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Abstract

Sweden's semi-natural grasslands and pastures have decreased radically during the 1900s, leading to a loss of butterfly populations and species associated with these habitats. Butterfly conservation efforts therefore should be concentrated towards finding suitable habitats that can either replace or support these lost habitats. Power line corridors in Sweden are cleared of vegetation every eight years with controlled cutting every four years, creating a habitat at an early successional stage suitable as a habitat and for butterfly dispersal. This study was divided in to two parts. The first part focused on how the butterflies *Aphantopus hyperantus* and *Coenonympha arcania* responded to power line corridors as a habitat edge, while at the same time being compared to a forest edge, in central Sweden. No significant response to the power line corridor as an edge was found and equally no significant response towards the forest edge was found. Therefore, foraging butterflies can move freely in to power line corridors from suitable habitats, making conservation efforts easier. But since no significant response was seen on a less permeable unsuitable matrix, the forest edge, further studies may be needed to see if this is true for more species. The second part of the study focused on linear movement in power line corridors, were *A. hyperantus*, *C. arcania* and *Melitaea athalia* were studied in a mark-release-recapture study in central Sweden. Movement in the power line corridor was very similar to movement in wooded grassland, concerning ranges and patterns. The density of individuals making movements did however differ between biotopes. Movement in the power line corridor was only made in relatively shorter ranges, opposite to what may be expected from a dispersal corridor, meaning that dispersal and movement in power line corridors may be closer to suitable habitats than dispersal corridors. This should be considered helpful to conservation efforts where dispersal and new habitats are important.

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Abbreviations

PLC – Power line corridor

GSD – Geografiska Sverigedata – Swedish geographical data

1 Introduction

Due to a change in farming and forestry practices in Europe, a large portion of butterfly habitats have been lost or degraded, which has resulted in 9 % of European butterfly species being considered threatened, while a further 31 % are in a state of decline (Van Swaay *et al.,* 2010). The declining extent of grasslands has led to a decrease of populations of bumblebees, birds, butterflies and plants (Thomas *et al.,* 2004; Goulson *et al.,* 2004) and the loss of certain species and populations of butterflies in Sweden (Nilsson *et al.,* 2013; Öckinger *et al.,* 2006). In Sweden, fragmentation of habitats and abandonment of agricultural land has lead to a decline of habitats associated with semi-natural grasslands for the past 50 to 100 years (Dahlström *et al.*, 2008; Eriksson *et al.,* 2002; Nilsson *et al*., 2013).

Fragmentation and loss of habitat is something that traditionally has been seen as a negative impact on population size, where foremost isolation has been seen as the driving force together with loss of area (Andrén, 1994). Although more recently, habitat quality and the total size of habitat patches have gained more attention. Söderström et al. (2001) found indications that species richness in vascular plants, butterflies, bumble bees, dung beetles and birds was more correlated with habitat quality than the landscape itself, except in contact with urban environments and agricultural land. It has also been proposed that the total amount of habitat in a local area is more important than the size of the specific habitat patch for species richness (Fahrig, 2013).

In the case of isolation, for butterflies most unsuitable habitat matrix does not hinder dispersal or movement. Where for example Thomas & Harrison (1992) found that butterflies where able to colonize habitat patches under 1 km away, and movements up to 3 km are not unusual (Fric *et al.* 2010). For the butterfly *Aphantopus hyperantus* dispersal by open corridors is preferred while dispersal in dense woodland is not preferred (Sutcliffe & Thomas 1996).

Suitable habitats for the majority of butterflies are generally flower rich meadows and pastures. Semi-natural grasslands, used for grazing, and hay meadows were a prominent part of farming in Sweden during the earlier parts of the 20th and the 19th century. Semi-natural grasslands are generally species rich, unfertilized, pastures. Both ways of management kept these areas relatively wooded. The extent of vegetation density, species composition and regional differences are still discussed (Dahlström *et al.,* 2006; Nilsson 2006). Nilsson (2006) found that in Southern Sweden in the municipality of Brohult, historical records showed that outlands can be largely varied depending on location. The area had a high mix of tree species, moving from spruce and pine dominated to birch dominated, with certain locales being described as having a "sparse" tree vegetation.

Dahlström *et al.* (2008) found that on a regional scale in Sweden about 97-99 % of traditional management had been lost to forests or arable fields since the 18th century.

At a national scale, the loss of traditionally managed meadows, like semi-natural grasslands, may be summed up in to two causes outlined below.

(1) Afforestation as well as conversion of agricultural land, are two driving forces that has decreased the actual extent of suitable habitats for butterflies. The area of arable land has decreased with 1.2 million hectares since the year 1919, which constituted the peak of arable land in Sweden (3.8 million hectares). More importantly to this study, 1.1 million hectares of meadows and grazed grassland has been lost between 1890 and 2010, resulting in about 500,000 hectares in 2010. The majority of meadows producing hay were converted to ley, where fodder is being produced like crops instead of being directly grazed, while arable land was either actively afforested or abandoned (Statistics Sweden, 2013).

(2) A shift in management timing where late season grazing and mowing has been largely replaced by earlier as well as all season grazing and mowing (Dahlström *et al.,* 2008; Nilsson *et al.,* 2013). The timing of mowing may have a large impact on the population of butterflies. This due to refuge and host plants being affected (Bruppacher *et al.,* 2016; Johst *et al.,* 2006; Kőrösi *et al.,* 2014; Fischer *et al.,* 2015).

Even a lack of management may be detrimental to certain species of butterflies, Kőrösi *et al.,* (2014) found that after 3 years of abandonment the number of butterflies was significantly lower than in meadows which were managed regularly. Contrary, Skòrka *et al.,* (2006) showed that fallow land that had been unmanaged for 10-20 years had a higher butterfly species richness compared to mown meadows. What may be noted is the difference in biotopes used in these two studies. Kőrösi *et al*., (2014) worked in relatively dry hay meadows and mesotrophic wet meadows which were each divided into four plots that were given different kinds of temporal management. Skòrka *et al.,* (2006) on the other hand worked in predominantly wet grassland where temporal management was divided into different parts of the whole region.

The loss of habitats inhabited by butterflies means that knowledge about biotopes that can support or potentially replace semi-natural grasslands is important. What is needed are areas with low shrub vegetation density and sparse tree vegetation. Due to the clearing done about every eight years with controlled trimming every four years in power line corridors (PLC) (Svenska Kraftnät, 2017), the vegetation is kept at an early successional stage which is found suitable for different kinds of butterfly species (Smallidge & Leopold, 1997). Because of this PLCs has been shown to be a viable habitat for butterflies (Berg *et al.,* 2016), and in some cases even more suitable than semi-natural pastures for certain species (Berg *et al.,* 2013; Leston & Koper 2016)

More frequent clearing and mowing is suggested to improve PLCs as habitats (Berg *et al.,* 2016). Positive results on butterfly abundance, but not species richness, have been found for more frequent clearing and mowing in PLCs. The largest positive effects on abundance were seen at 2 to 4 years after clearing (Komonen *et al.,* 2012). Annual mowing was preferred over biannual clearing and no clearing at all, although not every species of butterfly was benefited, while different kinds of temporal management had varying results (Leston & Koper, 2016). Another study found no significant difference between a one year interval, a four year interval or an eight year interval of management on the habitat quality of Karner blue butterfly (*Lycaeides melissa samuelis)* (Forrester *et al.,* 2015).

With PLCs being seen as potential habitats, their use as dispersal corridors between habitats for butterflies is also interesting. Corridors between habitats have been shown to increase populations of butterflies inside the connected habitats (Haddad & Baum 1999), while also increasing movement between them (Haddad 1999). Movement was also high despite corridors being of relative low quality (Haddad & Tewksbury 2005). The reason for higher densities of butterflies in connected patches may not only be due the connectivity between them, an increase in patch size as well as less edge effects caused by the corridor may influence the population (Haddad & Baum 1999).

To understand how butterflies respond to PLC edges and utilise PLCs for linear movement, two types of studies were conducted.

The first part of the study was conducted at two sites in central Sweden focusing on small scale responses to the presence of PLCs acting as borders. By comparing the responses by butterflies to a PLC acting as hypothetical border to a preferred habitat versus the response to a forest edge, the habitat usability and butterfly dispersal will be seen. The hypothesis was that the butterflies will to a larger extent avoid the forest edge than the PLC edge, this because of the denser and taller vegetation in forests as well as featuring less host plants and flowers.

The second part of the study was conducted on a larger extent as a mark-release-recapture study by two field assistants at the Swedish University of Agricultural Sciences (SLU) in 2014. The purpose of the study was to test to what extent butterflies use linear habitat elements such as PLCs and road verges as dispersal corridors or if these can act as a complete habitat where butterflies stay throughout their life cycle.

2 Method

2.1 Study species

The butterflies used in this study were the ringlet (*Aphantopus hyperantus*), the pearly heath (*Coenonympha arcania*) and the heath fritillary (*Melitaea athalia*). All of these species are common in Sweden and are featured in similar habitats which are outlined below. Due to only two individuals of *M. athalia* being captured during the first study (Behaviour at habitat boundaries), the species was excluded from that specific part of the study.

The three species all have a very similar active period where *M. athalia* has its first flight during the first week of June, *C. arcania* the second week and *A. hyperantus* the fourth week of June. *A. hyperantus* and *C. arcania* ends their active period around the beginning of August while *M. athalia* ends its flight in the middle of August. They all prefer similar habitats, like wooded grazed land and meadows, while *M. athalia* can also be found in clear cuttings, road verges and PLCs (Söderström, 2006). The *A. hyperantus* can utilize corridors as a means of transport between suitable habitats and seem to avoid dense woodland (Sutcliffe & Thomas 1996).

2.2 Behaviour at habitat boundaries

2.2.1 Study design

The study design is partially inspired by methods by Ross *et al.* (2004) and Ries & Debinski (2001). Captures, releases and observations were done during 9 days from the 19th of June 2017 to the 15th of July 2017, typically from 09:00 to 16:00, with about equal spacing between days. The testing required sunny weather from 15 °C, preferably above 20 °C. During 15 °C weather with the sun obscured by single clouds the butterflies would not fly after cooling.

The butterflies were captured carefully by hand net in both the semi-natural grassland and the PLC and placed in paper cups inside a portable ice chest. The butterflies were released one at a time in the middle of a 20 m x 20 m quadrat that was placed with one side in contact with the *biotope edge* while the remaining sides of the quadrat were defined as the *internal edge* (fig. 1). The previous cooling ensured that when the individuals were released the observer had time to create a distance between them and the subject before it was warm enough to take flight, while also keeping the maximum distance that would ensure visibility of the subject. Position of the observer relative to the release point was constantly adjusted in an attempt to not skew the chosen exit by repulsing butterflies. The flight time as well as time spent idle was recorded to retrieve the relative flight time, since the total flight time inside the quadrat would be different for each individual the relative time spent in flight against idling was chosen. If a butterfly did not leave the quadrat within 7 minutes it was marked as a zero and not used for further analysis. If a butterfly left the quadrat and did not return within 3 minutes, or kept going away from the quadrat without showing any indication of turning back, the exit was noted. If a butterfly returned to the quadrat the same way it exited within 3 minutes the session continued. During the study the prevailing wind direction was noted for each butterfly.

The study was made in two *locales* at each site, one in the semi-natural grassland facing the edge towards the PLC and one inside the PLC facing the forest edge (fig. 1). This was done to be able to make a comparison between the two types of edges.

Figure 1. The experimental design Left image: A 20m x 20m quadrat facing the hypothetical biotope edge (1) (dotted line) and numbered **internal** exits (2-4). Right image: The two **locales** at study **site** A (fig 2.). **Locale** A being placed inside the pasture facing the PLC edge (dotted line). **Locale** B being placed inside the PLC facing the forest edge (dotted line). Background image: GSD orthophoto, 1 m, Lantmäteriet (2016).

2.2.2 Study sites

The study was conducted at two sites placed 1.6 km from each other on the same PLC (A: N6646811 E660163, B: N6647572 E661572), in the county of Uppsala, 15 km from the town of Uppsala in central Sweden (fig. 2).

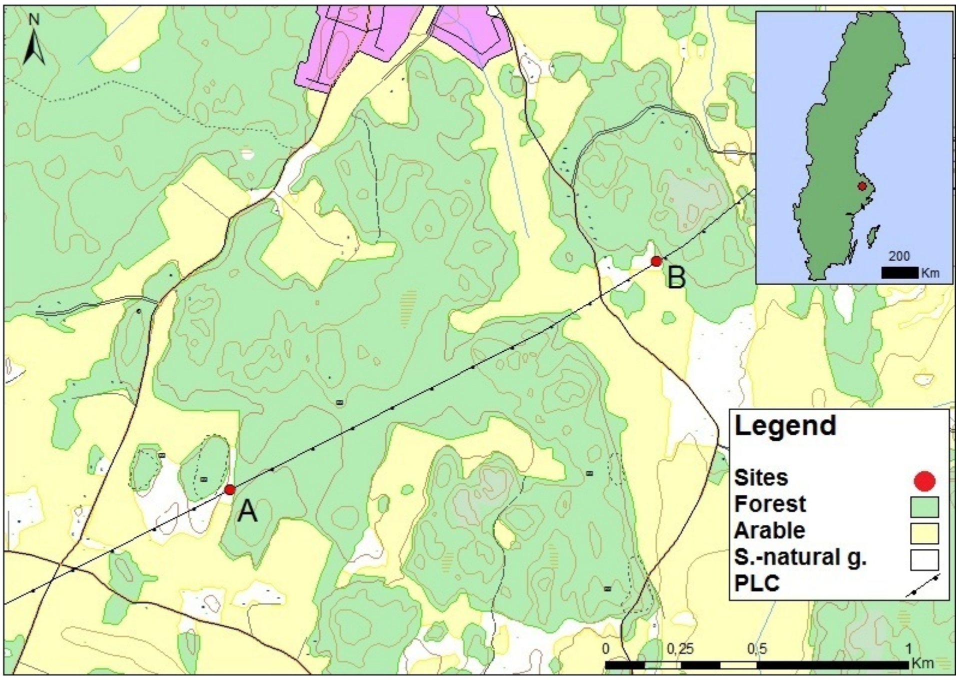

Figure 2. Site A and B used in the study. (A: N6646811 E660163, B: N6647572 E661572). Background image: GSD terrain map, Lantmäteriet (2015). Inset image: GSD Sweden map, scale 1:20 million, Lantmäteriet (2015).

Site A consisted of a semi-natural grassland, a quick overview revealed that the site had a large amount of trees and shrub (e.g. *Juniperus communis, Pinus sylvestris, Picea abies* and *Quercus robur*) as well as a large variety of flowers (e.g. *Anthriscus sylvestris, Ranunculus acris, Galium album, Geum rivale* and *Lathyrus pratensis*). The pasture was about 9.2 hectares and not in use and had not been for some time at the time of the study.

The bordering PLC was measured to be about 55 meters (using Google Earth Pro) wide and featured a similar height in grass as the pasture for the first few meters to then transitioning into tree and shrub at about two meters of height (fig. 3). Not considering the occurrence of birch, the PLC featured a similar set of species as the grassland, seen in a quick overview. The surrounding forest was relatively open with mixed evergreen and deciduous trees.

Figure 3. Site A, facing the PLC edge from inside the former pasture.

Site B consisted of a semi-natural grassland (about 1.8 hectares). A quick overview revealed that the site had less trees and shrubs in relation to site A, while featuring grass more abundantly (fig. 4). Flowers, trees and shrubs were mostly of the same species as in site A, although less abundant. The pasture itself was active but not in use exactly at the time of the study.

The PLC (about 46 m wide) featured trees and shrub appreciated to about two meters of height immediately beyond the fencing. The corridor was more densely vegetated than in the corridor of site A and had a more rocky terrain. The surrounding forest was relatively open with mixed evergreen and deciduous trees, although the quadrat used in the study was placed adjacent to a part of the forest which was mostly deciduous.

Figure 4. Site B, facing the PLC edge from inside the pasture.

2.3 Butterfly landscape movement

2.3.1 Study design

The capture and release of *A. hyperantus*, *C. arcania* and *M. athalia* was done by two field assistants during 2014 from the 14th of June to the 17th of July. Two people walked systematically through all types of grassland habitat on all days with suitable weather (no rain, ≥ 17 °C, no strong winds; in total 18 days during the study time period). The butterflies were captured with a hand net and marked on the underside of the hind wings with a unique id-code. Captured butterflies that had been marked previously were recorded as a recapture. The coordinates of the point of capture were recorded using a handheld GPS, and species, sex and the id-code of the butterfly was recorded.

The data was then received by the writer of this study in 2017. The data was first cleared of individuals that had only been captured once, and therefore did not produce any movement data, and individuals with faulty coordinates were also removed. Four individuals had two or more captures during the same date, making it difficult to know the order of movement. This was corrected by assuming that the point furthest away had been visited last and then changing the date of capture. Straight movement lines (feature lines) were created in ArcMap 10.2.2., using the dates of capture.

Biotopes including the PLC were manually digitized in ArcMap using a 0.25 meter resolution orthophoto and on site observations of the general landscape, resulting in six classifications (fig. 5). The classifications were broadly based on vegetation density and land use. The length of movement over each biotope was then calculated using the feature lines. Movements that were made over several biotopes were divided into respective biotope, creating one movement each for every biotope that was used. For example, if a butterfly flew 100 m through the forest (50 m) and the PLC (50 m), the result gives one individual movement in the forest of 50 m and one individual movement in the PLC of 50 m.

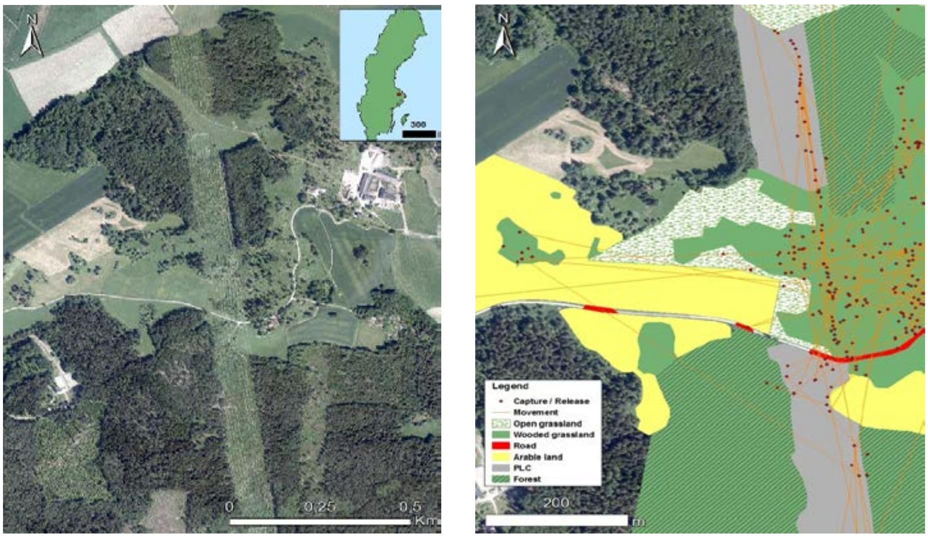

Figure 5. Left image: Overview of the study area (N6655951 E667657), Background image: GSD orthophoto, 0.25 m, Lantmäteriet (2016), Inset image: GSD Sweden map, scale 1:20 million, Lantmäteriet (2015). Right image: A zoomed in example of the study area. The capture points are shown together with their respective movement lines. The digitized layers of each biotope on top of an orthophoto with a 0.25 m resolution.

2.3.2 Study site

The study area was situated near Skoby, north of Uppsala, in an area estimated to about 144 hectares. The area contained one PLC crossing through forest, wooded grassland, arable land and open grassland (fig. 5). The PLC was measured to be about 100 meters wide (using Google Earth Pro) and featured shrub and trees estimated at about 2 to 3 meters of height. A maintenance road runs along PLC creating a cleared path, while a regular backroad runs across the PLC, which is hereafter referred to as the road.

2.4 Data analysis

2.4.1 Behaviour at habitat boundaries

For the analysis of the habitat exits a chi-square goodness of fit test was utilised. Firstly an equal distribution was assumed (25 % for each side of the quadrat), then a comparison between the habitat edge and the internal exits together (25 % edge, 75 % internal edges). Finally only the internal borders were compared against each other with an equal distribution (33

%). The null hypothesis (H_0) was that the observed distribution is not significantly different from the assumed distribution, where the alternative hypothesis (H_1) was a significant difference from the assumed distribution. Where the quadrat was bordering the forest the distribution between each side will probably not be equal since avoiding the forest, which is not suitable, would be beneficial for the butterflies, while the quadrat bordering the power line corridor will probably have an equal distribution since the PLC is usable for butterflies.

A Pearson chi-squared test of independence was used to evaluate if prevailing wind direction had a significant impact on chosen exit. The null hypothesis (H_0) for this test was that the wind direction and the chosen exit were independent from each other, while the alternative hypothesis (H_1) was that the chosen exit depended on wind direction.

The relative flight time between locales and species was done using Wilcoxon rank sum test. The null hypothesis (H_0) was that the flight times are not significantly different from each other while the alternative hypothesis (H_1) was that there is a significant difference in flight time. Normal distribution for the flight times was tested using the Shapiro-Wilk test of normality, using the null hypothesis (H_0) that the distribution was normal and the alternative hypothesis (H_1) that the data for flight times were not normally distributed.

2.4.2 Butterfly landscape movement

For the analysis of movement a Kruskal-Wallis rank sum test was done on the length of movement between all the biotopes, where the null hypothesis was (H_0) that there was no significant difference between the medians of movement length while the alternative hypothesis (H_1) was that there is a significant difference. It was expected that there would be a difference since all the biotopes have different vegetation and vegetation density.

Six frequency plots were made using the length of movement over each biotope, a Kolmogorov-Smirnov test was then done on the distribution of frequency. The null hypothesis (H_0) was that the samples are from the same distributions while the alternative hypothesis (H_1) was that they are not from the same distribution. A difference of movement patterns was expected because of the large differences between the biotopes stated above.

Statistical tests of significance were done using RStudio 1.0.153., assuming a significance level of 0.05.

3 Results

3.1 Behaviour at habitat boundaries

A total of 138 butterflies were captured and released during the experiment, 63 of them were *A. hyperantus* while 75 were represented by *C. arcania*. The majority of butterflies captured and used in the PLC were *A. hyperantus*, while *C. arcania* was in the majority in the grassland. Both in the PLC and the pasture the highest number of individuals left through exit number two, which was inside the habitat (tab. 1).

The goodness of fit analysis showed that there was a significant difference in chosen exit by butterflies of the quadrat in both the pasture (χ^2 (3) = 17.784, p<0.001) and in the PLC (χ^2 (3) = 10.364, p=0.016) (tab. 2). When comparing all internal habitat exits to the habitat edge no significant difference was found neither for pasture (χ^2 (1) = 0.883, p=0.347) nor the PLC (χ^2 (1) = 2.444 p=0.118) for chosen quadrat exit. When analyzing only internal borders, a significant difference was found both for the grassland (χ^2 (2) = 15.898, p<0.001) and the PLC (χ^2 (2) = 7.127, P=0.028) in chosen quadrat exit.

The Pearson chi-squared test showed that wind direction did not have a significant effect neither in the grassland (χ^2 (12) = 20.298, p=0.062) nor in the PLC (χ^2 (6) = 6.028, p=0.42) of chosen exit.

Table 1. *Number of exits for each side of the study quadrat. Habitat edge (1), internal exit (2-4).*

Exit	1	2	3	4
PLC	11	27	17	11
Pasture	14	32	19	7

Table 2. *The p-value for chi-square goodness of fit test with equal probabilities on exits by butterflies.*

	PLC	Grassland
All exits	χ^2 (3) = 17.784, p<0.001	χ^2 (3) = 10.364, p=0.016
Internal vs. edge	χ^2 (1) = 0.883, p=0.347	χ^2 (1) = 2.444 p=0.118
Internal only	χ^2 (2) = 15.898, p<0.001	χ^2 (2) = 7.127, P=0.028

The relative flight time in both locales were not normally distributed, pasture (p<0.001) and PLC (p<0.001). Using the Wilcoxon rank sum test, the relative flight time in the PLC was shown to be significantly longer than in the pasture (p=0.007) (fig. 6), for both species. *A. hyperantus* had a significantly longer relative flight time than *C. arcania* in both locales (p<0.001). *C. arcania* showed no significant difference in flight time in between the pasture and the PLC (p=0.556), while *A. hyperantus* also showed no significant difference in relative flight time in between the pasture and the PLC (p=0.331).

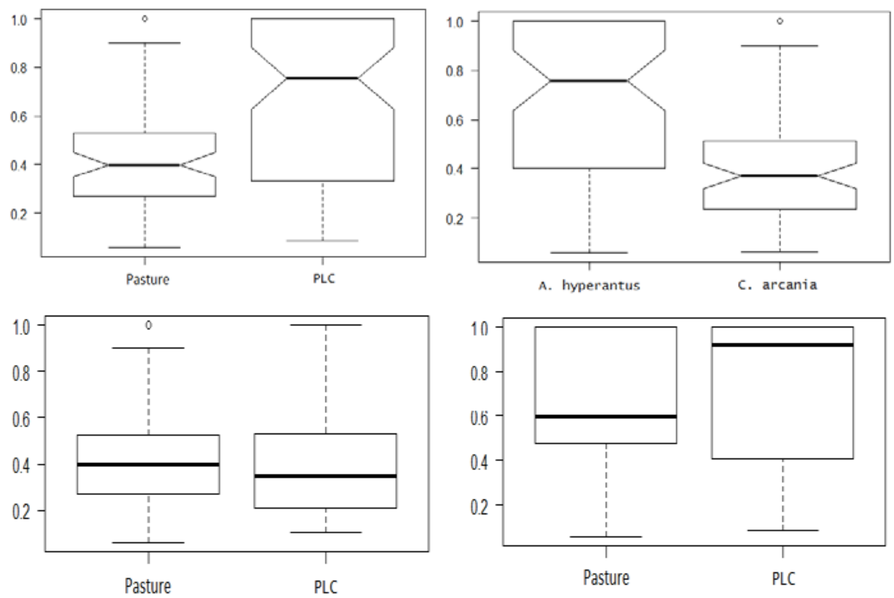

Figure 6. Upper left: A box plot showing the relative flight time from the pasture and the PLC, notches showing 95 % of confidence interval. Upper right: A box plot showing the relative flight time in percentages between *A. hyperantus* and *C. arcania,* notches showing 95 % of confidence interval. Lower left: The relative flight time in grassland and in the PLC by *C. arcania*. Lower right: The relative flight time in the pasture and in the PLC by *A. hyperantus.*

3.2 Butterfly landscape movement

After clearing the release-recapture data, 200 individuals remained making 217 movements at a total of 31.8 kilometres, the average movement was 159 meters.

Most travels were made in wooded grassland with 196 number of trips and 20 kilometres of travel (tab. 3). The PLC stood for the second largest number of movements with about 5 kilometres of travel length, but is outnumbered by the road in number of trips. Most captures and releases were made in wooded grassland (77 %), with the PLC (13 %) coming in second. The forest featured the longest average for trips with roads representing the shortest average and open grassland having the second shortest.

Table 3. *Shows the total length of travel in every biotope, the average length of travel, number of trips made in each biotope and number of captures in each biotope. *Number of movements where respective biotope was included, which does not exclude other biotopes during the movement.*

	Arable	**Forest**	**Open grassland**	**PLC**	**Road**	**Wooded grassland**
Length (m)	2030	2965	1150	4806	899	19935
Av. length (m)	112	123	46	114	12	110
Number of trips*	18	24	25	44	75	196
Captures and recaptures	2	11	7	54	22	322

None of the biotopes had normally distributed data ($p<0.05$). A Kruskal-Wallis test revealed no significant difference in the average length of trips for all the biotopes (χ^2 (17) = 17, p =0.454).

The road only featured short movements (fig. 7). The longest movements were made in the PLC but are only made up of two individuals, while wooded grassland had a larger amount of individuals at higher ranges. Most common for the PLC were trips at about 40 to 70 meters, while in wooded grassland 40 to 80 meters were most prevalent with a dip in between 60 to 70 meters.

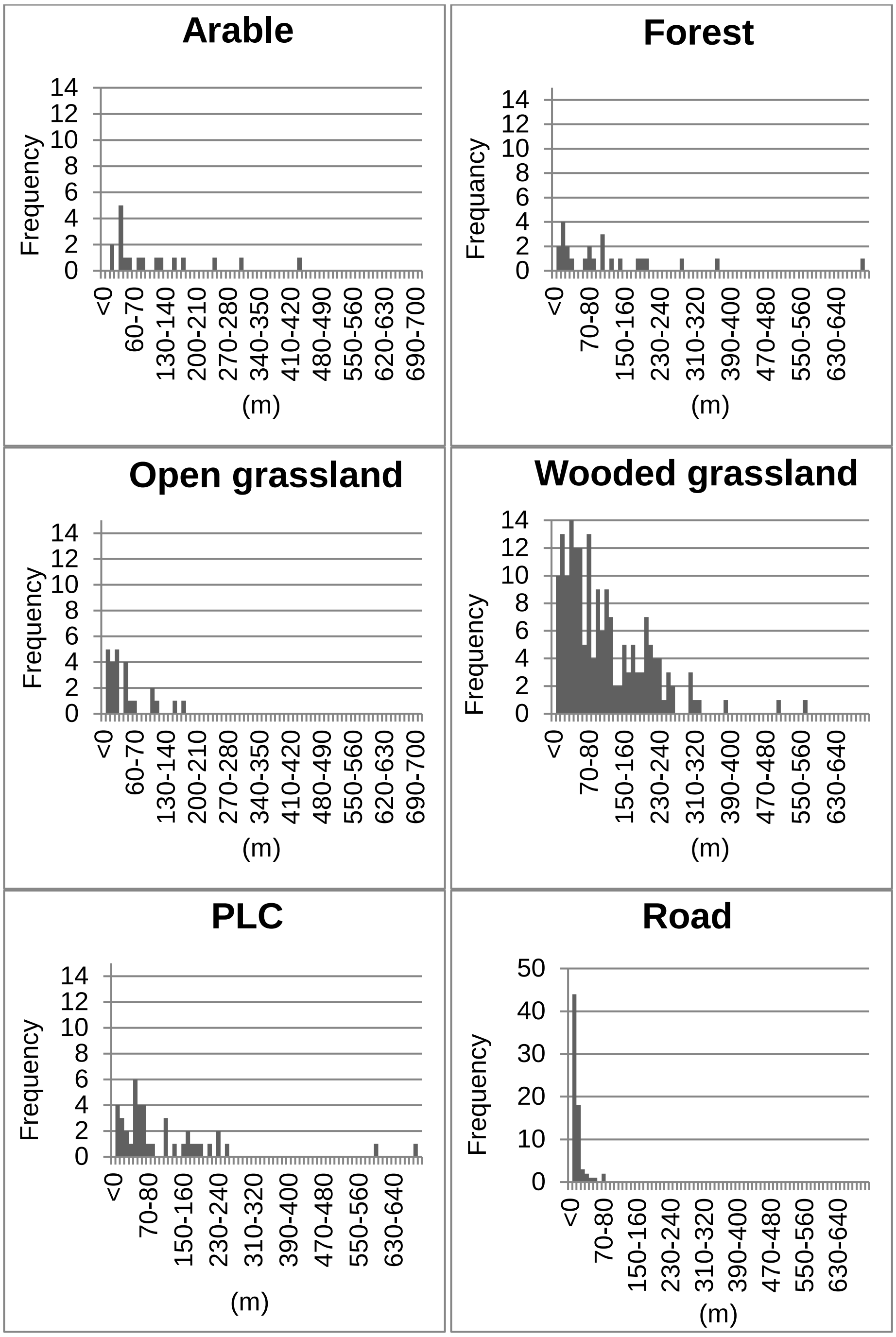

Figure 7. The frequency of flights at different lengths of travel for the different biotopes. Note “Road” having a different scaled y-axis.

The results of the Kolmogorov-Smirnov test on the distribution of the frequency showed that the road was most inconsistent with the other areas, being significant for all of them ($p<0.001$), the same being true for open grassland but with a lower significance (tab. 4). The PLC and the most frequently travelled wooded grassland were not significantly different (p=0.414). Apart from the road, the PLC was only significantly different from the open grassland (P=0.011).

Table 4. *Resulting p-value of the Kolmogorov-Smirnov test on distribution frequency for each biotope. Significant results marked in grey.*

	Arable	**Forest**	**Open grass-land**	**PLC**	**Road**	**Wooded grass-land**
Arable	x					
Forest	0.625	x				
Open grassland	0.020	0.041	x			
PLC	0.898	0.731	0.011	x		
Road	<0.001	<0.001	<0.001	<0.001	x	
Wooded grass-land	0.848	0.395	0.001	0.414	<0.001	x

4 Discussion

4.1 Behaviour at habitat boundaries

No difference was found between the internal exits and the biotope edge exit, while there was a difference amongst the internal exits and amongst all the exits. No difference was found between the forest edge and the PLC edge. This means that the butterflies can move in to the PLC as freely as in to the forest, which goes against the hypothesis that the forest edge would be more effective in stopping butterflies from moving in to it. This means that these specific butterflies do not respond to the forest as a barrier, which they hypothetically should as it is not their preferred habitat. This is also unlike the results of Ries et al. (2001) and Ross *et al.* (2004) (on which parts of this study is based) where it was shown that butterflies responded strongly to habitat edges, ranging from tree lines, forest edges to roads. Ries et al. (2001) used the habitat specialist *Speyeria idalia*, which responded strongly to all edge types, but also looked at a the generalist *Danaus plexippus* which only responded strongly to tree line edges and not road, grass edge nor absence of edge. Ross *et al.* (2004) also utilised a habitat specialist (*Parnassius smintheus*) which avoided habitat edges.

The butterflies' non response to habitat edges in this study means that the PLCs and the pastures are not isolated patches of habitat for the species used in this study. As seen by Thomas & Harrison (1992) colonisation and movement between suitable habitat patches by butterflies are only hindered by unsuitable matrix of above 1 km in length. Although looking at a smaller extent (10-22 m), change in behaviour by butterflies can be seen in relation to habitat edges (Schultz & Crone 2001). With these species used being relative generalists any sort of edge avoidance would be unsuitable in foraging behaviour. Using more specialised species would probably yield a different result. What is not accounted for in this study, pointed out by Ries et al. (2001), is any sort of return behaviour from unsuitable biotopes. The size of the quadrats used in this study design makes it difficult to detect these behaviours and speaks towards using either larger quadrats which includes the bordering habitat as well, or a rather different design altogether.

The significant difference between the internal edges is difficult to explain, especially since wind direction did not have a significant impact. This happened at both locales and sites which supports that it is not local conditions affecting the result, however, this cannot be ruled out. Precautions were taken by the observer to not affect the outcome of the study. This by staying as far behind as possible and also standing at different locations while waiting for first flight by the butterflies after cooling, however no effect was noticed by the observer.

The relative flight time for both species was significantly longer in the PLC than in the grassland, but the PLC had a much larger spread. This may be due to the studies in the PLC featuring more of *A. hyperantus,* this most probably because it was done later in the season when more *A. hyperantus* individuals were active*,* which had a significantly longer flight time, this may also explain the larger spread because of the more even mix of species. This is supported when looking at the relative flight time of the individual species in the grassland and in the PLC, which had no significant difference.

Since no difference was seen between the two locales, no slowing of movement was made in the PLCs. This means that despite the PLCs having more dense vegetation, shrub and grass, no negative effects were seen on flight times. What also may be affecting the results is the temperature during the different sessions, which was not measured during the field study nor adjusted for.

4.2 Butterfly landscape movement

Wooded grassland had the highest amount of travel length as well as number of movements, but had the largest amount of captures and releases. This is probably because of wooded grassland being the preferred habitat for these species. The same is seen in the rest of the biotopes where the pattern is that the number of captures reflects the total length of travel, this may mean that the sampling could affect the results.

The average length of travel displays a more uniform pattern where no significant difference was found between the biotopes. Except for the road which is not unexpected since it is simply, in most cases, traversed perpendicularly. Since road verges are one of the habitats that for example *M. athalia* can be found in, it stands to reason that more movements could be made there. If there were more travels along road verges it is not detected by the method. There is also the possibility that at the time of sampling the road verges were not as attractive as neighbouring habitats. If the road was used for linear movement within the verges or as transportation to another habitat the study method may be to coarse for those particular movements. Open grassland has also a noteworthy lower average in movement length than the rest of the biotopes, which might be due to it being relatively compact and not allowing any long transportation.

The higher average movement length for the majority of the biotopes may be due to the few individuals making longer ranges of movements, as can be seen in the frequency charts. The road and open grassland are the only biotopes without one or two individuals making movements above 400 meters. This is reflected in the Kolmogorov-Smirnov test where the road and the open grassland are the only ones that are significantly different from the rest.

With the remaining biotopes following similar patterns of movement frequency, it may be assumed that the butterflies are utilising the different biotopes as readily and in the same manner. For example, wooded grassland and the PLC have very similar distributions where the highest frequencies of flights are around 30 to 60 meters, and both show similar decrease of movements. This shows that butterflies, at least in this study area, move in similar manners and mostly differ in the quantity of butterflies. This means that the corridor may not support as many butterflies as the wooded grassland, but may act as a smaller habitat. One may assume that a pure corridor that only acts to facilitate movement between different habitats would have longer ranges. As with unsuitable matrix, movements are mostly done faster, longer and more directional than in suitable habitat by butterflies (Muriel & Kattan 2009; Schultz & Crone 2001). Since even unsuitable habitat can facilitate movement and colonization up to 1 km (Thomas & Harrison 1992) it is hard to know at this extent what constitutes facilitation of linear movement.

Mapping complicated butterfly movements by drawing a straight line between two points presents one problem. For example, as can be seen in figure 5, where one butterfly travelling from the western part of the study area to the southern part of the PLC does this by passing through four different biotopes including the forest. The movement took 23 days, meaning that there are a number of possibilities for movements. The butterfly could equally have moved east over open ground and then directly south using the PLC. The same is true for the road where it could be used as a mean of movement, but the coarse scale of the study design could affect the results.

The captures and releases along the PLC were done mostly along the maintenance road, as can be seen in figure 5. Since the PLC is occupied by mainly by tall vegetation the maintenance road may influence the butterfly movement. As observed in this study butterflies have no problem traversing taller vegetation, but the presence of a linear feature hosting flowering plants may affect the movements.

4.3 Further studies

When looking at the responses by the butterflies used in this study towards PLCs as habitat edges, no response was seen. The same is true for the forest edge. In further studies the use of more specialised species may yield a different result, and further help in finding any response towards the PLC edge. Furthermore, specific behaviour as for example turning angles and flight time in relation to the edge as used by Schultz & Crone (2001), Ries et al. (2001) and Ross *et al.* (2004) could be used maybe more successfully since the edges seem fully permeable when individuals decide to leave the quadrat.

Similar changes might benefit the linear movement study. Since different behaviour can be seen in unsuitable matrix and suitable habitats (Muriel & Kattan 2009; Schultz & Crone 2001), looking at specific behaviour in PLCs, like flight length, speed and direction may reveal more as to how they are used in movement behavioural terms.

5 Conclusion and implications for conservation

It is already known that PLCs are suitable to some species as a habitat (Smallidge & Leopold, 1997; Berg *et al.,* 2016; Leston & Koper 2016), as well in this study where the butterflies had similar rates of movement in relative flight time both in the pasture and the PLC. In this study it has been shown that butterflies can enter PLCs easily, meaning that suitable habitats in contact with PLCs are easily accessed and possibly easily colonized. Although, how habitat specialists respond to these edges may need to be considered firstly since they might have a stronger response. As with any conservation effort the effect on individual species need to be considered, since timing of management in PLCs may affect species differently (Leston & Koper, 2016).

Unlike previous studies (Schultz & Crone 2001; Ries et al. 2001; Ross *et al.* 2004) the butterflies did not show any significant response towards habitat edges, neither for the PLC nor the forest edge. With both edges being as permeable, movement into and from PLCs have the potential to mediate dispersal, although further studies are needed on more specialised species.

Linear movement patterns in the PLC indicate that the biotope is not only used for dispersal but may also act as a habitat, which has been seen in previous studies (Berg *et al.,* 2016; Leston & Koper 2016; Smallidge & Leopold 1997), and is also indicated by relative flight times which did not differ significantly between locales. Flight movement was done in similar length ranges for the wooded grassland and the PLC, this coupled with the fact that relative flight times were not significantly different between the pasture and the PLC indicates that the PLC may be a viable habitat, although further studies on specific flight patterns are needed.

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