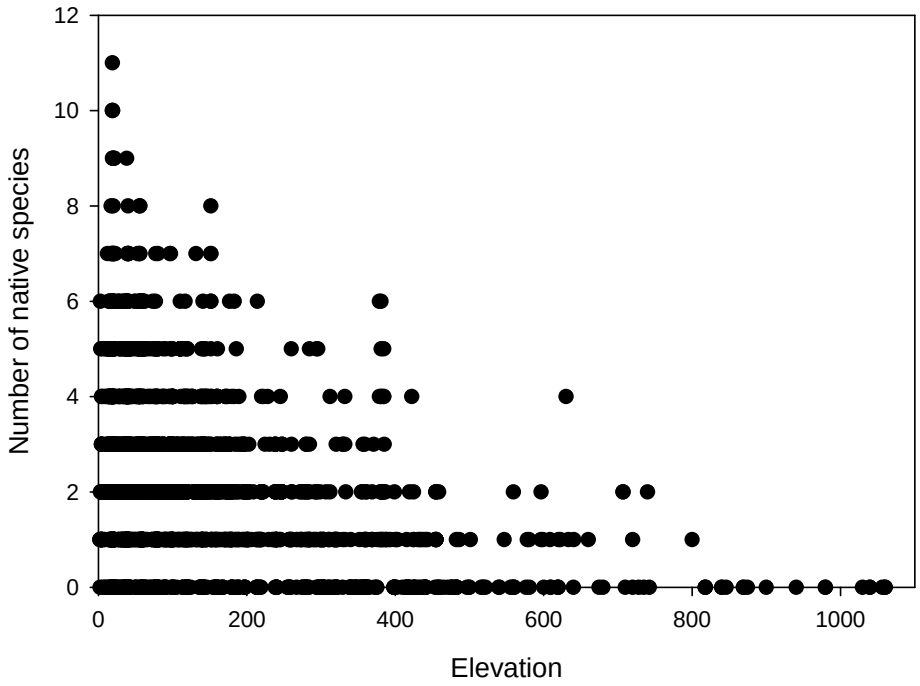

Figure 1: Number of native fish species from 2269 sites in the Waikato region plotted against elevation.

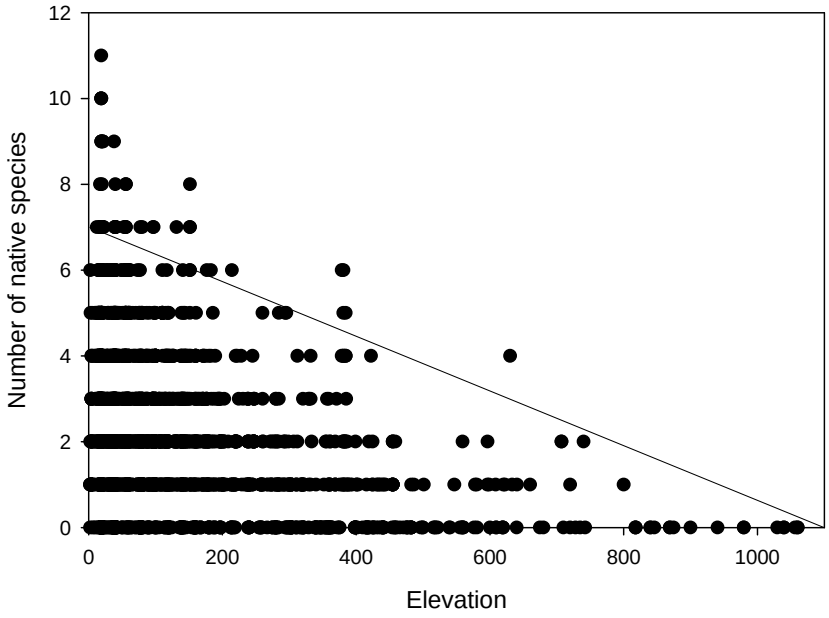

Figure 2: Fitting of line by eye line to include 95% of sites.

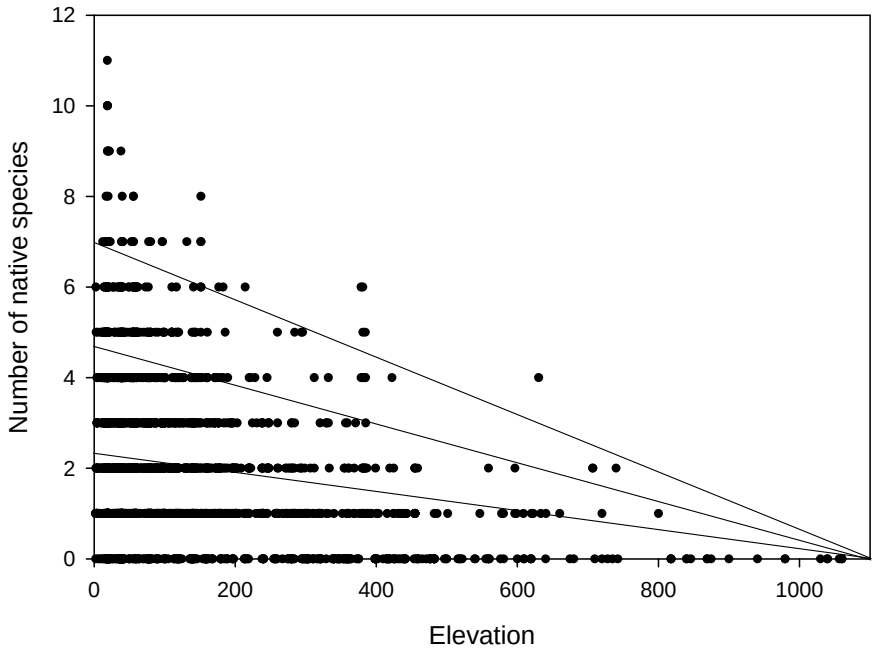

Figure 3: The area below the MSRL was trisected to give the scoring lines.

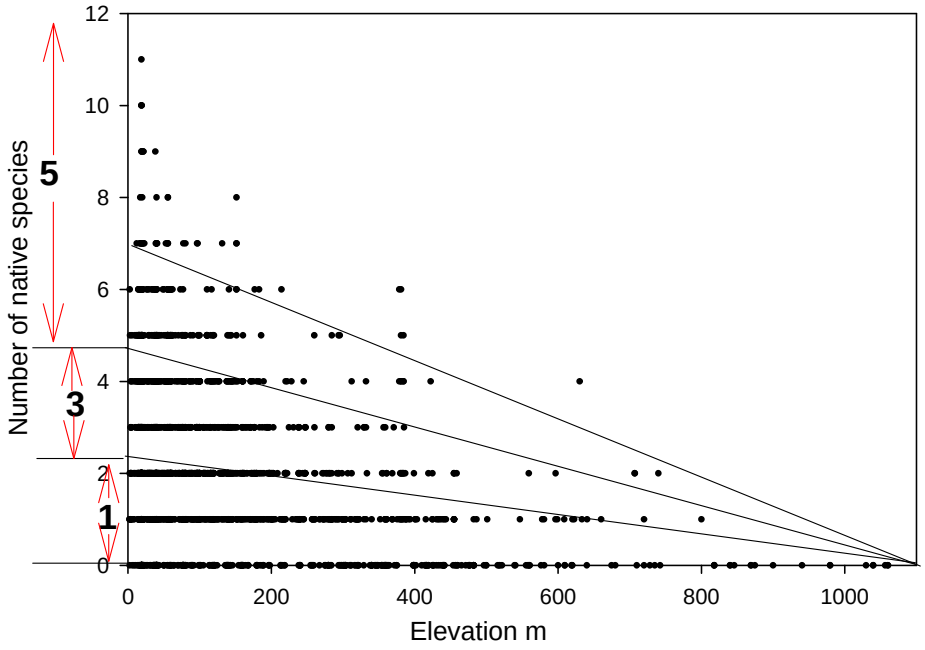

Figure 4: An example of site scoring from the lines below the MSRL.

2 The QIBI Quantile Regression approach

The quantile regression QIBI scoring is the same as the conventional approach (1, 3 & 5) but instead of being drawn by eye, the lines are calculated based on the number or percentage of sites below the line (Fig. 5). As with the conventional IBI, two lines are calculated, but now the lower line takes into account 33% of the data (below the line) and the upper line accounts for 66% of the data below the line. This is a vast improvement because the fitting by eye was flawed as it was not possible to tell how many sites were hidden by a single dot on a plot. The Quantile regressions were calculated using Proc QUANTREG in SAS[5].

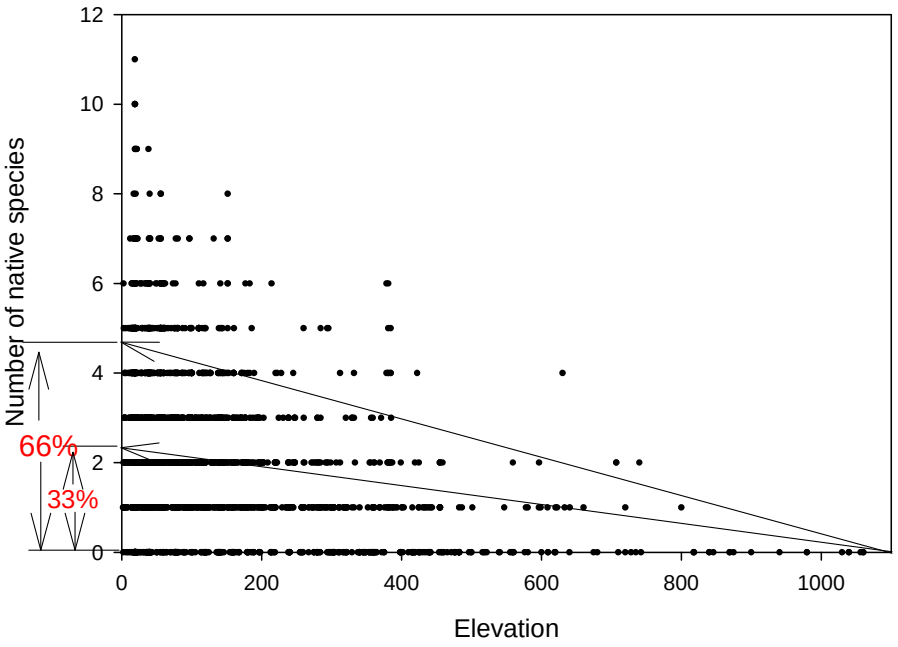

Figure 5: Plot showing quantiles calculated for the native species richness metric quantiles for 33% and 66%.

3 Waikato Fish QIBI metrics

Taxonomic richness

Metric 1 is the number of native and trout species; an attribute of freshwater biota's commonly used in biological assessment. We used native and trout species richness, as opposed to total species richness as other non-native species may prefer degraded habitats and thus increase species richness. 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 and trout 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

[5] SAS/STAT Version 9 SAS Institute, Cary North Carolina USA

these guilds. Native and trout pelagic pool species were included as the presence of the other alien species is indicative of degradation.

Tolerant species

Metric 5 is the number of 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 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. After consultation with EW staff we decided to leave Trout out of the exotic species category as we considered them to be ubiquitous and indicators of good habitat quality unlike the other exotic species.

The fish were classed into the five metrics shown in Table 1. The metrics are non-exclusive and are based on information from the literature and from personal experience[6].

[6] Joy, M. K., and R. G. Death. 2004. Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. Environmental Management **34**:415-428.

Table 1: The classification of fish species found in the Waikato region into the different metrics.

Scientific name	Common name	Metrics					
		Native (1)	Benthic-riffle (2)	Benthic-pool (3)	Pelagic-pool (4)	Intolerant (5)	Invasive (6)
Aldrichetta forsteri	Yelloweye mullet	1			1		
Ameiurus nebulosus	Catfish						1
Anguilla australis	Shortfin eel	1		1			
Anguilla dieffenbachii	Longfin eel	1	1	1			
Carassius auratus	Goldfish						1
Cheimarrichthys fosteri	Torrentfish	1	1				
Ctenopharyngodon idella	Grass carp						1
Cyprinus carpio	Koi carp						1
Galaxias argenteus	Giant kokopu	1			1	1	
Galaxias brevipinnis	Koaro	1	1			1	
Galaxias fasciatus	Banded kokopu	1		1	1	1	
Galaxias maculatus	Inanga	1			1		
Galaxias postvectis	Shortjaw kokopu	1		1	1	1	
Gambusia affinis	Mosquito fish						1
Geotria australis	Lamprey	1		1			
Gobiomorphus basalis	Cran's 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	
Mugil spp.	Mullet species	1			1		
Neochanna	Mudfish	1		1		1	
Oncorhynchus mykiss	Rainbow trout	1*			1*		
Perca fluviatilis	Perch						1
Poecilia reticulata	Guppy						1
Retropinna retropinna	Common smelt	1					
Rhombosolea retiaria	Black flounder	1		1		1	
Salvelinus fontinalis	Brook char						
Salmo trutta	Brown trout	1*			1*		
Scardinius erythrophthalmus	Rudd						1

* Trout are not native but have been given this status for the IBI as they are found throughout the region and help to assess biotic integrity since they are not indicators of poor conditions unlike other non-native species.

4 Calculation of total QIBI score

To calculate the total QIBI, the scores for the six metrics are summed to give the QIBI score for each sampling site. There are six metrics each for elevation and distance from the coast (maximum possible QIBI score of 60 and minimum 0).

5 Interpretation of results

As a guide to interpreting the final scores the integrity classes were given narrative class names similar to other IBIs. These categories are based on the distribution of site scores for the region, and these were readjusted using the percentiles from the reference site distribution. Table 2 shows the attributes and integrity classes with assessment of site scores. A histogram of the sites to give an indication for how the site you are interested in compares with the 2269 sites in the region used to build the model (Fig. 6).

Table 2: Attributes and suggested integrity classes for the Waikato QIBI

Total QIBI score	Integrity class	Attributes
47 - 60	Excellent	Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 75th percentile of Waikato sites.
36 - 46	Good	Site is above the 50th percentile of Waikato sites but species richness and habitat or migratory access reduced. Shows some signs of stress.
27 - 35	Moderate	Site is above 25th percentile. Species richness is reduced. Habitat and or access is impaired.
6 - 26	Poor	Site is impacted or migratory access almost non-existent.
0	No fish	Site is grossly impacted or access non-existent.

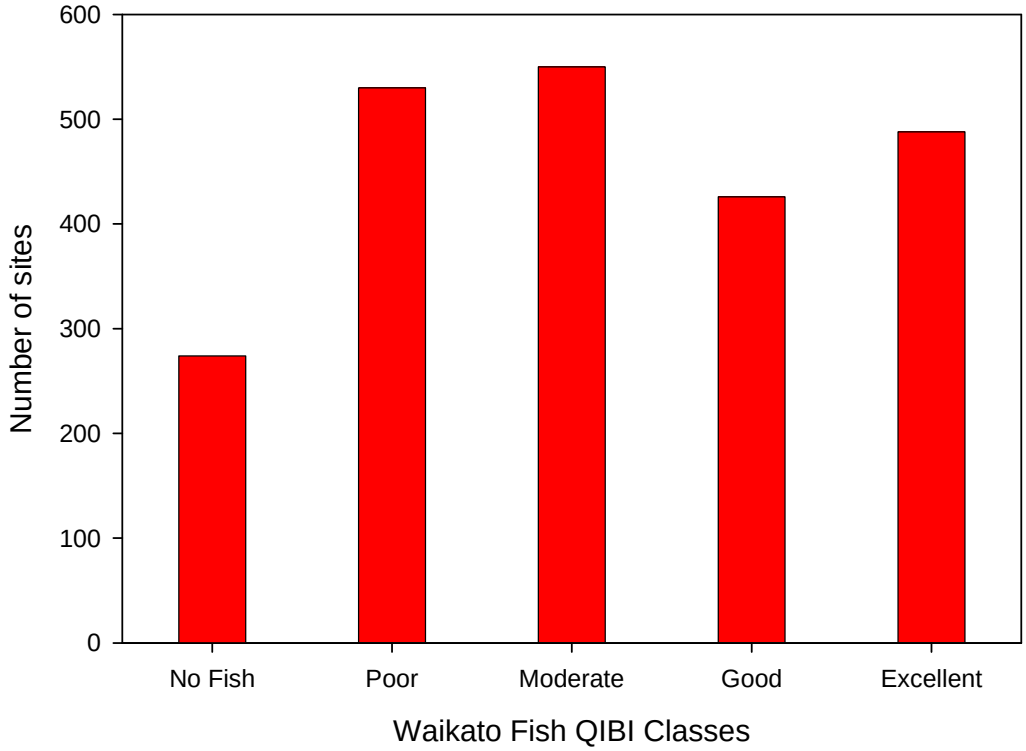

Figure 6: The distribution of the Quantile QIBI scores across the 2269 sites used to calibrate the QIBI in Waikato region.

6 Comparison between the conventional IBI and the Quantile IBI mapped over the Waikato Region.

A predictive model of fish distribution for the Waikato Region[7] was used to calculate the QIBI scores for all streams in the region and mapped out to show the patterns of fish biological integrity (Fig. 6). Many of the non-native fish species are at very low levels of frequency in the fish database used to build the predictive model, thus they were left out of the IBI calculations and the scores adjusted up accordingly to allow for the lost metric. The Quantile IBI predictive map (Fig. 7) shows a stronger differentiation between the very high and low IBI areas, and this is particularly obvious around the Coromandel and West Coast areas. The lowland areas show a more consistent spatial spread of low scores.

[7] Joy, M. K. 2006. A predictive Model of Fish Distribution and Index of Biotic Integrity (IBI) for Wadeable Streams in the Waikato Region. Environment Waikato Technical Report 2006/07 Ecology Group and Centre for Freshwater Ecosystem Modelling and Management.

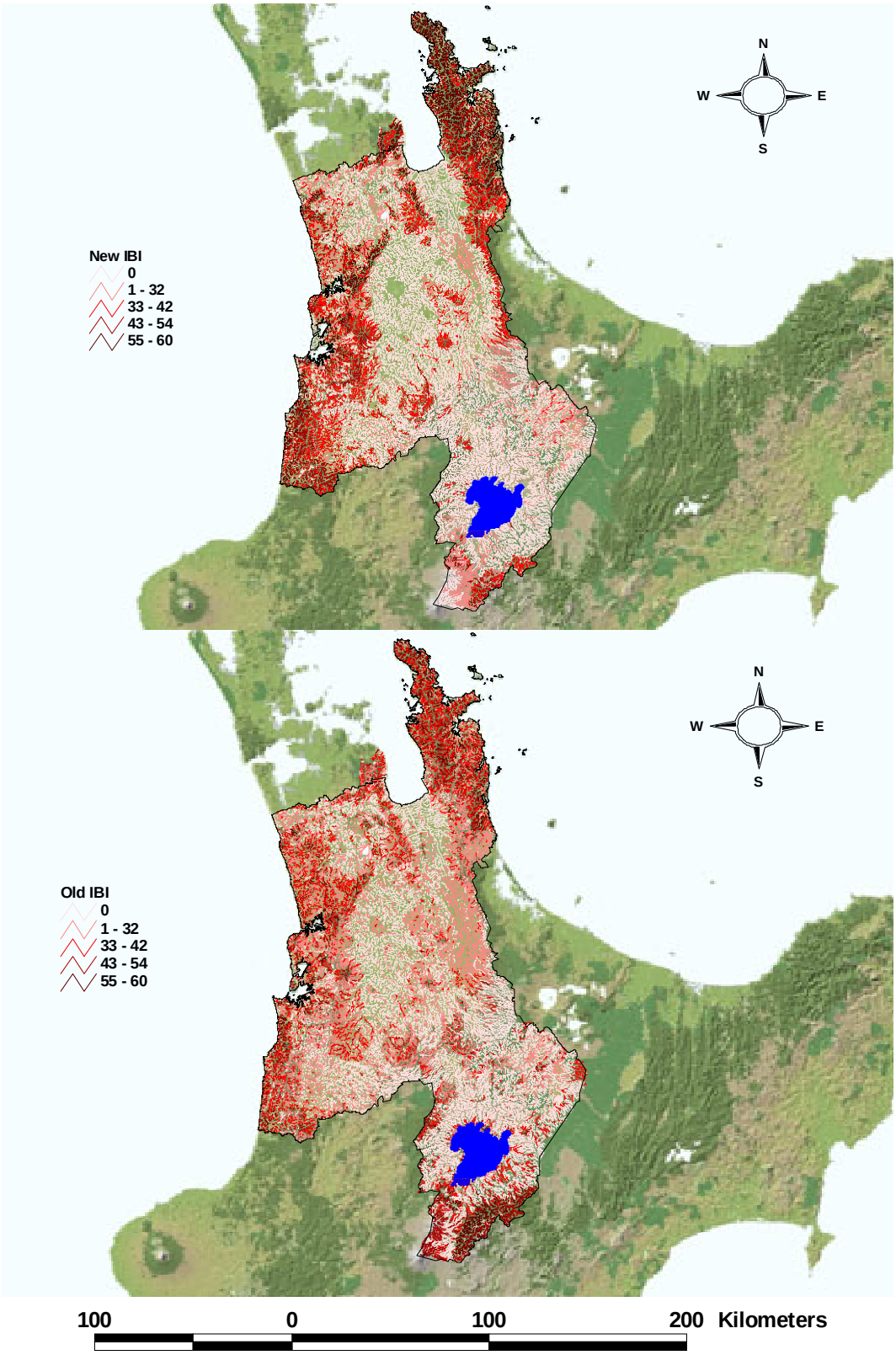

Figure 7: Spatial distribution maps of the new fish QIBI scores calculated from the predictive fish model compared to the old method of scoring[8]

[8] Joy, M. K. 2006. A predictive Model of Fish Distribution and Index of Biotic Integrity (IBI) for Wadeable Streams in the Waikato region. Environment Waikato Technical Report 2006/07 Ecology Group and Centre for Freshwater Ecosystem Modelling and Management.

Appendix 1

Instructions for using Waikato fish QIBI software

An example running a set of sites through the WaikatoFishQIBI software to calculate scores (Help files contain this information and more):

1. Open the excel file **WaikatoFishQIBI**
2. A new tool bar should appear, click on help button and instructions are available or navigate when prompted to folder where help file is kept.
3. On input sheet enter details in the Batch notes cell any information you want to appear on the output file. In 'site code or name' row put in site specific identification details.
4. 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 (with a space) is the distance (as the fish swims) of the site from the coast.
5. 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.
6. 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 QIBI toolbar. The QIBI 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.
7. To remove the graph click on the remove graphs button on the QIBI toolbar and start again for another site.
8. 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.