The Use of Hedgerows as Flight Paths by Moths in Intensive Farmland Landscapes

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Abstract

Linear boundary features such as hedgerows are important habitats for invertebrates in agricultural landscapes. Such features can provide shelter, larval food plants and nectar resources. UK butterflies are known to rely on such features, however their use by moths is understudied. With moth species suffering from significant declines, research into their ecology is important. This research aimed to determine whether UK moth species are using hedgerows as flight paths in intensive farmland. The directional movements of moths were recorded along hedgerows at 1, 5 and 10 m from the hedgerow face. The majority of moths recorded within the study were observed at 1 m from the hedgerow (68 %), and of these individuals, 69 % were moving parallel in relation to the hedge. At further distances, the proportion of parallel movements was reduced. These results suggest that hedgerows may be providing sheltered corridors for flying insects in farmland

landscapes, as well as likely providing food plants and nectar resources, emphasising the importance of resource based approaches to conservation for Lepidoptera.

Introduction

Hedgerows are important habitats for butterflies in UK landscapes and as many as 39 of the UK's 61 (resident or regular migrant visitors) butterfly species are thought to rely on hedgerow habitats to some extent (Lewington, 2003; Dover and Sparks, 2000). The sheltering effects of hedgerows and other shrubby habitats are known to be important for Lepidoptera (Dover and Sparks, 2000; Merckx *et al.,* 2010b). It is l that some of the thousands of UK resident moth species utilise hedgerows to a similar extent as butterflies, however this is much less researched (Waring *et al.* 2009; Manley, 2008; Butterfly Conservation, 2007; Fox *et al.* 2011; Fox *et al*., 2013; Kimber, 2014). A study into the benefits of woody hedgerows in farmland, found that moth abundance ws higher along hedgerows than in surrounding agricultural fields (Boutin *et al.,* 2011). Merckx *et al.* (2010b) suggested that one species in particular, the Pale Shining Brown (*Polia bombycina*), was likely to be following hedgerows, due to its mobility and habitat preferences.

The abundance of flying insects in farmland is known to be positively associated with sheltered linear features such as hedgerows and windbreaks, as such features reduce the influence of wind speed and hence convective cooling on such ectothermic organisms (Bowden and Dean, 1977; Lewis, 1969; Lewis, 1970; Lewis and Dibley, 1970; Merckx *et al.,* 2008; Passek, 1988). Research comparing the abundance of airborne insects along artificial windbreaks showed that higher numbers of individuals accumulated against features of lower permeability (Lewis and Dibley, 1970). Similar research on low hedgerows and airborne insects revealed that this accumulation also occurs along hedgerows under windy conditions (Lewis, 1969). Where tree windbreaks are concerned, it was found that wind speed was one factor in the abundance of insects recorded, however the vegetative composition appeared also to be influential (Lewis, 1970). A later study by Bowden and Dean (1988), found that over a long term study, insect abundance along hedgerows was associated with vegetative species richness rather than wind speed or direction. For shrubby linear features, it is likely that the association with flying invertebrates is due to a combination of factors, but it is clear that such features could provide both shelter and vegetative resource benefits to invertebrates.

A study of sheltered green lanes by Dover *et al.* (2000) found that significantly more butterfly species were recorded within green lanes than outside, and that the species composition was different. The study also highlighted the importance of hedgerows for the movement of butterflies. A later study by Dover and Fry (2001) aimed to simulate the effect of hedgerow resource visibility versus physical barriers on three free-flying butterfly species' movements. The authors simulated physical hedgerow structure with sheeting and the visual stimulus of hedge flowers with red and white tape. The research found that the three species reacted differently to the purely visual stimulus, with the High Brown Fritillary (*Fabriciana adippe*)/ Niobe Fritillary (*F. niobe*) complex following the tape, the Heath Fritillary (*Mellicta athalia*) unaffected, but Scarce Copper (*Heodes virgaureae*) responded to the tape stimulus as a barrier. The physical sheeting 'hedgerow' however acted as a partial barrier and as a corridor to all three species, with most individuals flying along the simulated hedgerow. These results suggest that species respond differently according to behavioural ecology, but that the physical structure of a hedgerow can be a barrier to the movements of some butterfly species, as well as a corridor (Dover and Fry, 2001). It is probable that macro-moth species have similar variation in their responses to linear landscape features such as hedgerows and field margins. This research aimed to determine the possible use of hedgerows as corridors by moths in agricultural landscapes, by means of nocturnal observations.

Study Site and Methods

Study Site

The Moulton College Estate Farm has only recently been entered into Entry Level Stewardship (2010 [Natural England, 2013a]), and although conservation driven management is incorporated, it is a low priority when compared with sites in Higher Level Stewardship (Natural England, 2013b). The 600ha site is composed of a mixed lowland farm with mainly arable areas and is run as both a commercial and teaching estate. Due to the high proportion of arable fields across the estate, many hedgerows are not laid, just flailed, resulting in dereliction. Additionally the Moulton estate is farmed intensively and most field margins are narrow and exhibit signs of chemical enrichment (high coverage of weedy nitrogen loving species; McCollin *et al.,* 2000). Survey points were chosen across the estate, along hedgerows in various conditions from 'gappy' and derelict, to thick and regularly managed. Hedgerows also needed to be readily accessible to researchers carrying equipment. Surveying was not carried out directly adjacent to any hedgerow gaps, due to the possible impact on movement and flight behaviour.

Methods

A study investigating the movements of bumblebee species in relation to hedgerows used an observational method to categorise bee movements as parallel, right angles, diagonal or irregular in relation to the hedgerow orientation (Cranmer *et al.,* 2012). Such observations were taken along a transect at distances of zero, 10, 20 and 30m from the hedgerow face (Cranmer *et al.,* 2012). Their method was adapted for use in investigating moth movements along hedgerows. As with the Cranmer study, points were chosen at different distances from the hedgerow (in this case 1m, 5m and 10m; Figure 1). For the purposes of this study (due to the sheer volume of moths on some night), the orientation of diagonal and right angled movements were not recorded. Moth behaviour is affected by certain lights, specifically those at the ultraviolet and blue ends of the spectrum, so any use of normal visible light torches might affect the. A red light torch was chosen instead for this study, as it would be less likely to affect behaviour (Gilburt and Anderson, 1996; van Langevelde *et al.*, 2011). Observations took place on warm nights (over 5°C), as Lepidoptera activity is known to be significantly affected by adverse weather conditions (Yela and Holyoak, 1997). A total of 13 observation sets (observations at each of the three distances) were made over the months of May-July in 2011, 2012 and 2013. Each set of observations was carried out for 45 minutes, with 15 minutes spent at each distance. At least two observation sets were carried out on each suitable evening at different hedgerows, between the hours of 23:30 and 02:00 hours, weather permitting.

Although many research projects have focused on movements of butterfly species, few studies have looked at moth movements. Mark-Release-Recapture experiments have frequently been used to analyse the dispersal of insects such as butterflies. This method has been adapted for moths, using light traps to capture and recapture moth species and study their dispersal around landscapes (Merckx *et al.,* 2009a; Merckx *et al.* 2010a; Slade *et al.,* 2013). This method could be used to investigate moth dispersal around farm landscapes, however it requires a large amount of human resources and has a low return rate (around 5% with regards Merckx *et al.,* 2009a and Slade *et al.,* 2013) and was therefore not chosen for this study.

Statistical Methods

The numbers of moths observed at each distance, and each direction were totalled. Analysis of the differences between groups were made using a Kruskal-Wallis test, due to the non-normal distribution of the data, and further pairwise comparisons were carried out between groups. All analysis was carried out in IBM SPSS version 21 (IBM, 2011).

Results

A total of 332 moths were observed in total throughout the study, with moth abundance varying depending on weather conditions. The majority of moths observed were seen at the 1 m observation point; with 68% (225) of all moths seen at this distance, 22% (73) at 5 m and 10% (34) at 10 m (Figure 1. A Kruskal-Wallis test revealed that the numbers of moths observed at 1, 5 and 10m were significantly different (H [3] =34.541, p=<0.001), with higher numbers of moths observed closer to the hedgerow.

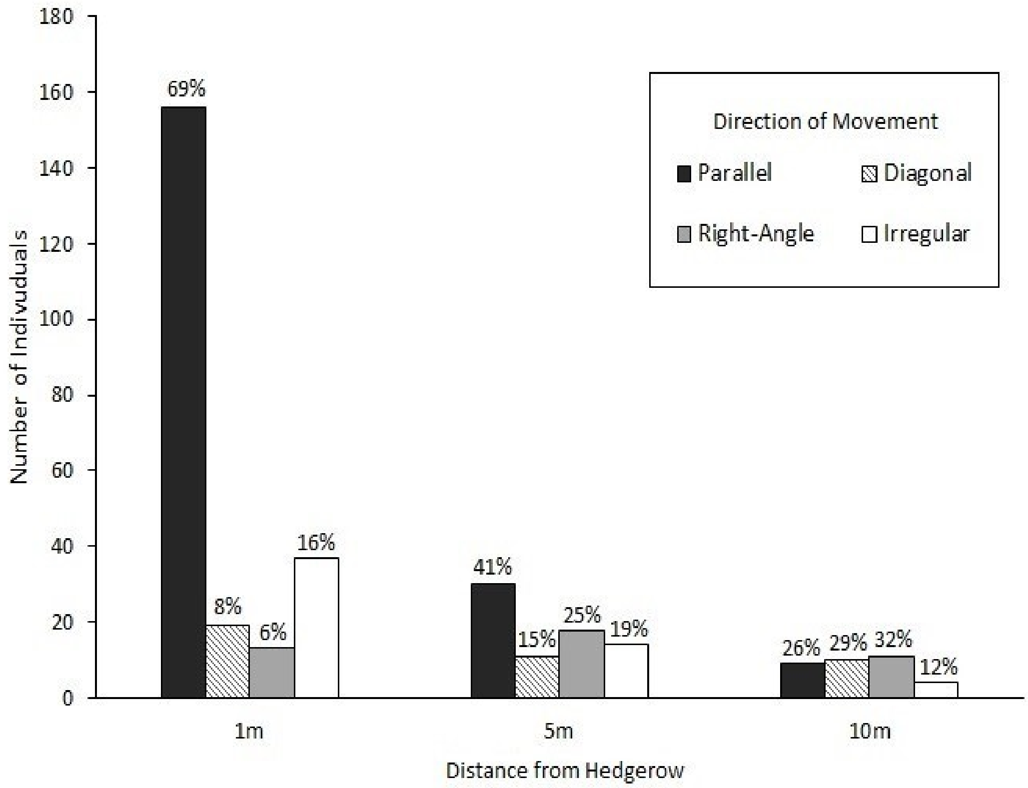

Figure 1: Numbers of observed moth movements at 1m, 5m and 10m observation points, parallel, diagonal, right-angle or irregular in relation to hedgerow face and percentages for each distance. Results from a total of 13 observation occasions across the study site from the summers of 2010, 2011, 2012 and 2013.

Of the moths seen at 1m, the majority of moths were observed as moving parallel to the hedgerow face (Figure 1). Direction of moths at 1m from the hedgerow was significantly non-random (Kruskal-Wallis test, H [3] =17.747, p=0.001).

Pairwise comparisons with adjusted p values showed a significant difference between the numbers of moths moving parallel and diagonal at 1m from the hedgerow (p=0.009), as well as between parallel and right angle (p=0.001), but not between parallel and irregular (p=0.068).

For moths observed at 5m, 30 of the 73 moths were seen moving parallel to the hedgerow face (41%). There was no significant differences between the directional movements of moths at 5m from the hedgerow (H (3) =1.964, p=0.580). At 10m, only 9 of the 34 moths observed were moving parallel to the hedgerow face (26%); the results for the 10m movement observations were not significant (H (3) =0.766, p=0.858). These results show that at further distances from the hedgerow, moths are moving in a range of directions, rather than just parallel.

Discussion

Moth abundance and hedgerow proximity

The majority of moths observed during the course of the study were seen at closer proximity to the hedgerow (68%). These results suggest that there may be more moth activity along hedgerows than further out along margins and within crop fields. The numbers of moths observed were less at 5 and 10m combined than at 1m from the hedgerow (Table 1). Indeed, Merckx *et al.,* (2009), found that abundance of moths was 92% higher along hedgerow margins than in the centre of fields, with these results being true for all nine species studied. These figures alone indicate that hedgerows may be key habitat features for macro-moths within agricultural landscapes. This result supports the findings from previous studies that hedgerows are important habitat features for invertebrates within agricultural landscapes and more specifically for butterflies and moths (Maudsley, 2000; Dover, 1990; Merckx *et al.,* 2010b; Slade *et al.,* 2013). Other researchers have found that butterflies may be using hedgerows as wildlife corridors and these results suggest that moths are also using hedges in a similar manner nocturnally (Dover, 1990). It is of course unclear whether moths are using the hedgerows as corridors for dispersal, shelter from wind or simply responding to the physical barrier effect of the hedge, as with some butterfly species (Dover and Fry, 2001). It is likely that factors such as size, mobility and resource requirements of moth species will have an impact on the behavioural ecology of a species and therefore its response to linear landscape features. Such varied responses have already been observed with moth species to hedgerow trees (Merckx *et al.,* 2010b; Slade *et al.,* 2013).

Moth movement and hedgerow proximity

The results at 1m from the hedgerow showed that most moths within this distance are moving parallel to the hedgerow. The highly significant Kruskal-Wallis results at this distance support the theory that moths may be using hedgerows as flight paths. Moths are likely to be following hedgerows as a visual stimulus, as well as for the possible sheltering effects from wind or rain (Dover and Fry, 2001). Due to moth preferences for white flowers as nectar sources, it is possible that flowers along hedgerows and margins could also be acting as a visual stimulus to moths, particularly those which are nectar feeders (Waring *et al.,* 2009; White *et al.*, 1994). There are several influencing factors which make such areas attractive as habitats in their own right, such as nocturnal nectars sources and egg-laying sites (see section: Moth behaviour observations).

The results from the 5m observation points showed no significant difference between directional movements at this distance. Although the results were not significant, the highest percentage of moths were still moving parallel to the hedgerow, which suggests that even further out from the hedgerow, some moths may still be using linear boundary features as flight paths, however it is more infrequent at this distance.

The results for 10m were also not significant. At this distance the highest percentage (32%) was for right-angled movements. Movements of moths at this distance may be of moths searching for food sources and egg-laying sites.

The use of hedgerows as flight paths for moths and their predators, such as bats, has implications for their management (Boughey *et al.,* 2011; Entwhistle *et al.*, 2001). In order to maintain the effectiveness of hedgerows as flight paths or 'corridors' they may require planting up where gaps have appeared, to avoid the loss of their functionality. Current management prescriptions under HLS suggest that hedgerow gaps should be filled where possible (Natural England, 2013a & 2013b). This finding of this study supports this management policy to some extent, but smaller gaps may provide valuable heterogeneity and allow for low movements across hedgerows. Continuous hedgerow may also create barriers to some populations, so some small gaps should be encouraged, to allow movements. Research into the Brown Hairstreak (*Thecla betulae*) butterfly, has shown a preference for south-facing, scallop-edged hedgerows for egg laying due to the preferable microclimates, something which is likely true for other ectothermic insect species (Merckx and Berwaerts, 2010), suggesting a need for less 'tidy', flat edged hedgerow.

Moth Behaviour Observations

Aside from the moth movement observations, some general notes were taken on moth behaviour along hedgerows. These 'irregular' moths were often moving backwards and forwards, up and down, across the hedgerow face. A number of these moths were seen eventually landing on hedgerow or adjacent margin foliage, possibly in search of egg-laying or feeding sites.

Some brief, observations made of moth behaviour at gaps in the hedgerows suggest that large gaps can have an influence on their value as corridors, as moths were seen travelling through larger gaps (around 20 moths over a forty-five minute period), rather than continuing along the hedgerow. Slade *et al.* (2013) found that a higher number of moths were captures adjacent to hedgerow trees than isolated ones (61% versus 27%), suggesting that the presence of trees alone are not influencing moth abundance. As suggested previously, the effect of physical structure is likely different for different moth species, and heterogeneity of hedgerows at a wider scale is important to be sure to provide suitable habitats for a wider range of species. Planting of gaps under HLS may disadvantageous for some species, so planting of gaps may be more beneficial for those 1m in length or over, allowing for some movements between fields and providing structural diversity.

Summary

The method used for observing moth movements was inexpensive, easy to carry out and proved successful as an initial way to gauge the use of hedgerows as dispersal routes by moths. The results of the study and related observations suggest that hedgerows and adjacent field margins are important habitat features for moth species in intensive agricultural landscapes with moths seemingly using linear boundary features as sheltered flight paths, feeding sources and egg laying sites. Further research should be conducted to confirm the effects of hedgerow gaps on moth dispersal in these landscapes. Along with unpublished data on moth visitation to hedgerow flowers (Coulthard, unpublished), this study confirms that hedgerows are important habitat features for moths as well as butterflies, which are already known to depend on hedgerows and other linear features in the UK landscape (Lewington, 2003; Dover and Sparks, 2000; Dover *et al.*2000, Dover, 2001; Ouin and Burel, 2002).

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