Broken River Rehabilitation Project
Final Report 2008

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A MDFRC Consultancy report for Goulburn-Broken Catchment Management Authority

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The Murray-Darling Freshwater Research Centre

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1. Introduction

The abundance of large woody debris (LWD) within lowland river channels is a major driver of both primary productivity and community structure of fish and invertebrates as well as other associated biota (Nicol et al 2002). In Australian lowland rivers the substratum generally consists of sand, silt or clay. In general these substrates are colonized by few invertebrates (Humphries et al. 1998). The principle substratum for biofilm development and macroinvertebrate colonization is large woody debris (Crook and Robertson 1999). Large woody debris supports a more diverse invertebrate community in comparison to other instream sediments (Humphries *et al*. 1998; Growns *et a*l. 1999) and increases instream habitat complexity (Pusey and Arthington 2003).

The presence of LWD influences fish habitat at a number of scales. The number of fish in a river is often related to the quality and heterogeneity of instream habitat (Koehn and O'Connor 1990). The presence and complexity of LWD assists in the creation of scour pools and slackwaters promoting habitat diversity for fish and refuge from flow and predators. Fish communities in streams with a poor diversity of habitat are usually dominated by fish species that are tolerant of a wide variety of habitats. These generalists are most often introduced species (Koehn and O'Connor 1990), which compete with native fish species for food resources.

Between 1960 and 1975 "river improvement" works were carried out in the Broken River in an effort to decrease the frequency of flooding. Works undertaken included the construction of levees and removal of LWD. In 2006 work was commenced to re-snag the Broken River. This report focuses on data from fish and macroinvertebrate surveys undertaken during the 2007-2008 sampling year (herein referred to as 2008), and compares it to similar work from the 2006-2007 sampling year (herein referred to as 2007) following the introduction of the LWD.

1.1 Objectives

The objective of this program is to re-snag the Broken River and to determine the impacts of re-snagging on the ecology of the river by monitoring fish and macroinvertebrates. More specifically, we aimed to:

- Determine whether there are temporal changes in the abundance, species richness and composition, and age structure of fish as a result of re-snagging.
- Determine whether there are temporal changes in the abundance and taxa richness of macroinvertebrates as a result of re-snagging.

1.2 Report Outline

In the following report we will present in a sequential manner a summary of the methods, preliminary results and conclusions of the first two years of the Broken River Restoration Project.

Within the results section we will briefly summarise the significance of the findings in terms of total abundance, species richness, species composition and age structure of fishes with respect to treatment and sampling year. We would expect to see a positive affect on the above parameters within the re-snagged treatments from one year of sampling to the next.

In addition to presenting the results of the re-snagging treatments, we also present what we have termed “incidental findings”. These are results which became evident throughout the project and relate to differences in the abundance and species composition of fishes upstream of Casey’s weir to those found downstream of the weir.

Following fish results we present the significance of the macroinvertebrate findings in terms of total abundance and species richness with respect to treatment and sampling year.

All results are then discussed by subject matter within a section named “results interpretation” which attempts to explain what the results mean and what factors have contributed to produce such results. Within this section we highlight the limitations of the study.

We wrap up the report with “management implications” and “future directions” by subject matter. Management implications highlight what we have gained from the re-snagging project. Whereas future directions suggests improvements that should be considered as the project moves forward into another year, and possibilities for separate research regarding the influence of Casey’s weir.

Following the appendix a budget for continued funding of the project can be found.

2. Methods

2.1 Site Selection

In December 2005 site assessments were undertaken along the Broken River to identify nine reaches approximately 500 m in length with either high (3 sites) or low (6 sites) existing wood densities. To be included, the study sites had to have a defined set of criteria (Table 1). Wood would then be added to 3 of the sites with low wood densities with the aim of eventually achieving a density of wood of $1m^3$ per 10 m^2 of reach. The remaining reaches would act as reference reaches. Sites were selected based on

- Site visit
- Survey by Earthtech
- Data from previous MDFRC & CRCFE projects
- Site accessibility

The nine sites selected are located within 3 reaches of the Broken River; Benalla to Casey’s weir (Reach 1); Casey’s weir to Gowangardie weir (Reach 2); Gowangardie weir to Shepparton (Reach 3) (Table 2).

Table 1. Proposed re-snagging treatments

Treatment	Condition
Reference 1	These sites will have a reasonable density of LWD, in good condition, which will be used to determine the natural density of LWD. This will establish the density of snags to be added to the treatment sites. No snags will be added to these sites. They should also have an intact riparian zone
Reference 2	These sites will have a low density of snags, possibly in poor condition. No snags will be added to these sites. They may have a degraded or rehabilitated riparian zone.
Re-snagged.	These sites will have a low density of snags, possibly in poor condition. Preferably they will also be, or have been, targeted for riparian zone rehabilitation.

Table 2. Selected sites within Broken River

Site	Wood density	Reach
Morago	high	Benalla – Casey's weir
Scholes Rd	re-snag*	(Reach 1)
Mokoan Park	low	
Quinn Rd	high	Casey's weir – Gowangardie weir
Burnells Rd	re-snag*	(Reach 2)
Goomalibee Bridge	low	
Cosgrove Rd	high	Gowangardie weir – Shepparton
Pine Lodge Rd	re-snag*	(Reach 3)
Keats Rd	low	

* Wood added to achieve a density of $1m^3$ per $10\ m^2$

2.2 Fish

Fish were surveyed in July, September, November 2007, and January, March and May 2008. Surveys were undertaken using a Smith-Root LR-24 backpack electrofisher employing the Sustainable River Audit sampling protocol (MDBC 2005). This meant that within each 500 meter reach of river, 8 shots of 150 seconds accumulated power-on time were undertaken, resulting in a total survey of 20 minutes active fishing. Fishing targeted the full range of habitats available at each site, increasing the chance of catching fish within each reach. Collected fish were identified, measured and returned to the river at or close to their point of capture. Declared noxious fish were euthanased and disposed of appropriately.

Electrofishing was complimented at each site with the deployment of 10 unbaited bait traps set along the length of the site. Bait traps were employed to catch small bodied fish that may not be targeted with the electrofisher. Collected fish from bait traps were processed in the same manner as outlined above.

Due to the extension of the re-snagged zone within the treatment sites in June 2007, the fishing zone of these sites proportionally increased within the snags from the 2007 sampling year to the 2008 sampling year. Apart from this minor adjustment between sampling years, each sampling event fished approximately the same zone within each site as the previous occasion to ensure between event replication.

2.3 Macroinvertebrates

Macroinvertebrates were sampled in November 2007 using snag-bags (Growns et al. 1999). Three snags from each reach were sampled. Collected animals were sorted and identified to the taxonomic resolution of Family. Once identified, numbers were converted to the mean abundance of animals per square meter of wood per site.

3. Results

3.1 Wood Density

Wood was added to three treatment sites along the river in May 2006 and again in June 2007 to achieve a minimum density of $1m^3$ per $10m^2$ along the 500 m length of the reach (Table 3)

Table 3. Total density of wood added at each re-snagged site (area of reach calculated at 500 m x 30 m)

Site	Volume (m^3)	Density (m^3) per $10m^2$
Scholes Road	1064	0.709
Burnells Road	735	0.490
Pine Lodge	1263	0.842

3.2 Fish

Over all sampling events (including the pre-works survey) a total of 2523 fish from 15 species (ten native and five introduced) have been caught across all sites. Native fish species captured were numerically dominated by Rainbow fish and Carp Gudgeons, whereas introduced species were numerically dominated by European Carp and Mosquito fish.

3.2.1 Pre-works Survey

Seven native fish species and three introduced fish species were collected from all sites with rainbow fish being the most abundant (Appendix

Fish

Table 4. Appendix

Fish

Table 4). There were substantially more fish collected from the sites with high densities of wood, and only small differences in numbers collected from the sites with low wood densities. There was little difference in the number of fish species collected from all sites whether they had high or low densities of wood with numbers ranging from 2 species at the Scholes Road site to 6 at the Mokoan Park site.

3.2.2 2007 Survey

Over the six sampling events conducted in the 2007 sampling season, a total of 1046 fish from 14 species (nine native and five introduced) were caught across all sites. Again, native fish species were numerically dominated by the small bodied Rainbow fish as well as Carp Gudgeons, whereas the catch of introduced species was numerically dominated by European Carp and Mosquito fish (Appendix

Fish

Table 4).

The first 12 months of post-works monitoring didn't reveal any treatment site trends. While there was an observable seasonal increase in the total abundance of fish captured within the re-snagged treatment, over the twelve month period this was not significant. It may be that one year was not a sufficient implementation period to see any significant trends across treatment sites.

There was, however, a significant difference in fish composition between reaches. Reach 1 above Casey's weir was dominated by small-bodied native fish, whereas the reaches below Casey's weir had a greater abundance of large-bodied native fish, in particular Murray Cod.

A point of interest from the 2007 sampling season was the relatively high capture rate of small Murray Cod estimated to be less than 12 months old (Ingram 2004) over the months of February, April and May from the re-snagged treatment site at Burnells Road.

3.2.3 2008 Survey

3.2.3 a) Total Abundance

With respect to total abundance of fishes, our key question was: Is there a significant difference in mean abundance of fish among treatments, and does mean abundance vary across the two sampling years? We answered this question by conducting a two-factor analysis of variance (ANOVA) which tests for:

a) Treatment effect: A significant difference in abundance of fish among the three treatments, irrespective of year.
b) Year effect: A significant difference in abundance of fish between years, irrespective of treatment.
c) Interaction effect: A significant difference in the pattern of abundance variation across treatments, between years.

We are most interested in test (c) because one could expect a gradual relative increase in the number of fish in the re-snagged treatment over the two year sampling period, if re-snagging was having a positive effect on the abundance of fishes in the Broken River.

However, tests (a) through to (c) were all insignificant (Treatment: F = 0.032, P = 0.968; Year: F = 0.026, P = 0.875; Interaction: F = 0.127, P = 0.882). We use the term "insignificant" in the strict sense, to mean that we do not have sufficient evidence to reject the null hypothesis, which essentially states that there is no effect of re-snagging on fish abundance. Figure 1 presents mean fish abundance across treatments and years.

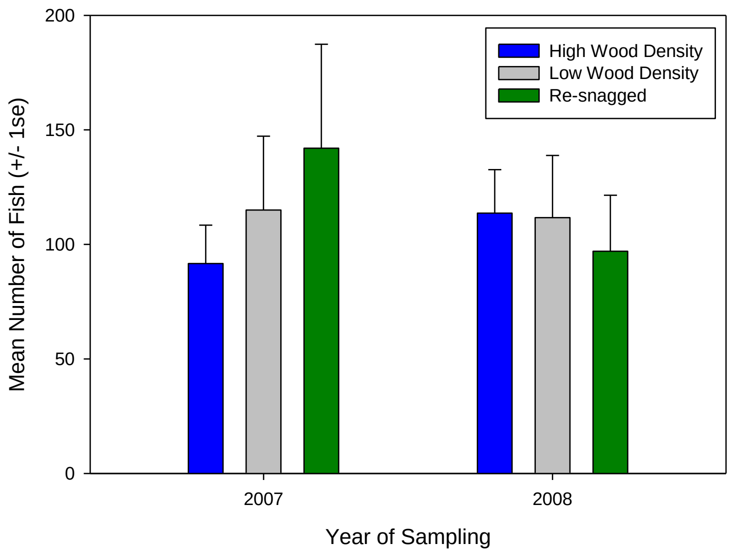

Figure 1. Mean number of fish (native and introduced species) recorded from each treatment and within each year.

The above analysis tests for an increase in total average fish abundance within the re-snagged sites over the two years that followed re-snagging. Ideally, we should be analysing the change in abundance among "pre-snagging" and "post-snagging" years.

Unfortunately, however, there was not sufficient time to obtain comparable pre-snagging data. All sites were only sampled during a single month, May, before snagging took place. Therefore, instead of looking at mean responses that are obtained by aggregating data across all months—as we have done above—we can examine the response of the fish community to re-snagging during the month of May only. Below, we determine whether the abundance of large-bodied native fish changes across a single pre-snagging year, and two post-snagging years, during the month of May. We focus on large-bodied natives as they are the species that are supposed to exhibit the strongest response to coarse woody debris.

Changes in the mean abundance of large-bodied natives amongst treatments and over the three years are presented in Figure 2. The greatest relative changes in the abundance of large-bodied natives occurred in the re-snagged treatment: Within the re-snagged treatment, there was a trend for large-bodied native fish to increase in abundance throughout the experiment (Figure 2). This increase was greater than a similar increase in large-bodied native abundance seen in the low-density control (Figure 2). However, the increase in large-bodied native fish abundance was very weak, and statistically insignificant (2-factor ANOVA, year x treatment interaction: $F = 0.23$, $P = 0.918$).

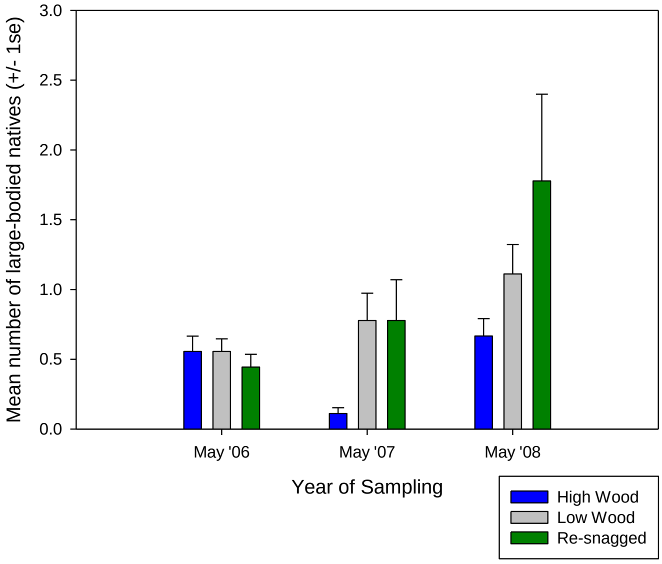

Figure 2. Mean abundance (+/- SE) of large-bodied natives sampled from each treatment, within each of the pre-snagging (2006) and post-snagging (2007-08) years, during May only.

3.2.3 b) Species Richness

Species richness is defined as the total number of species recorded from a specified site at a specified time. With respect to species richness, our primary question was: Is there a significant difference in fish species richness among treatments, and does species richness vary across the two sampling years? We answered this question by conducting a two-factor analysis of variance, ANOVA, which in this case tests for:

a) Treatment effect: A significant difference in fish species richness among the three treatments, irrespective of year.

b) Year effect: A significant difference in fish species richness between years, irrespective of treatment.
c) Interaction effect: A significant difference in the pattern of species richness variation across treatments, between years.

Again, we are most interested in the interaction effect, as one may expect a gradual increase in species richness in the re-snagged treatment, relative to the reference treatments, if re-snagging was having a positive effect on the number of fish species in the Broken River.

As was found for the total abundance data, there was not a significant effect of treatment, year or the interaction between these two factors on the number of fish species in the river (Treatment: $F = 1.246$, $P = 0.322$; Year: $F = 0.017$, $P = 0.9$; Interaction: $F = 0.066$, $P = 0.937$). These data can be visualised in Figure 3.

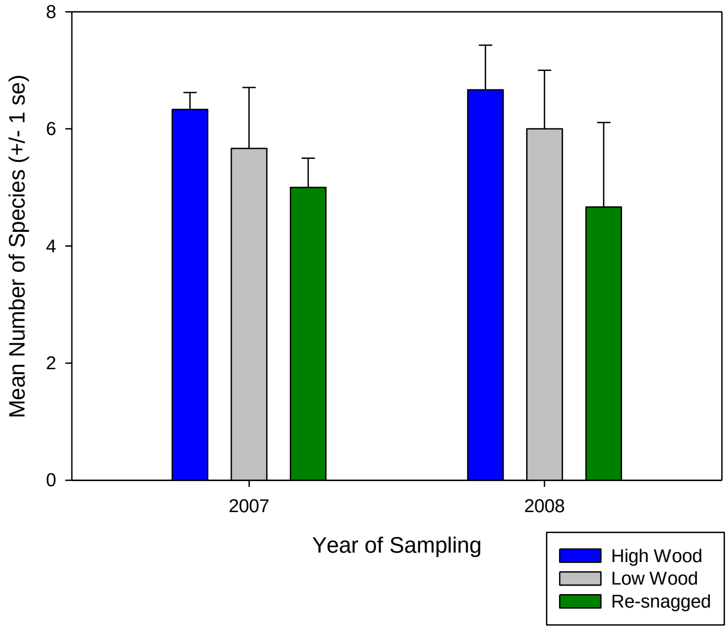

Figure 3. Mean number of species within treatments and years.

Interestingly, a pattern that was consistent across years was one whereby the re-snagged treatment returned the lowest mean species abundance (Figure 3). Of course, we cannot then infer that coarse woody debris lowers species diversity, because if this were true, then we might expect to see low species richness within the high wood density reference, which we did not (Figure 3).

3.2.3 c) Species Composition

When testing for variation in species composition we are testing not only for a change in the total number of species present, but a structural change in exactly which species are present across sites and how their relative abundance changes across sites. To illustrate, if re-snagging increases the abundance of native species relative to the abundance of introduced species, then the multivariate analyses we use here will detect such effects.

With respect to species composition, our primary question was: Is there a significant difference in fish species composition among treatments, and does species composition vary across the two sampling years? We tested for differences in fish species composition among treatments using non-parametric multivariate analyses ($\log(x+1)$ abundances). Figure 4A is a multi-dimensional scaling (MDS) plot that enables us to visualise similarities in species composition among treatments in 2007, while Figure 4B presents similarities in species composition among treatments for the 2008 data.

There was no significant difference in species composition among treatments or among years. Thus far, re-snagging has not significantly changed fish community structure relative to the reference sites, within the Broken River.

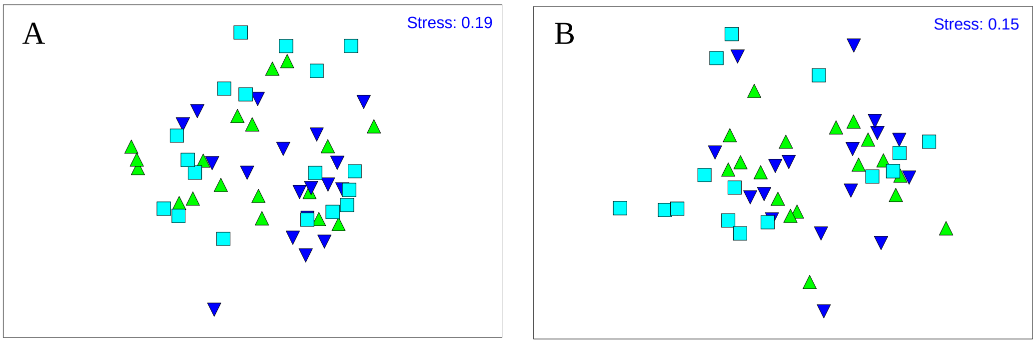

Figure 4. Multi-dimensional scaling (MDS) plot showing relative similarities in fish species composition among treatments in 2007 (A) and 2008 (B). Green triangles: low wood reference; blue triangles: high wood reference; aqua squares: re-snagged treatment.

3.2.3 d) Age Structure

Possible effects of re-snagging on the size structure of fish population were observed in Murray cod only. As such, we focus our analysis on this species. We assume lengths of Murray cod can be converted to age using the relationship presented by Ingram (2004). We ask the question: Is there an effect of treatment on the relative abundance of 0-1 year, 1-2 year and > 2 years cod within either the 2007 or the 2008 sampling period? We answered this question by conducting a two-factor ANOVA for each year separately. Each year had to be treated separately to meet ANOVA assumptions of sample independence; in the event that Murray cod remain at a site across years, then the same individuals would form different age-classes across years. These two ANOVAs test for the following, within 2007 and 2008:

a) Treatment effect: A significant difference in the abundance of Murray cod among the three treatments, irrespective of age-class.
b) Age-class effect: A significant difference in the abundance of individual Murray cod within each age class, irrespective of treatment.
c) Interaction effect: A significant difference in the relative abundances of age-classes across the three treatments.

Here, the interaction effect is really the only test we are interested in as this test will tell us whether the age-structure of cod differs significantly across treatments. As such, we only present results for test (c):

The interaction effect between treatment and age-class was not significant for either 2007 or 2008 (2007: $F = 0.741$, $P = 0.576$. 2008: $F = 0.512$, $P = 0.727$). However, one could suggest there are patterns that are consistent across years: Murray cod in their first two years of life seem to be most abundant within the re-snagged sites (Figure 4). As was the case for the species richness pattern, however, we cannot infer that coarse-woody debris is favoured by Murray cod within their first two years of life, because if this were the case then one would expect to see high abundances of these age classes in the high snag density controls (Figure 4).

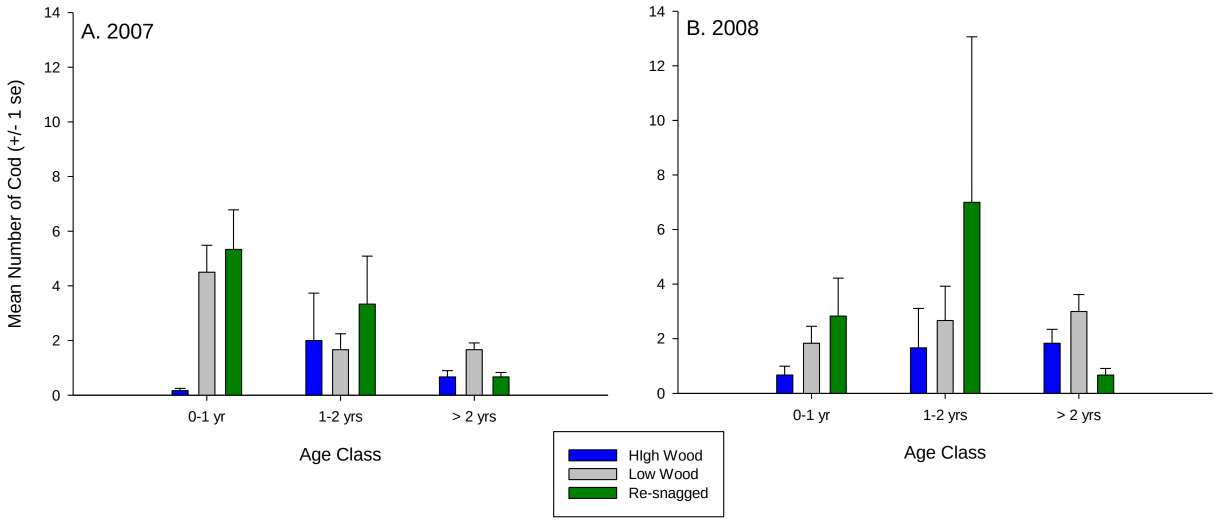

Figure 5. Mean abundance of three Murray cod age classes among treatments within each sampling year, 2007 (A) and 2008 (B).

3.2.3 e) Incidental results pertaining to fish

This project aimed to determine the impact of re-snagging operations on fish and macroinvertebrate community structure. However, throughout the course of the study, other patterns became apparent. In particular, there were very obvious differences in fish community structure between sites upstream of Casey's Weir and sites downstream of Casey's Weir. There were also noticeable differences in turbidity levels between reaches upstream and downstream of Casey's Weir. Therefore, we posed another set of questions:

1. Is there a significant difference in the abundance of small-bodied native fish upstream and downstream from Casey's Weir?
2. Is there a significant difference in the abundance of large-bodied native fish upstream and downstream from Casey's Weir?
3. Is there a significant difference in fish community composition upstream and downstream of Casey's Weir?

We conducted two-factor ANOVAs to answer questions 1 and 2, and utilised non-parametric multivariate analyses to provide an answer to question 3.

There was a strong, significant difference in the abundance of small-bodied native fish between reaches upstream and downstream of Casey's Weir (Treatment: F = 67.93, P = 0). The abundance of small-bodied native fishes is clearly higher upstream of Casey's Weir. This pattern was consistent across 2007 and 2008 (Interaction: F = 1.64, P = 0.221). Likewise, there was a strong, significant difference in the abundance of large-bodied native fishes between reaches upstream and downstream of Casey's Weir (Treatment: F = 6.65, P = 0.022). Unlike small-bodied native fishes, however, the abundance of large-bodied natives was significantly lower upstream of Casey's

Weir. Again, this pattern was consistent across both sampling years (Interaction: F = 0.09, P = 0.767). This can be visualised in Figure 6.

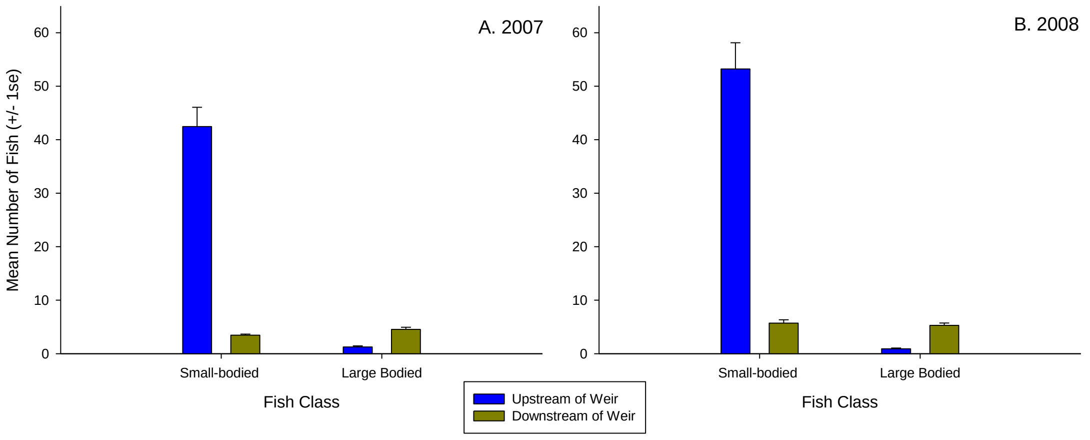

Figure 6. Mean abundance of small- and large-bodied native fishes sampled from reaches upstream and downstream of Casey's Weir.

Multivariate analyses also clearly show that not only do abundances change between reaches upstream and downstream of Casey’s Weir, but species composition of the fish community changes also (Figure 7). Figure 7 clearly shows that upstream and downstream reaches can be differentiated by their species composition. This difference is statistically significant for both years (ANOSIM test, 2007: R = 0.328, P = 0.001; 2008: R = 0.433, P = 0.001).

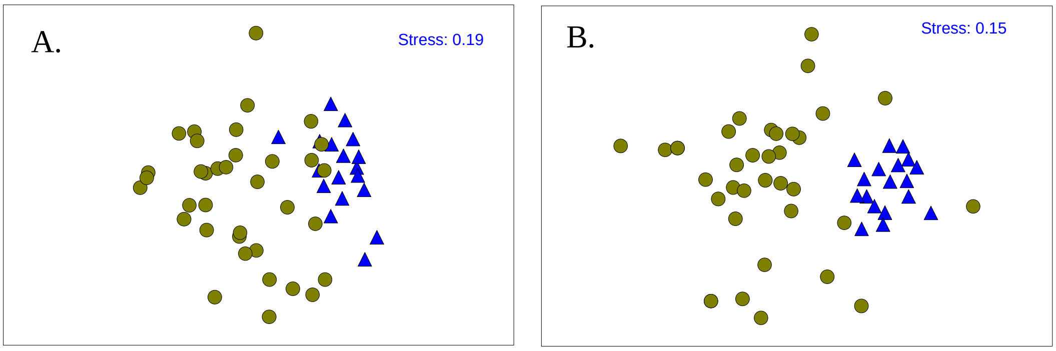

Figure 7. Multi-dimensional scaling plot showing differences in fish species composition upstream (blue) and downstream (brown) of Casey's Weir.

We have determined which species are primarily driving these compositional changes on either side of Casey’s Weir. Murray-Darling Rainbowfish, Australian smelt, carp-gudgeons, mosquitofish and Murray cod are the species responsible for approximately 80% of this compositional change (SIMPER routine, PRIMER), with the small-bodied fishes being more abundant upstream and Murray cod more abundant downstream. Thus, this multivariate analysis supports the univariate analyses on small- and large-bodied native fishes presented above.

3.3 Macroinvertebrates

Macroinvertebrates have been sampled on three occasions over the course of the project. During this time approximately 351000 animals from 45 families within 21 separate orders have been collected from snag bag samples.

3.3.1 Pre-works Survey

Twenty nine macroinvertebrate families were identified from all reaches. In all sites abundances were numerically dominated by the Dipteran family Chironomidae and Oligochaeta. There were no apparent differences between sites for either the number of families present within each reach or the abundance of invertebrates within each reach.

3.3.2 2007 Survey

Thirty two macroinvertebrate families were identified from all reaches. At all sites abundances were dominated by the Dipteran family Chironomidae. There were no apparent differences between reaches for either the number of families present within each reach or the abundance of invertebrates within each reach.

3.3.3 2008 Survey

<u>3.3.3 a) Total Abundance</u>

Approximately 62000 animals were collected from 29 macroinvertebrate families within 15 separate orders across all sites. Again Chironomids numerically dominated the abundances across all sites, with the Ecnomidae caddis fly and Oligochaeta second and third most abundant animals respectively.

With respect to total abundance of macroinvertebrates, our key question was essentially the same as for fish: Is there a significant difference in mean abundance of macroinvertebrates per m^2 of wood among treatments, and does mean abundance vary across the two sampling years? We answered this question by conducting a two-factor analysis of variance (ANOVA) which tests for:

a) Treatment effect: A significant difference in abundance of macroinvertebrates among the three treatments, irrespective of year.

b) Year effect: A significant difference in abundance of macroinvertebrates between years, irrespective of treatment.

c) Interaction effect: A significant difference in the pattern of abundance variation across treatments, between years.

We are most interested in test (c) because one could expect a gradual relative increase in the number of macroinvertebrates per m^2 of wood in the re-snagged treatment over the two year sampling period, if re-snagging was having a positive effect on the abundance of macroinvertebrates in the Broken River.

However, tests (a) through to (c) were all insignificant (Treatment: $F = 1.16$, $P = 0.344$; Year: $F = 0.53$, $P = 0.592$; Interaction: $F = 0.821$, $P = 0.61$). This essentially states that there is no effect of re-snagging on macroinvertebrate abundance. Figure 1 presents this visually, showing mean macroinvertebrate abundance per m^2 of wood across treatments and years.

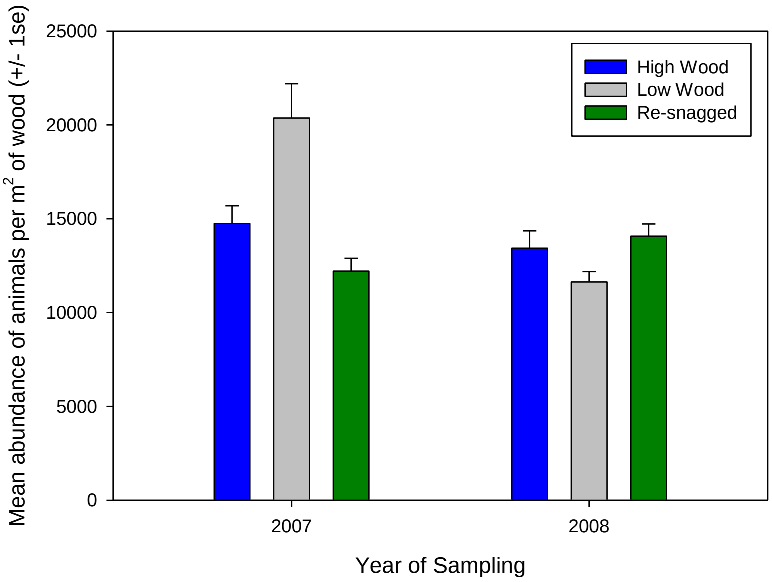

Figure 8. Mean abundance of macroinvertebrates per m^2 of wood amongst treatments for each sampling season.

3.3.3 b) Species Richness

With respect to species richness, or in the case of macroinvertebrates, taxa richness at the family level, our primary question was: Is there a significant difference in macroinvertebrate taxa richness among treatments, and does species richness vary across the two sampling years? We answered this question by conducting a two-factor analysis of variance, ANOVA, which in this case tests for:

d) Treatment effect: A significant difference in macroinvertebrate taxa richness among the three treatments, irrespective of year.
e) Year effect: A significant difference in macroinvertebrate taxa richness between years, irrespective of treatment.
f) Interaction effect: A significant difference in the pattern of macroinvertebrate taxa variation across treatments, between years.

Again, we are most interested in the interaction effect, as one may expect a gradual increase in taxa richness in the re-snagged treatment, relative to the reference treatments, if re-snagging was having a positive effect on the number of macroinvertebrate taxa in the Broken River.

As was found for the total abundance data, there was not a significant effect of treatment, year or the interaction between these two factors on the number of macroinvertebrate taxa in the river (Treatment: $F = 1.83$, $P = 0.131$; Year: $F = 0.476$, $P = 0.624$; Interaction: $F = 1.48$, $P = 0.184$). These data can be visualised in Figure 9.

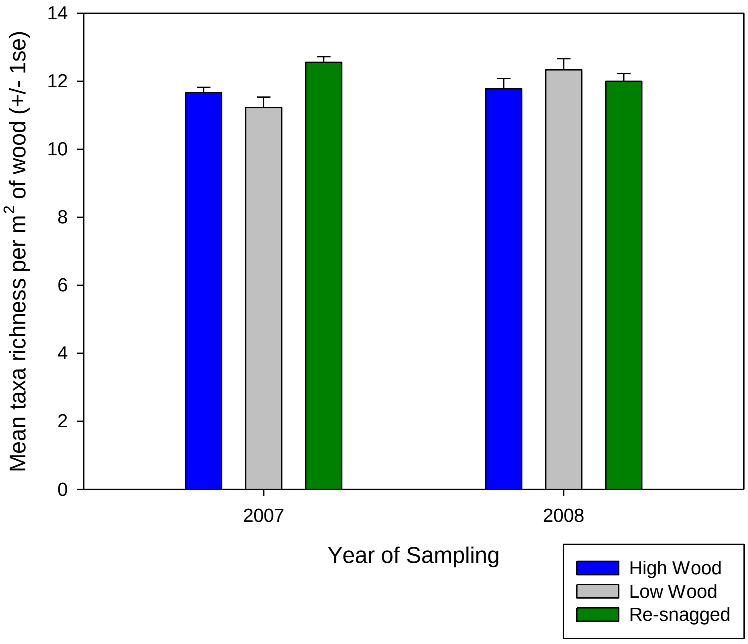

Figure 9. Mean macroinvertebrate taxa richness per m^2 of wood among treatments and across years.

4. Interpretation of Results

4.1 Effects of re-snagging on fish communities

Over the past two years there has been no significant effect of re-snagging on fish abundance. Similarly, there was no significant impact of re-snagging on fish species richness or community composition. A trend for an increase in the abundance of large-bodied native fish within the re-snagged reaches, relative to other reaches was observed, but this trend was weak and not statistically significant. Further, we observed a trend for higher abundances of young cod within re-snagged reaches, but again, this effect was insignificant. There are many possible reasons for the insignificant effect of re-snagging on fish communities and we discuss four such reasons below.

First, there is a very large degree of uncertainty surrounding the abundance of coarse woody debris at control sites. Indeed, observations made during the course of the study imply that the abundance of coarse woody debris at control sites may be just as high as that observed at re-snagged sites. If this were the case then the strength of the response of the fish community within the re-snagged reaches may be quite weak. The abundance of woody debris at each of the sites needs to be accurately quantified before we can interpret the results presented here in a meaningful way.

Second, the best way to scientifically measure the response of restoration activities such as this is with a BACI (Before, After, Control, Impact) experiment. That is, we need to set up an experiment with two factors: time and treatment. The “time” factor should have two levels: before and after. It is vital that the “before” data be just as detailed and comprehensive as the “after” data, if we are to make meaningful inferences about the efficacy of restoration activities. The experiment conducted here may not have appropriate “before” data; “before” data from a single month (May) is not only difficult to compare with “after” data from multiple months, but may not be enough information to ascertain what the fish community structure was actually like before the snags were placed within the re-snagged reaches. Future restoration projects must incorporate adequate “before” data so that their efficacy can be supported by strong, scientific evidence.

The third reason for an insignificant response of the fish community to re-snagging may be that the study was of an insufficient duration to detect a significant recolonisation of re-snagged reaches by fishes. Australian freshwater systems are notoriously variable from year to year, making the separation of ecological “signal” from background environmental “noise” very difficult. To separate signal from noise, large numbers of replicates are required—this study only could afford three within each treatment—as well as long-term monitoring. Perhaps prolonged monitoring of each site would reveal some significant effect of re-snagging on fish community structure.

4.1.2 Age Structure

This result suggests that young cod may be utilising re-snagged treatments for purposes of velocity shelter in areas that are otherwise subject to relatively fast flows (Nicol et al. 2005)

Burnells Road is the re-snagged site that was responsible for driving these patterns, recording abundant captures of young Murray cod in both sampling years. There appears to be a resident cohort of cod at the site, with 28 <1 year cod being caught in 2007, followed by 21, 1 year cod being caught twelve months later. It is impossible with our methods to determine that any of these fish are displaying site fidelity over an elapsed period of twelve months, however, the fish may be doing just this. Whether this is due to the artificial re-snagging, or whether the site has historically nurtured young cod, is too difficult to determine without a fish tagging program.

4.1.3 Incidental Findings

While the impact of treatment is yet to produce any trends in terms of fish abundance or composition, there have been some obvious patterns emerge over the past two years as a result of the influence of Casey’s weir. As mentioned above, the abundance and composition of fish in reach one is significantly different to that of reach two and three.

The reason for this unclear, however, the turbidity of the river is the most obvious cause. Above Casey’s weir the water is relatively clear, whereas below the weir, where the river is subject to outflow from Lake Mokoan, the water is often 200 ntu higher. Whether turbidity itself affects fish production, or whether our fishing methods are compromised by the water is uncertain. Previously our bait traps have caught large numbers of small bodied fish in reach one, however this method has generally been unsuccessful downstream of Casey’s weir; indicating that small bodied fish are scarce in the lower reaches.

Another explanation may be that the weir itself acts as a barrier to large fish passage, excluding many large bodied fish from the upper reach. With less large predatory fish in the upper reach, small fish production flourishes. Conversely in the lower reaches a more balanced predator-prey relationship exists keeping small fish production in check.

4.2 Macroinvertebrates

Macroinvertebrate density was not significantly different among the three wood treatments in this study. Indicating that macroinvertebrates were at the same density irrespective of the density of snags. Previous work has found that woody debris is an important substratum for primary production and biofilm development within turbid lowland rivers (Crook and Robertson 1999; Boulton and Lloyd 1991), and macroinvertebrates will readily colonise this structure and utilise it as a food source whenever it is available (Boulton and Lloyd 1991; Lloyd et al. 1991; Humphries et al. 1998; Johnson et al. 2003). It appears that at the densities of wood investigated during this study that macroinvertebrates were colonising at a similar rate and provided similar level of resources to maintain similar densities between treatments (Boulton and Lloyd 1991).

The time of sampling however did influence the macroinvertebrate density on the wood. With the June 2006 sample having a lesser density than both the November (2007) and December (2008) sampling events. This is likely to be due to seasonal fluctuations in density due to emergence and breeding patterns.

Macroinvertebrate mean taxa richness (Family) showed no significant differences among treatments. This again, most likely reflects that all samples were taken from snags, and that distinctive assemblages of macroinvertebrates are associated with this habitat, regardless of the density of the structure within a section of river (Lloyd et al. 1991, Humphries et al. 1998). Johnson et al. (2003) only found differences in macroinvertebrate assemblages associated with wood at a broader regional scale, not at the reach scale.

5. Management Implications

- There has been no significant impact of re-snagging on fish community structure. However, it may be that fish require more time to respond to the implementation of the treatments.
- There is some weak evidence that small Murray cod are favouring the re-snagged treatments. However, this weak response would have to be further monitored to ascertain whether the effect of re-snagging on young Murray cod is a significant one.

6. Future Directions

6.1 Re-snagging

- Unfortunately, our observations of the control sites imply that wood density at low wood treatment sites may actually be very high, thus limiting the efficacy of the experiment. As the project continues, it would be worthwhile re-quantifying the density and total volume of snags at all sites, to be sure that this is not a factor influencing the results.

- To accurately determine whether re-snagging is having a positive impact on fish residence or site fidelity within treatments, fish need to be tagged so that we can generate data on this aspect. Without this we can only guess as to a fish's movement.
- As discussed above, the results pertaining to the macroinvertebrates is not surprising in light of the project design. As such, the need to monitor macroinvertebrate colonisation within this project is of less importance than that of monitoring fish. Therefore, cutting of macroinvertebrate monitoring from the project would deliver significant savings (see budget at the end of report) without a significant loss of knowledge .

6.2 Incidental Results and Casey's Weir

- The study has shown that Casey's weir and/or the turbid water from Lake Mokoan has an impact on species abundance and composition. Indeed, the serendipitous correlations between turbidity and fish community structure represent the strongest patterns uncovered by this investigation. The research project proposed by Rick Stoffels, if funded, would provide thorough and rigorous understanding of the effects of turbidity on fish communities in the Broken River.

7. Acknowledgements

The authors initially wish to acknowledge Wayne Tennant for his support of this project from inception to its current state. We also wish to acknowledge Helen Gigney and Lyn Smith for their input to the planning phase of this project. We would like to thank Adam Richardson and Helen Gigney for periodic field assistance, and Karla Williams and Felicity Smith for assistance with macroinvertebrate sorting and identification. Finally we would like to thank Rob Cook for his suggestions regarding macroinvertebrate trends.

All fish sampling was conducted under Victorian Fisheries research permit RP922.

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Appendix

Fish

Table 4. Comparison of total catch per species for the pre-works, 2007 and 2008 sampling seasons (nb. pre-snag survey was limited to one survey).

	Small Bodied Native Species					Large Bodied Native Species					Exotic Species				
Year	Australia Smelt	Carp Gudgeon	Murray Jollytail	Murray-Darling Rainbowfish	Unspecked Hardyhead	Golden Perch	Murray Cod	River Blackfish	Silver Perch	Trout Cod	European Carp	Goldfish	Mosquitofish	Oriental Weatherloach	Redfin Perch
Pre-snag	12	36	0	198	0	2	8	0	2	1	11	0	12	0	1
2006-07	160	331	1	248	1	23	98	0	2	5	118	15	44	0	0
2007-08	42	302	0	238	0	35	99	2	2	0	67	32	106	1	31

Table 5. 2008 sampling season species abundances at each site.

Reach	Site	Small Bodied Native Species					Large Bodied Native Species					Exotic Species				
		Australia Smelt	Carp Gudgeon	Murray Jollytail	Murray-Darling Rainbowfish	Unspecked Hardyhead	Golden Perch	Murray Cod	River Blackfish	Silver Perch	Trout Cod	European Carp	Goldfish	Mosquitofish	Oriental Weatherloach	Redfin Perch
	Morago	7	100	0	25	0	3	0	0	0	0	8	1	28	0	29
	Scholes Rd	6	86	0	67	0	3	0	0	0	0	5	2	34	0	6
1	Mokoan Pk	20	103	0	65	0	4	0	1	0	0	2	9	26	0	6
	Quinns Rd	8	8	0	8	0	12	5	0	0	0	2	15	4	1	0
	Goomalibee	1	1	0	13	0	9	24	1	0	0	9	4	2	0	0
2	Burnells Rd	0	1	0	9	0	0	42	0	0	0	2	0	0	0	0
	Cosgrove Rd	0	1	0	44	0	2	15	0	1	0	9	1	4	0	0
	Keats Rd	0	1	0	6	0	0	13	0	1	0	9	0	5	0	0
3	Pine Lodge	0	1	0	1	0	2	0	0	0	0	21	0	3	0	0
Total		42	302	0	238	0	35	99	2	2	0	67	32	106	1	31

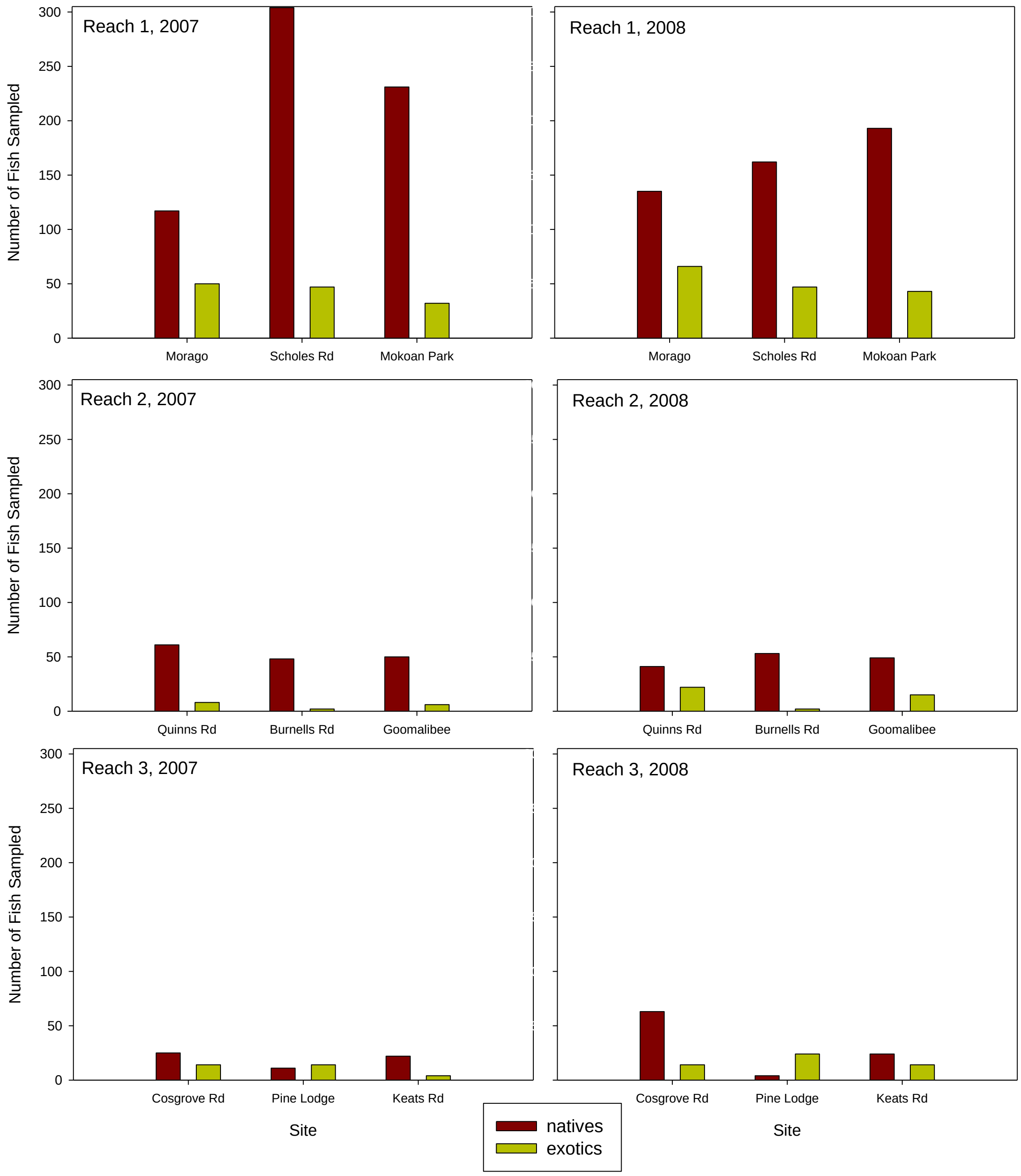

Figure 10. Yearly comparison of the total abundance of native and exotic fish captured at each site.

Table 6. Mean water quality parameters within each reach per sampling season.

	Conductivity (µS/cm)		pH		Dissolved Oxygen (mg/L)		Temperature (ºC)		Turbidity (ntu)	
Reach	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Reach 1	159.13	161.67	7.22	7.02	6.75	7.63	20.38	16.07	46.91	39.29
Reach 2	268.25	285.17	7.68	7.56	8.03	8.45	19.64	15.69	165.16	142.56
Reach 3	290.88	331.11	7.61	7.58	7.75	8.54	19.62	15.36	133.46	137.84

Macroinvertebrates

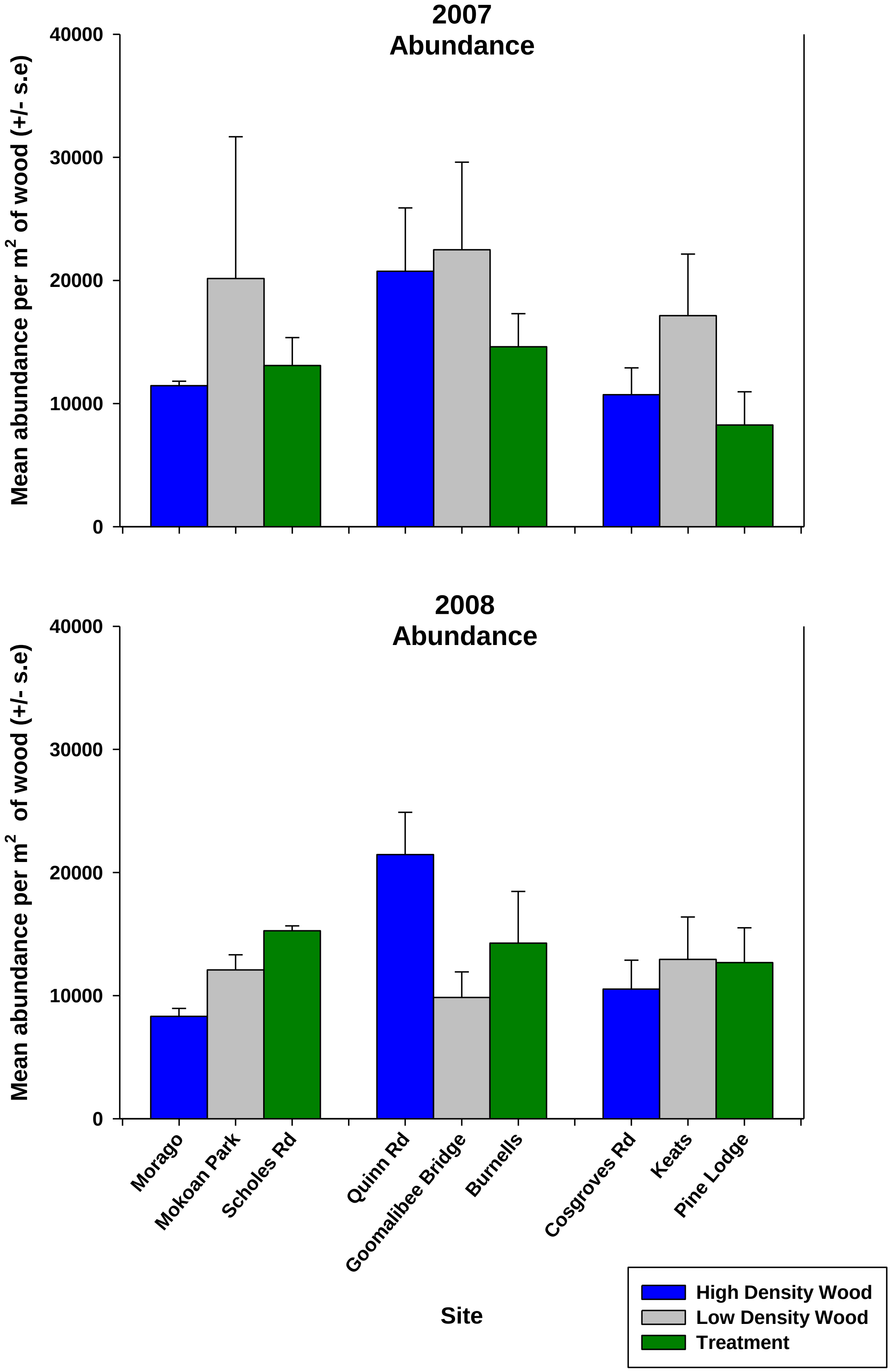

Figure 11. Mean abundance of macroinvertebrates per square metre of wood across all sites for each sampling season.

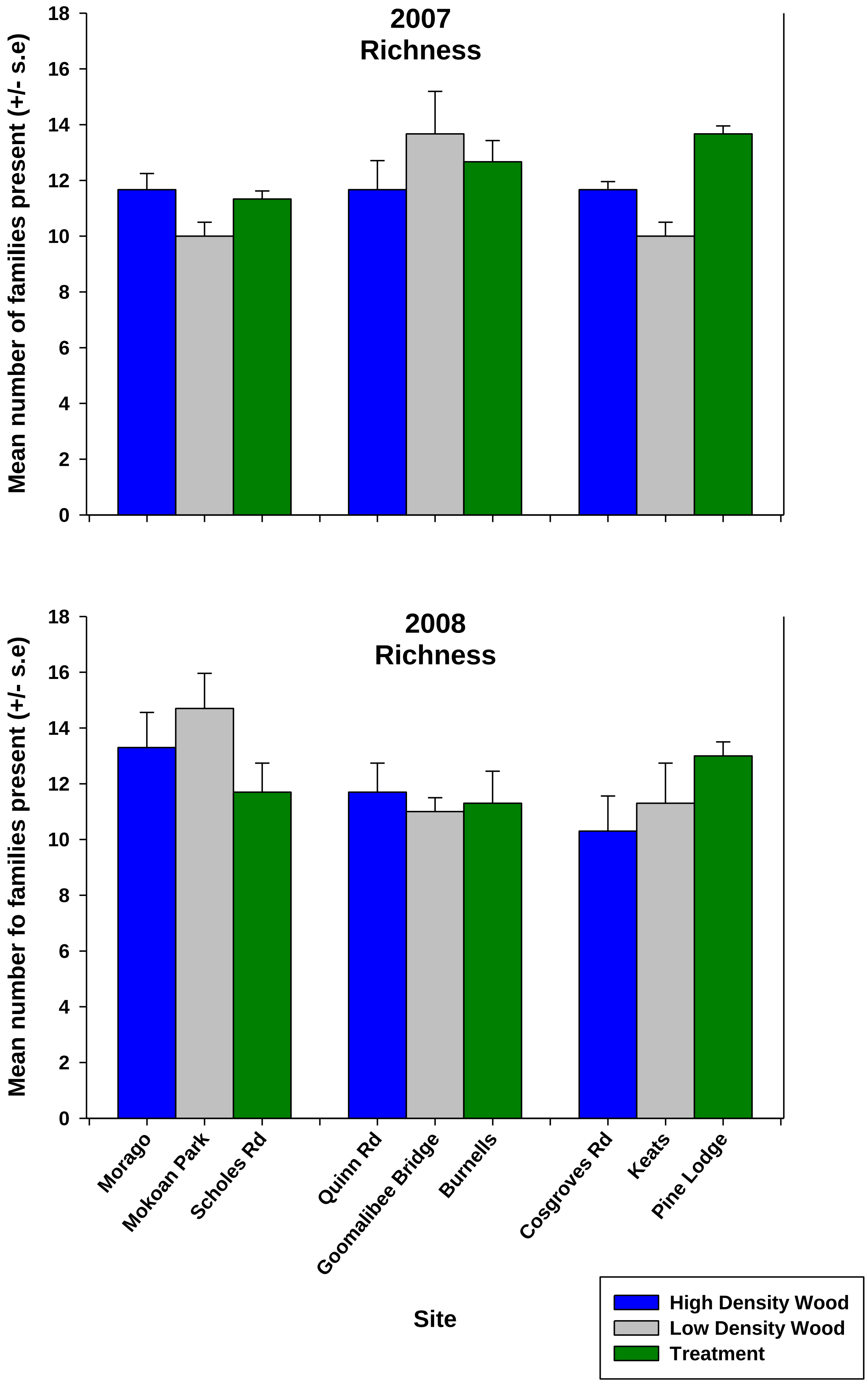

Figure 12. Mean taxa richness across all sites for each sampling season.

Budget July 2008 to June 2009

Fish

Sampling: Six bi-monthly sampling events will be undertaken throughout the year. Samples will be collected around LWD and from slackwaters within each reach. Sampling will be undertaken using a backpack electrofisher around LWD and in slackwaters with techniques developed for the Sustainable Rivers Audit (SRA) (MDBC 2005). Native fish will be released at point of capture and introduced fish will be euthanased.

Data

Information gained will be abundance, richness and size classes of fish present. Size classes can be used to indicate changes in age structure of the populations.

Budget July 2008- June 2009

Milestones

MILESTONE	OUTPUT	Date	Progress Payment
1	Bi-monthly fish monitoring and interim report (fish data)	31 July 2008	$ 6000
2	Bi-monthly fish monitoring and interim report (fish data)	30 September 2008	$ 6000
3	Bi-monthly fish monitoring and interim report (fish data)	30 November 2008	$ 6000
4	Bi-monthly fish monitoring and interim report (fish data)	31 January 2009	$ 6000
5	Bi-monthly fish monitoring and interim report (fish data)	31 March 2009	$ 6000
REPORT		29 June 2009	0
Total cost			$30000.00

All costs are inclusive of labour, travel and operating expenses

Option for extension of Macroinvertebrate Component

Sampling: One sampling event will be undertaken in spring 2008. Sampling will be undertaken using snag-bags (Growns *et al*. 1999) from 3 LWD per reach (total number of samples = 27)

Data: Information gained will be on abundance and richness at the taxonomic resolution of Family.

Field work, sorting and identification of samples, additional $60000

Project Team

Project leader Dr Daryl Nielsen

Technical support Officer

Commencement

The project will commence once verbal approval is received from GBCMA