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Riparian forestry management and adult stream insects

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Abstract

The impacts of coniferous plantation forestry on the biology of upland streams in the UK are firmly established. Whilst benthic communities have been well studied, very little research has considered the impacts of riparian forestry management on adult stream insects, yet the essentially terrestrial adult (reproductive) phase may be important in determining the abundance and distribution of larval stages. Riparian vegetation has a potentially strong impact on survival and success of adult stages through alteration of microclimate, habitat structure and potential food sources, in addition to effects carried over from larval stages. Here, current riparian management strategies are analysed in the light of available information on the ecology of adult stream insects. On the whole, management practices appear to favour adult stream insects, although an increase in tree cover in riparian areas could be beneficial, by providing more favourable microclimatic conditions for adults. This conclusion is drawn based on rather limited information, and the need for further research into the effects of riparian forestry management on adult stream insects is highlighted.

Keywords: microclimate, plantation, life history, riparian vegetation

Introduction

Since the beginning of the twentieth century, but particularly in the last 60 years, upland areas of Great Britain, particularly Wales and Scotland, have undergone extensive afforestation with exotic coniferous plantation (Stoner and Gee, 1985). Consequently, the catchments of many upland streams are heavily forested. Afforestation of riparian areas exacerbated the effects of acidification that was already occurring in the UK uplands (UKAWRG, 1988) and contributed to the deterioration of upland stream water quality (Harriman and Morrison, 1982; Neal *et al.*, 1992). Research into the effects of riparian forestry on invertebrate communities has focused almost exclusively on the benthic larval stages, notably the decline in primary productivity of streams due to channel shading (Winterbourn *et al.*, 1985) and alteration in physicochemical conditions and food resources, which result in changes in the diversity and abundance of benthic communities, due to the loss of taxa that are acid sensitive or herbivorous (Ormerod *et al.*, 1987, 1989, 1993; Gee and Smith, 1997). Management advice for riparian forestry areas has been focused similarly (Weatherley *et al.*, 1993; Forestry Commission, 2000; Broadmeadow and Nisbet, 2002). No attention has been paid to the role of adult stages of aquatic insects in determining the distribution and abundance of populations. Many of the taxa that are numerically abundant in upland streams, notably Plecoptera, Trichoptera and Diptera, have adult stages which are effectively terrestrial, and which spend their lives in the riparian zone (Collier and Smith, 1998; Petersen *et al.*, 1999; Delettre and Morvan, 2000; Briers *et al.*, 2002). Mortality of adult stages in the terrestrial environment is high, in the region of 90% (Jackson and Fisher, 1986; Werneke and Zwick, 1992; Enders and Wagner, 1996), and hence factors influencing the distribution, survival and reproductive success of adults may be important in determining the abundance and distribution of larval stages (Statzner, 1977; Zwick, 1990; Timm, 1994; Harrison and Hildrew, 1998).

Adult stream insect ecology has only recently become an area of sustained research interest and, hence, information on the potential impacts of riparian forestry management is scattered and patchy. Firstly, relevant aspects of adult stream insect ecology have been reviewed, in conjunction with data obtained during studies (Briers *et al.*, 2002; Briers *et al.*, 2003) of forested, clear-cut and moorland upland streams in the Plynlimon experimental catchment area (Hudson *et al.*, 1997). Current principles for the management of riparian forestry areas in the UK (Forestry Commission, 2000; Broadmeadow and Nisbet, 2002) are then analysed to determine whether management could be improved and areas for future study are highlighted.

From larva to adult — growing up with issues

Whilst research on the impacts of riparian forestry on stream insects has focused mainly on larvae rather than adults, much of the work also has relevance to adult stream insect ecology. Changes in larval food sources and stream physicochemical conditions associated with afforestation of riparian areas influence the size of adults at emergence indirectly through reductions in larval growth rates (Sweeney, 1984; Weatherley and Ormerod, 1990; Sweeney, 1993; Thomsen and Friberg, 2002). The smaller size at metamorphosis achieved by species in forested streams is linked to reductions in adult longevity, fecundity and reproductive success (Peterssen, 1987; Flecker *et al.*, 1988; Taylor *et al.*, 1998). Adult longevity is particularly important for species of stoneflies and caddisflies that feed as adults and spend longer periods in a terrestrial phase (Hynes, 1942; Petersson and Hasselrot, 1994; De Figueroa and Sanchez-Ortega, 2000).

In addition to influencing adult size at metamorphosis, alteration in developmental rates due to changes in food and stream temperature affects the timing of emergence. A comparison of the emergence dates of species of Plecoptera common to the clear felled Afon Hore and afforested Afon Hafren in mid-Wales, which differ in temperature (Crisp, 1997) and organic matter availability (Davies, 1996), [see Briers *et al.*, (2002) for details of the sites and species involved] showed a significant difference between the sites (paired t-test, $t_8 = 2.60$, $P = 0.032$), with species emerging on average 13 days later in the forested Hafren. Changes in the timing of emergence periods may have effects on the suitability of conditions for mating or flight and the availability of food sources, aspects of adult ecology that are covered in more detail subsequently.

Riparian microclimate

Microclimatic conditions experienced during the adult phase have an impact on survival and longevity. Air temperature and relative humidity are of particular importance, with higher temperatures and lower humidity reducing the adult lifespan of aquatic groups (Jackson, 1988; Collier and Smith, 2000). Riparian vegetation has a key role in determining riparian microclimatic conditions. Conditions within mature forests with dense canopy cover are generally cooler with lower wind speeds and higher relative humidity, compared to areas outside the forest, such as clear cut or pasture (Chen *et al.*, 1993; Collier and Smith, 2000). The generally hotter, less humid and more variable conditions outside forestry could reduce adult insect lifespans. In a laboratory study of three New Zealand stoneflies, Collier and Smith (2000) found that the 96 hour LT_{50} (temperature at which 50% of individuals died over 96 hours) was exceeded for 25% of the time in a pasture riparian zone, compared to 0.1% of the time in a native forest catchment over two weeks during the emergence period.

Microclimate also influences the flight activity of aquatic species (Brindle, 1957; Waringer, 1991; Peng *et al.*, 1992a; Briers *et al.*, 2003). In common with terrestrial groups (e.g. Williams, 1961) flight activity of aquatic adults appears to be affected primarily by air temperature, but wind speed and humidity also influence flight in some groups. Many aquatic species, particularly Ephemeroptera (Savolainen, 1978), Diptera (Downes, 1969) and Trichoptera (Peterssen, 1989) form mating swarms. Swarming behaviour is inhibited at low temperatures (Solem, 1976; Savolainen, 1978; Peterssen, 1989; Jackson and Resh, 1991), therefore the lower temperatures characteristic of dense riparian forestry may restrict opportunities for species to swarm and mate.

Habitat structure

The extent and nature of riparian forestry alters the structure of the riparian habitat. Some studies have suggested that dense riparian vegetation may restrict the dispersal of individuals away from the stream channel and, hence, influence the likelihood of colonisation or transfer of individuals between neighbouring sites (Jackson and Resh, 1989; Petersen *et al.*, 1999). Studies of stonefly dispersal at moorland, clear-cut and forested streams in mid Wales (Briers *et al.*, 2002) found that the rate of decline in numbers with distance from the streams did not vary with riparian land-use. However, in a lowland agricultural landscape in France there was a clear effect of habitat structure on the dispersal of Chironomidae (Delettre and Morvan, 2000). The differences between the two studies in responses to variation in riparian vegetation may reflect variation in adult behaviour. Chironomids (and other swarming species) utilize trees and other vegetation as markers for mating swarms (Downes, 1969; Savolainen *et al.*, 1993), whereas stoneflies do not swarm. Variation in riparian vegetation structure may also alter the predation risk faced by adult insects emerging from streams. Riparian areas support an abundance of predators, including birds, lizards and spiders, that exploit adult aquatic insects (Jackson and Fisher, 1986; Machtans *et al.*, 1996; Sabo and Power, 2002; Sanzone *et al.*, 2003) and may contribute significantly to the mortality of adult stages.

Food sources

Ephemeroptera, Chironomidae and most Trichoptera are not known to feed in their adult phase, but many species of stoneflies (Hynes, 1942, 1976; De Figueroa and Sanchez-Ortega, 2000; K.H. Macneale, *pers. comm.*) and some caddisflies (Petersson and Hasselrot, 1994), require to feed to mate and mature eggs successfully. There is very limited information on the terrestrial nutritional requirements of species, but pollen, lichen, fungi and algae are common components of adult stonefly diets (Hynes, 1942; De Figueroa and Sanchez-Ortega, 2000; Smith and Collier, 2000) and hence multiple sources of food may be important. Differences in food supplies between riparian vegetation types may therefore influence longevity and egg production of stonefly species (Sweeney, 1993; Smith and Collier, 2000).

Current riparian forestry management in relation to adult stream insects

Guidelines for the management of riparian areas of plantation forestry in the UK (Forestry Commission, 1990, 1991, 2000; see also Broadmeadow and Nisbet, 2002) have focused on the establishment and maintenance of 'buffer strips' – uncultivated areas whose primary function is to protect the stream channel and riparian zone from acidic drainage and sediment from adjacent forestry (Forestry Commission, 2000). The recommended size of the buffer strip on each bank varies between 5 and 20 m depending on the size of the stream channel. Management of buffer strips is aimed at maintaining open/partially wooded (primarily broadleaf) conditions. Trees providing heavy shade are to be used only sparsely and not within 10 m of the stream channel to prevent excessive shading and encourage the growth of ground vegetation to trap sediment from adjacent forestry (Forestry Commission, 2000).

The majority of adult aquatic insects do not disperse a significant distance away from the stream channel. Typical dispersal distance may vary with taxon, but the decline in numbers with increasing distance from the channel has been commonly represented as a negative exponential or inverse power function (Griffith *et al.*, 1998; Petersen *et al.*, 1999; Briers *et al.*, 2002). For this reason, it is the areas immediately adjacent to the stream channel that are likely to be most important to the majority of the adult stream insect population.

The maintenance of a diverse range of riparian vegetation as currently recommended is likely to be beneficial to adult stream insects. Tree cover will provide more suitable microclimatic conditions, food sources and shelter from predation. Isolated individual or small groups of trees can play an important role as markers for swarming species (Peng *et al.*, 1992b). However. the extent to which variation in microclimatic conditions is reduced within forestry relative to open ground is highly dependent on the size of the forest patch Relatively small patches of trees suffer from strong microclimatic edge effects (Chen *et al.*, 1995; Brosofske *et al.*, 1997) and, hence, more extensive riparian tree cover may be necessary to provide suitable microclimatic conditions.

The location of riparian forestry should also be considered. While it is clearly undesirable to maintain highly shaded conditions over the length of the stream channel, with the limited dispersal of some taxa [90% of adult stoneflies travelled less than 11 m away from upland streams in Wales, regardless of riparian vegetation type (Briers *et al.,* 2002)] it is important to maintain some forestry immediately adjacent to the channel. If such patches are located some distance away from the stream channel, the greater dispersal distances required to reach them will increase the risk of predation or desiccation.

Areas for future study

Information on the ecology of adult stream insects is far from complete, so the conclusions that can be drawn on the potential impacts of riparian forestry management are limited. Of a number of areas where further information is required, two are explored here.

ADULT VERSUS LARVAL REQUIREMENTS

A recent study (Winterbourn and Crowe, 2001) has shown that some species of adult aquatic insect show significant directionality of flight relative to the location of riparian forest patches. Winterbourn and Crowe (2001) interpreted this as a function of larval habitat requirements, but areas suitable for larvae may not necessarily coincide with areas favourable for adult survival and this may lead to differences in the distribution patterns of different life stages of the same species. Some work is already underway exploring this area (S. Flint and M. Dobson, unpublished data), but this is clearly an area where further research would be beneficial to determine the relative contribution of adult and larval life stages to small scale abundance and distribution patterns relative to riparian vegetation.

ADULT FOOD SOURCES

The significance of terrestrial feeding for adult stoneflies and some caddisflies, which are often abundant in forested upland streams, is well established. However, the implications of variation in adult food supply in different riparian vegetation types for the reproductive success of species is far from clear. Location of appropriate food sources is likely to be an important factor in adult habitat selection (Harper, 1973) and further information on adult requirements would contribute to management of riparian forestry.

Conclusions

Despite the potential importance of adult success in determining the abundance and distribution of benthic larval stages, the adult phase of aquatic insect lifecycles has been neglected when considering the impact of riparian forestry management. Riparian areas in forestry have a number of roles and management of these areas will ultimately represent a trade-off between sometimes conflicting requirements of the different functions. An evaluation of riparian management policies in the light of available information on the factors influencing adult aquatic insect success suggests that current practices are generally beneficial to adult aquatic insects, although a greater emphasis on areas of riparian forest cover, more in keeping with policies in the United States e.g. Palone and Todd (1997) might well improve the success of adult aquatic insects by providing a more favourable microclimate, improving adult survival. However, there is clearly a need for further research to evaluate the effects of riparian forestry management on adult stream insects.

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