Decline in the Hutt River Trout Fishery: change in the weather or change in the land?

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ABSTRACT

A number of trophy brown trout (*Salmo trutta*) fisheries in rivers of the central North Island of New Zealand, as administered by the Wellington Fish and Game Council, have shown rapid decline over the last 5 years. Over this period there has been increasing water abstraction, waste disposal and land use intensification within the region, along with a number of large flood events during or just following the trout spawning season. The current research compiles data on changes in flow regime, water quality, and habitat characteristics, and uses regression tree analysis to link these potential drivers with population declines, in the Hutt River. Results indicate that rainfall induced discharge conditions during or soon after emergence appear to be the major determinant of year class strength and hence population size. Changes in adult trout holding habitat also show some significant changes over time, but these geomorphological characters do not significantly correlate with changes in the adult trout fishery.

Keywords: Brown trout (*Salmo trutta*) fisheries, population decline, flow regime, water quality, habitat

INTRODUCTION

In New Zealand the introduction of brown trout (*Salmo Trutta*) was first provided by legislation in 1867, with brown trout being introduced from 1867 – 68, rainbow trout (*Oncorhynchus mykiss*) were introduced from 1878 - 1883, and salmon through the early 1900s (Viner, 1987). Salmonids were immediately successful, forming largely self sustaining populations, widely distributed throughout New Zealand, owing largely to the availability of free stone gravel bottomed rivers, and cool clean waters, which provided adequate tributary or mainstem spawning for almost all river systems. New Zealands trout fisheries are currently among the most internationally recognized trout fisheries in the world, due to the relatively widespread distribution of the salmonid populations, their large size, and the scenic beauty of the country.

Unfortunately, New Zealand's larger rivers, including their iconic headwater fisheries, are coming under increasing pressure from developers including hydroelectricity companies. The main stem rivers and smaller lowland rivers, which are often the ordinary "*close to home*" fishing sites for many anglers, are coming under increasing pressure from agriculture and horticultural activities, flood protection activities, deforestation, urbanization, and waste disposal. As a result the majority of lowland freshwater ecosystems in New Zealand are impacted. Over the last decade in particular, anglers and the regulatory bodies that govern salmonids populations in New Zealand have become increasingly concerned that the trout fisheries are under threat.

The decline, and collapse of fish populations has been widely reported internationally over the last decade (Elvira, 1995; Casey & Myers, 1998; Myers & Worm, 2003; (Borsuk et al. 2006) Javier, 2008), and frequently attributed to human interventions including over harvest and habitat loss and degradation (Wang, Lyons & Kanehl, 2001; Reynolds *et al*, 2005; Javier, 2008). Long term empirical studies of fish population fluctuations and response to environmental variables in New Zealand however, are limited (Minns, C.K, 1990; Jowett, 1990; Joy, Henderson, & Death, 2000; Joy & Death, 2001; Joy & Death, 2004). Recent research by Dr Mike Joy (2010) which analysed the temporal changes in New Zealands trout distributions over the past 37 years from the National Freshwater Fisheries Database (NIWA), showed significant declines in trout presence, the steepest being over the last decade. These New Zealand temporal trends in salmonids populations are supported by data held by the Wellington Region Fish and Game council, which shows from drift diving surveys, that regional trout population numbers are trending downwards, with the steepest declines occurring over the last 5 years.

While the decline and collapse of fish populations internationally has been well documented, the underlying mechanisms driving these trends are still not well understood (Javier, 2008), with the debate ranging widely on the roles of density dependent vs density independent processes and their relative importance (Harrison & Cappuccino, 1995; Turchin, 1995, 1999; Ricklefs & Miller, 2000; Javier & Ricon, 2004; Ernesto, Franco, & Budy, 2005; Javier & Pedro, 2004; Javier, 2009). In regards to disseminating the relative roles of biotic and abiotic drivers of population change, New Zealand research is limited (Jowett, 1990; Kristensen & Closs, 2008), and has predominately focused on the impacts of hydrology on trout populations (Jowett & Duncan, 1990; Leprieur *et al*, 2006; Hayes, Olsen, Hay, 2010; Young *et al*, 2010)

The aim of the present study was to investigate primary environmental variables including hydrology, geomorphological alteration, and changes to water quality against a 30year trout fishery data set, to elucidate the overall drivers of population changes over this period.

We hypothesised that fluctuations in the adult trout population would be primarily driven by recruitment success influenced by hydrological regime during trout spawning and emergence (May to November), in the two to three years prior to the adult trout count. We expected that flushing flows during this period would reduce spawning success and negatively impact on emergence and juvenile survivorship, resulting in a weaker year class and negatively impacting on recruitment to the adult trout fishery.

MATERIALS & METHODS

Study area

The current research focuses on the Hutt River, which is the principal trout fishery river in the Wellington Fish and Game region. The Hutt river is approximately 55km long, and has its source in the bush clad and rugged Tararua Range to the North of Wellington and discharges into the Wellington Harbour at Petone (Wellington Regional Council, 1995). The river emerges briefly into the open at Kaitoke before entering a steep mostly inaccessible 10km gorge levelling out at Te Marua where urbanisation begins. The Hutt catchment is bounded to the southeast by the Rimutaka Range and to the northwest by the Western Hutt Hills and foothills of the Taraua Ranges (Wellington Regional Council, 1995).

The area of the Hutt catchment is approximately 65,615 hectares and is predominately rugged hill and mountainous country, consisting of native forestry, pine forestry development, and agriculture through its headwaters, and agriculture and urbanisation along the valley floor. The bedrock consists of greywacke and argillite and the river alluvium is predominantly greywacke (Wellington Regional Council, 1995). The mean annual low flow and median flows at Birchville (Upper Hutt) are $22.54m^3$ and $12.29m^3$ respectively (Watts pers comm., 2009). The Hutt River, as with many lowland rivers is impacted by intensive river management, historic deforestation, plantation forestry, urban encroachment, and hydrological alteration.

The Hutt River is ranked 47th out of more than 800 water bodies nationwide in terms of angler days (Unwin and Amage 2003), and is the 3rd highest, in respect to angler days per annum, of the 51 water bodies in the Wellington Fish and Game region. The Wellington Acclimatisation Society first liberated brown trout (*Salmo trutta*) into the Hutt River in 1874 and until 1941, tens of thousands of trout were liberated annually (Smith, 1990). After 1941, artificial stocking became irregular and ceased in 1976. The river is normally open to fishing all year round and in recent times, a comparatively low bag limit of 2 has been imposed along with a maximum size limit of 450mm to protect the breeding stock.

The Study was conducted along the length of the Hutt River, and comprised eight drift dive sites varying in length from 1km to 1.5km and covering 9.550km in total, which is 23% of the fishable length of the Hutt River (Figure 1).

Drift Diving

Drift diving is the most common technique for assessing the abundance of trout in New Zealand rivers and is described in Teirney and Jowett (1990). Sites are chosen which represent the geological diversity of the river, generally upland, middle, and lowland representative reaches are included. The length of each reach is determined by the number of pool/riffle and runs present, and is generally a function of the width of the active channel. Sites generally include 3 character replicates.

Divers, properly equipped with scuba dive equipment, form a straight line, spaced evenly across the river at right angles to the river's banks and float down the river with the current looking for trout as they go. Diving generally starts at the beginning of a pool and ends at the beginning of a riffle. The number of median (20 – 40cm) and large (>40cm) rainbow and brown trout are recorded, and expressed as number of trout, in each category, per kilometre. These categories generally fall into 2+, and 3+ and older age classes, depending on the time of year. Small trout (5 - 10 - 20cm) are also counted, or presence absence noted, these usually fall into the 0+ to 1yr category. This data is not generally used in analyses of population size as the technique cannot reliably estimate their relative abundance, because of the inadequacy of divers to cover the habitats they occupy (very shallow riffle habitats), and the inaccuracies of counting larger numbers due to schooling behaviours (100+).

Six to eight divers are used during the surveys, with over 23% of the fishable length of the Hutt River (8km) dived annually during summer since 2004, with records for the Birchville site going back to 1982, the Whakatikei site going back to 1985, Te Marua site since 1986, and the Taita and Kaitoki sites going back to 1987 (Wellington Fish and Game, unpublished data) (Figure 1). Accurate repeatability of the count assumes a similar proportion of the trout population is counted each year. Low underwater visibility, inexperienced divers, and inadequate diver coverage are believed to be the three most critical sources of error.

Medium, large, and total brown trout per km was plotted for each site, and analysed for correlations between the sites, trends over time, and correlations between population change and environmental variables.

Geomorphological Analysis

Geomorphological analysis of the Hutt River utilised a set of aerial photographs of the active channel acquired on eight occasions between 1982 and 2009 (1982, 1985, 1996, 1999, 2002, 2004, 2007, 2009). Imagery was supplied in georectified, digital format, 'GIS ready' by GWRC, rectified with reference to information on 2001 orthophotography. Digital imagery was analysed in ArcMapTM 9.2 GIS and the: area of active channel; area of wetted channel; and area of pool habitat, were classified and digitised to generate an assessment of compositional change within the maximum active channel since 1982.

Geomorphological parameters were analsyed for changes over time, and correlations between the variables and changes in brown trout fishery data.

Hydrology and Water quality analysis

Hydrological data was provided by GWRC (Greater Wellington Regional Council) for the Hutt River from their recording sites at Kaitoki (NZMS260, S26:942 150) and Birchville (NZMS260, S26:). Water quality data, from 1989 – 2009, was provided by NIWA (National Institute of Water and Atmospheric Research) from their State of Environment Monitoring sites on the Hutt River at Kaitoki (NZMS260, S26:942 150) and Boulcott (NZMS260, R27:712 992). Water quality data comprised all major water chemistry parameters including: DRP (dissolved reactive phosphorus), SIN (soluble inorganic nitrogen), Ammonia, temperature, pH, Conductivity, DO % (percentage dissolved oxygen), turbidity, and clarity.

Hydrological data was analysed for annual and trout spawning recruitment period (May to November), mean low flow, mean flow, mean flood flow, and maximum flow, and for correlations between hydrological parameters and changes in the Hutt River adult brown trout fishery (primarily low flow and flood flow events). Water quality data was analysed for annual mean, maximum, and minimum parameters along with mean, maximum, and minimum parameters for the trout spawning and emergence period (May to November), along with correlations between the water chemistry variables and changes in the Hutt River Trout Fishery.

Hydrology and water chemistry was analsyed for correlations between the variables during the trout spawning and emergence period (May to November) and the adult brown trout fishery two years later for medium trout, and 3 years later for large trout.

Regression tree analyses

Data for the 109 environmental variables were compiled and analysed using regression tree analysis to select the best predictors of trout abundance, or change, over time.

RESULTS

Drift Dive

Drift dive information plotted for each site shows considerable variation from year to year (Figure 2) with generally higher numbers of trout recorded during the early 1980's. slumping during the 1990's, and peaking again during the early 2000's (2000 to approximately 2007) (figure 3 & 4). Overall the highest number of trout were consistently recorded at Melling (mean ± se = 92± 12.45)(figure 3), and the lowest number consistently recorded at Kaitoki (mean ± se = 9.38 ± 0.77) (figure 3). However the Kaitoki site (stdev = 4.26) followed by the Te Marua site (stdev = 6.76) show the least amount of variation in adult brown trout population numbers over time. While the trout numbers are generally hypervariable from year to year, with a broad cyclic pattern, Regression tree analysis showed a weak downwards trend (F = 1.8437, df = 1,3, p = 0.38)(figure 4), which if continued at the same rate would result in the Hutt river brown trout fishery becoming extinct by 2021 (figure 4).

Geomorphology

The geomorphological analysis, while showing a significant 33% reduction in active channel area (R^2 = 0.73) (figure 5), and a significant 80% reduction in minimum pool size (R^2 = 0.82) (figure 6), showed no significant relationships with changes in the Hutt river brown trout fishery over time, in any of the analyses. All other geomorphological parameters measured showed no significant change overtime. Ground truthing of habitat mapping from the 2009 aerial photos, showed an extremely high level of accuracy with all pools geo-referenced located on ground (figure 7).

Water quality and Hydrology

Their was a marked difference between the Kaitoki and Boulcott sites water quality parameters, with Kaitoki showing less annual variation and generally lower contaminant loadings representative of the euthrophic nature of the site, which is in native forest. Water quality deteriorates as it flows down the Hutt River from increasing urbanisation, and following inputs from its tributaries, especially the Mangaroa stream which is impacted by farming. Water quality parameters as measured at Boulcott reflect higher levels of enrichment, and a historically broader range in parameters which has decreased over recent years potentially due to reductions in point source discharges to the tributaries (figure 8). Water quality data show a broadly cyclic pattern to annual parameters reflecting annual fluctuations in mean flow rates (figure 8). Statistical analyses showed no significant relationship between changes in the adult brown trout fishery, and changes in water quality over time.

Hydrological analyses show an increasing trend (R^2 = 0.0406) in the 7day MALF over time (F=0.0435, df =1,3, p =0.8364) from 2m^3/sec in 1982 to 3m^3/s in 2009, but no significant relationship was found between changes in low flow and changes in the adult brown trout fishery (figure 9). A weak negative correlation however, was found between the adult brown trout fishery and mean flow over time (F=1.6418, df = 1,3, p =0.2114), with higher mean flows weakly correlated with decreases in the adult brown trout fishery (R^2 =0.0594) (figure 10).

Statistical analyses showed a significant correlation between flood events greater than 200m^3/s during the trout spawning season and change to the adult trout fishery two years later (R^2 = 0.2569) (figure 11), indicative of disturbance related reduced recruitment success.

Regression tree analyses

Over 109 environmental variables were assessed, using regression tree analysis, against change in the Hutt river brown trout population over time. Overall year was the strongest predictor (R^2 = 0.6444) of change in the adult trout population with an overall significant downwards trend (F = 1.8437, df = 1,3, p = 0.38) (figure 4). When year was removed, mean annual flow was the second strongest predictor of change in trout population (R^2 = 0.3545).

The regression tree analysis showed a weak negative relationship between total nitrogen during the trout spawning period (R^2 = 0.1033) and changes in the adult trout fishery, followed by phosphorus levels during the trout spawning period (R^2 = 0.095) and changes in the adult trout fishery.

DISCUSSION

The objective of this study was to investigate the temporal changes in the Hutt river brown trout fishery and elucidate the environmental conditions which drive population changes. Results show that overall variation in year to year discharge during the trout spawning period was the major determinate of population dynamics of brown trout in the Hutt River, with a significant correlation between discharge events greater than $200m^3/s$ during the trout spawning period and declines in the adult brown trout fishery two years later. Maximum recruitment or survivorship as indicated by adult trout fishery population numbers, seems to occur at the most frequent discharge conditions, and extremes in high flow results in suppressed recruitment or survivorship as reflected in decreases in the adult trout fishery two to three years later from this event. Extremes of low flow were not shown to significantly drive population changes in the current study. This result is supported by both national and international research which has shown that disturbance events during trout spawning and emergence are the primary drivers of trout fishery population change (Javier, 2005; Leprieur *et al*, 2006; Leprieur, 2009; Graciela, Almodovar & Elvira, 2009).

The cyclic pattern to these flood events and corresponding alterations in the trout fishery are likely due to Southern Oscillation weather patterns, which is known to have a significant effect on New Zealand weathers. During the positive (la Nina) phase, there is a tendency for increased cyclonic activity in the North Tasman and more blocking anticyclones to the south east of New Zealand, which results in frequent warm moist northerly or northeasterly airstreams over the country with warmer than normal temperatures nationwide and wetter conditions in parts of the North Island. Similar relationships between adult trout populations and flood events during spawning have been identified in the Motueka Catchment of New Zealand by the Cawthron Research Institute.

Other environmental variables including mean annual discharge, and total nitrogen and phosphorus during trout spawning, play at most a limited role in population change. Water quality within the Hutt River was shown to be generally good, reflecting the pristine state of its headwaters, the absence of any point source pollution, and only marginal inputs of non point source pollution through its tributaries and due to increasing urbanization through the lower catchments. While significant habitat change has occurred in the Hutt River since 1982, these changes do not seem to strongly correlate to changes in the Hutt River Trout Fishery.

In conclusion, discharge events greater than $200m^3/s$ as recorded in the Hutt River during brown trout spawning and emergence, are the most significant driver of population declines in the adult brown trout fishery. Changes in the main stem habitat, while significant, are not strongly correlated with changes in the adult fishery, and changes in water quality are at best marginally correlated, though this could be due to the relationship between declines in water quality which are associated with increased high discharge events. The cyclic pattern to the brown trout fishery population and hydrological events could be a consequence of southern oscillation weather patterns.

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Figure 1. Drift Dive sites for the Hutt River

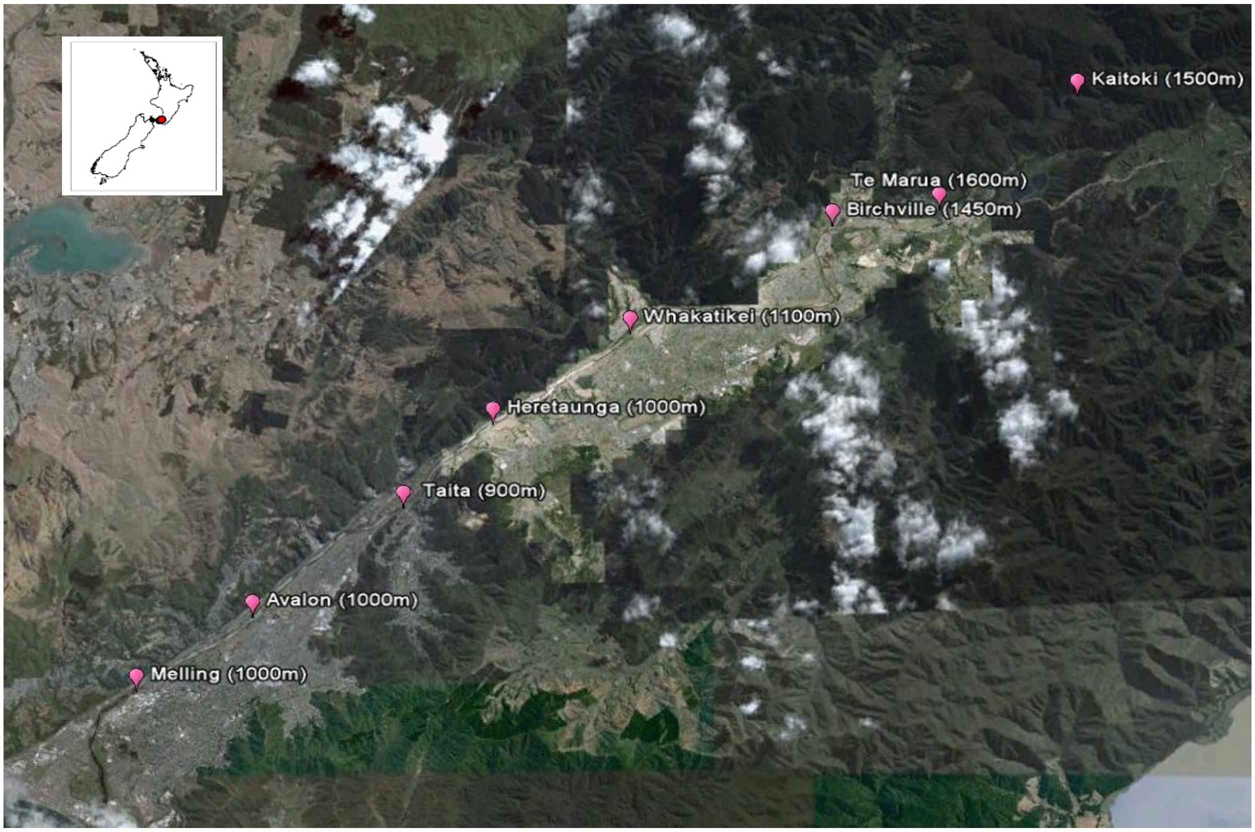
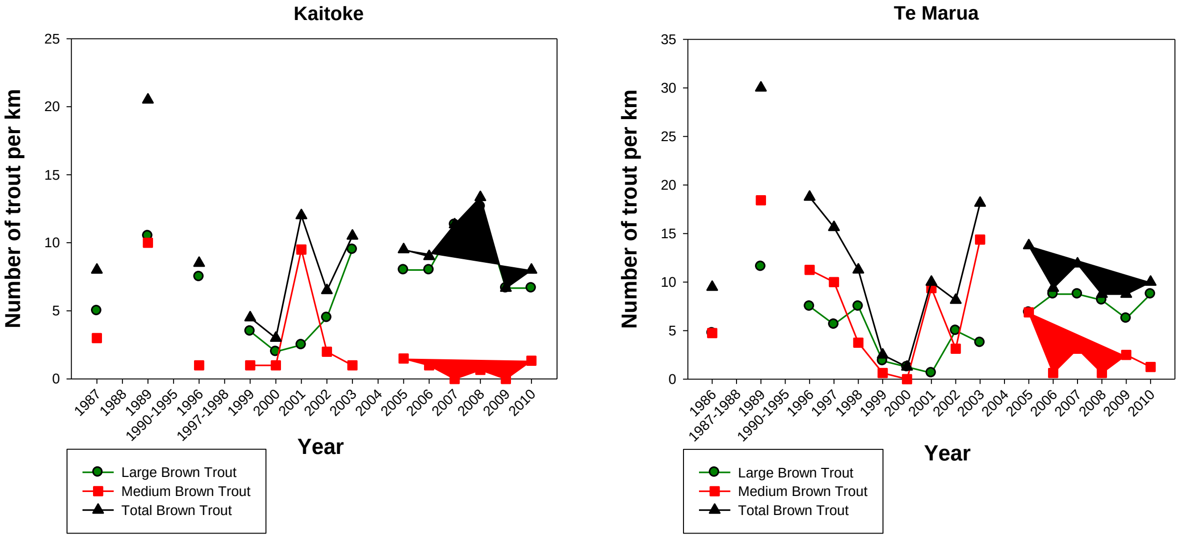
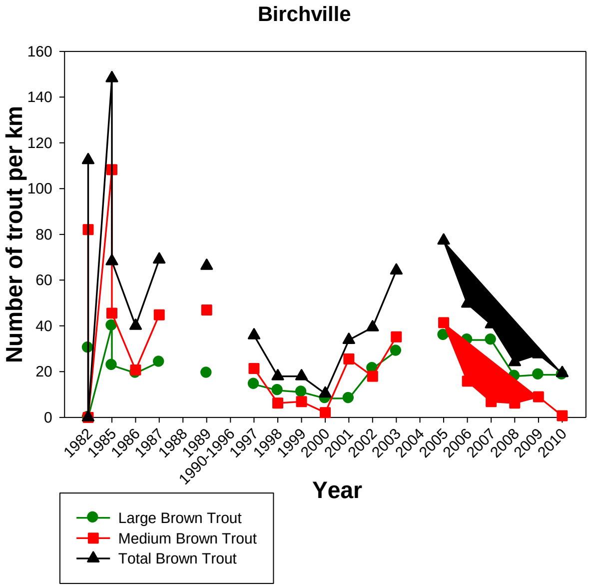
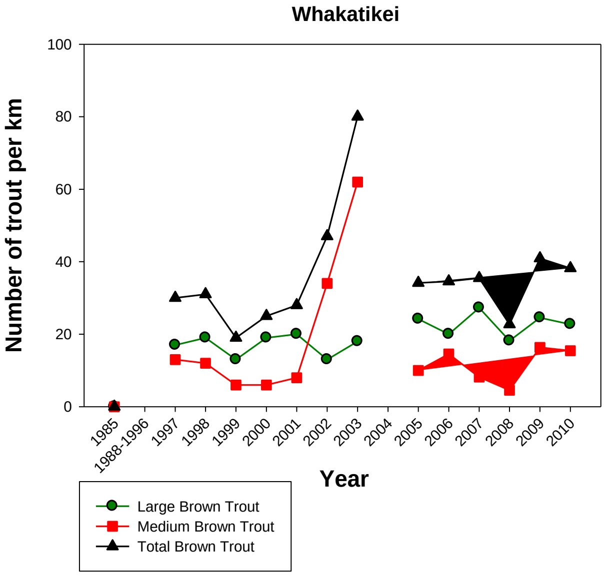
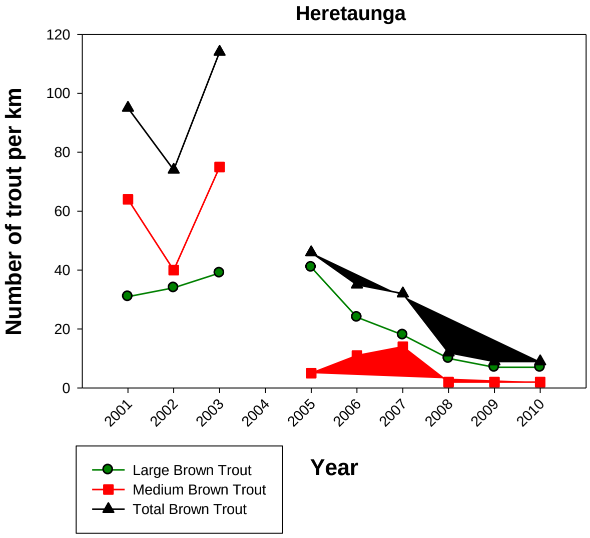


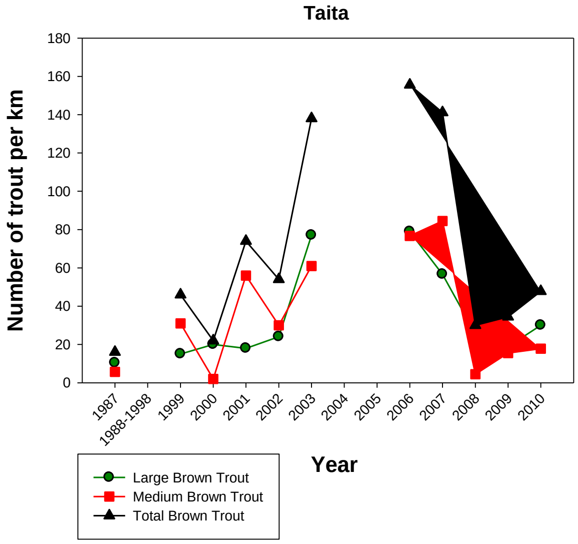
Figure 2. Medium, large, and total brown trout (*Salmo trutta*) per km over time, for each of the eight drift dive sites




Birchville
Number of trout per km
0
20
40
60
80
100
120
140
160
1982
1985
1986
1987
1988
1989
1990-1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Large Brown Trout
Medium Brown Trout
Total Brown Trout


Whakatikei
Number of trout per km
0
20
40
60
80
100
1985
1988-1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Large Brown Trout
Medium Brown Trout
Total Brown Trout


Heretaunga
Number of trout per km
0
20
40
60
80
100
120
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Large Brown Trout
Medium Brown Trout
Total Brown Trout


Taita
Number of trout per km
0
20
40
60
80
100
120
140
160
180
1987
1988-1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Large Brown Trout
Medium Brown Trout
Total Brown Trout

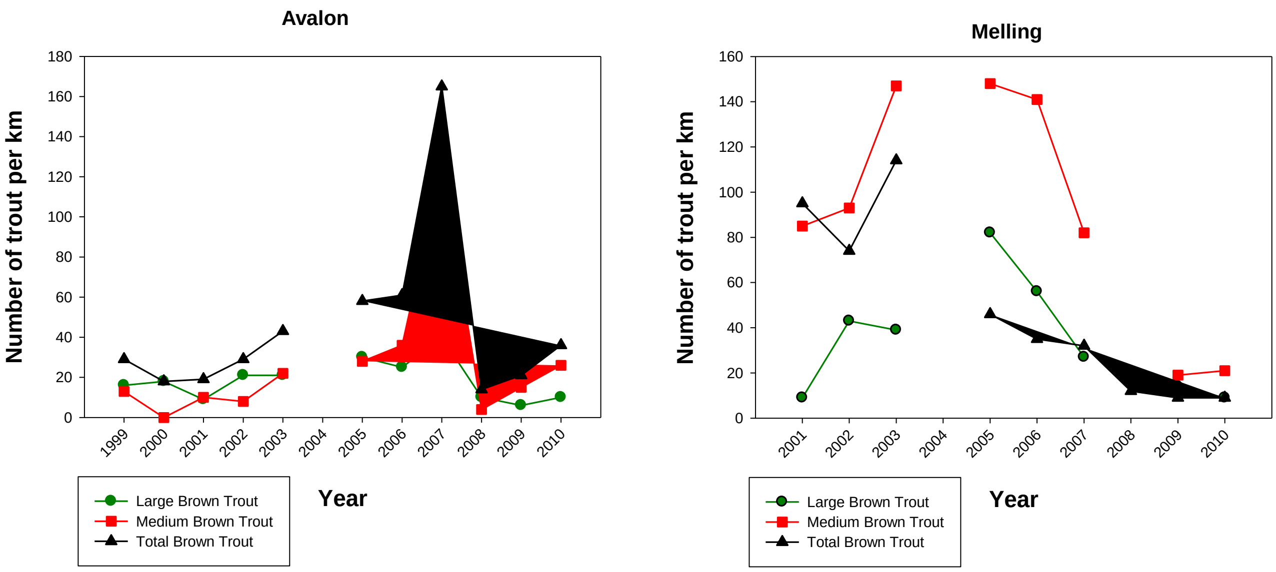


Figure 3. Total brown trout (*Salmo trutta*) per km for each drift dive site over time

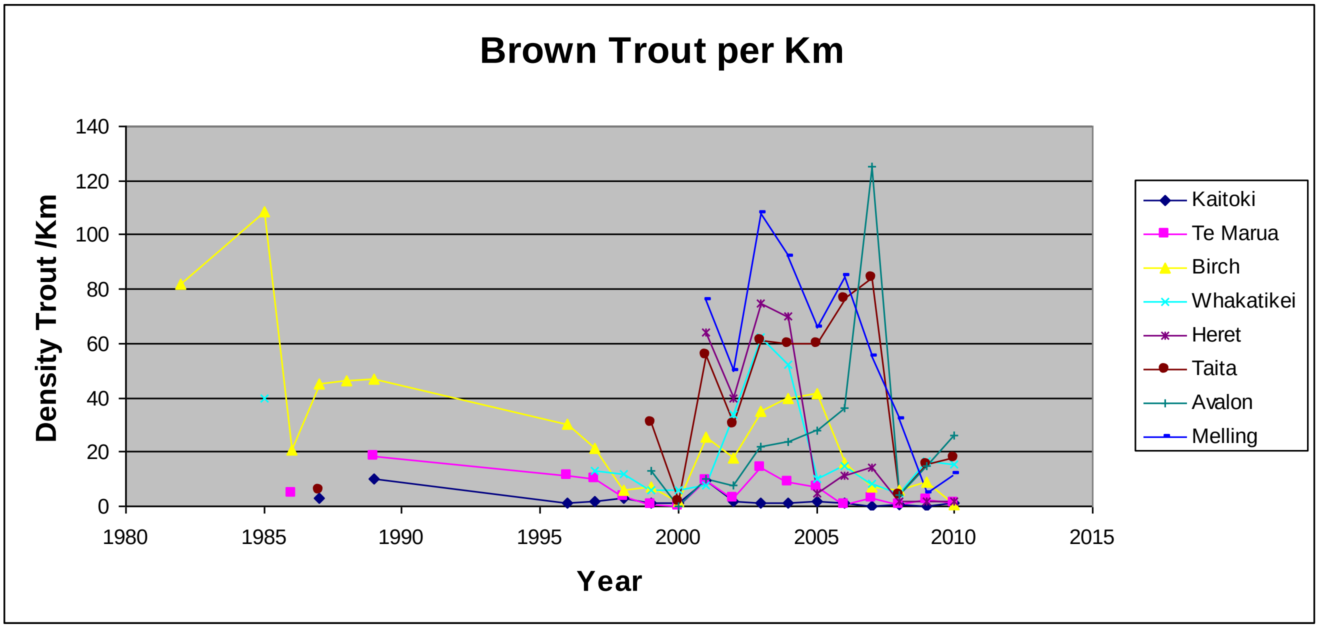
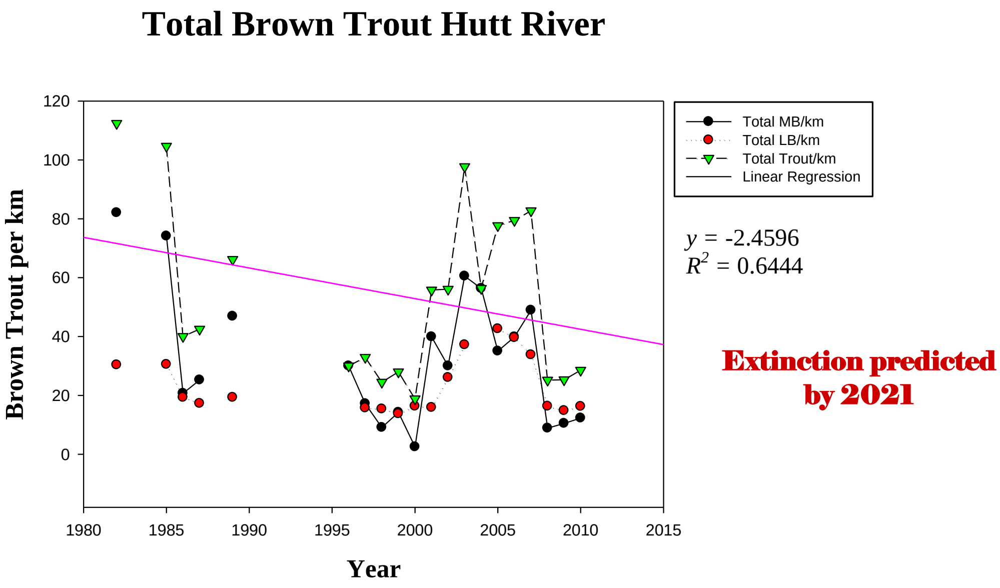


Figure 4. Cumulative medium, large, and total brown trout per km for the Hutt River, over time



Extinction predicted by 2021

Figure 5. Change in active channel over time

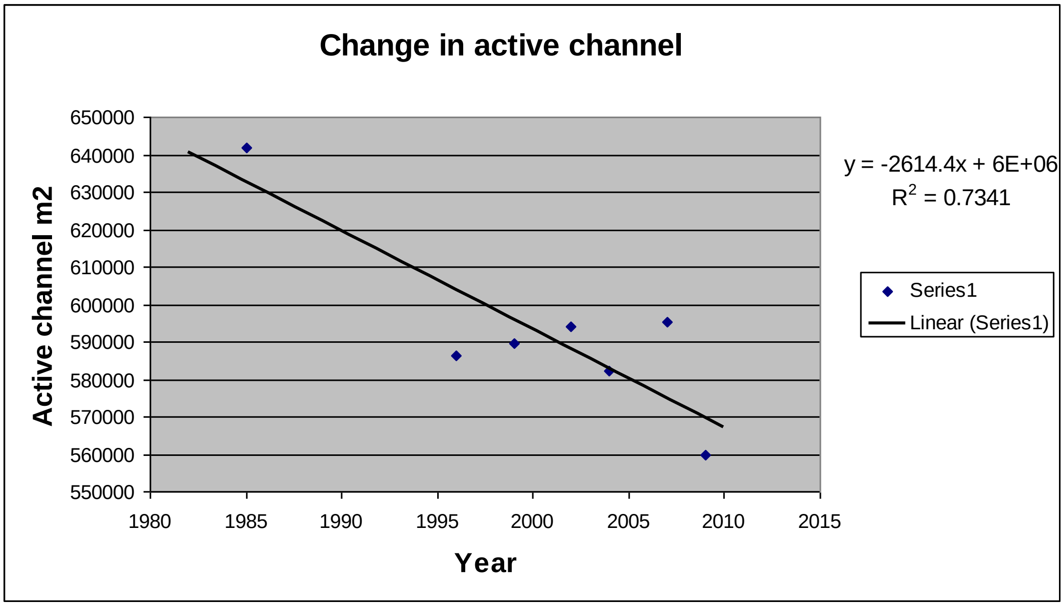


Figure 6. Change in minimum pool size over time

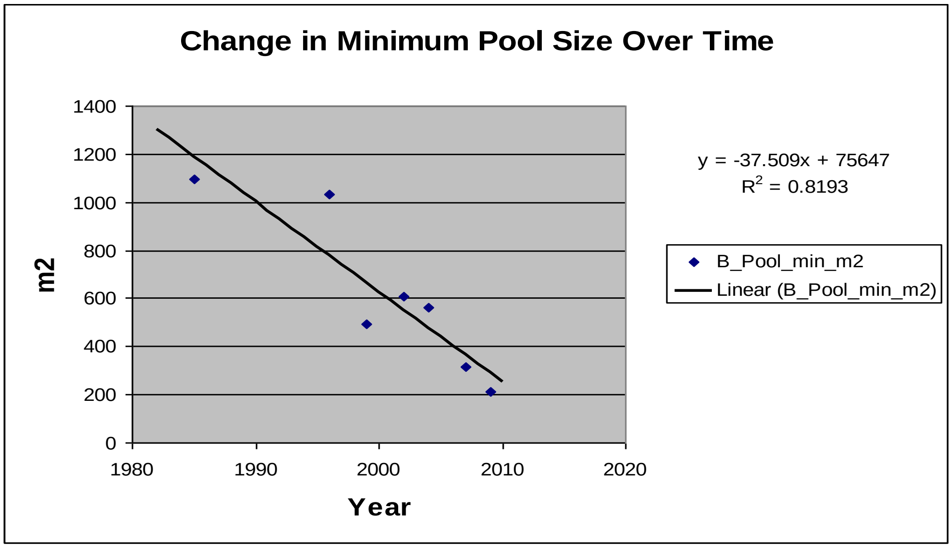
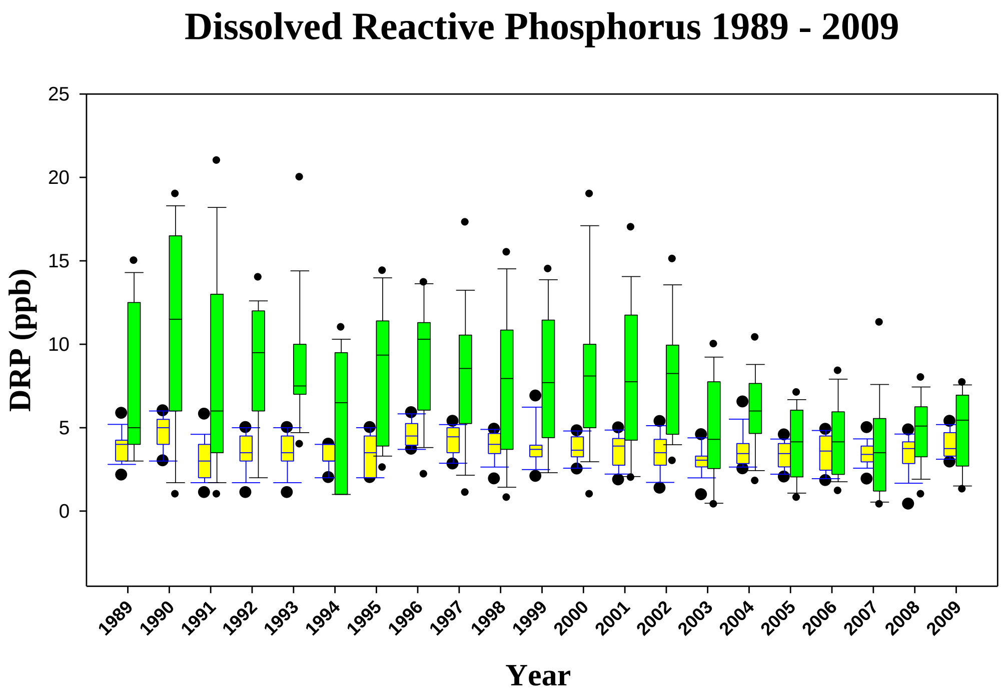
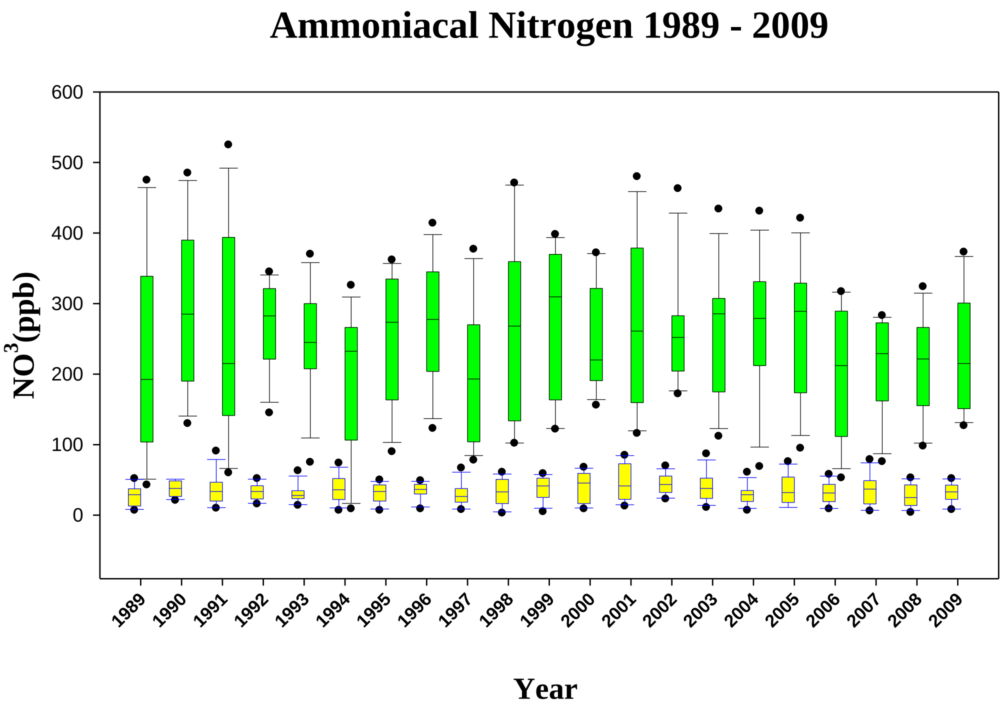
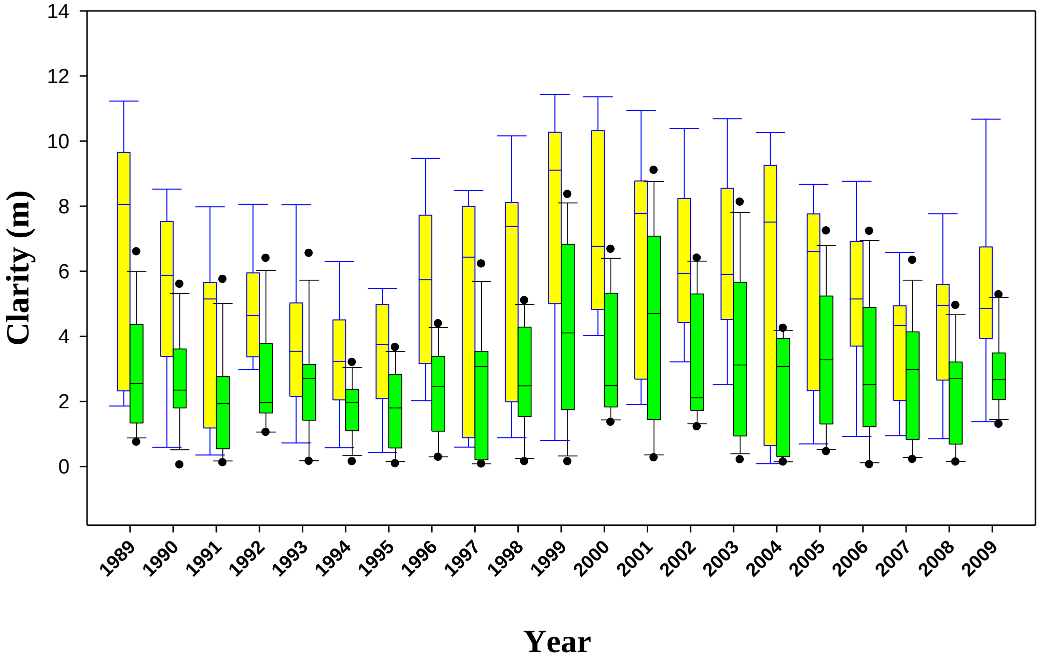


Figure 7. Habitat mapping

Figure 8. Water quality parameters: Dissolved Reactive Phosphorus, Ammoniacal Nitrogen, Clarity, and temperature, as measured at Kaitoki and Birchville from 1989 to 2009 (data provided by NIWA)






Clarity 1989 - 2009

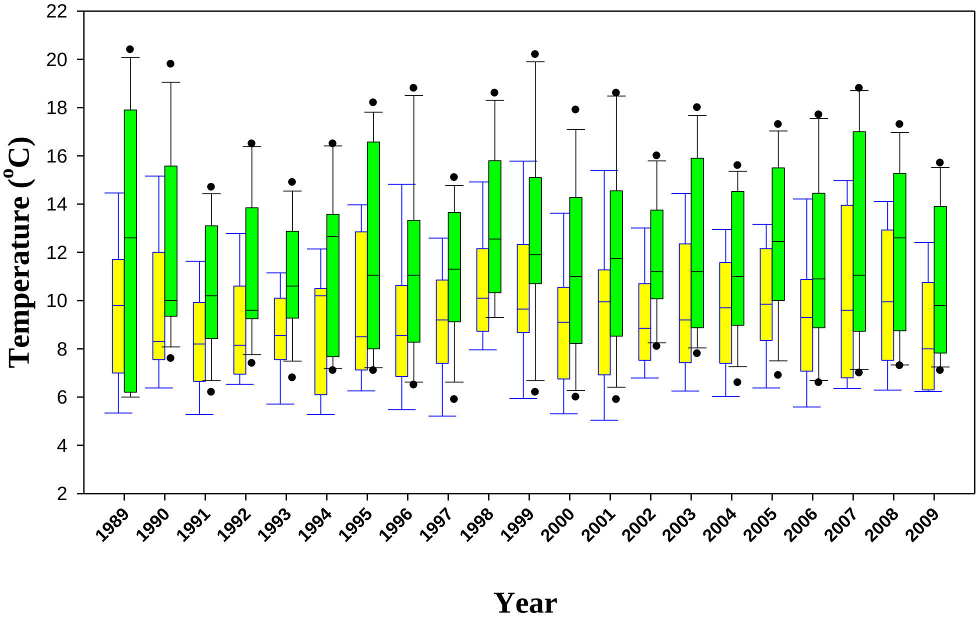
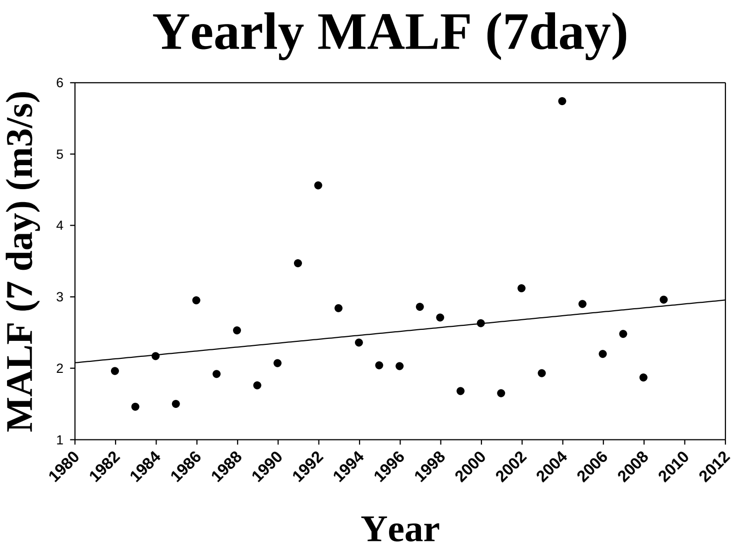

Temperature 1989 - 2009

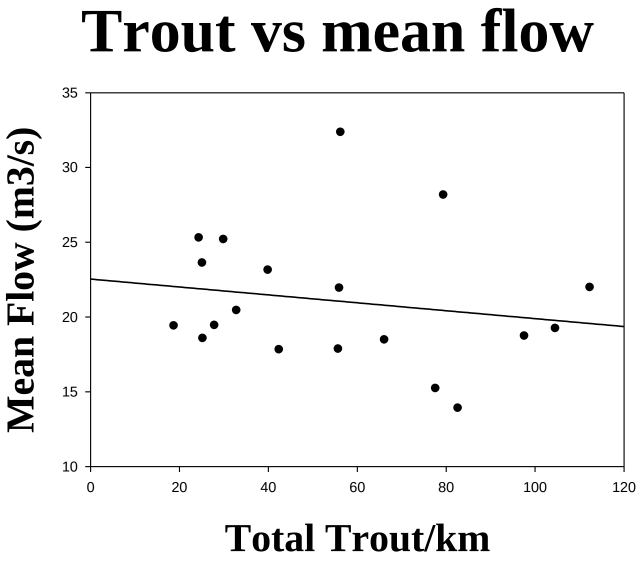
Figure 9. Annual 7 day MALF plotted against year from 1980 to 2009 (*F*=0.0435, *df* =1,3, *p* =0.8364)



y = -0.0211

R^2 = 0.0406

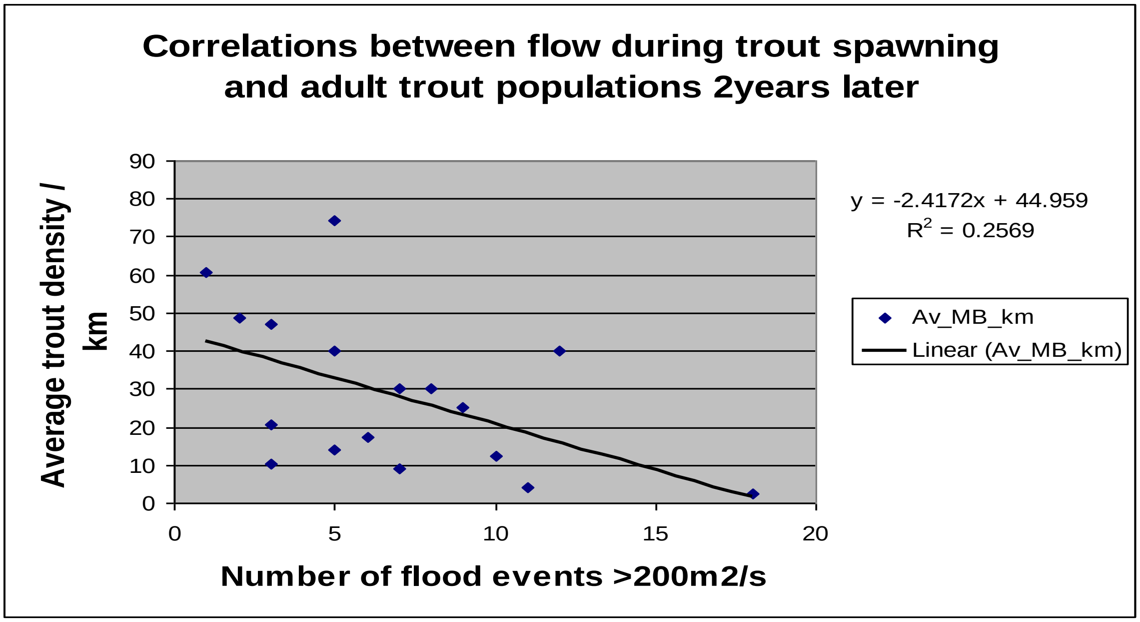
Figure 10. Total annual brown trout (*Salmo trutta*) per km plotted against mean annual flow (*F*=1.6418, *df* = 1,3, *p* =0.2114)



y = +0.0274

R^2 =0.0594

Figure 11. Correlations between flood events greater than 200m^3 during trout spawning (May to November) and annual mean adult brown trout (*Salmo trutta*) populations per km, 2 years later



Borsuk, M. E., P. Reichert, A. Peter, E. Schager, and P. Burkhardt-Holm. 2006. Assessing the decline of brown trout (Salmo trutta) in Swiss rivers using a Bayesian probability network. Ecological Modelling **192**:224-244.