The impacts of commercial woodland management on woodland butterfly biodiversity in Morecambe Bay, UK

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SUMMARY

Although the effects on biodiversity in woodland managed for conservation have been studied for a range of species, there is very little empirical data on the potential impacts of commercial woodland management on biodiversity in the UK. This study measured species richness and abundance of diurnal butterflies as a proxy for the habitat quality of three different woodland management techniques in the Morecambe Bay limestone woodland region. Butterflies were sampled at two sites; Gait Barrows and Witherslack, where three woodland management techniques were carried out: low management woodland (woodland with no recent intervention); traditional coppice management for conservation; and commercial woodland management. Both coppice management for conservation and commercial management had significantly higher butterfly species richness and abundance when compared to low management woodland; neither butterfly species richness nor abundance were significantly different between the traditional coppice management for conservation and commercial woodland management. UK Biodiversity Action Plan fritillary species (high brown fritillary *Argynnis adippe;* pearl bordered fritillary *Boloria euphrosyne;* and small pearl bordered fritillary *Boloria selene*) were not significantly different between the traditional coppice management for conservation and commercial management.

BACKGROUND

In 2007 the 'Woodfuel Strategy for England' led to government targets to bring an additional 2 million tonnes of wood each year to the wood fuel market by 2020 (Forestry Commission 2007). Much of this is intended to come from currently 'under-managed' woodland, defined as woodland where no management intervention has taken place for a minimum of 20 years. In the UK, reduction in woodland management has been attributed to the economic decline of products derived from coppicing, and has led to an increase in the percentage of woodland which is regarded as low management woodland since 1980 (Hopkins and Kirby 2007).

Traditional management techniques such as mixed broad-leaved coppicing are highly valued in terms of biodiversity due to the creation of a continuous mosaic of open spaces and early successional stages (Van Calster *et al.* 2008). The impact is such that many woodland species reliant on early to mid-successional stages are now in decline (Hopkins and Kirby 2007). There is evidence that the creation of woodland gaps promotes biodiversity of open habitat species (Quine *et al.* 2007), however there is very little empirical data on the impacts of commercial woodland management on biodiversity in the UK.

Biodiversity is a key component of sustainable forest management (Jones-Walters and Mulder 2009), with the Convention on Biological Diversity committed to reducing biodiversity declines (Secretariat of the Convention on Biological Diversity, 2006). Common indicators of woodland biodiversity have shown major recent declines in population and distribution which include: birds (RSPB 2008); plants (DEFRA 2009); invertebrates (Warren & Bourn 2011); and mammals (Hill and Greenaway 2008). All of this evidence points to a serious decline in woodland biodiversity in the UK.

The aim of this study was to investigate potential impacts of harvesting wood for woodfuel on biodiversity through comparison of butterfly communities. This includes studies from woodland under three different management techniques: low management woodland; traditional coppice management for conservation; and clear felling for commercial woodland management.

ACTION

Study area: This study was conducted in the Morecambe Bay limestone area within the North-West of England, comprising a woodland resource of 12,946 ha. The top three predominant woodland categories are: broadleaved (36.5%); coniferous (25.3%); and mixed (24.7%); with total low management woodland equating to 3,371 ha (26%) (Forestry Commission, England 2010). In this study, areas managed under conservation objectives were primarily broadleaved oak woodland and hazel coppice. Commercial managed woodland comprised clear-felled coupes of western hemlock, larch, and Scots pine within predominantly broadleaved woodland.

Morecambe Bay contains one of the last remaining strongholds of the UK BAP fritillary species observed in this study, and is the only site in the region where populations of the high brown fritillary and the pearl bordered fritillary have increased (Ellis 2006) (Fig. 1).

Study sites were based in the Witherslack estate in south Cumbria (54^{0}16'N; -2^{0}52'E), and Gait Barrows National Nature Reserve located in north Lancashire (54^{0}11'N; -2^{0}47'E) Figure 1.

Seven main study sites were selected within two locations: High Park Wood (54^{0}16'N; -2^{0}52'E), Low Park Wood (54^{0}16'N; -2^{0}52'E), Hagg Wood, Knott Wood (54^{0}16'N; -2^{0}52'E), Lawns Wood (54^{0}16'N; -2^{0}52'E), Gait Barrows NNR (54^{0}11'N; -2^{0}47'E), and Thrang Wood (54^{0}11'N; -2^{0}47'E).

Butterfly sampling: Key indicator species were defined as

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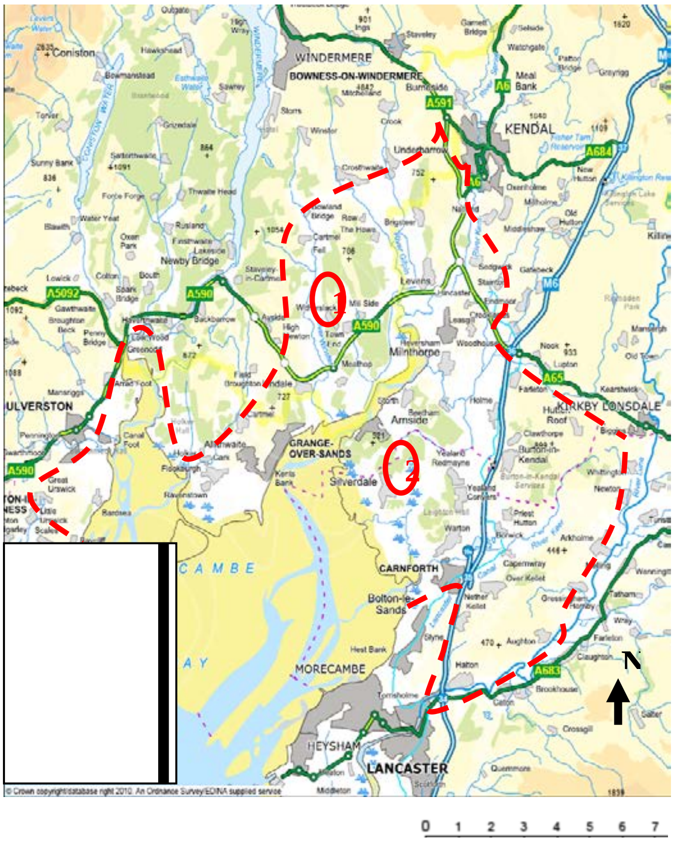

Figure 1. Location of study sites in the Morecambe Bay area: 1 = Witherslack Woodlands; 2 = Gait Barrows NNR. Dashed line represents Morecambe Bay limestone boundary. Reproduced by permission of Ordnance Survey © Crown copyright.

those species in need of priority protection (UKBAP species): high brown fritillary *Argynnis adippe;* pearl bordered fritillary *Boloria euphrosyne;* and small pearl bordered fritillary *Boloria selene.* Recent analysis of population trends since 1990 across the UK has indicated that the high brown fritillary has declined by 69%; the pearl-bordered fritillary by 42%; and the small pearl-bordered fritillary by 19% (Fox *et al.* 2011), with most declines occurring in woodlands as a result of habitat loss or change (JNCC 2010a; JNCC 2010b).

Butterflies were recorded following the standard transect methodology adopted by 'The Centre for Ecology and Hydrology's Butterfly Monitoring Scheme' (Pollard & Yates 1993). Using this method allows the results from this study to be compared with national trends (Croxton *et al.*, 2005; Lenda *et al.*, 2012), and existing data sets. Butterfly species were identified by sight or caught and released using a net for species difficult to differentiate and identify. Transects were visited in different order during fifteen visits to avoid bias due to time-related butterfly activity patterns. For data analysis the total number of individuals per species, and the total number of species, were pooled over the total number of visits.

Each of the 7 sites were divided into 5 transects dependent on the predominant management regime adopted in each woodland. Transects were divided into sections ranging from 5 – 15. The transects established prior to this study were Witherslack conservation transect and Gait Barrows butterfly conservation transect. Low management transects at both Gait Barrows and Witherslack are treated as a control when identifying trends in the different woodland management treatments. Although Witherslack commercial management transect only comprises one transect, this spans over two woodlands separated by a road, and has 3 separate sections

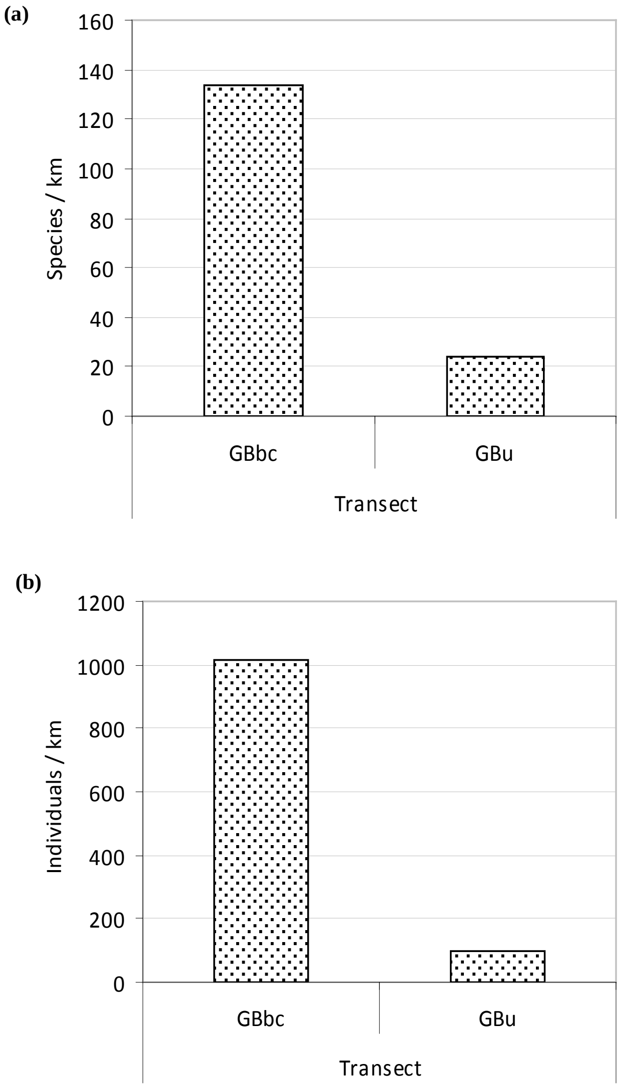

Figure 2. A comparison of species richness **(a)** and abundance **(b)** in transects at Gait Barrows measured as number of mean butterflies per kilometre per section, using only data from the 15 weeks when all five transects were walked. GBbc = Gait Barrows butterfly conservation transect; GBu = Gait Barrows low management transect

that have been commercially managed resulting in the current open habitat censused in this study..

Statistical analysis: Diversity between transects was calculated using the Brillouin index which measures diversity of non-random samples (Magurran 2004). The dependent variable observed was the total number of individuals per species.

The Kolmogorov-Smirnov test of normality was undertaken ($p < 0.05$), results indicating that the conservation transect at Witherslack and the conservation transect at Gait Barrows did not meet the assumptions of parametric statistics. As such, non- the Kruskal Wallis and Mann Whitney statistical tests of significance (see Van Emden 2008).

The number of weekly transects walked that met the strict criteria of the UK Butterfly Monitoring Scheme methodology and where data was recorded for all five transects (including observations with zero counts) equated to 15. Therefore only 15 weeks of data were used in the data analysis.

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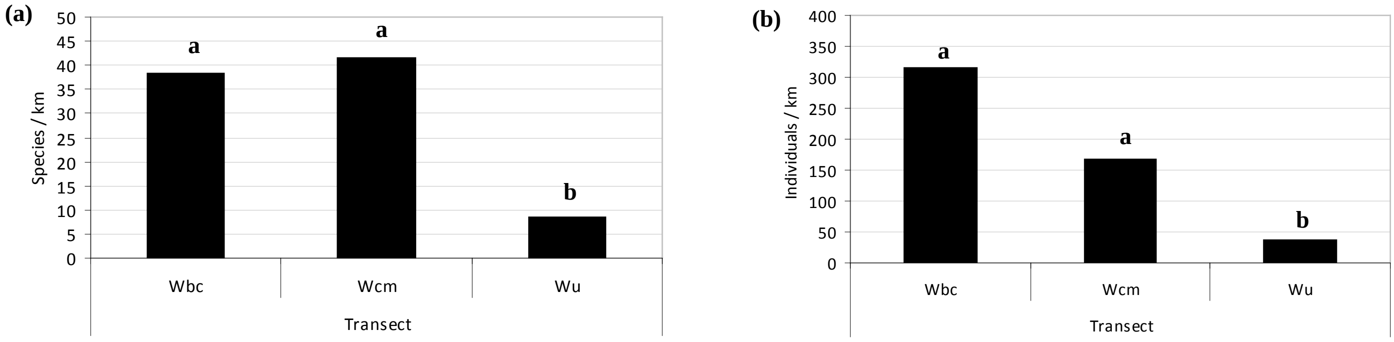

Figure. 3 A comparison of species richness **(a)** and abundance **(b)** at Witherslack, measured as number of mean species per kilometre per section, using only data from the 15 weeks when all five transects were walked. Values that differ significantly $p < 0.01695$ do not share any letter. Wbc = Witherslack conservation transect; Wcm = Witherslack commercial management transect; Wu = Witherslack low management transect. Using Mann Whitney, comparisons between 3 groups as oppose to 2 denote that the α value be reduced to 1- ($\sqrt[3]{0.95}$) = 0.01695. Therefore, probability of correctly failing to reject the H0 is 1 – 0.01695

Transect length varied for each of the five sites, therefore species richness and abundance were calculated as the number of individuals and species per kilometre per section.

CONSEQUENCES

The Mann Whitney test conducted on data from Gait Barrows revealed that both species richness ($Z = -3.273$, $P < 0.001$) (Fig. 2a) and butterfly abundance ($Z = -2.924$, $P < 0.01$) (Fig. 2b) were significantly higher at the conservation transectcompared to low management habitat.

At Witherslack, Mann Whitney tests revealed that (based on the adjusted α value of $P = 0.01695$ to prevent the probability of a Type I error) butterfly conservation and commercial management habitats were significantly richer in butterfly species (Wc: $Z = -2.659$, $P < 0.01$; Ww: $Z = -3.067$, $P < 0.01$) (Fig. 3a) and abundance (Wc: $Z = -3.145$, $P < 0.001$; Ww: $Z = -2.814$, $P < 0.01$) (Fig. 3b) than low management habitat. However there was no significant difference in species richness ($Z = -0.634$, $P = 0.557$) and abundance ($Z = -1.408$, $P = 0.173$) between the butterfly conservation and commercial management habitat (Fig. 3a, 4b). There was no significant difference in parametric analyses were used; consisting ofeither species richness or abundance ($P > 0.05$) of UK BAP fritillary species between butterfly conservation sites and commercially managed habitat. Brillouin indices derived from butterfly conservation and commercially managed habitat at Witherslack equate to 2.21 and 2.34 respectively, compared to the low management woodland with a value of 0.33, where 95% of total individuals comprised of speckled wood. All species observed at the low management site were also recorded in woodland managed for both butterfly conservation and commercial woodland management. Conservation areas at Gait Barrows National Nature Reserve demonstrated the highest levels of butterfly biodiversity with a Brillouin indices value of 2.69.

UK Biodiversity Action Plan fritillary species richness and abundance between butterfly conservation and commercial management habitat: Comparisons between Witherslack conservation transect and Witherslack commercial management transect were undertaken to compare management sections between sites (Table 1 and 2). Sections that contained UK Biodiversity Action Plan fritillary species were identified as being positively affected by the associated management applied. However, it is noted that initial results cannot determine causal factors.

At Witherslack, Mann Whitney tests revealed that (based probability of a Type I error) open habitat, thinned, and low management woodland were not significantly different in butterfly or fritillary abundance between the Witherslack conservation transect and Witherslack commercial management transect (Table 2).

The results of this study show that management regimes for commercial woodland management and coppicing for butterfly conservation both significantly increased butterfly biodiversity when compared to low management woodland at Witherslack. All species observed at the low management site were also recorded in woodland managed for both butterfly conservation and commercial woodland management. Conservation areas at Gait Barrows NNR demonstrated the highest levels of butterfly biodiversity.

Thomas (2005) shows that butterflies can effectively represent other groups of insects, with butterfly species richness and their abundance often used as an appropriate indicator of habitat quality (Croxton *et al*., 2005; Lenda *et al*., 2012). Furthermore, research shows that rare species of butterfly are correlated with overall butterfly species richness; emphasising their effective indicator ability (Pearman and Weber, 2007). Therefore, presence of UK BAP fritillary species observed in commercially managed woodlands may be of considerable importance, The results are even more striking when we consider that both total butterfly species richness and abundance (Fig. 4ab; Brillouin values: Wbc 2.21; Wcm 2.34), and UKBAP fritillary species richness and abundance ($P = 0.282$), were not significantly different between butterfly conservation and commercial management sites at Witherslack. Work needs to be done to identify strategies that lead to substantial and sustainable harvesting of woodfuel to maximise the benefits for biodiversity shown here.

DISCUSSION

If current wood prices continue to rise, commercial woodland management may provide the economic incentives required to bring low management woodland back into management. This is particularly relevant when we consider the costs of restoring or creating open woodland habitat for conservation. In the UK, 10% of land area is protected as Sites of Special Scientific Interest, with 8% designated as National Parks (9.3% England, 19.9% Wales, 7.2% Scotland) (Warren & Bourn 2010). Within the Morecambe Bay limestone area,

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approximately half the sites are owned or leased by conservation organisations; 55% are Sites of Special Scientific Interest, and over 73% are supported by agri-environment or woodland grant schemes (Bulman *et al*., 2008). Moving away from this core area, woodland under active management in England accounts for 52% (Forestry Commission England 2011) while in the Northwest, only 10% of woodlands have any grant or licensing activity (a potential indication of woodland management), and 37% remain under low management (Northwest Regional Development Agency 2010). Findings indicate that biodiversity benefits are not significantly different between sites managed for butterfly conservation and sites managed under commercial management objectives at Witherslack (Table 2). Therefore, it may be that some of the costs associated with management for conservation may be recovered through commercial forestry practices that generate an income.

These results are consistent with previous research into the conservation benefits of mixed broad-leaved coppice management on open habitat biodiversity (Bulman *et al*., 2008; Van Calster *et al*., 2008). Results observed in woodland managed under commercial objectives are also consistent with other research which shows that increased light through the formation of gap habitat and early successional stages,

Table 1. Management status and butterfly abundance per section for Wbc = Witherslack conservation transect; Wcm = Witherslack commercial management transect. Management comparisons across Wbc and Wcm for butterfly abundance and fritillary abundance (based on the adjusted α value of P = 0.01695 to prevent the probability of a Type I error) (Table 2)

Transect	Section	Length (m)	Management status	Individuals	UK BAP Fritillaries	Individuals / km	UK BAP Fritillaries / km
Wbc	1	155	U	34	0	219	0
	2	210	O	162	46	771	219
	3	190	O	164	19	863	100
	4	425	O	207	33	492	78
	5	202	U	13	0	64	0
	6	197	T	31	0	157	0
	7	100	T	20	0	200	0
	8	197	T	36	2	183	10
	9	312	U	42	1	128	3
	10	325	U	26	0	80	0
Total	**10**	**2313**		**735**	**101**		
Mean						**318**	**44**
Wcm	1	102	U*	8	0	78	0
	2	153	U	18	0	118	0
	3	131	U	7	0	53	0
	4	476	O	193	21	410	44
	5	88	U	2	0	23	0
	6	143	U*	15	0	105	0
	7	90	O	16	0	178	0
	8	312	U	25	0	80	0
	9	218	O	68	1	312	5
	10	100	T	14	1	140	10
	11	91	O	32	0	352	0
Total	**11**	**1904**		**398**	**23**		
Mean						**210**	**12**

Codes for management status: * indicates the transect follows the path of a road that runs through the associated management type; O indicates management as a result of timber harvesting via clearfelling operations, or conservation management through coppicing; U indicates low management woodland - defined as woodland where no management has taken place for a minimum of 20 years; and T indicates thinning of woodland.

Table 2. Individuals per km were calculated by dividing the number of individuals observed per section by the length of that section in km.

Management compared	**P value (Ind/km)**	**P value (Frit/km)**
Open habitat	0.0339	0.0323
Thinned	0.1797	0.3173
Low management	0.2395	0.0679

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associated with both coppicing and felling, increases vascular plant species richness (Kirby, 1990; Kirby *et al*., 2005) and is highly significant in the composition and abundance of many bird assemblages (Díaz, 2006; Quine *et al*., 2007). Clear-felling in artificial plantation forests within Europe have been shown to increase diversity and support highly specific bird assemblages (Paquet, 2006), with highest species richness of carabid-beetle assemblages also noted in early successional stages after clear-felling (Koivula, 2002). In addition to this, open space habitat containing broadleaved trees within conifer plantations in Ireland has also shown to be of major importance to hoverfly biodiversity (Gittings, 2006).Moreover, a significant increase in species richness and abundance of plants has been noted after partial harvesting of mixed oak woodland (Gotmark *et al.,* 2005), a practice which has been noted to have a positive impact on oak regeneration (Götmark, 2007).

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