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Short review

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DO TREES MAKE A DIFFERENCE? AN EVALUATION OF THE IMPACT OF RIPARIAN VEGETATION ON THE ECOLOGY OF NUTRIENT POOR HEADWATER STREAMS

ABSTRACT: The presence of riparian vegetation is shown to affect both physical and biological properties of headwater streams. Riparian vegetation mediates food resource availability for macroinvertebrates and fish within streams through addition of allochthonous material such as leaves, woody debris and terrestrial invertebrates. Riparian shade can also reduce biomass and production of autochthonous algae. The potential role of riparian vegetation in enhancing biodiversity and productivity of headwater streams is discussed, with reference to improving salmonid fish stocks in the headwater streams of Ireland and Great Britain.

KEY WORDS: riparian vegetation, macroinvertebrates, allochthonous, shading, periphyton

1. INTRODUCTION

The riparian zone has been defined as the zone of direct interaction between terrestrial and aquatic environments (Swanson *et al.* 1982). This zone is capable of supporting a diverse and highly productive plant community due to the high moisture content and high nutrient richness of the alluvial soils. Regular disturbance by flooding, wind and invertebrate pests create a patchwork of early and late succession plant species resulting in a diverse community and a variety of complex vertical structures (LaRue *et al.* 1995). Alteration of riparian vegetation is potentially the single most important anthropogenic factor affecting the structure and function of stream invertebrate communities (Sweeney 1993) and it achieves this in two ways, physical alteration of the stream and manipulation of biological processes within the stream (Fig. 1).

2. PHYSICAL FACTORS

Stream ecosystem theory suggests that riparian vegetation is the primary controlling factor in stream biology, through its physical influences and organic inputs (Cummins *et al.* 1984). Bank side vegetation has been found to stabilise stream banks and prevent soil eroding from surrounding lands and it reduces the amount of nutrients leaching from the land and entering the system (Hynes 1975, Sabater *et al.* 2000). The presence of a riparian canopy lowers the temperature of the water beneath, which can reduce activity in fish and benthic invertebrates (Kishi *et al.* 2005). Riparian vegetation creates in-stream habitats. Roots of trees and shrubs which project into the stream edge, provide shel-

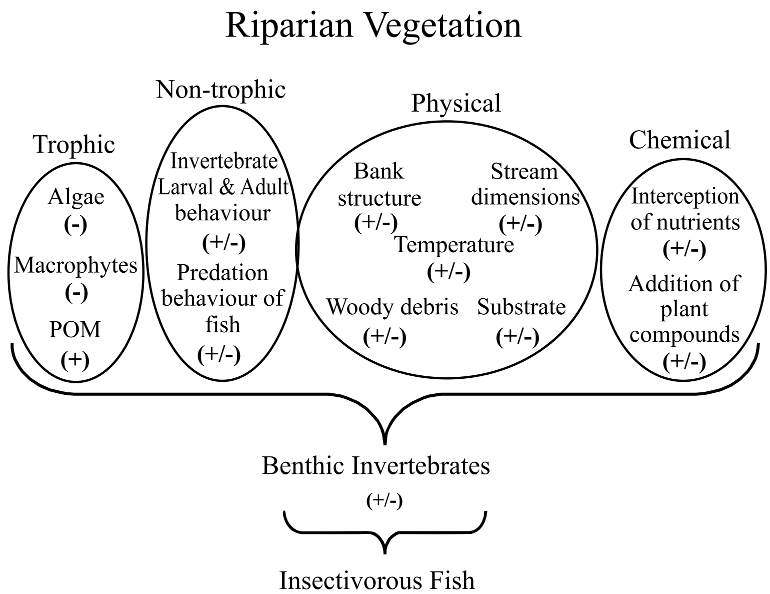

Fig. 1. The impacts of riparian vegetation on a stream ((+) indicates a positive effect, (-) indicates a negative effect on individual variables within stream).

ter and protection for benthic invertebrates and fish (Cummins *et al.* 1984, Sweeney 1993). Allochthonous material from riparian vegetation, such as woody debris and leaves, falls into streams, is retained and thereby forms habitats that provide vital refuges for macroinvertebrates and fish (Dobson and Hildrew 1992, Gurnell *et al.* 2002). Riparian vegetation can lower in-stream macrophyte growth by limiting light and nutrient availability resulting in faster flowing, wider streams (Sweeney *et al.* 2004).

3. BIOLOGICAL FACTORS

3.1. Shade effect and algal growth

A major influence of riparian vegetation on streams is its shading effect. Shading lowers the amount of light reaching the stream benthos, therefore reducing the amount of light available for algae and macrophytes to utilize in photosynthesis (Hill and Dimick 2002). It has been shown that reduced light incidence can result in a lowering of algal biomass (Sabater *et al.* 2000, Mosisch *et al.* 2001). Algal biomass has been found to be much higher in unshaded streams (Kjeldsen 1996) than in shaded streams. Light reduction directly affects algae by varying species composition (Necchi 2004) and physical structure of algal cells (Boston and Hill 1991). Some algal taxa respond to low light by increasing photosynthetic ability through physiological changes in cell structure (Hill and Dimick 2002). The degree of shading on the stream is critical. Productivity of algae decreases as shade increases though not in a linear fashion (Quinn *et al.* 1997). Such decreased algal growth has been found to be associated with a decrease in invertebrate abundance (Friberg *et al.* 1997). For a given stream, therefore, invertebrate abundance might be expected to decline as shade increases. There is some evidence to support this assertion; streams with no shading have been found to contain a higher invertebrate abundance, with greater numbers of collector gatherers, filter feeders, herbivore shredders, piercers and predators, than shaded streams which in turn exhibit greater numbers of shredders (Hawkins *et al.* 1982). Streams with coniferous riparian vegetation have been found to have lower benthic invertebrate abundance than streams with deciduous vegetation, due to a greater density of canopy and heavier shading (Whiles and Wallace 1997).

This general trophic relationship between riparian shade and primary and secondary productivity may not apply to all systems. Fuller *et al.* (2004) suggest that shading only controls periphyton when nutrient levels, particularly phosphates, are sufficient to sustain production. They showed that shade had little effect on periphyton growth when stream nutrients were limiting, as for many upland systems in Ireland and the UK, and that macroinvertebrate densities in such nutrient poor streams are higher under riparian shade than in open grassland stretches. This effect could be important in the context of upland catchment management.

Riparian vegetation may also affect streams through indirect changes to water chemistry. Leaf litter has been found to chemically suppress algal growth in ponds (Ridge *et al.*1999). Decomposing leaf litter releases chemical inhibitors which suppress the growth of algae. This mechanism, similar to the addition of barley straw in lakes, may occur in running waters, leading to reduction in algal growth in streams with high leaf litter input.

3.2. Allochthonous inputs

It has long been accepted that riparian vegetation controls the input of allochthonous materials into streams (Hynes 1975, Vannote *et al.* 1980). Organic matter in the form of leaves is known to act as the main food source for many detritivorous invertebrates (Sweeney 1993, Heino 2005). Shredder abundance is shown to be positively correlated with the amount of coarse particulate organic matter (CPOM) present in a system (Richardson 1991, Friberg 1997). Leaves and woody debris falling into streams are broken down by detritivorous macroinvertebrates, fungi, and bacteria, which themselves act as a food source for other macroinvertebrates (Franken *et al.* 2005, Wright and Covich 2005). Leaf litter exclusion experiments have shown a decrease in abundance and biomass of macroinvertebrates (Wallace *et al.* 1999). In extreme cases, leaf litter exclusion can result in the loss of a species (Eggert and Wallace 2003). The presence of woody debris within a stream increases retention of deciduous leaves and coniferous needles (Pretty and Dobson 2004), thus increasing the amount of detritus available for macroinvertebrates. Exclusion of woody debris decreases abundance, biomass and production of benthic fauna (Wallace *et al.* 1999). Allochthonous inputs of leaf litter and woody debris may, therefore, be a limiting factor in stream secondary productivity.

Allochthonous terrestrial and adult aquatic invertebrates drop from riparian canopies into streams and drift on the water surface, making up a large proportion of the diets of insectivorous fish (Dineen 2005). The relationship between allochthonous invertebrates and riparian trees is not straightforward. Significantly more terrestrial invertebrates have been found to drift in forested than in grassland streams (Edwards and Huryn 1996), although density of terrestrial invertebrate drift does not correlate with density of trees (Wipfli and Musslewhite 2004), suggesting that it is the presence of riparian trees that is important rather than their abundance. The type of riparian trees may be important, however, as more invertebrates, sometimes up to 30% (Romero *et al.* 2005), have been found to fall from deciduous canopies than from coniferous canopies (Allan *et al.* 2003).

3.3. Terrestrial adults

Riparian vegetation is not only important to aquatic invertebrate larvae but may also be important to emergent adults in providing food and shelter. Petersen *et al.* (2004) state that the riparian vegetation is the main habitat for adult aquatic insects, where adult Plecoptera for example, feed on fungi and pollen (Smith and Collier 2000). Riparian vegetation functions as the main corridor for adult insect dispersal along a stream and is also important for reproduction in aquatic invertebrates. Trichoptera, for example, use trees and shrubs as a platform for mating (Gullefors and Petersson 1993) and other Trichoptera taxa lay their eggs beneath riparian vegetation (Harrison and Hildrew 1998, Hoffmann and Resh 2003).

4. DISCUSSION

This evaluation of riparian vegetation suggests that trees exert both positive and negative effects on in-stream primary and secondary productivity. This is particularly important from a fisheries management context. Insectivorous fish feed on invertebrates from both aquatic and terrestrial sources. Therefore, trees have a direct influence on food resources through introduction of terrestrial invertebrates and also an indirect influence through influences on autochthonous invertebrates. Terrestrial invertebrates entering a stream from riparian vegetation, however, will only have a positive effect on fish species that have a substantial proportion of their diet based on terrestrial food subsidies. The impact of riparian vegetation on the productivity of a particular stream will be due to a complex suite of factors including riparian tree species and density, nutrient status of the stream and a stream's physical characteristics and disturbance regime. Thus, riparian restoration may have a positive effect on the productivity of one stream but a negative effect on another. Many studies have found that benthic invertebrate abundance in streams bordered by deciduous riparian vegetation is lower compared to communities in streams flowing through riparian grasslands. On the contrary, other studies have found that riparian vegetation does not have this effect particularly in nutrient poor streams similar to our study sites in the Burrishoole catchment, north-west Ireland. The landscape of this region is mostly blanket bog and poor quality grassland. Most of the sparse above ground vegetation in this catchment is either coniferous forestry plantation or the invasive evergreen shrub *Rhododendron ponticum* L.. Therefore, this is an ideal catchment to determine how streams with deciduous riparian vegetation differ from common grassland streams and whether riparian vegetation has a positive effect on stream productivity.

4.1. Examination of the Burrishoole catchment

This study was carried out in conjunction with a previous study into the effects of riparian vegetation on salmonid feeding habits within the same catchment, we aim to determine how differences in riparian vegetation affect whole stream productivity. The study which examines basal resources and 1° and 2° production aims to determine whether the presence of deciduous vegetation is beneficial, not only in increasing macroinvertebrate diversity and abundance, but also in providing improved food resources for commercially important salmonid stocks. The study also sets out to determine the effects of non-native riparian vegetation on streams within the catchment. The study was carried out by examining standing stock of POM, algae and benthic invertebrates across grassland, deciduous riparian and *Rhododendron* riparian strips throughout the entire catchment, monthly and over the period of one year. Preliminary results suggest that there was little difference in invertebrate abundance between grassland and deciduous riparian types, though invertebrate community structure differed, but only modestly, between riparian types. Macroinvertebrate diversity appears to be highest throughout the year in deciduous canopy stretches. Particulate organic matter (POM) standing stocks seemed to be highest underneath deciduous canopy but chlorophyll *a* concentration appears not to differ significantly across grassland and deciduous riparian type. There appears to be, however, important seasonal trends. Chlorophyll *a* in grassland streams was highest in winter and lowest during summer months, whilst concentrations were highest in streams bordered by deciduous vegetation in the spring and lowest during summer. These trends are possibly due to algal suppression by grazing invertebrates during the summer months, however, further investigations will need to be carried out to ascertain a definitive answer. Initial investigations into the effects of *Rhododendron* in the riparian zone have exhibited lower invertebrate abundance and diversity than streams with deciduous or grassland vegetation. Standing stock of algae is also reduced, whilst POM present in the benthos remains consistent with streams with deciduous riparian vegetation. Much of this organic matter, however, is made up of *Rhododendron* leaves, which appear to break down very slowly and do not support a high abundance of shredder species.

5. CONCLUSIONS

From our initial investigations in the Burrishoole catchment the expected result of restoring native deciduous trees would be a slightly greater diversity of benthic macroinvertebrate fauna and an increase in POM availability. We do not predict a significant change in algal productivity or invertebrate abundance in the study streams. An increase of in-stream habitat would also not be expected as our study has not shown a greater abundance of woody debris in streams with deciduous canopy, this possibly being due to the high disturbance regime of our study streams. The threat posed, however, by *Rhododendron* dispersal along riparian zones is quite severe, and steps should be taken to replace this invasive species with native deciduous vegetation.

It is unlikely that the findings and recommendations from this study on headwaters in north-western Ireland can be applied to other regions of Ireland and Great Britain, as many of the results may only stand for streams with similar physical, chemical and biological parameters. The study does, however, raise an interesting question. What is the importance of POM in low nutrient headwater streams? If chlorophyll *a* concentrations and macroinvertebrate abundance differ only modestly between streams which have a significantly different standing stock of POM, what effect is the POM having on macroinvertebrate communities?

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