BEFORE THE HEARINGS PANEL

IN THE MATTER OF

HEARINGS ON SUBMISSIONS CONCERNING THE PROPOSED ONE PLAN NOTIFIED BY THE HORIZONS MANAWATU-WANGANUI REGIONAL COUNCIL

Report of Dr Mike Joy on behalf of Fish and Game New Zealand and The New Zealand Royal Forest and Bird Protection Society

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1 QUALIFICATIONS AND EXPERIENCE

1.2 My name is Michael Kevin Joy. I hold a BSc, MSc (1st Class Hons) and a PhD in Ecology from Massey University. For the last fifteen years I have been a researcher in freshwater ecology, especially native fish distribution and freshwater bioassessment. I have been employed at Massey University Palmerston North since 2003 as a lecturer, now Senior Lecturer, in Ecology and Environmental Science.

1.3 My areas of expertise are bioassessment of water and habitat quality in flowing waters, especially in relation to freshwater fish, and spatial distributional modelling using Geographic information systems (GIS).

1.4 I am a member of the New Zealand Freshwater Sciences Society, the New Zealand Ecological Society, the Australian Society of Fish Biology and the New Zealand Royal Society.

1.5 In the last seven years I have published more than 17 peer reviewed scientific papers on freshwater ecology and bioassessment, mostly in relation to New Zealand freshwater fish, and the majority of these papers are published in international journals. I have published two book chapters on native fish and bioassessment. I have also published many reports for most Regional Councils in the North Island, and have supplied software to run bioassessment models developed for these regions.

1.6 I have supervised more than 15 postgraduate (honours, Masterate and PHD) student research projects mostly directly related to freshwater ecology and bioassessment.

1.7 I was awarded the New Zealand Ecological Society Ecology in Action Award in 2009.

1.8 I have refereed scientific manuscripts for 7 journals and one book.

1.9 I have been involved in a number of hearings in relation water quality, freshwater fisheries, fish distribution, river ecology and instream habitat. Some examples are:

- Meridian Energy application Mokihinui River hydro Dam
- Trustpowers' re-consenting of the Patea Hydro Dam
- Horowhenua and Manawatu District councils wastewater discharge consent applications
- Fonterra Longburn discharge consent applications
- Meridian Energy's project Mill Creek wind farm application

2. SCOPE OF EVIDENCE

2.1 I have been asked by both the Royal Forest and Bird Society and Fish and game New Zealand to provide evidence on the relationship between land-cover/land-use and the distribution of freshwater fish in the Manawatu-Wanganui Region and nationally. I have been asked to cover aspects relating to the impacts on the habitat requirements of fish by land-use changes and the concomitant diffuse nutrient and sediment run-off to water as well as point-source discharges.

3. EXECUTIVE SUMMARY

3.1 New Zealand's freshwater fish are undergoing a major decline, more than half (65%) of the species are now classified by the Department of Conservation as threatened. Two other large freshwater species, the freshwater crayfish, (koura) and freshwater mussel (kakahi), have also recently been added to the threatened list. The mussel is reliant on the presence of fish, because part of the mussel reproductive life-cycle involves attaching to fish gills. Not surprisingly they are on the threat list.

3.2 To investigate the causes of these declines nationally and regionally an investigation of the New Zealand freshwater fish database was undertaken.

3.3 Analysis of native fish distribution at more than 22,546 sites nationally, showed significant differences in the status of fish communities in catchments with differing landcover. Catchments predominantly made up of pasture, urban or exotic forest had significantly fewer sites containing native fish than catchments of predominantly natural vegetation. This negative relationship between pasture and native fish presence and positive relationship between natural catchment vegetation and native fish presence has been found in many other studies.

3.4 Analysis of temporal trends in native fish distribution over the past 37 years showed significant declines, especially over the last decade. Investigations of the trends by catchment land-cover type showed the biggest declines were at pasture, tussock, and urban sites, while exotic forest sites showed no significant change and there was a significant improvement at native forest and scrub sites.

3.5 The freshwater fish database was also investigated to look for trends in trout distribution in relation to land cover and over time. When the sites were separated in to catchments of different landcover types, marked differences were found in the proportion of sites containing trout. The highest proportions of sites with trout present were the catchments predominantly in natural vegetation. Whereas sites with catchments predominantly in pasture had significantly less trout followed by, exotic forest, and urban sites had the lowest proportion of sites containing trout.

3.6 Temporal analysis of trout distribution over the past 37 years, over the whole country showed significant declines, the steepest declines were over the last decade. Investigation of these temporal trends by land-cover type showed significant declines at all landcover types except exotic forest sites.

3.7 An Investigation of how different proportions of landcover in catchments affect the presence of trout was investigated using predictive models. These models revealed a very high level of predictive accuracy and illustrated that the proportion of pasture and natural vegetation in catchments were very strong predictors of trout presence or absence. Further investigations showed that there was a strong negative relationship between proportion of catchment in pasture and trout presence, while increasing levels of natural land cover in catchments had a positive relationship with trout presence.

3.8 An analysis of the distribution of native fish in the Manawatu catchment revealed some striking anomalies. A suite of sensitive native fish is missing from large parts of the catchment where they would be expected to be. To quantify this incongruous distribution a predictive model was developed using data from the rest of the North Island to show where the fish would occur if habitat geology climate and landcover conditions were the same as in the Manawatu catchment. In other words, where the fish should occur if they were not in the Manawatu catchment but all else was equal. The process used to construct this model is well established in the freshwater ecology literature. Model accuracy is very high at around 90% correct prediction, which is better than similar models worldwide. The predictive model of distribution was compared to the actual distribution and showed that banded kokopu and redfin bully are missing from around 50% of the habitat they should be at. For koaro, they are missing from 84%. It should be noted that this is a conservative assessment of the amount of habitat lost as the model was built using data from the rest of the North Island that is already impacted by landuse alteration and pollution. Thus, the predictions are not those of a pristine rivers rather rivers with less impacts than the Manawatu.

3.9 To test for possible causes of the distributional anomalies an experiment was setup to let fish make the choice of two tributaries of the Manawatu River while under observation. The experiment conclusively showed that when fish were given a choice between the Manawatu River and the Oroua River they preferred the Manawatu. However, when given the choice between the Manawatu and the Mangaore River they convincingly chose the Mangaore. These choices match the actual distribution with the sensitive species absent from the Oroua River, whereas the Mangaore has good native fish populations including all the sensitive species. Analysis of water samples taken at the time of the experiment showed that choices were associated with lower nutrient levels.

3.10 The native fish distribution in the Manawatu River catchment is negatively related to the parts of the catchment with high areas of erosion. When viewed as a map, the area containing no sensitive fish species is the same area that had a high proportion of slip scars after the 2004 floods and vice versa. This negative relationship between sediment has been documented before but the importance of deposited sediment has only recently been quantified. Micro scale habitat use analysis of native fish using radio tags in the Manawatu catchment revealed that fish spend much of their time deep in the stream substrate in the interstitial spaces (the spaces between rocks and cobbles) up to 1 metre down. This “third dimension” is crucial in determining the number of fish in a given area of stream but is lost as sediment is deposited on the stream bed.

4. TEMPORAL AND LANDCOVER TRENDS NATIVE FISH

4.1 More than half on the freshwater fish species in New Zealand (32/49; 65%) are classified as threatened by the Department of Conservation[1]. Two other large freshwater species the freshwater crayfish (koura) and freshwater mussel (kakahi) have also been added to the list. The mussel (kakahi) is reliant on the presence of fish as part of it life-cycle involves attaching to fish gills they are dependent on intact fish communities for their survival.

4.2 To examine trends over time and in relation to landcover in native fish communities' data for the last four decades was extracted from the New Zealand database. However, it is not simply a matter of comparing number of species found at a site unless there has been a long record of sampling at the same site because the distribution of New Zealand freshwater fish fauna is driven largely by elevation and distance from the coast due to the prevalence of migratory fish species (McDowall 1998, Joy et al. 2000, Joy and Death 2001). This results in a natural trajectory of reducing species richness with increasing distance from the sea and elevation. Therefore, to make comparisons between sites these factors must be taken into account. A Fish Index of Biotic Integrity can achieve this requirement as fish community expectations are adjusted for elevation, distance and existing conditions (Joy and Death 2004a).

4.3 The use of fish communities to define freshwater ecosystem integrity has had a relatively long history. Originally developed using fish in the USA by James Karr during the early 1980s the Index of Biotic integrity is now used worldwide (Ganasan and Hughes 1998, Roth et al. 1998, Toham and Teugels 1999, Drake and Pereira 2002). A fish Index of Biotic Integrity (F-IBI) has been developed for all New Zealand (Joy and Death 2004a) and regionally for the Waikato (Joy 2006, 2007a), Auckland (Joy 2004a), Hawke Bay (Joy 2005) and Wellington (Joy 2004b).

Temporal and landcover trends native fish methods

4.4 The fish data came from the New Zealand Freshwater Fish Database maintained by the National Institute of Water and Atmospheric Research (NIWA) and contains records of fish distribution for around 100 years (McDowall and Richardson 1983, McDowall 1991). The data has been supplied by many different individuals and institutions and in 2008 contained more than 23000 records. Each entry includes the site location details and the species of fish and large crustaceans found there, using a number of survey methods. The amount of detail varies from just presence absence and not habitat details to complete site descriptions and very accurate abundance and fish size measures. However, due to the differences in survey methodology and measures of abundance all data were converted to presence absence. To analyse the trends in the database related to landuse the River Environment Classification (REC)[2] landcover classes were applied to all sites. The

[1] http://www.doc.govt.nz/getting-involved/consultations/closed/new-listing-of-threatened-status-of-new-zealand-freshwater-fish/

[2] http://www.niwa.cri.nz/ncwr/rec

major landcover classes; pastoral, urban, indigenous forest, scrub, urban and exotic forest were used.

4.5 Thirty seven years of freshwater fish and crustacean presence-absence data were obtained from the NZFFDB that was all entries on flowing water dating from January 1970 to June 2007. This consisted of 22,546 sites, over broad geographic coverage (Fig. 1).

Figure 4.1 The position of the 22,546 sites in the NZFFDB from 1970-2007 used for native fish trends and trout trend analysis.

Sampling trends

4.6 The number of sites added to the database has increased over time but there were different patterns of increase related to landcover. Sites sampled in exotic forest, urban and scrub landcover showed a gradual increase, approximately doubling every decade. Sampling indigenous forest sites increased at a much greater rate but peaked in the 1990s, while pasture sites increased exponentially over the entire period. In the last decade the number of pasture sites added accounted for more than all the other classes combined (Fig. 2).

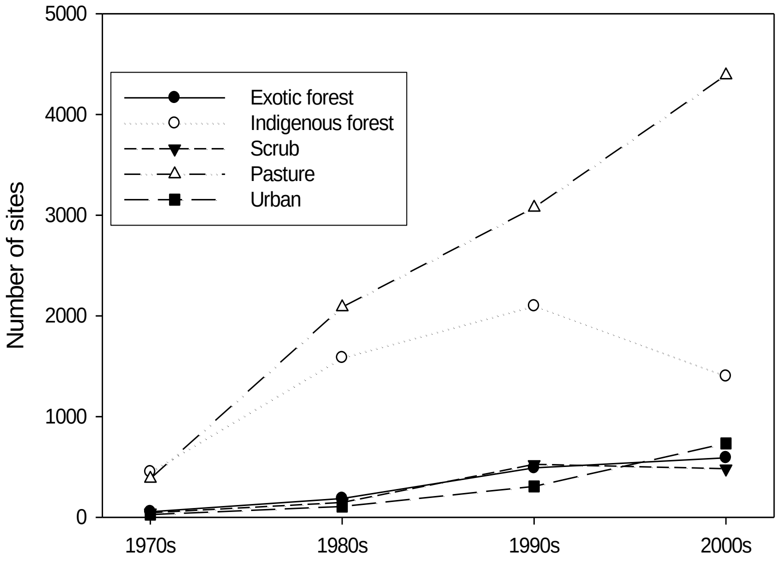


Figure 4.1 Sites added to the database over decades by landcover type

Statistical analyses

4.7 The relationship between landcover and fish communities were analysed by comparing the mean IBI scores using analysis of variance (Proc ANOVA (SAS 2000)). Temporal trends in fish community structure were analysed by comparing IBI scores over years and decades for all sites and then by individual REC class to find the landcover types underlying and differences and trends. Statistical analysis of temporal trends was done using regression models (PROC GLM (SAS 2000)). To visualise these trends mean decadal scores and variances were plotted. The reaches that had multiple sampling events were assessed for changes in IBI scores over time using Spearman Rank Correlation (PROC CORR (SAS 2000)). The results were reported as the number of significant relationships positive or negative. To further investigate the changes at sites sampled more than once, sites that had been sampled previous to 2000-2007 were compared with the 2000-2007 period by counting the number of reaches that had more or less species.

Temporal and landcover trends native fish results

Index of biotic integrity scores in relation to landuse

4.8 The average IBI score was significantly higher at indigenous forest and scrub sites than the other land cover classes (ANOVA $F_{6, 22539} = 243$; $P < 0.0001$) (Table 1; Fig. 3). Pasture sites had the lowest scores but were not significantly different from urban, exotic and unvegetated sites.

Table 4.1 Descriptive statistics for IBI scores by REC class

REC class	*Pasture*	*Urban*	*Exotic*	*Bare*	*Indigenous*	*Scrub*
Mean	29.68	30.33	30.47	31.4	36.22	36.51
Median	32	34	32	40	38	40
Std deviation	17.62	16.69	19.93	20.09	17.85	19.27
Std error	0.18	0.49	0.55	0.88	0.24	0.56
Number of sites	9932	1167	1319	522	5530	1194

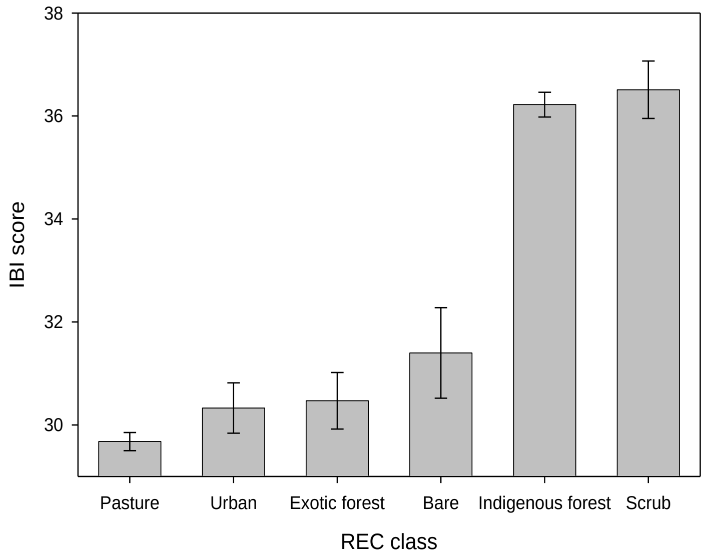


Figure 4.3 Average IBI score for all sites grouped by REC landcover class (whiskers = SE).

Temporal trends in biotic integrity scores

4.9 The IBI scores for all sites show there has been a significant decline in fish communities over the last 37 years. This decline was significant for both years and decades (Table 4.2) with the biggest reduction in the last decade (Fig. 4.4). To assess which of the landcover classes contributed to this decline the different classes were analysed separately. Indigenous forest sites showed a significant increase over the period peaking in the 1990s (Fig. 4.5; Table 4.2). Pasture sites showed a significant decrease in IBI scores for the period especially in the last decade (Fig. 4.6; Table 4.2). The sites in scrub landcover showed no significant trend over time (Fig. 4.7; Table 4.2). Urban sites showed a significant decline in IBI scores over the 37 years (Fig. 4.8; Table 4.2). The exotic forest sites showed a dip the 1990s but the trend over the period was not significant (Fig. 4.9; Table 4.2).

Table 4.2 Results of regression analyses for all sites and land cover classes using IBI scores for years and decades. (bold values indicate a significant negative trend P < 0.05)

REC landuse class	Number of sites	All years		Decades	
		F-value	*P-value*	*F-value*	*P-value*
All sites	**22545**	**191.2**	**0.0001**	**223.7**	**0.0001**
Pasture	**9931**	**92.0**	**0.0001**	**118.4**	**0.0001**
Indigenous	5529	41.5	0.0001	24.7	0.0001
Urban	**1157**	**29.6**	**0.0001**	**19.9**	**0.001**
Scrub	1193	3.9	0.047	1.21	0.27
Exotic	1318	2.4	0.13	0.09	0.77

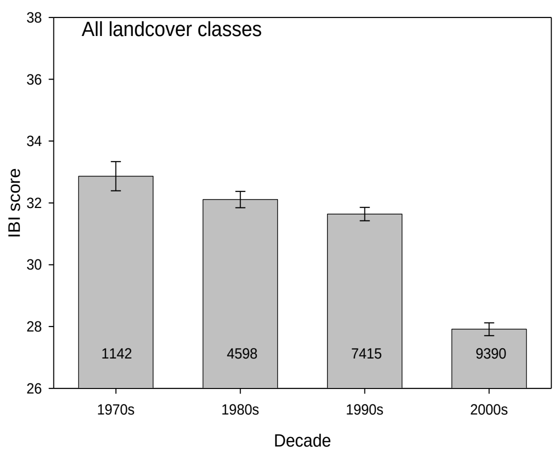


Figure 4.4 Average decadal BI score for all sites (number of sites inside bars whiskers = SE)

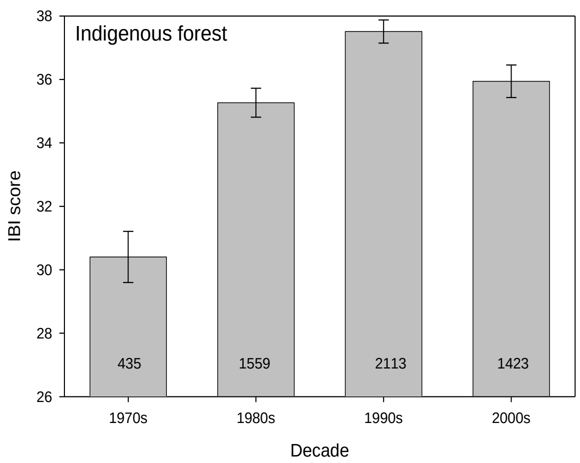


Figure 4.5 Average decadal IBI scores for REC landcover Indigenous forest sites (number of sites inside bars whiskers = SE).

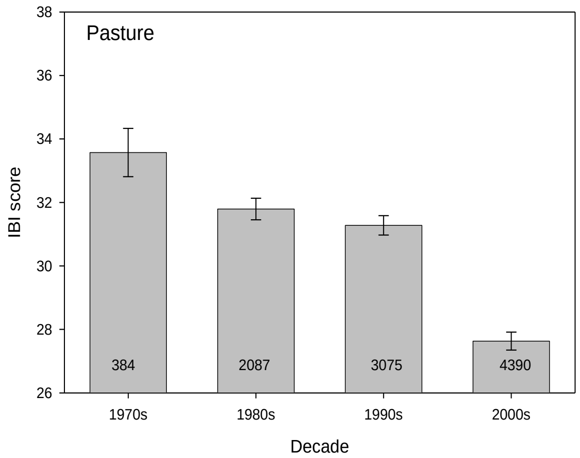


Figure 4.6 Average decadal IBI scores for REC landcover pasture sites (number of sites inside bars whiskers = SE)

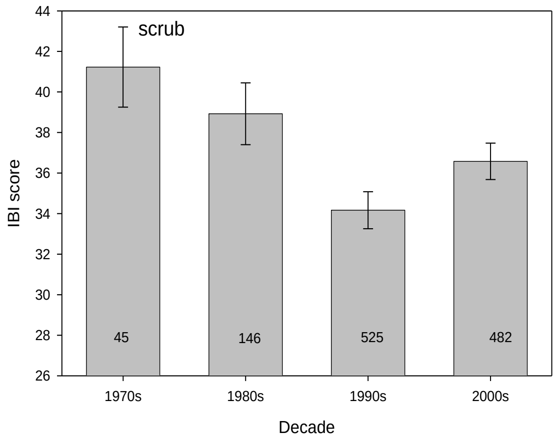


Figure 4.7 Average decadal IBI scores for REC landcover pasture sites (number of sites inside bars whiskers = SE)

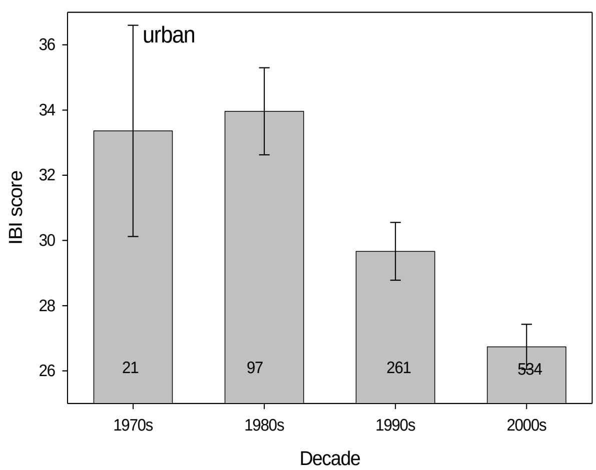


Figure 4.8 Average decadal IBI scores for REC landcover urban sites (number of sites inside bars whiskers = SE)

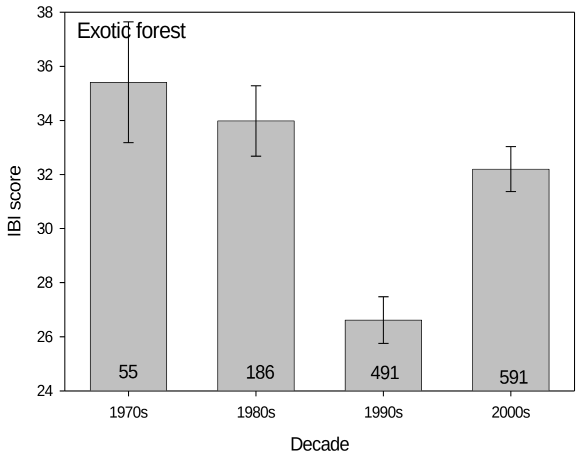


Figure 4.9 Average decadal IBI scores for REC landcover pasture sites (number of sites inside bars whiskers = SE)

5. TEMPORAL AND LANDCOVER TRENDS TROUT

5.1 As with the native fish trends assessment the data on fish distribution came from the New Zealand Freshwater Fish Database (NZFFD) maintained by the National Institute of Water and Atmospheric Research (NIWA) and contains records of fish distribution for around 100 years (McDowall and Richardson 1983, McDowall 1991). The data has been supplied by many individuals and institutions and in 2008 contained more than 23,000 records. Each entry includes the site location details and the species of fish and large crustaceans found there, using a number of survey methods. The amount of detail varies from only presence/absence and no habitat details, to complete site descriptions and detailed abundance and fish size measures. However, due to the differences in survey methods and measures of abundance all data were converted to presence/absence, as comparison requires consistent levels of data accuracy. To analyse the trends in the database related to land use the River Environment Classification (REC)[3] land-cover classes were applied to all sites. The major land-cover classes; pastoral, urban, indigenous forest, scrub, and exotic forest were used.

Data limitations

5.2 The fish distribution data used in this report were not collected expressly for this analysis, rather they are a collection of sites sampled for many reasons by many different operators. Thus, there will be differing levels of sampling intensity and ability of operators; notwithstanding this the large number of sites should override this limitation to some extent. Furthermore, it is likely that sampling efficiency has improved over the 40 years, but the effect of this would be a tendency to increase scores over time. To help get around the shortcomings mentioned above of variable sampling intensity and ability, only presence/absence (p/a) data were used, and abundance data where available, were converted to p/a. However, the limitation of using p/a data is that there is a

[3] http://www.niwa.cri.nz/ncwr/rec

tendency to underestimate changes to fish communities because the reduction in a species abundance happens long before local extinction.

Statistical analyses

5.3 To visualise temporal trends the proportion of sampled sites for each decade were plotted on graphs. To test for significant trends the Mann-Kendall test was used on the yearly proportions of sites that contained the species being analysed. The Mann-Kendall test (Hirsch and Slack 1984) involves computing a statistic S, which is the difference between the number of pair wise slopes that are positive minus the number that are negative. If S is a large positive value, then there is evidence of an increasing trend in the data. If S is a large negative value, then there is evidence of a decreasing trend in the data. The null hypothesis or baseline condition for this test is that there is no temporal trend in the data values, i.e., "H 0: no trend". The alternative condition or hypothesis will usually be either "H A: upward trend" or "H A: downward trend."

5.4 In the database there were a number of sites that had been sampled more than once over the 37 year period and these were analysed for trends by:

1. a count of the number of resampled sites where trout had been encountered in the past but were not there in subsequent samples
2. a count of the number of resampled sites where trout had not been encountered in the past but were in subsequent samples
3. a count of the number of resampled sites where trout had never been encountered over time
4. a count of the number of resampled sites where trout had been found on all occasions

Temporal and landcover trends trout results

5.5 There were distinct differences in the proportion of river reaches that had trout present within the REC land cover classes. For all land cover classes around 25% had trout present. Urban land cover had the lowest proportion of sites containing trout but also the least number of sites. Scrub sites had a surprisingly low proportion of sites with trout, as were exotic forest but again all were relatively poorly sampled. Pasture sites had the highest number of samples but less than one third contained trout and at native forest and for tussock catchment sites more than one third of these sites had trout present.

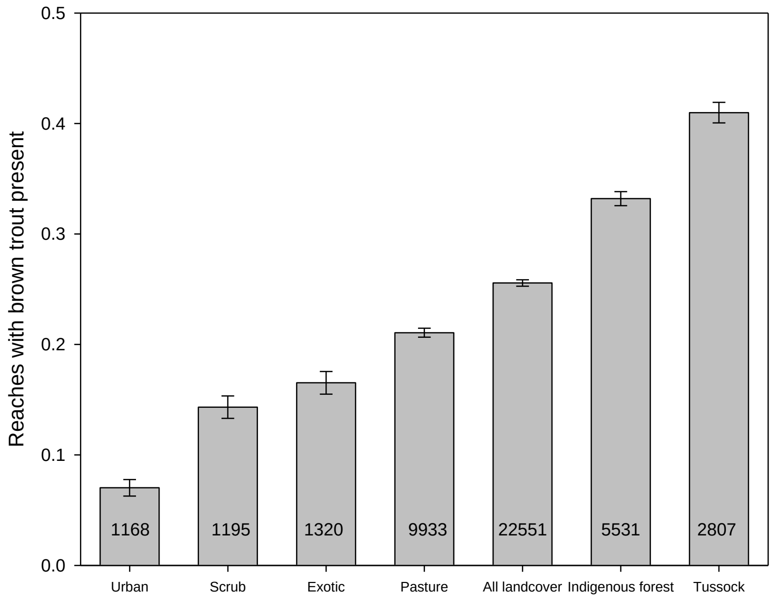


Figure 5.1 Proportion of sites containing brown in each REC land cover class, and number of sites in each class

5.6 The trend analysis revealed that the proportion of sites where tout were present was reducing at all sites and land cover classes (all Kendall & Z-score values negative Table 1). Brown trout were showed significant downward trends except at exotic forest sites. Similarly rainbow trout showed a downwards trend at all land cover classes but it was not significant at native forest, exotic and urban sites.

Table 5.1 Results of Mann-Kendall trend tests for changes in the proportion of sites containing salmonid species from 1970 – 2007. (bold indicates a significant negative trend P < 0.05)

Landcover	*Trout species*	*Kendall Statistic (S)*	*Z-score*	*P value*
All sites	**Rainbow**	**-255**	**-3.19**	**0.000**
	Brown	**-297**	**-3.72**	**0.000**
Native	Rainbow	-141	-1.76	0.08
	Brown	**-193**	**-2.41**	**0.02**
Exotic	Rainbow	-129	-1.69	0.09
	Brown	-144	-1.87	0.06
Pasture	**Rainbow**	**-187**	**-2.43**	**0.01**
	Brown	**-179**	**-2.33**	**0.02**
Urban	Rainbow	-480	-1.52	0.13
	Brown	**-166**	**-2.70**	**0.01**
Tussock	**Rainbow**	**-186**	**-2.42**	**0.02**
	Brown	**-160**	**-2.08**	**0.04**

5.7 The graphs below (Figure 4 and 5) showing the decadal proportions of sites containing trout reveal the proportions of sites over time in each land cover class and the consistent declines over the last 4 decades.

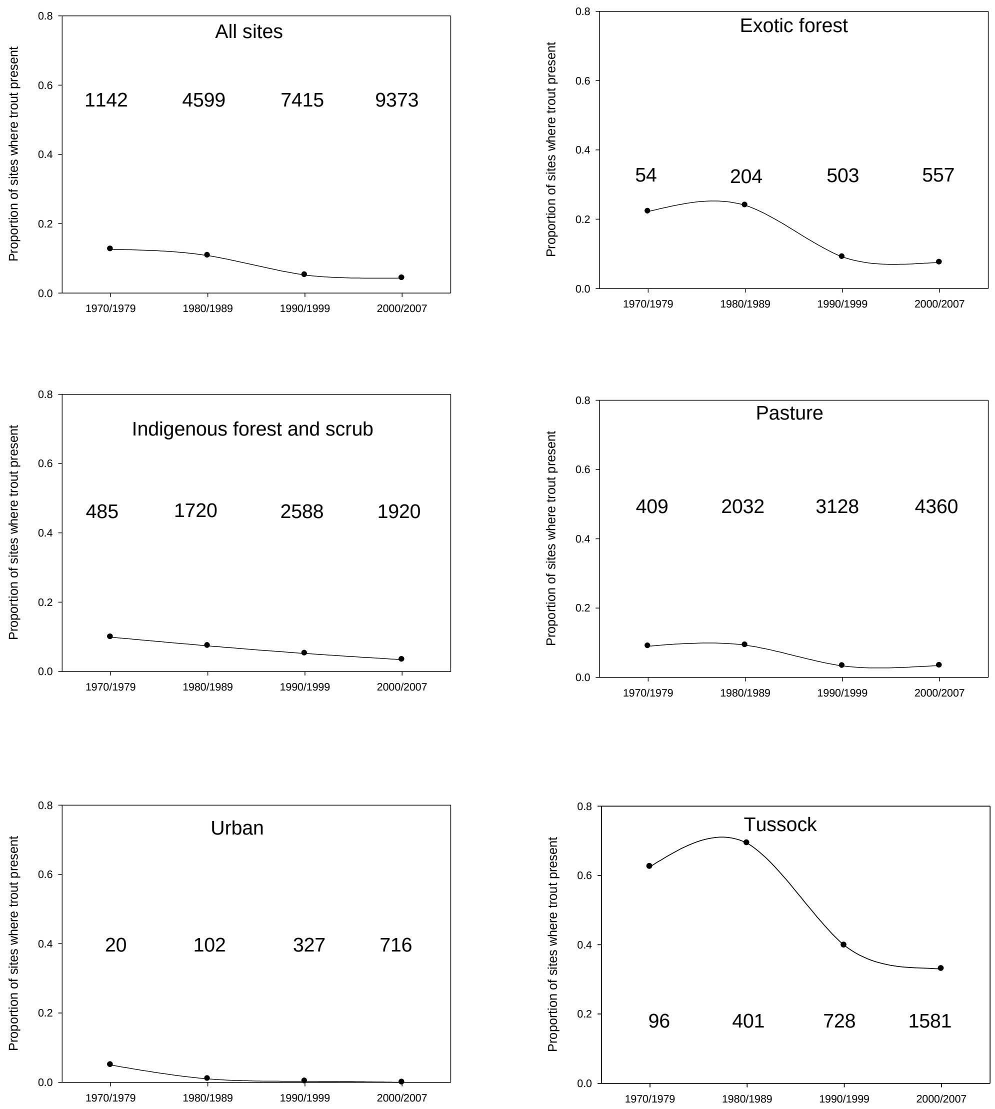


Figure 5.2 Decadal changes in the proportion of rainbow trout present at sites, and number of sites sampled for each land use

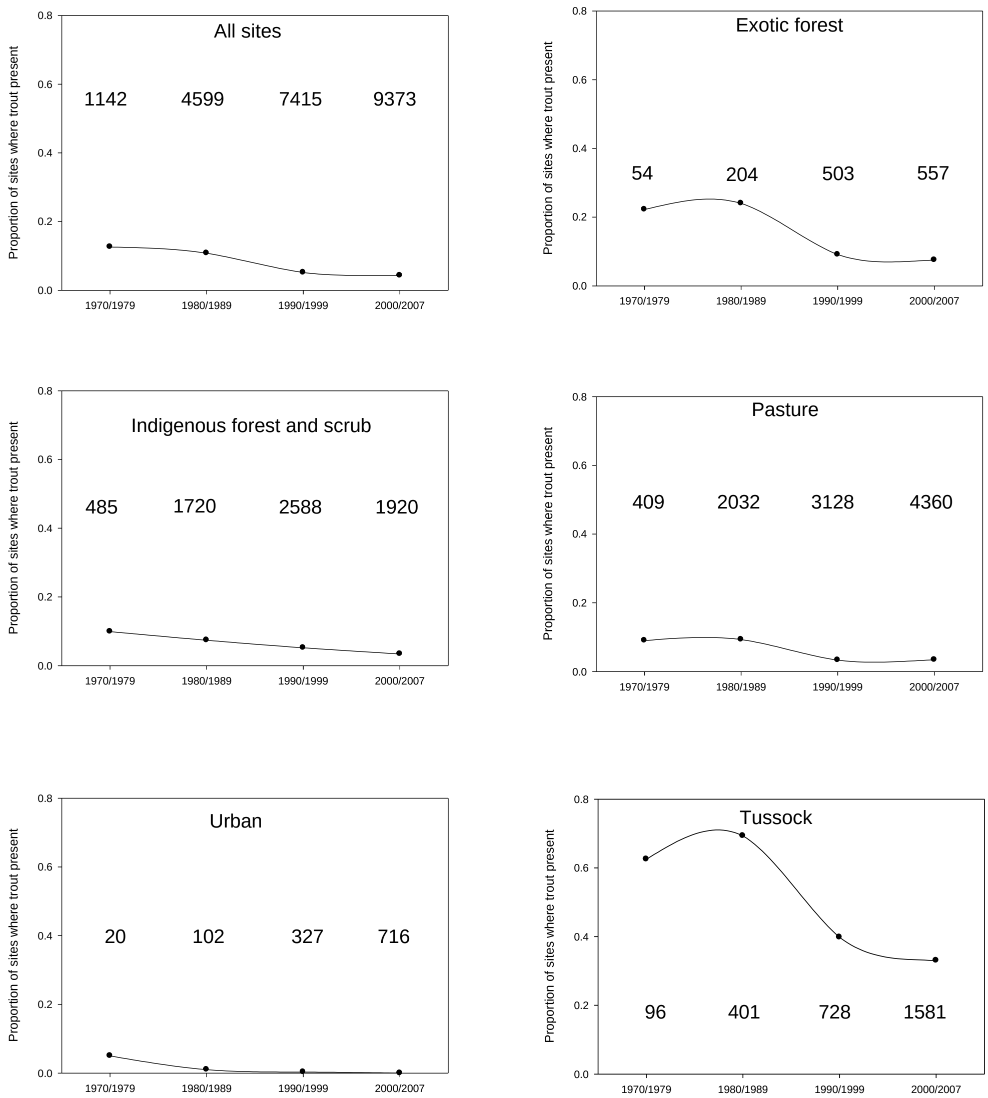


Figure 5.3 Decadal changes in the proportion of brown trout present at sites, and number of sites sampled for each land use

Changes in number of species at resampled reaches

5.8 A number of reaches in the database had been sampled more than once over the 37 years and these were analysed to look for changes. These results were equivocal due to the lack of temporal consistency in multiple sampled sites and low number of resampled sites (<5%).

Table 5.2 Changes in trout presence/absence at multiple sampled reaches

Change in trout presence at river reach	***Number of sites***
Increasing (from no trout to trout)	204
Decreasing (from trout to no trout)	231
Always present	476
Up & down	121
Total number of resampled sites (more than 1 sample at same reach)	1032

Predictive brown trout spatial modelling

5.9 To investigate the associations between landcover and the spatial distribution of brown trout in New Zealand two predictive modelling approaches were employed. First an artificial neural network model (ANN) (Joy and Death 2004b) and second, a boosted regression tree (BRT) (Elith et al. 2008b) were constructed. To create the models the NZFFDB records of brown trout presence or absence were used and the environmental habitat variables were obtained from the Freshwater environments of New Zealand database (FWENZ)[4]. Both processes involve quantifying mathematically the relationship between the habitat (measured remotely via GIS - climate, geology, flow, land-cover etc.) and the presence or absence of brown trout. Once this relationship has been defined then the relationships between each habitat variable and the presence of trout graphically through sensitivity plots.

Artificial Neural Network predictive model results

5.10 Using all the trout presence absence data from the NZFFDB a very accurate model of brown trout distribution was constructed. The cross-validated Cohen's Kappa value[5] for the final model was 0.50, and the AUC value[6] was 0.85 (an AUC value > 0.08 is classed as excellent discrimination by Hosmer and Lemeshow (2000)). After a pruning process whereby the best predictors are selected 15 variables from the FWENZ database were used for the predictive model (table 3).

Table 5.3. Variables selected by model as most important and ranked by their importance

Rank	Predictor variable
1	Distance to coast from reach
2	Stream order
3	Elevation
4	% of catchment in LRI category (alluvium)
5	Coefficient of variation of annual catchment rainfall
6	Proportion of catchment with slope >30° (steep)
7	Mean minimum July air temperature

[4] Wild, M., T. Snelder, J. R. Leathwick, U. Shankar, and H. Hurren. 2005. Environmental variables for the freshwater environments of New Zealand river classification. NIWA Client Report CHC2004.086.

[5] This is a measure of the success rate for the model its improvement over chance, and cross-validated means the assessment was done on data not used in the model construction (Titus, K., J. A. Mosher, and B. K. Williams. 1984. Chance-corrected classification for use in discriminant analysis. The American Midland Naturalist **111**:1-7.)

[6] Hosmer, D. W. and S. Lemeshow. 2000. Applied logistic regression. 2nd ed edition. A Wiley-Interscience publication, New York NY.

8	Runoff weighted mean minimum July air temperature
9	Catchment average of calcium
10	% of riparian area in LCDB category (indigenous forest)
11	% of riparian area in LCDB category (pastoral)
12	Annual potential evapotranspiration of catchment
13	% of riparian area in LCDB category (scrub)
14	December catchment solar radiation
15	June catchment solar radiation

5.11 To visualise the relationship between the variables in the model and sensitivity analysis was used where the variable of interest was changed through its full range from lowest to highest while keeping all other variables at their mean value and observing how the probability of occurrence of trout changed (Fig. 5.4). Looking at the plots, each line is the probability read from the y axis of finding trout for each of the variables from lowest at the left to highest amount at the right. For example the middle right plot in Figure 5.4, the scale at the bottom is no catchment in pasture at left to 100% catchment in pasture at right and the same for scrub and indigenous forest. Looking at that plot you can see that the probability of finding trout increases as the proportion of indigenous forest increases from 45% with no indigenous forest in the catchment to a probability of 70% when indigenous forest dominates the catchment. The same plot shows that the probability of finding trout increases with pasture to a point then drops after the catchment reaches about 70% pasture.

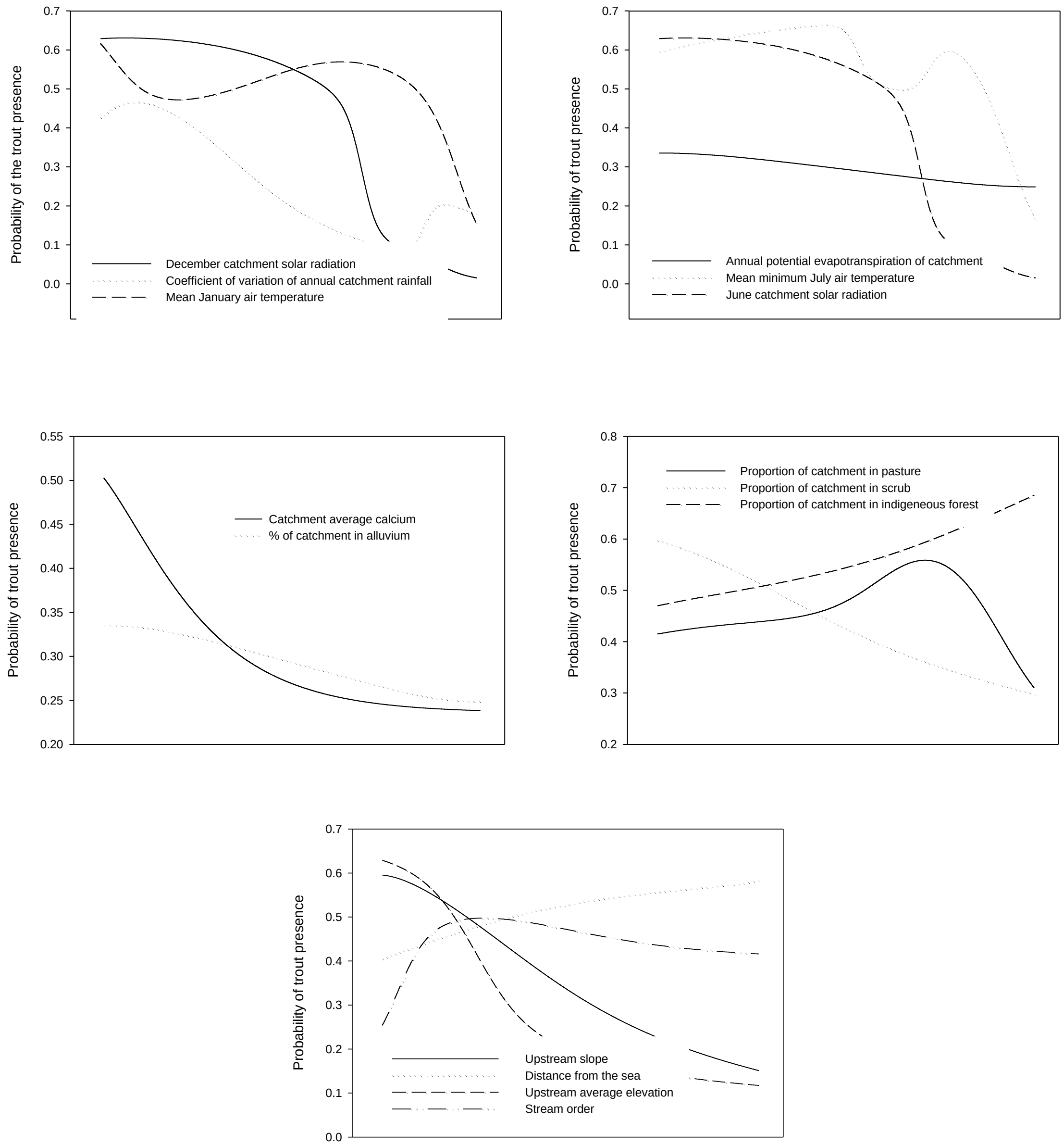
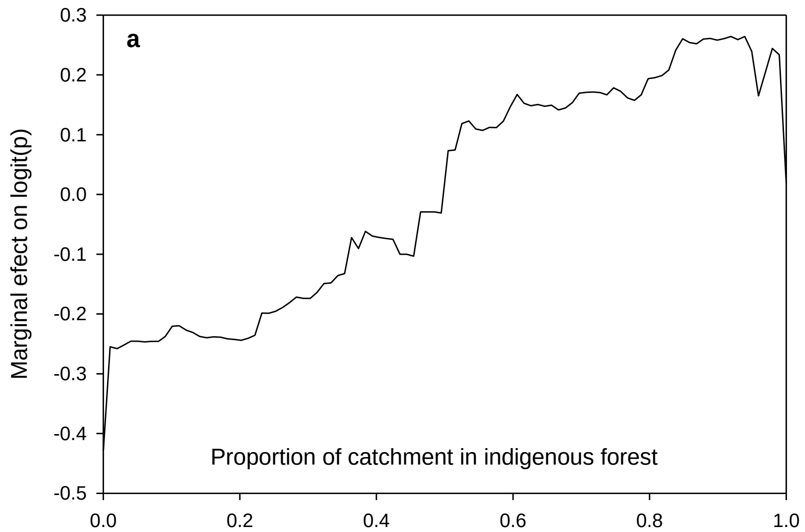


Figure 5.4 Sensitivity plots showing influence of variables on predictions. Variables increase in value from minimum on left of y axis to maximum on the right.

Boosted regression tree results

5.12 The final boosted regression tree using the same 15 variables selected by the ANN above had a cross validated AUC score of 0.89 (se 0.004) (an AUC value > 0.08 is classed as excellent discrimination by Hosmer and Lemeshow (2000)). This excellent predictive ability of the BRT was similar to the ANN model, and to see how the predictions related to the land cover variables the two of interest pasture and native forest were plotted using partial dependence plots (Figure 5.5). Figure 5.5a shows that the probability of finding brown trout increases as the proportion of the catchment in indigenous forest increases. The opposite is the case for the proportion of catchment in pasture (figure 3b), as the proportion of the catchment in pasture increases the probability of finding brown trout decreases.



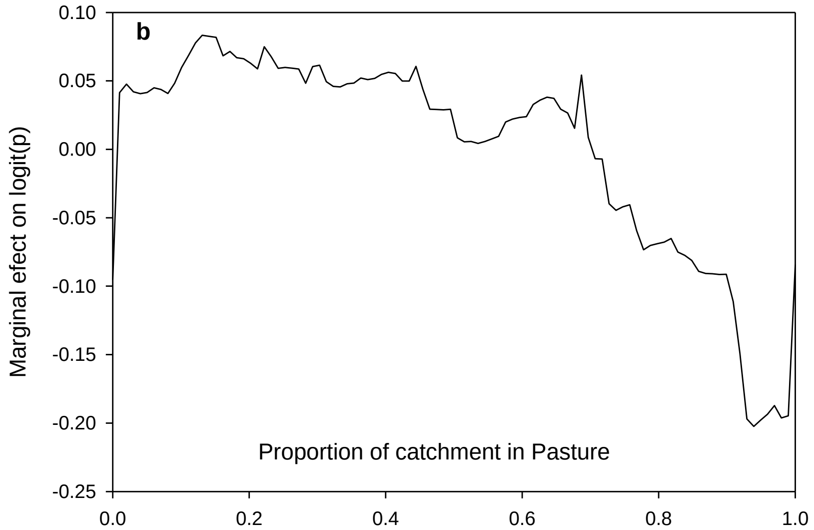


Figure 5.5 Functions fitted for the proportion of catchment in pasture (a) and indigenous forest (b) by a boosted regression tree related to the probability of occurrence of brown trout. Note different scale on each plot.

6. SEDIMENT EFFECTS ON STREAM LIFE – MICROHABITAT ANALYSIS OF A NATIVE FISH COMMUNITY

6.1 The majority of New Zealand's native freshwater fish are benthic (bottom dwelling fish lacking a swim bladder) thus, deposited sediment has long been thought likely to be a key habitat attribute. However, because deposited sediment is not measured in any consistent way in New Zealand large scale studies have not highlighted its importance. Many researchers have reported finding fish deep down in the substrate matrix in the interstitial spaces between cobbles and boulders, but no quantitative study had been done. Large scale spatial patterns of native fish absence associated with areas of high sediment have been observed in the Manawatu River (see section on distributional anomalies above and the figures below). The river reaches with high levels of catchment in slip scars corresponds highly with places where the native fish w9ere predicted to be but are absent (fig. 6.1 & 6.2)

6.2 To quantify the relationship between native fish and the stream substrate 139 fish were captured and tagged with a passive integrated transponder (PIT tag) and their habitat use monitored using a hand-held transponder wand to track them at 29 day and night sampling occasions over the one year (McEwan et al. 2008, submitted). The micro-scale habitat use was quantified using a substrate map made of 250 mm grids over 100 metres of stream length. This enabled the association between presence of individual fish and substrate to the micro-scale with individual rocks. When each fish was located its position was logged and then associations between presence of each species and specific habitat attributes were analysed.

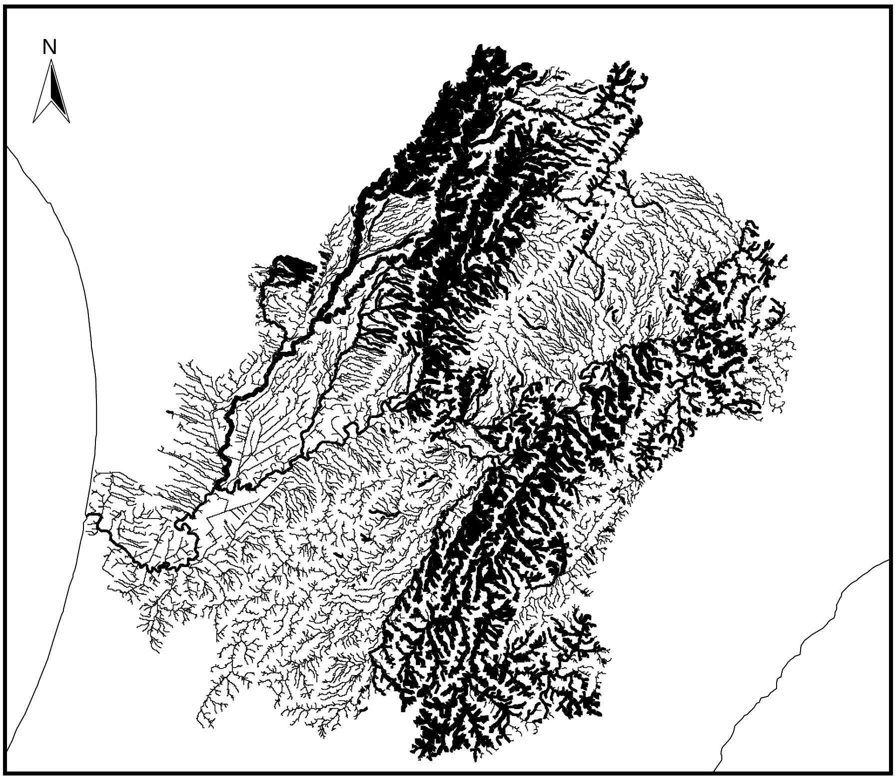


Figure 6.1 Accumulated proportion of catchment with slip scars from 2004 flood thicker waterway lines are higher proportions (square root transformed).

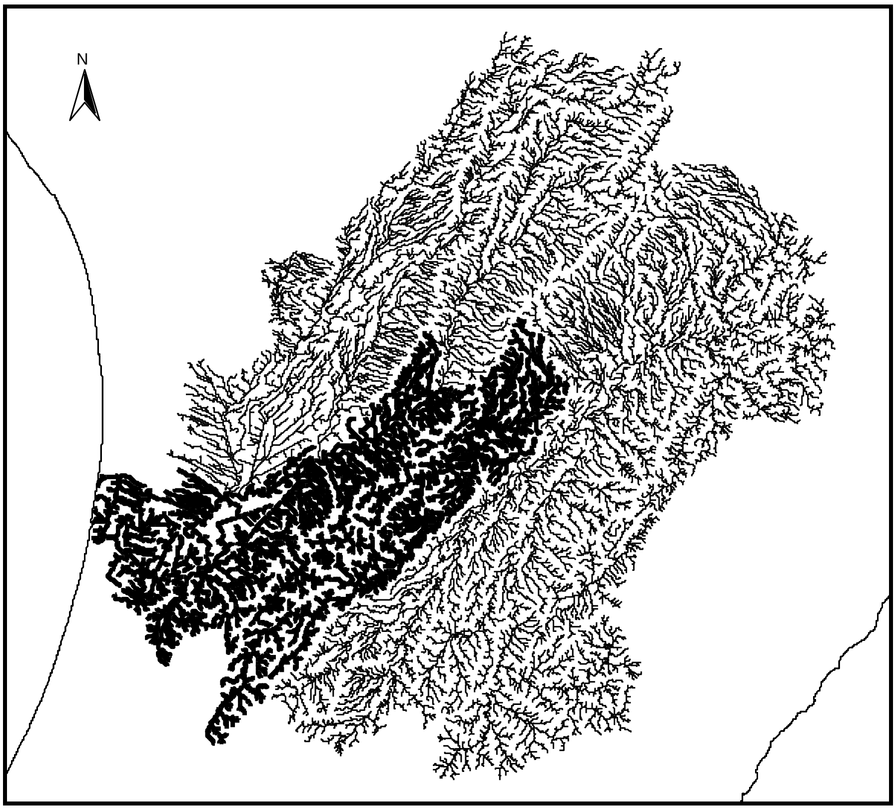


Figure 2.2 The Manawatu River catchment thicker lines indicate waterways where sensitive fish species (koaro, banded kokopu, shortjaw kokopu or redfin bullies) occur or would have to traverse to get to where they occur.

Results of micro-scale study

6.3 1094 individual data points were analysed, each data point was a known fish detected to a point in the substrate within a 0.25m square. Detection rates were high at 76%, 71%, and 83% respectively for redfin bully, shortjaw kokopu and koaro. The type and strength of relationship between the habitat attributes varied between the different species but most were related to sediment. The relationships also varied depending on day or night (not shown). Redfin bullies and shortjaw kokopu shared similar habitats in the substrate during the day. Both being strongly associated with interstitial spaces, koaro however, favoured shallow areas of high water velocity and surface turbulence. Koaro were also showed high levels of affiliation with interstitial spaces and large substrate and was similar for day and night.

Table 1. Significant association between fish and microhabitat variables from Mann Whitney tests of where fish were located at 0.25 m grid

Species	Habitat variables with significant **positive** associations	Habitat variables with significant **negative** associations
Redfin bully	Interstitial spaces large and small, substrate size, instream cover, and depth	Surface turbulence, water velocity
Shortjaw kokopu	Stability, large and small interstitial spaces, substrate size and instream cover	Surface turbulence, water velocity
Koaro	Surface turbulence, water velocity, substrate size, Interstitial spaces large	Depth

6.4 All three species showed strong affiliations with substrate especially the interstitial spaces. The density of individual fish in the study reach was considerably higher than that observed in similar reaches elsewhere in the Manawatu catchment. The "third dimension" of habitat provided by the interstitial spaces allows a much higher population density than if the spaces were not available.

6.5 Approximately 2 kilometres below the study site a hydroelectric dam discharges water into the Mangaore River this flow adds considerably to the flow in the River and as the water comes from high in the catchment with very little modification the resultant flow into the lower Manawatu River is of higher water quality than surrounding similar Rivers. The very high fish density found in the Mangaore in comparison to similar Manawatu tributaries either North or South of the Mangaore River suggest that this flow is an attractant to upstream migrating fish.

7. MANAWATU RIVER, FISH DISTRIBUTION ANOMALIES

7.1 Many surveys of fish distribution have shown anomalous gaps in the spatial distribution of a number of sensitive native fish species in the Manawatu Catchment. Extensive searches of the Oroua River, Pohangina River and upper Manawatu River in the last 15 years have failed to reveal any migratory galaxiid species (adult whitebait - banded kokopu, shortjaw kokopu and koaro) or redfin bullies (Joy 1998, 1999a, b, Death and Joy 2000, Phillips and Joy 2002, Joy and Death 2003, Joy and Death 2004a). Redfin bullies are migratory species known to be sensitive to anthropocentric perturbations (Joy and Death 2004a).

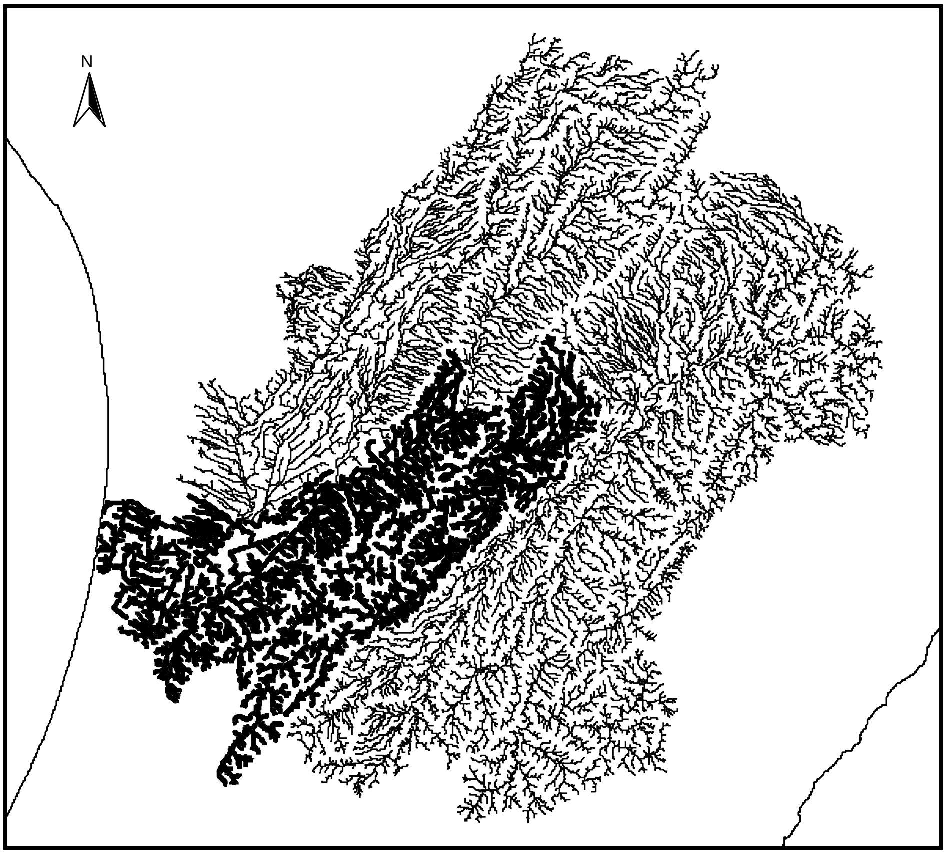


Figure 7.1 The Manawatu River Catchments, dark lines indicate waterways where sensitive fish species (koaro, banded kokopu, shortjaw kokopu or redfin bullies) occur or would have to traverse to get to where they occur.

7.2 To quantify the extent of this anomaly spatially and numerically a predictive model (Joy and Death 2004b) of fish community distribution was constructed for the entire North Island of New Zealand with the Manawatu catchment data excluded. This model The Manawatu catchment fish distribution data was kept out of this model so it wouldn't effect prediction when subsequently applied to the Manawatu catchment. This predictive model was optimised and validated and then used to predict the distribution of fish in the Manawatu Catchment allowing comparison with actual present distribution of the fish to allow for comparison. Effectively this comparison allows for an objective assessment of where fish would be distributed based on habitat suitability if they were in anywhere else in the North Island.

7.3 The Manawatu fish distribution model was used to calculate the length of waterway the fish should occur at if the conditions were the same as the rest of the North Island by multiplying the probability of occurrence from the model by the length of waterway to give a currency for comparison (Joy 2007b). Next the actual lengths of waterway fish species actually occur at were calculated and the differences for each species between observed and expected distributions calculated.

Assessment of habitat loss results

7.4 There was no difference in the predicted and actual distribution of shortjaw kokopu as they were not predicted to be in any of the tributaries they are absent from (Table 1). However, the other three species showed significant lack of congruence between observed and expected distribution. Banded kokopu and Redfin bullies were absent from half of their predicted habitat and the koaro is absent from 84% of the habitat it should occur at.

Table 7.1 The length of the Manawatu River each of four sensitive native fish species were predicted to occur at using a model using the rest of the North Island, and the actual length of river they are now found at.

Habitat loss	*Koaro*	*Banded kokopu*	*Shortjaw kokopu*	*Redfin bully*
Length of Manawatu River fish should occur at	975km	537km	14km	690km
Length of Manawatu River fish actually occurs at	156km	279km	14km	327km
Proportion of habitat lost	84%	48%	0%	53%

Figure 7.2 Photos of stream bed showing the impact of sediment, the upper picture shows interstitial spaces and the lower photo shows the spaces filled with sediment.

8. EXPERIMENTAL TEST OF RIVER SELECTION BY NATIVE FISH

8.1 The fish distribution anomalies described above appeared to relate to choices being made by migrating fish to avoid tributaries carrying the influences from high proportions of pasture in the upper catchment and or point source discharges. To attempt to quantify the distributional anomalies an experiment was run to test if fish would or could chose between flows in two tributaries of the Manawatu River system (Croskery 2009).

River selection by native fish methods:

8.2 Redfin bullies were used in the experiment as they were relatively easy to catch in a downstream tributary (The Mangaore Stream), and redfin bullies have lost 50% of their expected range in the Manawatu River system (Table 1).

8.3 Two 500 litre bladder tanks were filled using a petrol powered pump with river water from the Manawatu River and on the same day from one of two tributaries being tested; the Oroua River and the Mangaore River. Water was taken as near to the junction of the tributary being tested with the main stem as possible, but restricted to where a four wheel drive utility and large trailer could get access. The Oroua River water sample was taken from the end of Kaimatarua Road, and the Mangaore from the access near SH57 close to Shannon. The Manawatu River water was taken from the access point at the end of Hamiltons Line (above both the Mangaore and Oroua confluences).

8.4 The water from the tanks were run through the choice tank over two separate experiments, one for the Oroua River versus the Manawatu and one for the Mangaore versus the Manawatu River. In each case fish were placed into the lower chamber 5 individuals at a time, given 20 minutes to equilibrate then allowed to swim into either of the choice chambers (Fig. 1). The flows from different tributaries were regularly swapped sides to ensure there was no bias from the apparatus.

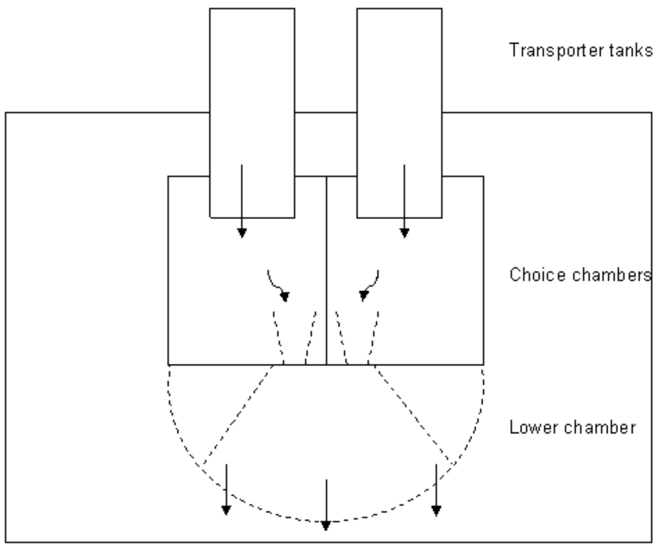


Figure 8.1 Graphical depiction of the choice chamber apparatus used to test fish preferences for different flows in the Manawatu River

8.5 The fish were given 10 minutes to make a choice, then the choice made – which flow chosen or if no movement and the length of fish was recorded for later analysis. 106 fish were used in the Oroua v Manawatu trial and 100 in the Mangaore v Manawatu trial (total 206 fish). Preference choices by fish were analysed using Chi-square and Binomial test (PROC FREQ; (SAS 2000)).

Choice test Results

8.6 The first trial was the Manawatu versus Oroua Rivers, the redfin bullies significantly rejected the Oroua River when given the choice of that or the Manawatu River (χ^2 df_2 = 16.3, p = 0.0003 or Binomial test Z = 1.7, p = 0.044). The second trial of the Manawatu River versus the Mangaore, significantly more fish chose the Mangaore or rejected the Manawatu (χ^2 df_2 = 11.4; p = 0.0027 or Binomial test Z = 1.8, p = 0.036).

8.7 To assess any landscape scale variables associated with the choices made by the fish, data on the landcover proportions above the sample sites was compiled from the Freshwater Environments of New Zealand Database (Wild et al. 2005). Another potential impact on fish choice is sedimentation levels of waterways so another variable was included. A surrogate for sedimentation is the number of slip scares in the catchment, thus, the proportion of the catchment containing slip scars after the 2004 floods were estimated from aerial photos and these values were accumulated down the Manawatu River network[7].

Water chemistry and GIS land use variables for choice rivers

8.8 Water samples were taken at the time of trials and analysed for nutrient levels (Table 8.2; water temperature and pH were similar so not included). For the Manawatu versus Oroua River trial the Oroua River had significantly higher total nitrogen ($F_{1, 10}$ = 5.16, P = 0.046) but no difference in total phosphorus ($F_{1, 10}$ = 0.94, P = 0.35). The Mangaore versus Oroua River trial there was significantly higher levels of Total Nitrogen in the Manawatu River ($F_{1, 4}$ = 25, P = 0.007), there were also higher levels of Phosphorous in the Manawatu River than the Mangaore ($F_{1, 4}$ = 9.3, P = 0.04; Mangaore values assumed to be 0.01).

Table 8.2 Total nitrogen and phosphorus levels taken at time of each trial run (all in mg/L)

	Oroua vs. Manawatu test				Mangaore vs. Manawatu test			
Trial	Manawatu		Oroua		Manawatu		Mangaore	
	Total N	Total P	Total N	Total P	Total N	Total P	Total N	Total P
1	0.85	0.1	1.03	0.04	0.84	0.03	0.33	<0.01
2	0.79	0.03	1.13	0.07	1.35	0.07	0.26	<0.01
3	0.82	0.04	1.08	0.04	0.97	0.04	0.18	<0.01
4	0.85	0.03	1.02	0.04				
5	0.87	0.03	1	0.07				
6	0.63	0.03	0.64	0.08				
Mean	0.80	0.04	0.98	0.06	1.05	0.05	0.26	<0.01

[7] Anne-Gaelle Ausseil Landcare Research contract with Massey University

8.9 The differences in landcover proportions above sample points for the Manawatu and Oroua Rivers were minimal, but the proportion of slip scar area in the Oroua River was twice that of the Manawatu River (Table 8.3). There were large differences in landcover proportions between the Mangaore River and Manawatu Rivers above sample points. There was twice as much indigenous forest and half the proportion of pasture in the Mangaore catchment, similar proportions of scrub for both but much less slip scar area in the Mangaore catchment. Overall, the choices made by the fish were consistently for the tributary with lower levels of pasture, or higher levels of indigenous vegetation and or lower levels of slip scar in catchment.

Table 8.3 Proportions of the river catchments above where water samples were taken for trials in different landcover classes and slip scars after the 2004 floods. (From the land cover database and freshwater environments of New Zealand database)

Land-cover	Oroua	Manawatu	Mangaore
Indigenous forest	0.22	0.15	0.32
Pasture	0.56	0.62	0.39
Scrub	0.11	0.19	0.18
Slip scars	0.02	0.01	0.00

9. CONCLUSIONS

9.1 New Zealand's freshwater fish are undergoing a major decline - 65% of the species are now classified as threatened. The only two other large freshwater species that were once regularly seen are the freshwater crayfish, (koura) and freshwater mussel (kakahi), have now also recently been added to the threatened list. It is not surprising that the mussel has joined the list as it is reliant on the presence of fish, as part of its life-cycle involves attaching to fish gills so they are dependent on fish for their survival. This decline in native fish distribution is undoubtedly primarily due to the impacts of agriculture, from the multiple impacts of sedimentation due to forest clearance and poor land management in hill country, and well as nutrient contamination from excess fertilisation and from animal waste. Metropolitan wastewater and industrial discharges also contribute to the impacts. Analysis of 22500 sites over almost the last four decades shows that native fish and trout communities have been in decline, and that the decline has intensified in the last decade. When the trends were analysed based on the catchment landcover, clear patterns were revealed with the poorest fish communities and they showed that there were declines greatest at pastoral and urban sites. These declines in the freshwater faunas nationally reveal the decline in water and habitat quality and the failure of the regulators and regulations to protect freshwater environments.

9.2 The Manawatu River catchment is a regional example of the reasons for the national decline in freshwaters. A suite of sensitive (not tolerant of pollution) native fish has a much restricted distribution in the catchment, having lost 50% to 80% of their prior distribution. Investigation of this anomaly revealed that the places they were missing from were areas high in agriculture and particularly sediment producing hill country. Experiments with fish given a choice of river flows from these degraded catchments showed the fish consistently and significantly chose catchments with less of the catchment in agriculture and sediment and lower nutrient levels.

9.3 Recent work using radio tagged native fish has confirmed and quantified the importance of sediment free substrate for native fish. Most of the fauna is benthic, and therefore these fish spend much of their time in the large gaps between cobbles and boulders known as interstitial spaces, often at depths of more than 300 mm. This crucial habitat has been lost from much of the Manawatu catchment due to sediment deposition, but deposited sediment is not measured in any consistent way in the Manawatu or nationally.

9.4 The substantial and alarming decline in the freshwater fauna described in this submission should serve as a wakeup call for all New Zealanders. This obvious decline in the condition of New Zealand's freshwaters as revealed by the disappearance of much of the stream life indicates a systemic failure of central and local government in their role as protectors of the environment for future generations.

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