Meadow brown (Maniola jurtina) and marbled white (Melanargia galathea) butterfly populations on two managed grasslands in Devon, UK: Implications for conservation

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Meadow brown (*Maniola jurtina*) and marbled white (*Melanargia galathea*) butterfly populations on two managed grasslands in Devon, UK: Implications for conservation

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Abstract

This paper reports on the effects of a management regime on two grassland sites in an agricultural landscape by using butterflies as indicators over a six-year period. This paper investigates what effects the management has had on two groups of phytophagous butterflies; habitat generalists (polyphagous) and habitat specialists (oligophagous). It identifies two species to study, the meadow brown *Maniola jurtina* and marbled white *Melanargia galathea.* The study was conducted in Devon, UK in 2007. Butterfly and plant communities were studied by transect counts on two differently managed grassland sites (Site A: 8 ha and Site B: 4.04 ha). A total of 27 butterfly species were recorded. In regression analysis, the number of butterflies at site A had increased significantly over the six study years ($P < 0.05$). Generalist butterflies showed a significant increase ($P < 0.05$) and so did the specialist species (P = < 0.05). The numbers of individual generalist and specialist species showed no significant difference. Meadow brown showed an erratic increase in numbers over the six study years with no significance and marbled white has increased significantly ($P < 0.05$). The comparison between Site A and Site B showed that there was a significant difference between meadow brown populations ($P < 0.05$) and marbled whites were present at Site A and absent from Site B. Plant diversity was significantly different from each year studied ($P < 0.001$) and had decreased at Site A between 2002 and 2007. Plant diversity was significantly different at Site A and Site B ($P < 0.001$). Significant increases of butterfly populations were found at the sample site A due to a change in the management of the grassland. Habitat specialists were more affected by increasing grassland coverage (reduced heterogeneity) than habitat generalists. The goal therefore is to see a much more diverse landscape with habitat corridors linking important habitats and where farmers and landowners are striking a balance with intensive agriculture and thus conserving species diversity. The development of studies into the long-term effects of rough grassland sites on butterfly diversity is needed in the near future, to enable conservationists, government bodies and the landowners themselves to implement a landscape scale conservation scheme.

Keywords: Butterflies, Grassland, Generalist, Specialist, Habitat conservation

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1. Introduction

The 21st century is a time of rapid, perhaps unprecedented environmental landscape change and as a result, biodiversity is changing. The persistence of plant and animal populations in agricultural landscapes is important for both maintaining ecosystems and the conservation of threatened species (Öckinger and Smith, 2007a). Continued fragmentation, deterioration and loss of wildlife habitats, pollution and the acceleration of climate change pose significant problems for many species (Fox *et al.*, 2006). Butterflies have been shown to be very sensitive to changes from biotic and abiotic factors and have fared worse than birds or vascular plants over recent decades (Asher *et al.*, 2001). Fox *et al.* (2006) states that there are currently 56 native species of butterfly in the UK and Ireland, although none of these are endemic. A further four species were resident but have become extinct in the UK since 1800. Three species occur as regular migrants, breeding in the UK every year but not surviving in significant numbers during the winter. The UK Biodiversity Action Plan (UKBAP) set out by the Government in 1994 in response to Article 6 of the Convention on Biological Diversity identified those butterflies that were most at threat and highlighted them on the Species Action Plans (SAP) (UKBAP, 2007).

There are eleven species of butterfly that currently have high conservation status, six of which are grassland habitat species (UKBAP, 2007). Asher *et al.* (2001) states that these species are termed 'habitat specialists' and are commonly confined to specific habitat 'islands' that are patchy in the modern landscape. These species are relatively sedentary and rarely use linear habitats and their larval food plants only usually include one or two species (monophagous and oligophagous respectively). Comparing that to the attributes of wider countryside species whose ability to use a broader range of habitats, including linear habitats and several species of larval food plants will as a result have extensive and continuous distributions. The decline in the distribution of butterfly species, of not only the habitat specialists but also the habitat generalists demonstrates that the majority of butterfly species are at risk because of changing land management and habitat fragmentation and loss (Feber and Smith, 1995; Thomas *et al.*, 1998; Krauss *et al.,* 2003; Wenzel *et al.,* 2006).

Asher *et al.* (2001) found that within each habitat type, every resident butterfly species requires several particular features in order to complete its life cycle successfully. The key feature within the habitat is the presence of larval food plants, growing in the right conditions to allow successful development from ova, through to larva and pupa (Carter and Hargreaves, 1986). Most adult butterflies also require food resources as well as sheltered areas, either to establish territories or for basking, or to provide the warmth needed for ova and larval development (Asher *et al.*, 2001). Pollard and Yates (1993) state that butterflies act as useful indicators because aspects of their biology predispose them to be sensitive to, and react rapidly to, changes in their environment. Fox *et al*. (2006) state that their short lifecycles mean that they react quickly, whilst the limited dispersal ability, larval food plant specialisation and close-reliance on the weather and climate make many butterfly species sensitive to fine-scale changes. Another reason is because of excellent data sets detailing past and present distribution, population size and phenology (Fox *et al*., 2006). Butterfly indicator species can be used to assess the impacts of climate change, the progress of UK Biodiversity Action Plans, agri-environment schemes and Sites of Special Scientific Interest (SSSIs) (Pollard and Yates, 1993).

The majority of British butterflies are insects of grassland habitats, notably of herb-rich sheltered grassland (Oates, 1995). Studies by Wenzel *et al.* (2006), looking at the decline of butterflies on grassland, showed that a loss of plant diversity and species

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richness could be an important reason for the observed decrease. The decline of monophagous butterflies was most dramatic, whereas oligo- and polyphagous (see Krauss et al., 2005) species showed less dramatic decreases. Therefore, the right management of grassland habitats is crucial to protect the process (or processes) upon which rare species and valued habitats are dependent. Grazing times and intensity, states Oates (1995), is crucial for the conservation of sensitive species and for the control of problematic vegetation. With butterflies, timing of grazing is important in creating and maintaining the necessary continuity of the combination of different grassland structures essential for the various stages of butterfly life cycles, including the provision of adequate nectar supplies, pairing, night roosting and rough weather shelter.

More than half of all recently documented insect extinctions are of Lepidoptera, (Dunn, 2005) and due to threatened butterflies having specific ecological requirements, their most serious and immediate future threat is changing habitat management (Asher *et al.*, 2001). Habitat reduction generally converts large blocks of habitat into landscapes with many, relatively small fragments, which could potentially alter the costs and benefits of species dispersal (Thomas *et al.*, 1998). The destruction and fragmentation of habitats is the main cause of extinction (Steffan-Dewenter and Tscharntke, 2000; Schtickzelle *et al.,* 2005). In the UK the highly modified landscape is thought to be restricting butterflies to the remaining fragments of semi-natural habitat. Connor and McCoy as cited in Steffan-Dewenter and Tscharntke (2000) describes the hypothesis of habitat-heterogeneity, which claims that large areas tend to contain a greater diversity of environmental conditions and thereby support more species-rich communities. Conversely, the intensification of agriculture has seen the fragmentation of habitats and the increasing isolation of species (Schneider *et al.*, 2003; Wallis De Vries *et al.*, 2007). Habitat specialist species are showing the most evidence in decline, whilst to a lesser extent so are the habitat generalist species (Fox *et al.*, 2006). León-Cortés *et al.* (2000) demonstrated that there are two main features of habitat specialist that may render them vulnerable: first, that relatively subtle changes to the environment may drive populations of specialists extinct, and second, specialists may have small initial distributions thereby rendering them more vulnerable than less specialised species to similar population-level rates of decline. The process of fragmentation seems certain to continue and could potentially lead to further local extinctions (Thomas *et al.,* 1998; Asher *et al.,* 2001). Similar declines are mirrored in European (Wenzel *et al.,* 2006) and American (Keeler, et al., 2006) habitats highlighting the same concerns over fragmentation and local extinction.

Thomas (1995) found that the majority of British butterfly species that are regarded as having closed local populations exist as metapopulations. The Metapopulation theory (see Gilpin and Hanski, 1991) suggested that species would not survive on individual fragments of habitat, but require a network of sites between which they can move. Schtickzelle *et al.* (2005) found that the ideal way of improving the carrying capacity of habitat patches is through the restoration of existing habitat. The creation of new habitat and/or the enlargement of existing ones to potentially improve the viability of met populations could follow this. Thomas (1995) states that in fragmented habitats, dispersing individuals who emigrate from a good breeding habitat (source) may arrive at a poor-quality habitat (sink), which is populated because of repeated immigration rather than because the butterfly is able to reproduce successfully. Öckinger and Smith (2007a) observed that in highly fragmented landscapes, not only can populations become isolated from each other but also the distances between different resources needed by single individuals increase. If resources become too isolated from each other they may become unavailable for the focal species, with negative consequences for population persistence in the landscape. Emphasis needs to be on conservation of these habitats (Thomas,

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1995) by focusing on ways of increasing rates of colonisation as well as on trying to minimise rates of extinction. Öckinger and Smith (2007b) state that for the long term population persistence of a species the preservation of semi-natural habitats in the wider agricultural landscape is necessary to prevent local extinction.

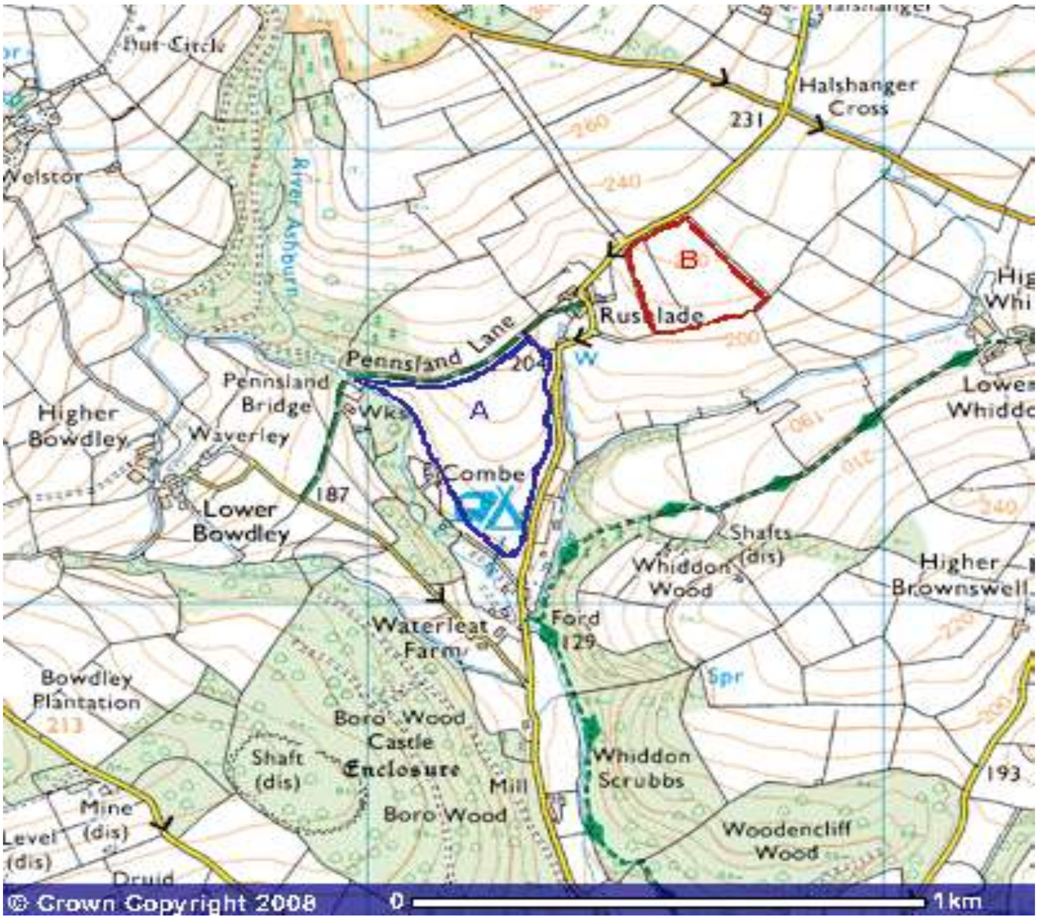
Over 70% of the English land surface is farmed (DEFRA, 2006). As a consequence, the countryside has been maintained largely by farming and most semi-natural areas have, historically, been managed under an agricultural regime (see Fig. 3) (Hopkins and Wilkins, 2006). Tallowin *et al.* (2005) showed that there was considerable evidence to suggest that the quality of agricultural grassland as a habitat for farmland wildlife had declined. The evidence, using birds as the indicator, was the reduction and, in some cases, the regional extinction of farmland species. The effect of extensive grassland management and extensive grazing on grass and livestock production has been investigated in some situations (Kruess and Tscharntke, 2002; Tallowin *et al.,* 2005; Scimone *et al.,* 2007). Further studies have suggested that there will be a requirement to increase the output of food and feed from grassland and that this will put pressures on low-input systems that currently combine production with environmental objectives (Hopkins and Wilkins, 2006). Recent studies by Isselstein *et al.* (2007) looked at the development and analysis of grazing systems that have a potential to support the biodiversity and nature conservation value of grassland while maintaining a reasonable level of agricultural output. The study found that intensive grazing systems showed a reduction in pasture productivity, nutritive value of herbage and livestock production. Grassland sites must contain both nectar and host plant resources for successful larval and butterfly survival and reproduction (Collinge *et al*., 2003). Scimone *et al.* (2007) stated that there is an important need to try and find an optimal balance between livestock production and grazing impact on plant biodiversity and suggested that management systems need to consider the background environment and that more knowledge of the mechanisms involved is needed at farm and landscape scales.

This paper investigates the differences between two differently managed grassland sites and the effects that this has on two species of butterfly, the meadow brown (*Maniola jurtina*) and the marbled white (*Melanargia galathea*) in Devon, UK. Using the data obtained from this study this paper then makes recommendations for the conservation of important UK grassland habitats. This paper will answer questions such as: what is the difference in butterfly abundance between the two differently managed grasslands? How does the difference in vegetation structure affect the two species? Has the change in the land management had an affect on the diversity of butterflies? This paper reports on 6 years of butterfly surveys using fixed transect routes.

2. Methods

All species in this study belong to the order Lepidoptera. Both species occupy grassland habitats, the meadow brown is a very common (National Data: 10+ individuals seen on one visit from 3108 ten km squares (Asher *et al.,* 2001)) polyphagous species, occupying a wide range of grassland habitats such as downland, heathland, coastal dunes, hay meadows, verges, hedgerows, woodland rides and waste ground. The marbled white is a common oligophagous butterfly that favours areas of unimproved grassland, where its larval food plants, mainly red fescue (*Festuca rubra*), forms a tall sward that is cut or grazed infrequently, however the full range of larval food plants is not known (Asher *et al.,* 2001). 'Neutral grassland' states Rodwell (1992) comprises semi-natural swards dominated by grasses with associated dicotyledonous herbs but lacking any pronounced calcicole or calcifuge element. Such vegetation is found mostly on lowland clays and loams of acid to neutral reaction and largely treated as agricultural land. For this work a database of butterfly observations was recorded in Transect Walker 2.0 and plant data was recorded using Microsoft Excel spreadsheet software. Plant nomenclature is taken from Rose (1981) and butterfly nomenclature is taken from Asher *et al.* (2001).

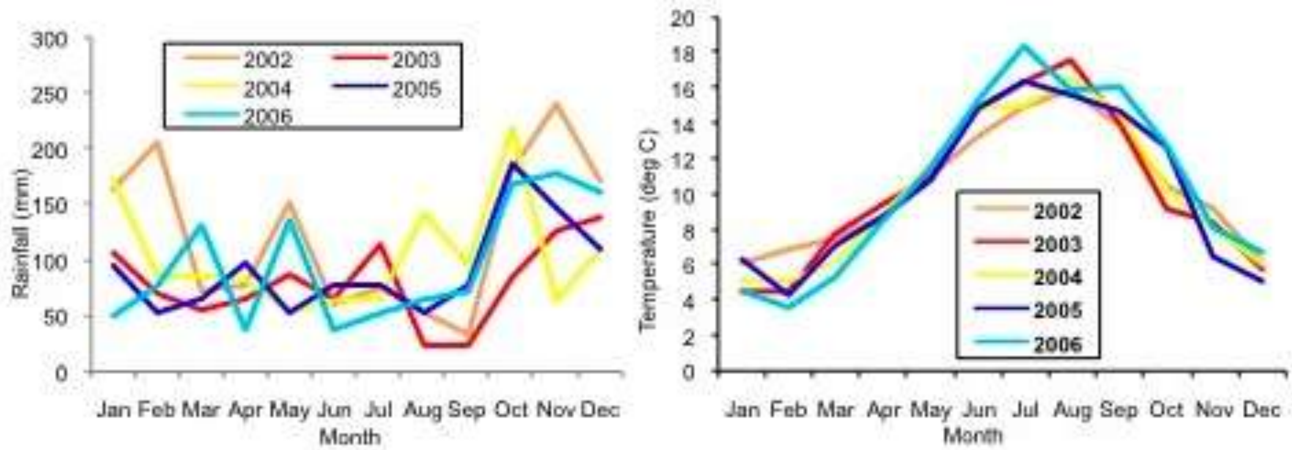
Figure 1. Site A and B location (grid ref. SX7572) (Ordinance Survey, 2007)



2.1 Site Selection

Butterfly abundance was recorded at two sites in Ashburton, Devon (Fig. 1). Site A was recorded for a period of 5 years (2002-2007) whilst Site B was recorded in 2007. Site A is on the edge of Dartmoor at Waterleat, Ashburton (SX753724). The soils are loam with stones and the climate is mild and damp due to the influence of the sea approximately 10 miles away. The site's altitude is between 150m and 200m. Approximately 8 hectares of the site is improved and semi-improved grassland that has been heavily grazed for many years by sheep and cattle. It was originally 8 smaller fields and old aerial photographs show that the hedgerows within the site were still present in 1969 but had gone by 1975. There is one length of remnant hedge remaining. The grassland has been fertilised annually and limed in the past to improve it for grazing. The field is relatively flat-topped with two sides sloping (around 30^{o} in places). The steeper parts have been less intensively managed (less inputs and grazing), presumably due to difficulty in access. Site A now consists of a habitat of rough grassland and is now managed by topping every 2 years to proximately 20 cm and removing weedy and woody species when necessary. A light grazing of cattle once a year is permitted (2.5 cattle per ha). Site B is 4.04 hectares of grazed cattle pasture and is managed by grazing in the early spring, shut up for hay from May to August and grazed after taking a hay crop. The landscape in the area is pastoral, mainly cattle and sheep pasture, with some woodland plantations and natural deciduous woodland. The climate in southwest England is generally mild compared to other parts of the UK. Monthly rainfall is very variable in this area and the controlling factor in determining rainfall is air humidity. The sea temperature off southwest England is at its maximum in late summer and autumn, and is coolest in late winter and spring, and as a result rainfall tends to be most in autumn and least in spring. Temperature shows both a seasonal and a diurnal variation. On average February is the coldest month and July and August are the warmest (Fig. 2.)(Met Office data, 2007).

Figure 2. Mean rainfall (mm) and mean temperature (^{o}C) for South-West UK, 2002-2006 (Met Office data, 2007).



2.2 Butterfly and habitat recording

Butterflies were recorded at site A at approximately weekly intervals between April and September in 2002, 2003, 2004, 2005, 2006 and 2007 (by Assistant Conservation Officers working for the Barn Owl Trust, TQ13 7HU) and for 10 consecutive weekly intervals between July and September 2007 at site B (by the author). Abundance of butterflies was measured using the transect recording method developed and described by Pollard and Yates (1993) for the Butterfly Monitoring Scheme. To provide a degree of standardisation three criteria were observed. These were: (1) counts were started after 10.45 BST and completed before 15.45 BST, (2) counts were made only above 13 ^{0}C, and then only in sunny conditions unless the temperature was 17 ^{0}C or above and (3) counts were not made when the wind speed was in excess of five on the Beaufort scale. Recorders walked a measured fixed transect route (Site A = 1047 m; Site B = 962 m) which was divided into sections corresponding to habitat and/or boundary type (Fig. 3.). For each section all butterflies were recorded. Details of management type and habitat characteristics were recorded for each section of the transect route.

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Figure 3. Site A and B Transect routes (grid ref. Site A: SX752723; Site B: SX756727) (Google Maps, 2008).

2.3 Plant monitoring

The complete survey of vascular plants for site A was compiled from 2 independent data sets, one in 2002 and one in 2004 (by Assistant Conservation Officers working for the Barn Owl Trust, TQ13 7HU) to achieve a total list of plant species at the site. In 2007 plant data was collected on Site A and B using 3 x 50m transect ropes at each site with a marker at 2m intervals. The grassland was divided into 3 main areas to compare: Zone I - flat area, heavily grazed and fertilised; Zone II - south west facing slope, ungrazed since 2001, less fertiliser; Zone III – west facing slope, lightly grazed, less fertiliser. The transects were placed on grassland 'typical' of each area away from hedges and scrub to avoid edge effects. Sampling was carried out on one side of the transect to avoid trampling. A 50x50cm quadrat was used to assess plant species abundance, measured as a percentage. At site A the transect ropes were used in the same surveying place (marked by posts in the ground) for each of the previous 2 years. At site B the three 50m ropes were marked out in a Y-shape in the centre of the site. At site A, from the 3 years, there were a total of 225 quadrats and from site B a total of 75 quadrats (Fig 3a.) (Kent and Coker, 1992).

Figure 3a. Site A and B plant transect locations (not to scale)(Google Maps, 2008).

2.4 Data analysis

Four issues are examined in this paper at species level. The first looks at the general trend of the butterfly population at Site A. The second looks at the general trend between habitat specialists and habitat generalist populations at Site A. The third looks at the general trend between the meadow brown and the marbled white butterfly at Site A. The forth looks at the comparison between the meadow brown and the marbled white butterfly at Site A and Site B. Butterfly abundance was calculated by the dependent variable being defined as the total butterfly count for the season and for each year for each site, standardised to a count per unit length of transect walked. The statistical analysis of the data was performed using the software 'Minitab 15.0'. The trend in population numbers between 2002-2007 at Site A was performed using regression analysis and the differences of two variables were performed using the paired and un-paired *t*-tests. The differences in plant species diversity (D) were performed using ANOVA and un-paired *t*-test using 'PRIMER **5**'. All data were tested on whether they satisfy the assumption of normality (Eddison, 2000).

3. Results

3.1 Butterfly Results

In total 27 butterfly species were identified at two grassland sites. From 2002 to 2007 a total of 7229 butterfly individuals comprising 27 species were identified at Site A. In 2007, a total of 229 butterfly individuals comprising 11 species were identified at Site B. The overall trend in numbers of all butterfly species (n=27) shows that there is an increase from the years 2002 to 2006 at site A (Fig. 4). Butterfly numbers were at 208 individuals in 2002 and had increased to 2242 individuals by 2006, which shows a ten-fold increase within 4 years. The regression analysis shows that there is a significant change in the

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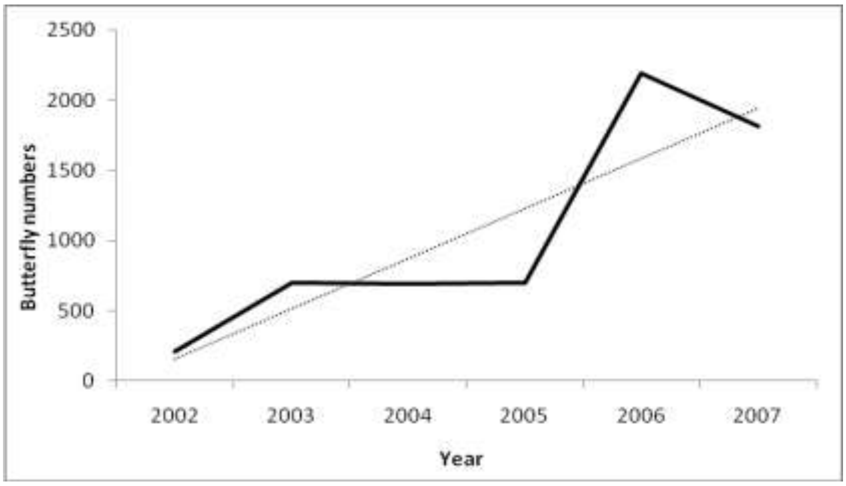
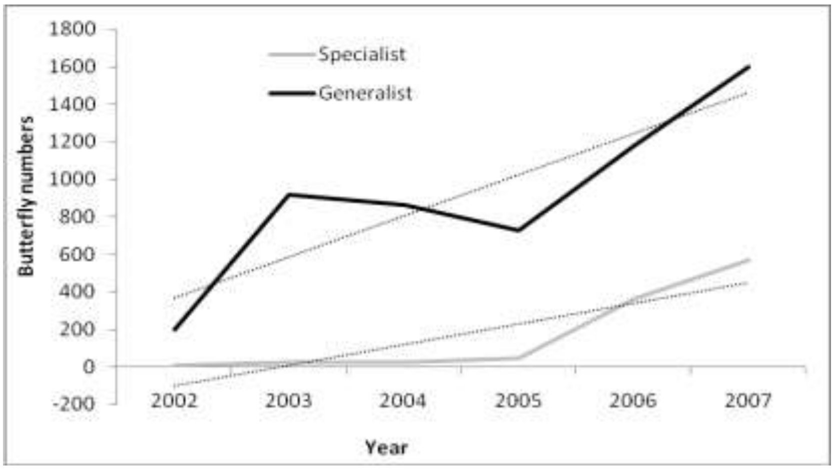
butterfly population over time due to a change in the management regime (R^2 = 75.4%; F = 12.23; df = 1.5; P < 0.05).

Figure 4. Trend in the numbers of butterflies from 2002-2007 at site A between the years 2002-2007 (Solid line: butterfly numbers; dashed line: line of best fit).



Butterflies were divided into two groups, habitat specialists and habitat generalists. The groups were determined by the amount larval stage food plants each species uses. Specialists comprised less than 3 plant species and generalist comprised more than 3 plant species. The difference in numbers between habitat specialists and habitat generalists shows that habitat generalists are significantly different (t_5= 6.17; P < 0.01) from habitat specialist species of butterfly over the years 2002 to 2007 at Site A (Fig. 5). The trend in habitat specialists shows that there is an increase in the numbers of butterflies over the years 2002-2007. The regression analysis shows that there is a significant change in the habitat specialist butterfly population over time due to the management regime (R^2 = 75.2%; F = 12.13; df = 1.5; P < 0.05). The trend in habitat generalists shows that there is an increase in the numbers of butterflies over the years 2002-2007. The regression analysis shows that there is a significant change in the habitat generalist butterfly population over time due to the management regime (R^2 = 76.8%; F = 13.26; df = 1.5; P < 0.05).

Figure 5. Trend in numbers of specialist and generalist butterflies at site A between the years 2002-2007 (solid lines: butterfly numbers; dashed lines: lines of best fit).



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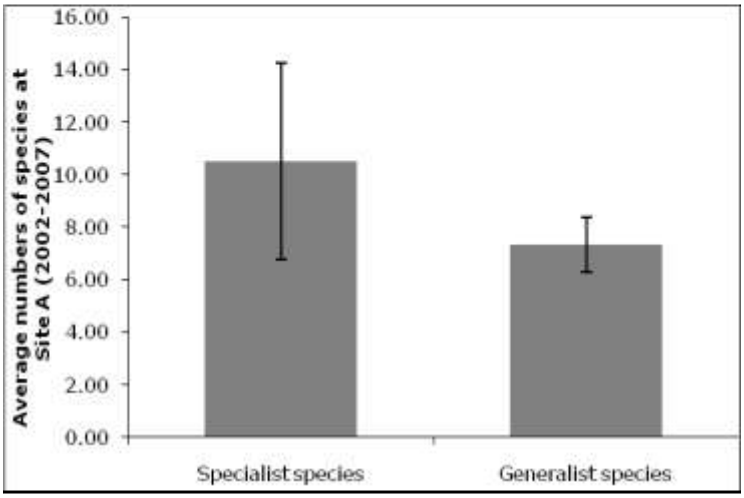
The differences between the mean numbers of habitat specialists and habitat generalist species show that there are more specialist species than generalist species at site A between the years 2002 and 2007 (Fig. 6.). However, the results show that there was no significant different between specialist and generalist species (t_{10} = 2.01; $P > 0.05$). Specialist numbers were at a mean of 10.5 species over the 6 years and generalist numbers were at a mean of 7.5 species over the six years. This would indicate that although there have been more species of specialist butterflies at Site A, the generalist species have increased significantly over the six years (refer to Fig. 5.).

Figure 6. Average number of specialist species and generalist species at Site A between the years 2002-2007.



The trend in the numbers of meadow brown butterflies at Site A shows a general increase between the years 2002-2006 (Fig. 5.). However the regression analysis shows that the trend is not significant (R^2 = 62.0%; F = 6.52; df = 1.5; $P > 0.05$). The population of meadow brown is erratic; in 2002 the population count was 186 individuals which shows an increase of 372% within one year, in 2003 the count was 879 but fell to 490 by 2005 which shows a 56% decrease and by 2006 the population had increased again by 190%. The trend in the numbers of marbled white butterflies at Site A shows a significant increase between the years 2002-2007 (Fig. 7.). The data was analysed using regression (R^2 = 74.5%; F = 11.67; df = 1.5; $P < 0.05$). The population of marbled white has shown an increase every year; in 2005 the count was 24 individuals and by 2007 the count was 330 individuals, which shows an increase of 1275%.

There is a significant difference between the mean numbers of meadow brown butterflies at Site A compared with Site B (t_{10} = 3.02; $P < 0.05$). There were approximately 5 times more meadow brown butterflies recorded at Site A than at Site B over the 10 weekly transects. There were an average of 3.7 marbled white butterflies recorded at Site A and none were recorded at Site B over the 10 weekly transects (Fig. 8.).

Figure 7. Total numbers of meadow brown and marbled white at Site A (Solid lines: butterfly numbers; dashed lines: lines of best fit).

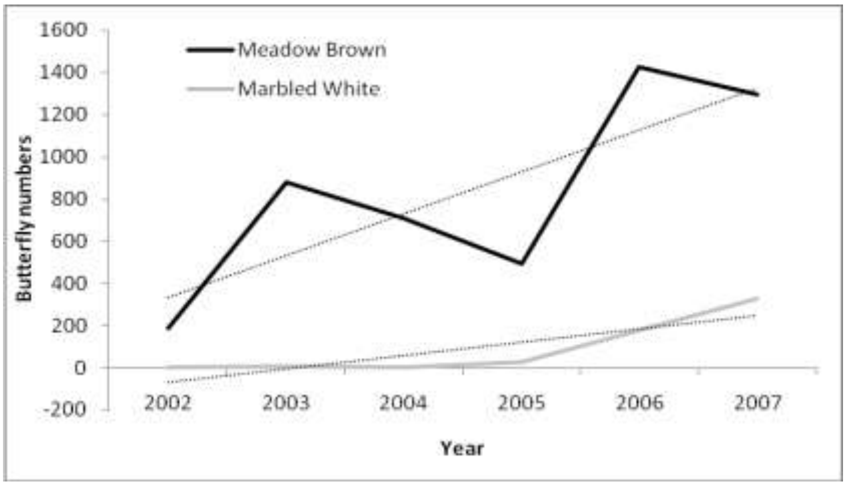
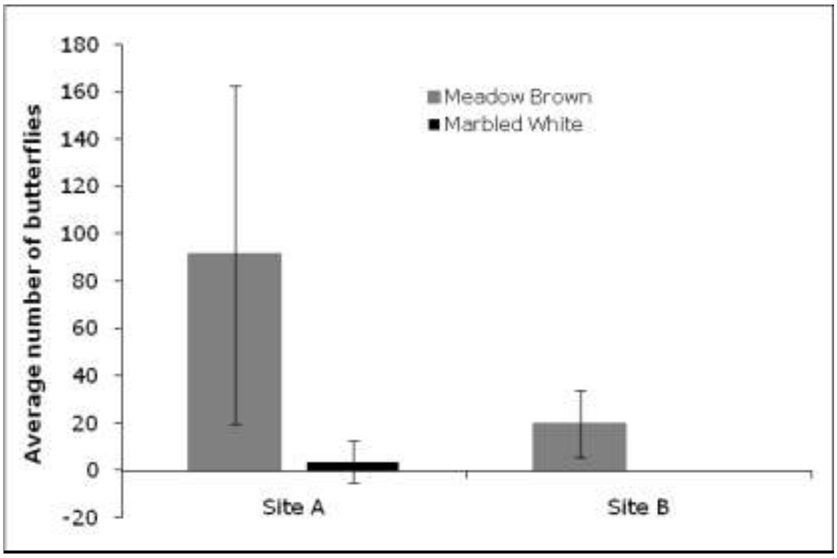


Figure 8. Average numbers of Meadow Brown and Marbled White at Site A and Site B



3.2 Plant results

The plant diversity at Site A has decreased since 2002; the Analysis of Variance shows that the plant species diversity is significantly different (F = 20.21; df. = 2, 129; P < 0.001) across the three-recorded years. The Simpson's Diversity (D) for 2002 was mean 0.7528 (n = 44), 2004 was mean 0.6005 (n = 44) and 2007 was mean 0.6245 (n = 44) (Fig. 7.). This shows that species diversity has declined by an average of 14% from 2002-2007. The plant diversity at Site A in 2007 and Site B in 2007 is significantly different (t_{30} = 5.79; P< 0.001) from each other. The Simpson's Diversity (D) was mean 0.6245 (n = 44) at Site A in 2007 and the Simpson's Diversity (D) was mean 0.7092 (n = 44) at Site B in 2007. This shows that the diversity of plant species is less at Site A than in Site B in 2007.

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4. Discussion

The butterfly species recorded in the present study represent an important part of the UK butterfly fauna (about 50% of all UK species (Asher *et al.* 2001)). Just over one third of the sampled species are grassland specialist, which means that grassland management of pastures plays an important role in the maintenance of grassland specialised butterfly fauna. Hardy *et al.* (2007) states that understanding the resource requirements of animal populations is fundamental to conserving native species in modified landscapes. As a consequence of the reduction of natural and semi-natural habitats and the increasing use of external inputs such as fertilisers and pesticides, agricultural intensification is one of the major causes of biodiversity loss and as such permanent landscape elements, such as grasslands play a crucial role in maintaining biodiversity in cultivated landscapes by providing habitats or refuges for many species (Batáry *et al.*, 2007).

The hypothesis stating that the management change has significantly affected the butterfly population at a grassland site in Devon was accepted. Significant increases of butterfly populations were found at the sample site A where a change in the management of the grassland occurred six years previous to this study (grazed pasture with added agri-chemicals to a rough grassland now unimproved). This confirmed the results of Wallis De Vries *et al.* (2007), that the effect of a lenient grazing intensity enhanced butterfly species diversity. Another study examining management effect (low vs. high grazing intensity) on butterfly diversity is contradictory to this paper, with Kreuss and Tscharntke (2002) having showed negative effect in Germany. One explanation of the general absence of grazing effect could be that the study area in Kreuss and Tscharntke (2002) was much larger than the study site A in this paper, which was unfertilised, free of chemicals, and much less intensively grazed (2.5 cattle per ha). This supports the claim made by Tscharntke *et al.* (2005) that in a landscape where biodiversity is high, the effectiveness of agri-environment schemes or the effects of management intensity is low. The potential outcome may be that even moderately grazed grassland could support a rich butterfly fauna. However, if the move is even further away from grazing management, in the direction of abandonment, it can be harmful for the biodiversity as was shown on butterfly abundance by Swengel (1996).

The examined taxa showed different responses to the study site A. Habitat specialists were more affected by increasing grassland coverage (reduced heterogeneity) than habitat generalists, with the floral results of this paper showing a negative trend in diversity. The negative effect of grassland coverage on specialist butterflies could be due to a reduction in the plant heterogeneity of the grassland site as a direct consequence between grassland cover and the diversity of the surrounding agricultural landscape. Grassland specialist butterflies may benefit more from high habitat heterogeneity in large grasslands compared to habitat generalists. This result is consistent with the main findings of Schneider *et al* (2003) that patch characteristics (area, isolation and quality) influence butterfly dispersal and that resource density and carrying capacity was identified as a factor in the highly fragmented UK agricultural landscape. Hardy *et al.* (2007) states that understanding the resource requirements of animal populations is fundamentally important if native species conservation in modified landscapes is to be achieved. Butterflies use a wide range of resources, which can be divided into consumables (food) and utilities (egg laying, pupae, roost, etc.). Butterflies are dependent on plants at two stages, adults and larvae (Dowdeswell, 1981). Larval host plants have long been regarded as key resources for defining metapopulation patchworks among butterflies (Thomas, 1995). Hardy *et al.* (2007) states that it is evident that as species distributions decline, because of habitat

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fragmentation, so do resources (both nectar and larval host plants). The results of regression analysis on generalist and specialist butterflies suggest that food availability could be the factor that is limiting the increase of specialist butterflies at the same rate as the generalist butterfly species. Grassland coverage could be an important factor, which may have strong effects on the species composition (the species of butterfly found at Site A) of butterfly assemblages. Similarly, this also suggests that specialist species might be affected by a decrease in the plant species diversity, which was found to be reducing over the six study years. This result possibly shows that the specialist butterfly species need heterogeneity at the landscape level. Furthermore, phytophagous species could originate from the surrounding habitat matrix (Krauss *et al.,* 2003; Krauss *et al.,* 2004; Krauss *et al.,* 2005).

The regression results of the meadow brown and the marbled white species both showing increases in numbers over the six study years and that they closely follow the same trend pattern as the results found in the specialist and generalist data. However, only the marbled white has shown a steady increase year on year. The national population trend of the meadow brown shows a 5% decrease for a 10-year period (1995-2004) although it still remains one of Britain's most abundant butterfly species (Fox *et al.,* 2006). The observations of meadow brown show a typical 'boom and bust' scenario, even though the general pattern shows an increase in numbers. The weather patterns for the six study years show little fluctuation in mean temperature and the rainfall, although variable showed not to be affecting meadow brown numbers in subsequent years. Therefore the 'boom-bust' scenario could be demonstrating that the carrying capacity of the grassland site has almost reached its optimum level to support the species. Schmitz (2007) states that insect populations are well known for their boom-bust nature and this dynamic occurs as numbers fluctuate around optimal populations with factors (climate, predators and/or pathogens) that should be working to reduce their numbers. Combined with the resulting loss of plant diversity at the site, the loss of nectar sources due to the management (removal of invasive vascular flowering plants) regime and the isolation of such a unique grassland habitat it is unlikely that the meadow brown will continue to increase indefinitely. Schtickzelle *et al.* (2005) states that in practical terms, the restoration of existing habitat patches is the most obvious way of improving the carrying capacity of the patch system. Then, the creation of new patches and the enlargement of existing ones could considerably improve metapopulation viability, provided the new patches are in the colonisation range of the species. Whilst the meadow brown is not listed on the UK Biodiversity Action Plan the ramifications for the future could be that other more endangered grassland butterfly species follow the same trend on the study site and fall into decline.

The national population trend of the marbled white butterfly shows a 15% decline for a 10-year period (1995-2004) however, the distribution trend has shown an 11% increase (Fox *et al.,* 2006). This could possibly be as an indication to climate change and range expansion as described by Parmesan *et al.* (1999). Colonies of marbled whites occur on unimproved grassland where a range of grass species forms a tall sward that is cut or grazed infrequently (Asher *et al.,* 2001). The results of this study show a significant increase in the marbled white population over the six study years. This suggests that there is sufficient larval food plants and also at the present time sufficient nectar sources for adults. Fox *et al.* (2006) states that the number of new 10km squares recorded around the marbled white's core range in southern England and Wales provides strong evidence of continued, natural colonisation. However, if the study site A continues to decrease in diversity and rank grasses become more dominant the marbled white may show a downturn in population increase. Future work should be carried out to assess the changes that the plant diversity will have on butterfly diversity and therefore the impacts this could have on other wildlife (insects, small mammals and ground nesting bird populations).

The plant diversity results suggests that grazing with livestock greatly contributes to changes in vegetation and the associated insect community through alteration of plant growth, plant architecture and plant diversity (Kreuss and Tscharntke, 2002; Wallis De Vries *et al.,* 2007). Although the *t*-test plant diversity comparison of the two study sites shows site B to be more diverse, the agricultural use (grazing, cutting, application of pesticides and fertilisers) of the site has a negative effect on butterfly numbers and species diversity. The result of the comparison of butterfly numbers at the two sites shows a significant difference between the meadow brown and the marbled white. There were five times as many meadow browns at site A than B and there were no recorded marbled whites at site B. Plant diversity is considered a major determinant of diversity at a higher trophic level (Hutchinson as cited in Kreuss and Tscharntke, 2002). The results show that by changing the management (i.e. reduction of grazing pressure) increases the species richness and abundance of phytophagous butterflies.

The main factor for presence or absence of butterfly species is predicted to be the larvae's requirements for habitat quality (Thomas *et al.* 2001). The results show that site B has a limitation (sward height, plus fertiliser and pesticide use) to allow butterflies to breed successfully and the numbers of observed adults at the site could be as a result of 'drift' from the site A (good breeding habitat) or other local breeding habitats rather than butterflies that were seen as a result of larval development at the site (Fried *et al.,* 2005). Another study is contradictory to this, having found that habitat isolation appears to be less important, as butterfly were found to be able to cope with the habitat mosaic (Krauss and Steffan-Dewenter, 2003). Agriculture can contribute to the development and conservation of high-diversity systems, which may support important ecosystems services such as biological control and pollination (Tscharntke *et al.,* 2005). Importantly, agri-environment schemes can reduce biodiversity loss by promoting extensification of agricultural practices at field scales. However the effectiveness of such schemes would be enhanced by a compulsory measure enforced by UK government for conserving biodiversity in farmed landscapes (Concepción *et al.,* 2008).

The results suggest that conservation of biodiversity in agricultural systems (such as in managed grasslands) benefits from a landscape perspective (Tscharntke *et al.,* 2005). Another important factor is habitat specificity, because habitat specialist species react differently from habitat generalist species (Driscoll, 2005). Habitat specificity can be determined by the species tolerance to temperature, precipitation, solar radiation, and many species are most abundant where these environmental conditions are ideal. However, there will be exceptions because local abundance depends on competition, predation and chance events that disturb all natural populations (Lindenmayer and Burgman, 2005). Thomas (1995) states that grasslands that were once continuous are becoming increasingly fragmented by intensive agriculture (the total cover of grasslands decreases on a landscape scale, Table 1.). The findings of this study have wider ramifications than for Britain as butterflies across Europe are under threat from biotope fragmentation, abandonment and urban growth (Van Swaay and Warren as cited in Hardy *et al.,* 2007). The issues of fragmentation could affect the specialist species and under environmental change, this could lead to a situation where communities will become increasingly dominated by generalist species (Tudor *et al.,* 2004).

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Table 1. Practices of agricultural intensification on local and landscape scales (Tscharntke *et al.,* 2005).

LOCAL INTENSIFICATION	Shortening crop rotation cycles	**LANDSCAPE INTENSIFICATION**	Farmers specialising on one or few arable crops instead of mixed farming
	Decreasing crop diversity		Converting perennial grassland into arable
	Fertiliser increase		Destroying edge habitats
	Pesticide increase		Reallocating land to increase field size
	Winter, not spring sown cereals		Increasing landscape homogeneity
	Deep ploughing, not minimum tillage		Giving up low-intensity land use
	Cultivating monocultures		Avoiding set-aside fallows and cultivating formerly abandoned areas
	Increasing size of arable fields		Reducing resistance to invasion of introduced species
	Lowering water table by drainage		Fragmenting natural habitats

The results suggest that while the site A is showing butterfly species increasing since the change in management population persistence over small fragmented habitats may depend on immigrants from larger source populations of large habitats. Therefore extinction risk on small grassland 'islands' may be much higher, especially in the fragmented agricultural landscape (Tscharntke *et al.,* 2002). Agricultural land with conservation-managed grasslands (margins, edges, corners or unused land/set-a-side) that is lacking in many agri-landscapes would benefit from a fragmentation strategy. First described by Tscharntke *et al.* (2002) denotes that the advantages of having habitats, such as grasslands in agricultural landscapes, of small or intermediate size should be scattered enough to cover a wide area so that diversity and spreading of risk are maximised and that habitats are close enough to allow dispersal among fragments. This will potentially reduce the extinction risk of species sensitive to fragmentation and predator-prey stabilisation.

5. Conclusion

The change in management practices at the landscape scale demonstrate that the habitat heterogeneity hypothesis as described by Rozenzwig (1995 as cited in Krauss *et al.,* 2004) is of utmost importance to the conservation of wildlife in the farmed landscape. The hypothesis predicts higher species numbers because of higher habitat heterogeneity. The goal therefore is to see a much more diverse landscape with habitat corridors linking important habitats and where farmers and landowners are striking a balance with intensive agriculture and thus conserving species diversity. The results show that the management of grasslands should be such that the plant species diversity does not fall too low so that nectar and larval food sources are available. The findings produced so far give a guide as to how the changing of agricultural grassland management can benefit wildlife on a landscape scale. However, until the analyses can be broadened to include more sample habitats, with measurements being based on rigorous survey techniques for representative sample of sites over a much wider range of grassland habitats, neither the strength of relationships nor the independence of variables can be totally relied upon. The surveys would need to be carried out by the researcher and not to rely upon the work of others for the data compilation. The development of studies into the long-term effects of rough grassland sites on butterfly diversity is needed in the near future, to enable conservationists, government bodies and the landowners themselves to implement a landscape scale conservation scheme.

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