Ecological condition and biodiversity value of urban riparian and non-riparian bushland environments: Ku-ring-gai, Sydney

Christopher Ives[1], Mark P. Taylor[1] and Peter Davies[2]

1 Department of Physical Geography, Macquarie University, North Ryde, Sydney, NSW 2109. Email: mark.taylor@mq.edu.au
2 Ku-ring-gai Council, Gordon, Sydney, NSW.

Abstract

The management, conservation and enhancement of biodiversity and ecological functioning within riparian bushland present significant challenges for many local councils, natural resource managers and agencies. The protection of bushland is particularly important in urban areas where much of the remnant bushland habitat lies along creek systems and is subject to ongoing and significant development pressure.This paper examines the terrestrial invertebrate biodiversity of bushland as an indicator of ecological condition within the Ku-ring-gai Local Government Area in north Sydney. The results reveal that riparian zones are significantly taxonomically richer than 'upland' non-riparian areas and that invertebrate assemblage structures are significantly different between these two habitat patch types. Fire was found to significantly influence the taxonomic structure of invertebrate communities, although further research is required to better understand this relationship. Habitats that had undergone bush regeneration were found to have significant variation in invertebrate faunal structure, particularly within riparian zones. While the results are considered preliminary, they do demonstrate the enhanced ecological value of riparian zones compared to non-riparian areas. The results presented herein are the first attempt to identify the specific ecological value of riparian zones compared to other remnant urban Sydney bushland habitats. The results provide invaluable ecological evidence that can be used to support the protection of riparian bushland patches from future urban development.

Keywords

Urban, bushland, riparian, invertebrates, biodiversity, management

Introduction

Ku-ring-gai Local Government Area (LGA), located in north-eastern Sydney, is renowned for its abundance of open space and bushland reserves adjacent to suburban development. However, this poses an array of challenges and environmental pressures, particularly with respect to the retention of the maximum possible levels of biodiversity. The research described herein evaluates and characterises different habitat patches (both riparian and upland), their treatments (recently burnt or mature forest) and bushland status (regenerated or unmodified) within Ku-ring-gai LGA. This was achieved through analysis of terrestrial macro-invertebrate populations, which were selected due to their efficacy as indicators of ecosystem biodiversity and functioning.

This study was conducted to help inform and guide Ku-ring-gai Council's bushland and environmental management practices so as to optimise both expenditure and effectiveness.

The principal points of enquiry were as follows:

- To characterise the biodiversity and ecological condition of bushland areas within Ku-ring-gai LGA, thus enabling future monitoring of biological responses to management practices.
- To evaluate the ecological condition and identify biodiversity differences (using terrestrial invertebrate faunal assemblages) between various habitat types within bushland reserves.
- To determine if and how bushland management practices such as fire and bush regeneration affect biodiversity, as signified by biodiversity indices.

Study area description

Ku-ring-gai Council is considered one of Sydney's 'leafy' municipalities, containing some 1100 ha of bush reserves. However, substantial urban development on the flat, shale ridge top land means that remnant bushland reserves consist largely of narrow riparian corridors set within steep, sandstone valleys, which are often connected to large national park reserves downstream. Many of the ecologically rare and arguably more valuable reserves remain small in size and vulnerable to the influence of urban edge effects (*cf.* Schoer, 1983). These effects include urban sediment deposition, weed invasion, nutrient and contaminant enrichment from road surfaces and domestic fertilizers, and introduced predators. Whilst riparian systems are naturally highly biologically diverse (Naiman & Decamps, 1997), they are particularly vulnerable to urban influences from upstream. Ku-ring-gai's urban streams have been found to carry greatly increased nutrient loads (Leishman, 1990), enriching riparian soils and promoting the invasion and survival of exotic plants (Lake & Leishman, 2004). Irrespective of these effects, Ives *et al.* (2005) found that riparian corridor width is positively correlated to native woody plant diversity within Ku-ring-gai catchments.

Alteration of the natural fire regime since human occupation to minimize bushfire risk has had a significant impact upon the Ku-ring-gai landscape. As a consequence, many small reserves in Ku-ring-gai are never burnt, resulting in changes to long term vegetation structure. Consequently, the effect of fire on bushland invertebrate populations (a proxy for biodiversity) will be considered here.

Historically, bush regeneration within Ku-ring-gai has been undertaken in a largely *ad hoc* manner, focusing primarily on weed removal and improved aesthetics, with limited consideration of specific site characteristics or comprehensive ecological implications and requirements (*cf.* Grimbacher & Hughes, 2002). This has resulted partly from a paucity of knowledge relating to the ecological effectiveness of different bush regeneration techniques. Whilst a number of attempts to understand this have already been made with respect to the Ku-ring-gai area (*cf.* Grimbacher & Hughes, 2002; Pik *et al.*, 2002), more detailed research is required to understand the ecological complexities and interactions in order to compose clearly stated goals and outcomes that are fundamental to effective bushland management (Buchanan, 1994).

Methods

Study sites

Nine sites within the Ku-ring-gai LGA were selected and subsequently divided into a number of 'patches', according to their environmental characteristics (see Figure 1). Several sites contained patches of bush regeneration whilst two were selected to function as relative 'controls' as these were subject to limited urban impacts. The habitat characteristics of the patches sampled included landscape position (riparian or upland), fire history (recently burnt or mature forest) and bushcare status (regeneration site or unmodified).

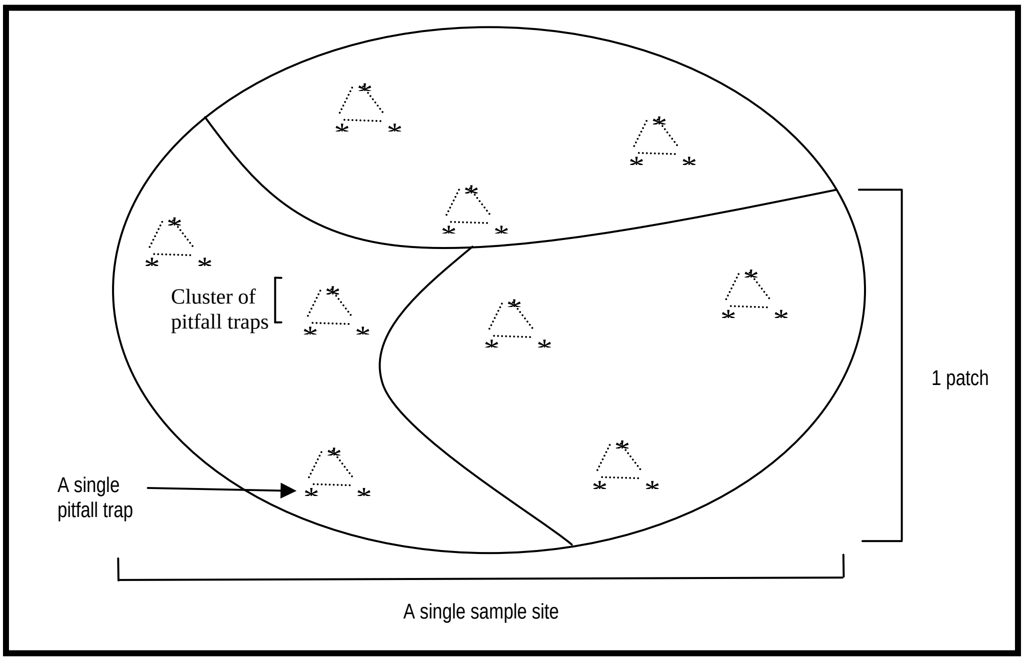

Figure 1. The typical pitfall trap configuration for a sample site. Each pitfall trap is part of a cluster of 3 with at least 15 m between each trap, forming a sample point. Three sample points (9 individual traps in total) are used to characterise a single habitat patch, with a number of patches usually present within each sample site.

Sampling method and experimental design
Pitfall traps were used to sample invertebrates. A pitfall trap consisted of a 6.5 cm diameter, 10 cm deep plastic container, filled 50 % with 70:30 ethanol:water to kill and preserve specimens. The traps were buried flush to the ground surface and left for 7 days during January 2006 prior to collection.

Traps were spatially arranged to encompass the characteristics of sample sites (Figure 1). At each sample site, two to three separate habitat areas (patches) were sampled, e.g. unburnt upland; burnt upland; and bush regenerated riparian. This resulted in a yield of 18 to 27 traps at each sample site. The geography of some locations, such as long narrow riparian strips, meant that the sample design in figure 1 was unsuitable. In these circumstances, traps assigned to specific habitat patches were arranged in a linear transect so that each pitfall trap was >15 m apart. Captured invertebrates were sorted to order level and abundances recorded.

Statistical analyses of the invertebrate samples
Data were available for statistical analysis from 66 pitfall trap clusters, hereafter referred to as "samples". Only 2 traps were available for sample 43. The primary aim of the statistical analyses was to determine whether the invertebrate faunas of riparian and upland forests differed in terms of diversity (numbers of taxa present), composition (presence or absence of particular taxa), or structure (relative abundances of taxa). In addition, possible faunal differences between mature and regeneration forests, and between recently burnt and unburnt forests, were also investigated. The basic statistical model examined the effects of the 3 treatments: landscape position (riparian or upland), regeneration status and fire history. The statistical interaction between riparian-upland and regeneration status was also examined (note: upland refers to areas not influenced by riparian processes). The interaction term tests whether the effects of bush regeneration status on invertebrate fauna are different between riparian and upland forests (or whether the observed differences between riparian and upland forests are conditional on regeneration status). The sampling regime did not allow a fully crossed factorial analysis of all 3 treatments because there were no burnt riparian sites. Council policy excludes riparian zones from hazard reduction burns. Furthermore possible interactions between burning and other treatments could not be examined due to varying sample sizes among treatments. 'Site' was included as a random factor in statistical models, to account for the fact that samples from the same site are expected to have some similarities, regardless of treatment. All other factors (the 3 treatments) are treated as fixed effects.

For all analyses, the basic statistical model used was:

$$Y = \alpha + \text{UPLAND} + \text{REGEN} + \text{BURNT} + \text{UPLAND}\times\text{REGEN} + \text{SITE} + e1$$

Y is the product or the environmental response obtained from modelling the characteristics of the various habitats samples. α = the intercept or mean; e = residual or unexplained error; UPLAND, REGEN and BURNT = the effects of being in an upland, regeneration or burnt area, respectively; UPLAND×REGEN = interaction term.

Diversity metrics
Six diversity metrics were calculated for each sample. The metrics provide measures of richness (how many taxa), equitability (how evenly individuals are distributed among taxa) or a combination of these features (diversity). Taxonomic richness (*S*) is a measure of the number of taxonomic groups (at whichever level is of interest, in this case, order) represented for a particular sample, whilst Margalef's richness (*d*) is a measure of the number of taxa for a given number of individuals. Evenness (*J'*) indicates the relative distribution of individuals among taxa present in a community. Given the unbalanced sampling design, Generalized linear mixed models (GLMM) were used to test whether sample diversity varied among treatments.

Multivariate analyses
Patterns of taxonomic composition were examined by calculating a Bray-Curtis (BC) dissimilarity index (Clarke & Warwick, 2001) on presence-absence data between all pairs of samples, in which samples with no taxa in common have maximum dissimilarity (BC = 1). The resulting dissimilarity matrix was used in a non-metric multidimensional scaling (MDS) ordination (Clarke and Warwick, 2001). This was used as the basis for a multivariate multiple linear regression analysis (McArdle & Anderson, 2001) to test whether taxonomic composition varied among treatments.

Patterns of assemblage structure or relative abundances were examined by calculating BC dissimilarity on square root transformed data between all pairs of samples. The resulting dissimilarity matrix was used in a MDS ordination and as the basis for a multivariate regression analysis to test whether assemblage structure varied among treatments (i.e. DISTLIM, Anderson, 2004). The square root transformation ensures dissimilarity values are not determined by a few, very abundant taxa. The SIMPER routine in Primer (Clarke & Warwick, 2001) was used to identify which taxa contributed most to the composition and structural dissimilarity between riparian and upland samples.

Results

Diversity

Generalised linear mixed model (GLMM) results for Taxonomic richness (Figure 2) and Margalef richness (Figure 3a,b) were significantly higher in riparian samples than in upland samples with p-values of 0.040 and 0.041 respectively, based on t-tests with 53 degrees of freedom. Taxonomic and Margalef richness were also significantly higher in unburnt than in burnt samples (p-values of 0.015 and 0.002 respectively).

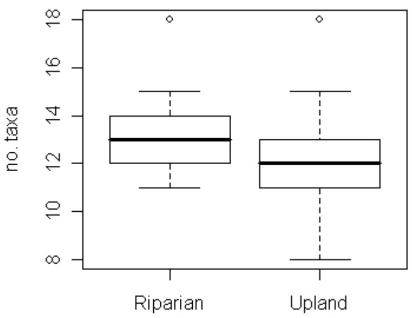

Figure 2. Box plot of invertebrate taxonomic richness (S) in samples from riparian and upland forests. Outliers are shown as open circles.

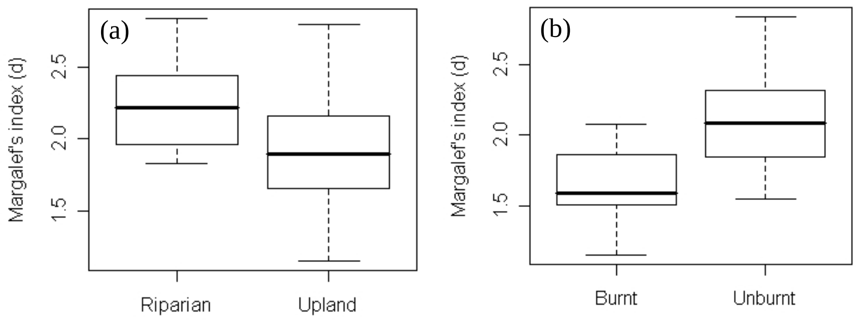

Figure 3a,b. Box plots of Margalef's richness index (d) in samples from riparian and upland forests (left) and burnt and unburnt forests (right).

Evenness was significantly lower in samples from regeneration upland forests than in samples from mature upland forests (UplandxRegen interaction P-value = 0.050), but did not differ between samples from mature and regeneration riparian forests (Figure 4a). The low evenness in regeneration upland samples reflects high abundances of Collembola (springtails) and, to a lesser extent, Diptera (flies) and Formicidae (ants). The very high Collembola abundances in regeneration upland samples result in significantly higher total abundances compared to other samples (Figure 4b). Shannon and Simpson diversity metrics showed no detectable differences among treatments.

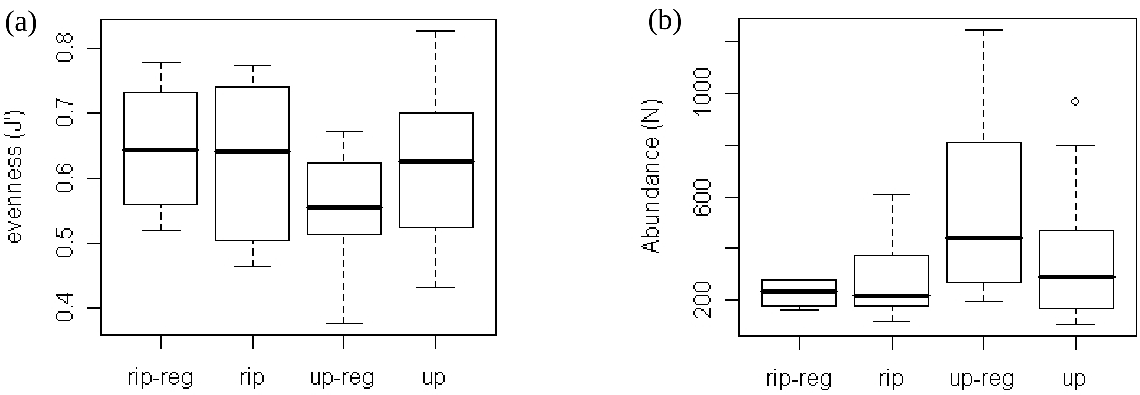

Figure 4a,b. Box plots of (a) Evenness (*J'*) and (b) total abundance (*N*) in samples from regeneration riparian (rip-reg), mature riparian (rip), regeneration upland (up-reg) and mature upland (up) forests. Outliers are shown as open circles.

Multivariate analysis
Taxonomic composition varied significantly among riparian and upland samples (P = 0.001), and among burnt and unburnt samples (P = 0.006) (Figure 5a). The assemblage structure varied significantly (at P<0.05) among riparian and upland samples (P = 0.001), and between mature and regeneration samples (P = 0.001) (Figure 5b). There was a particularly significant interaction between UPLAND and REGEN terms (P = 0.004), with pairwise comparisons (e.g. mature upland versus regen upland). This seems to reflect greater differences between mature and regeneration samples for riparian forests than for upland forests.

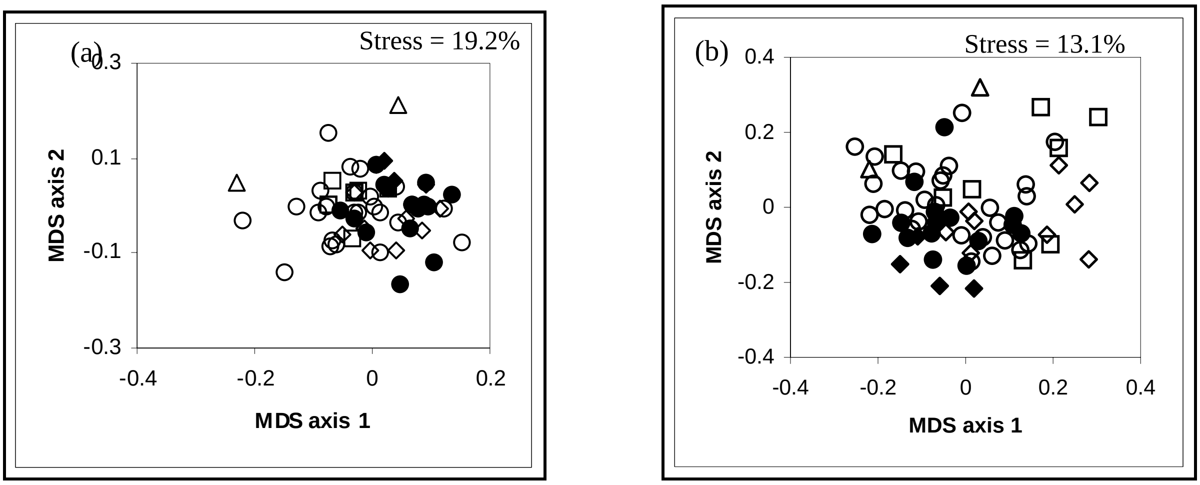

Figure 5a,b. Non-metric multidimensional scaling ordination of invertebrate samples based on Bray-Curtis dissimilarity of presence-absence data (a), and square root transformed abundance data (b). Distance between samples in the ordination space indicates Bray-Curtis dissimilarity: samples with many taxa in common are plotted close together. For both plots, solid symbols represent riparian samples and open symbols represent upland samples. Other treatment levels are indicated by symbol shape: circle = unburnt mature forest; diamond = unburnt regeneration forest; square = burnt mature forest; triangle = burnt regeneration forest.

Discussion

These analyses provide preliminary evidence that taxonomic composition and structure (relative abundances) of macroinvertebrate assemblages in riparian forests differ to those in upland forests, and that riparian forests support higher taxonomic richness than upland forests. These differences suggest that bushland management should reflect the different habitats present within a particular reserve.

Our data shows that faunas in regeneration forests have a different structure to faunas in mature forests, especially in riparian areas. Bush regeneration appears to result in reduced taxonomic evenness in upland habitats (Figure 4a), suggesting that a small number of species (often opportunistic or disturbance resistant) become more dominant. This trend was not observed for riparian zones. There were also significant differences observed in invertebrate assemblage between regenerated and non-regenerated bushland sites, with greater differences in riparian zones (Figure 5b). This suggests that bush regeneration has a greater impact on the invertebrate faunal assemblage within riparian zones. However, it is not possible from the data analysed thus far to determine whether this impact is ecologically favourable. Indeed, the observed reduction in evenness at upland sites suggests that bush regeneration may in fact lead to a simplification of the invertebrate faunal structure. If this is the case, it differs from the results observed by studies such as Grimbacher and Hughes (2002). This study suggests that bushcare practices should be tailored to the type of habitat being regenerated to reflect the underlying ecology of a site. Riparian zones in particular appear to be more sensitive to disturbance than upland areas, and as such need to be managed accordingly.

Results from this study indicate that in upland areas recently burnt forests support fewer taxa than unburnt forests (Figure 3b) with significant differences in taxonomic composition and assemblage structure (Figure 5a,b). The use of fire as a bushland management tool needs to be evaluated carefully in light of the ecological impacts it has on invertebrate faunal structures. However, the effects of burning in riparian forests were unable to be investigated because no sites were available for this study.

The results presented here are based on a small study with relatively few independent sample sites and an unbalanced sampling design with a coarse taxonomic resolution. Nevertheless, the patterns observed are broadly consistent with current understanding of riparian systems as well as with the known differences between regenerating and mature forests and the effects of burning on flora and fauna (York, 2000).

Conclusion

This study provides a valuable contribution to understanding the variation of biodiversity between different habitat types across Ku-ring-gai Council LGA. In particular, the observed greater invertebrate richness in riparian zones combined with an appreciation of associated vegetation biodiversity (Ives *et al.*, 2005) provides a useful platform for Ku-ring-gai Council to investigate further the effect of riparian buffer width on ecological condition. While the findings cover a relatively small geographic area, they may be applicable to other similar landscapes. Further research at a more detailed taxonomic resolution is required to confirm and strengthen many of the relationships identified here with respect to the use of fire and bush regeneration techniques for management. Whilst it is apparent that the ecological functioning of urban bushland is complex, it is clear that the management of these valuable remnant bushland resources need to reflect the inherent complexity in order to achieve optimal biodiversity conservation.

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