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Effects of golf courses on local biodiversity

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Abstract

There are approximately 2600 golf courses in the UK, occupying 0.7% of the total land cover. However, it is unknown whether these represent a significant resource, in terms of biodiversity conservation, or if they are significantly less diverse than the surrounding habitats.

The diversity of vegetation (tree and herbaceous species) and three indicator taxa (birds, ground beetles (Coleoptera, Carabidae) and bumblebees (Hymenoptera, Apidae)) was studied on nine golf courses and nine adjacent habitats (from which the golf course had been created) in Surrey, UK. Two main objectives were addressed: (1) to determine if golf courses support a higher diversity of organisms than the farmland they frequently replace; (2) to examine whether biodiversity increases with the age of the golf course.

Birds and both insect taxa showed higher species richness and higher abundance on the golf course habitat than in nearby farmland. While there was no difference in the diversity of herbaceous plant species, courses supported a greater diversity of tree species. Furthermore, bird diversity showed a positive relation with tree diversity for each habitat type. It was found that introduced tree species were more abundant on the older golf courses, showing that attitudes to nature conservation on courses have changed over time. Although the courses studied differed in age by up to 90 years, the age of the course had no effect on diversity, abundance or species richness for any of the animal taxa sampled. We conclude that golf courses of any age can enhance the local biodiversity of an area by providing a greater variety of habitats than intensively managed agricultural areas.

Keywords: Golf courses; Conservation; Carabid beetles; Birds; Bumblebees; Biodiversity

1. Introduction

Over the last 30 years, household expenditure on recreation has increased substantially in the UK, for example in 1996 an estimated £9 billion was spent on day trips to the countryside. Recreation and leisure activities do not always pose a significant problem to the environment (Coppock and Duffield, 1975), though impacts on wildlife (Chettri et al., 2001) and habitats (Boyle and Samson, 1985) have been reported. Furthermore, the effect of transport (Cincotta et al., 2000), noise (Mikola et al., 1994) and pollution (Sun and Walsh, 1998) are all concerns expressed by governmental bodies. Activities including hill walking (Riffell et al., 1996), power boating (Bell, 2000), wildlife-photography and skiing (Burger, 2000) have all been shown to disturb wildlife and habitats.

Few of the aforementioned activities have such an intimate interaction with the environment as golf. The game has seen a tremendous increase in popularity over the last 100 years and there are now over 2600 golf courses in the UK and over 31,500 worldwide.

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Golf course establishment has increased by over 42% in the last 30 years (Daniels, 1972) and currently, the UK holds over half of all golf courses found in Europe (Anonymous, 1996). Annual participation in the game increased by 18% between 1987 and 1996 and at that time an estimated 12% of the population played golf over a 12-month period (Anonymous, 1996).

The demand on Britain's 22 Mha from the growing human population and the demand for golf courses has led to changes in course design and management. Following the traditional style of links courses, established in Scotland during the 14th century, the beginning of the 16th century saw the introduction of open inland courses dominated by heathland habitat (Anonymous, 1989). It was not until the 19th century that a new style of golf course was seen to evolve from the landscape garden designs of Lancelot 'Capability' Brown. These parkland golf courses were different from previous, in that shelter in the form of trees and bushes surrounded the course and patches of woodland were found throughout. By 1972, over 54% of golf courses in the UK were parkland courses (Dair and Schofield, 1990).

There has been increasing concern about the magnitude of global biodiversity loss (Gaston, 1996). In the UK, biodiversity is highly concentrated in the south east of the country, as is much of the human population and the majority of golf courses (Gaston, 1996; Lennon et al., 2000; Beebee, 2001). Habitat modification (Terman, 1997), chemical contamination (Murphy and Aucott, 1998), water management (Cohen et al., 1993) and urbanisation around golf courses (Markwick, 2000) are all concerns that have been expressed by those who claim that courses are a poor use, ecologically speaking, of land (Platt, 1994). However, until recently, there was little evidence to support the view that golf courses are good or bad for the environment at a landscape scale. What little information there is suggests that golf courses are not significant sources of water pollution (Cohen et al., 1999) and may be the equal of many natural habitats in terms of animal and plant diversity (Terman, 1997; Gange and Lindsay, 2002).

To date, there is only a handful of research studies that have employed a strict scientific method to the study of wildlife on golf courses with most focusing on links courses (Green and Marshall, 1987; Blair, 1996; Terman, 1997, 2000). All studies have shown that golf courses compare well in terms of wildlife abundance and diversity to that of adjacent areas of land. A feature of these studies (e.g. Blair, 1996; Terman, 1997) is that the diversity of taxa on golf courses has been compared with areas of pristine natural habitat. As shown by Gange and Lindsay (2002), a more realistic question to ask, in terms of landscape ecology, is how the biological diversity of a golf course compares with that of the habitat from which the course was constructed. Gange and Lindsay (2002) present four simple case studies, where in each instance it was found that the diversity of insects and birds on a golf course was higher than that of the surrounding agricultural land. However, this was a short-term study of about 11 weeks and only two courses studied were in the UK. Approximately 60% of the UK is arable and pasture farmland (equally divided between the two), forms of land use known to be of low ecological value and shown to degrade biodiversity (Altieri, 1999; Chamberlain et al., 2000). As land targeted for golf development in the last 20 years has been almost exclusively farmland, it is the aim of this paper to extend the studies of Gange and Lindsay (2002), in terms of duration and replicate number. We sought to determine whether golf courses harbour different levels of biodiversity than the habitats they replace and whether abundance and species richness of certain animal taxa differ between old and young courses. These studies are important, because it is well known that effective course management lies in the understanding of the natural processes, which operate within the course (Brennan, 1992).

2. Materials and methods

2.1. Sites and taxa studied

All sites used in this study are located in the county of Surrey, UK and all golf courses were of the parkland design. It has been suggested that the age of a golf course is an important factor in its wildlife value (Dair and Schofield, 1990), and so courses were selected that fell into one of three age groups, with three replicates in each group. These groups were 1–10, 20–30 and 90 years plus. Nine golf courses and nine adjacent farmland areas were sampled in total. All adjacent areas of land were within 0.5 km of the golf course and all consisted of pasture grassland used for cattle or sheep grazing. The adjacent areas were demarcated by the farm boundary and chosen to reflect the land use that was in existence before a course was created, or what the land would support if it were not a golf course. Hereafter, each course or adjacent area is termed a 'site', thus there were 18 sites in total. Aerial photographs of each site were obtained and the total area of each was calculated.

When measuring diversity, a complete inventory for all species is impossible due to time and effort. We chose well-known indicator species (Kremen, 1992; Pearson, 1996; Simberloff, 1998) that were relatively easy to observe and identify. Vegetation was sampled, as this is the habitat template and dominance and diversity in plant communities dictate the composition and diversity of animal species (Southwood et al., 1983). Birds (Furness and Greenwood, 1993; Gregory and Baillie, 1998), ground beetles (Coleoptera, Carabidae (Butterfield et al., 1995)) and bumblebees (Hymenoptera, Apidae (Saville et al., 1997; Carvell, 2002)) have repeatedly been used as indicator species and were the taxa chosen for this study.

2.2. Recording techniques

Eleven bird censuses were conducted, approximately one every 3 weeks at each site, between 12 November 2001 and 30 June 2002. The Variable Circular Plot (VCP) method was used (Reynolds et al., 1980), which is a form of distance sampling developed from line transects (Buckland et al., 1993). The method does not assume all individuals present are recorded and the observer can miss up to 50% of individuals and still obtain reliable density (Bibby et al., 2000). The VCP method is ideal for bird sampling when habitats within areas are patchy and has proved to be a powerful reliable estimator of bird density for a range of different species (Buckland et al., 1993; Fancy, 1997; Nelson and Fancy, 1999). Birds were only recorded if they were seen utilising the site, i.e. perching, feeding or nesting. We did not record birds by their song alone; because we were not confident of our ability to use sound reliably. This was a deliberate decision, because we wanted to eliminate any possible incidental use of a site (e.g. flying over) and to only record direct utilisation (defined above). Our bird estimates are therefore conservative, but as unbiased as possible.

A square grid drawn to scale and consisting of squares totalling 100 m × 100 m was placed on each aerial photograph. Using this grid, 16 points were randomly selected in each site, each being greater than 200 m apart. The observer stood at each of the 16 points for 5 min and counted all the birds visible. Approaching each point carefully and moving vigilantly between points avoided disturbing any birds. Using reference points (trees, shrubs, fences, etc.) from the aerial photographs, the distance each individual bird was from the point was recorded to the nearest metre. One golf course and one adjacent site were sampled each day with no censuses conducted in high winds or heavy rain. Sampling took place between 06:00 and 10:30 h when bird activity is greatest (Bibby et al., 2000).

The program DISTANCE 3.5 (Thomas et al., 1998) was used to calculate bird density. The program fits field data to a selection of different models (key functions) using series expansions to fine-tune the fit. The data were ungrouped and in cases where the model fit was weak, the data were truncated at varying lengths and percentages, as recommended by Buckland et al. (1993). Means of the 16 data points for density, species richness and diversity in each site on each date were calculated to provide overall site values for analysis.

All invertebrate sampling was conducted for 2 months from 1 May to 30 June 2002. Pitfall traps, consisting of plastic containers 10 cm deep and 5 cm in diameter filled with 30 ml of ethylene glycol as a preservative, were sunk into the ground. These are the most commonly used and highly effective traps for catching ground beetles (Greenslade, 1964; Southwood and Henderson, 2000). Using aerial photographs, 20 traps were randomly placed throughout each site. Samples were collected and stored every 10 days, and identification of species was performed with reference to Lindroth (1974) and Forsythe (2000). Means of the 20 data points for density, species richness and diversity in each site on each date were calculated to provide overall site values for analysis.

Line walking is the most frequently cited method for bumblebee censusing and was the method adopted in this study (Saville et al., 1997; Walther-Hellwig and Frankl, 2000). Surveys were conducted between midday and 15:00 h and consisted of 4 × 100 m line transects, randomly located within each site using aerial photographs. Each site was surveyed 15 times between

1 May and 30 June 2002. Every bumblebee seen whilst walking was either identified on the wing or captured with a net, identified, recorded and released. Recording was only conducted on clear bright days, of low winds. Means of the four transects points for density, species richness and diversity in each site on each date were calculated to provide overall site values for analysis.

Vegetation sampling was divided into two categories (1) trees (sampled in November 2001) and (2) herbaceous species (sampled from 1 June to 18 July 2002). Using aerial photographs, six 50 m × 50 m quadrats for tree sampling and twenty 5 m × 5 m quadrats (hereafter termed 'plots') for herbaceous plants were selected in each site. Tree quadrats were randomly placed, while herbaceous quadrats conformed to stratified random samples, by the avoidance of heavily wooded areas or the actual pasture, or greens, tees and fairways. Within each quadrat, total tree abundance for each species present was recorded. Herbaceous species were sampled using a 38 cm linear steel frame, containing ten 3 mm diameter point quadrat pins. The frame was placed randomly 20 times in each plot, giving a total of 200 pins sampled per plot. The number of touches of all living plant material was recorded in 2 cm (below 10 cm) or 5 cm (10 cm and above) height intervals on each pin. Data for the 200 pins were summed and means calculated of diversity, height of vegetation and species richness (Brown and Gange, 1989). Values for each plot were then averaged to provide site means for analysis.

2.3. Statistical analysis

All data on species richness, abundance, and diversity were analysed using site means as replicates. Bird species were categorised by feeding type (1) insect feeders, (2) other carnivores, (3) seedeaters and (4) omnivorous species. The Shannon–Wiener diversity index (*H*) (Magurran, 1988) was used to estimate diversity for all taxa, except for herbaceous species where Williams Alpha diversity (Southwood and Henderson, 2000) was used. Data was tested for normality and homogeneity of variance and where appropriate square root transformations were made. Zero values were rare and did not compromise any of the analyses. A repeated measures analysis of variance, using date and site as the main effects was performed on diversity, abundance and species richness for each organism group. Meanwhile, single factor analysis of variance was used to examine whether course age had an effect on density and diversity of each group.

3. Results

3.1. Vegetation

Tree diversity was higher on the golf course habitats than the adjacent land sites ($F_{1,16} = 6.42$, $P < 0.05$), with a mean of 10.4 species per 2500 m^2 being found in golf course habitats compared to 7.4 species per 2500 m^2 on the adjacent lands. The proportion of native trees in the landscape differed between course types ($\chi^2 = 0.75$, $P < 0.01$), with oldest courses having significantly fewer natives (74.1%) than middle aged (81.8%) or young courses. The proportion of native trees on youngest courses (84.7%) was lower, but not significantly so, compared with that of the surrounding farmland (91.9%). No differences were found in the herbaceous vegetation (diversity, species richness or height) between the two habitats.

3.2. Bird species

Bird diversity was significantly higher on the golf courses than the adjacent areas of land ($F_{1,16} = 7.67$, $P < 0.05$; Fig. 1a). A significant interaction term between site and date was found in the analysis ($F_{10,160} = 1.94$, $P < 0.05$), because the two habitats did not show a similar pattern of change through the season. The golf course habitats had higher species richness than the adjacent sites ($F_{1,16} = 13.92$, $P < 0.05$), with an average of 13 bird species seen on each sample date, compared to 11 species on each date in the adjacent sites.

There was no difference in the density of birds between the habitat types, and neither was there any significant change in bird abundance over time (Fig. 1b). However, there was a highly significant association between bird species diet and habitat type ($\chi^2 = 19.36$, $P < 0.01$). Higher proportions of insect feeding birds (28%) were found on the golf course habitats compared to the adjacent land types (19%). Meanwhile, omnivorous species (e.g. the Rook (*Corvus frugilegus*) and Magpie (*Pica pica*)) were found in higher pro-

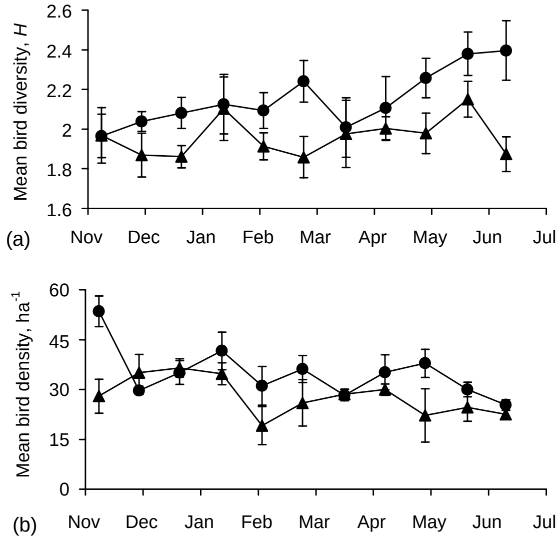

Fig. 1. (a) Mean bird diversity (*H*) and mean bird density (numbers per ha) (b) on golf course habitat (●) and adjacent land sites (▲). Vertical bars represent one standard error.

portions within the adjacent sites (56%) than the golf course habitat (46%). The age of the golf course had no effect on bird density, diversity or species richness.

A significant relationship was found between bird diversity and tree diversity in each habitat type (Fig. 2). Of most interest was the fact that the slopes of the regression lines for each habitat type were significantly different ($t = 2.29$, d.f. $= 14$, $P \leq 0.05$), indicating that for any given value of tree diversity, bird diversity was higher on the golf courses than the adjacent land sites. However, the lines appeared to converge, such that at high tree diversity, one might predict no difference between the courses and adjacent areas.

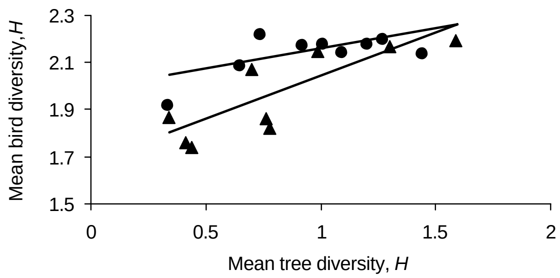

Fig. 2. The relationships between bird diversity and tree diversity, for nine golf courses ($r^2 = 0.706$; $F_{1,7} = 16.796$; $P < 0.05$) (●) ($y = 0.265x + 1.902$) and nine adjacent sites ($r^2 = 0.705$; $F_{1,7} = 16.75$; $P < 0.05$) (▲) ($y = 0.366x + 1.663$).

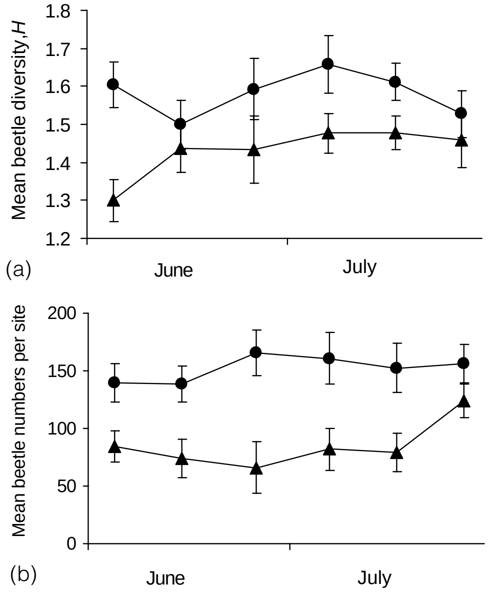

Fig. 3. (a) Mean Carabid diversity and mean total numbers caught (b) on the nine golf courses (●) and nine adjacent sites (▲). Vertical bars represent one standard error.

3.3. Carabid species

There was some evidence that beetle diversity differed between the two habitat types ($F_{1,16} = 4.21$, $P = 0.057$, Fig. 3a). However, numbers of beetle individuals captured were much higher on the golf courses than the adjacent sites ($F_{1,16} = 20.40$, $P < 0.001$, Fig. 3b) and an average of 8.4 different species were found on each date on the golf courses, compared with 6.5 species on the adjacent sites ($F_{1,16} = 6.59$, $P < 0.05$). There was no significant interaction term between site and date for any of the beetle data, indicating that beetles followed similar temporal patterns in the different areas. The age of the golf course had no effect on beetle abundance, diversity or species richness.

3.4. Bumblebee species

There was no difference in diversity (Shannon–Weiner *H*), of bumblebees between golf course habitats and adjacent sites (Fig. 4a). However, bumblebees

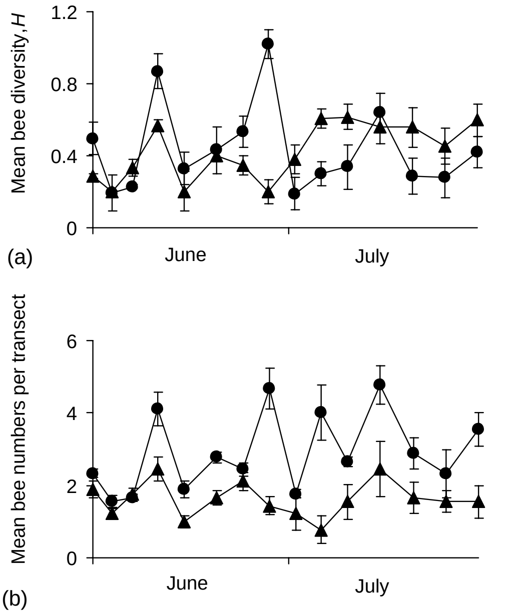

Fig. 4. (a) Mean bumblebee diversity and mean total numbers caught (b) on the nine golf courses (●) and nine adjacent sites (▲). Vertical bars represent one standard error.

showed a highly significant difference in abundance and species richness per 100 m when comparing the two habitat types. The golf courses had higher abundance ($F_{1,16} = 19.41$, $P < 0.001$) and higher species richness ($F_{1,16} = 24.41$, $P < 0.001$) than the adjacent farmland. An average of six species per transect were found on the courses, compared with three species per transect at the adjacent sites. Both bumblebee diversity ($F_{15,240} = 1.94$, $P < 0.05$) and abundance ($F_{15,240} = 2.12$, $P < 0.05$, Fig. 4b) showed a significant interaction term between site and date. This was because for both variables, values on the adjacent land stayed relatively constant through time, whereas the course showed fluctuating values. In the case of diversity, values for the course were higher early in the season, but lower in late season, thereby contributing to the fact that there was no overall effect of site in the ANOVA (above). The age of the golf course had no effect bee diversity, abundance or species richness.

4. Discussion

These results show that, for the taxa studied, golf courses can contain levels of biodiversity equal to or above that of the habitats they replace. Gange and Lindsay (2002) discuss how enhancing biodiversity is about conserving species local to an area, not just increasing numbers. Every species has specific habitat preferences and green keepers can contribute greatly to conservation by providing such habitats for endangered local species. We suggest that the variety of habitats that a golf course provides is potentially greater than that of farmland, thus enabling a greater diversity of species to exist. By increasing habitat heterogeneity within a landscape, golf courses can enhance the diversity of a local area.

The age of the golf course had no effect on diversity for any of the taxa studied. This was surprising, because one might think that over time a greater variety of habitats on a golf course would become established, thereby enhancing biodiversity. One possible explanation lies in the identity of the vegetation in the different sites. Older courses were found to harbour a greater amount of introduced tree species, many of which were planted for their aesthetic, rather than ecological value. Introduced tree species provide poorer habitats for birds than native trees (Fuller, 1997) and they can affect biodiversity by changing the composition, structure and community pattern of an ecosystem (Peterken, 2001). Although the diversity of native trees was often lower on the golf courses, we found that for any given value of tree diversity, bird diversity was higher on the golf courses than the adjacent land sites, with each habitat displaying a different temporal change through time. These results are consistent with other studies (Blair, 1996; Terman, 1997; Gange and Lindsay, 2002). It is known that mass planting of introduced species in plantations, like conifer forests, does reduce bird diversity (Fuller, 1997), but in the case of golf courses, bird diversity could be reacting to the stand diversification produced by the array of exotic and native species rather than individual introduced species.

It should be noted that the regression for golf courses is clearly dependent on one datum, that of the lowest value for tree diversity, suggesting that further work needs to be done to assess the validity of the relation. However, an important point is that if the slope of the regression for golf courses was close to zero, this would imply that bird diversity was high, irrespective of tree diversity. Such a result suggests that other habitats on the golf courses are very important in affecting the diversity of birds that inhabit the area. Furthermore, we found that the regression lines tended to converge, suggesting that at high tree diversity, farmland would be the equal of the golf course in terms of bird diversity and could even exceed it. Extrapolation of regression lines is dangerous and only further research can confirm or refute this hypothesis.

A second explanation for the lack of course age effects is the mobility of the groups we studied. Birds, ground beetles and bumblebees are all highly mobile creatures and all of them would have no difficulty colonising new golf course developments. For taxa that are less mobile or slow to disperse, course age may well affect their occurrence, and again this highlights the need for further research in this area.

A final point regarding the lack of course age effects concerns the dietary requirements of the organisms studied. Although different bird feeding types were found between the sites (below), none of the birds, beetles or bumblebees found could be considered as extreme dietary specialists. Even species common on the courses, (but not recorded on the farmland) such as the green woodpecker (*Picus viridis*) (which feeds on ants) or the song thrush (*Turdus philomelos*) (which prefers snails) are just as likely to find food on a 5-year as they are on a 100-year old course. However, the abundance of this food may change with time (e.g. one would expect ant colonies to increase with course age) as will the structure of the habitat in which it is found. Future research should take into account the degree of specialism of the taxa studied, in order to determine whether older courses harbour greater numbers of specialist species and whether this is related to food or habitat availability. Certainly, one would expect more specialists in older sites (Southwood et al., 1983) and these are often the rare species in a community (Gaston, 1996).

It is most likely that combinations of environmental factors are shaping bird diversity on the golf courses including topography, nest sites, the 'health' of the site (Furness and Greenwood, 1993), and food source. The two habitats attracted different types of bird species (insect feeding birds were more common on the golf course habitats compared to the adjacent sites, while omnivorous species were rarer) due to the vegetation composition of each habitat, invertebrate abundance and the land-use of each habitat. The adjacent sites were pasture farmland which has repeatedly been shown to contain homogenous habitats and low levels of biodiversity (Gregory and Baillie, 1998; Chamberlain et al., 2000; Stoate et al., 2001). Birds do not abide by man-made boundaries and confusion can arise as to which birds are using the site and which are just using the course as a stepping stone to other habitats. To overcome this problem, individuals were only recorded if they were seen utilising the site. Given that we also did not use song as a measure of presence, we believe that our estimates of bird diversity on courses are very conservative and show an encouraging diversity of birds on courses. Many bird species are becoming increasingly rare due to intensive agricultural farming, loss of preferred habitat, pollution and land-use changes (Gill, 1990; Gregory and Baillie, 1998). It is possible that the presence of golfers could disturb birds and impact on breeding patterns but evidence suggests bird communities can withstand intermediate levels of human activity like golfers (Riffell et al., 1996; Chettri et al., 2001).

It has been suggested that golf courses could act as 'sink' habitats, into which species are attracted, only to be killed by exposure to pesticides (Terman, 1997). While, in theory at least, this is quite possible, there appears to be no scientific evidence to support or refute this suggestion. While not being specifically tested for in our study, we found no evidence to support this idea. In all the bird surveys we conducted, not a single dead bird was seen whose death could be attributed to anything other than predation. Furthermore, certain bird species, whose decline in numbers have been attributed to agricultural pesticides (e.g. *T. philomelos*, Bullfinch, (*Pyrrhula pyrrhula*) and Kestrel, (*Falco tinnunculus*)) were all found feeding on golf courses, but not on the adjacent areas.

Species richness and abundance of carabid ground beetles were higher on the golf course habitat than the adjacent sites. The difference in beetle numbers can be attributed to courses having heterogeneous habitats, which provide varying microclimates (Gange and Lindsay, 2002). Carabid species are vital omnivorous predators in arable fields, providing farmers with a natural self-regulating pest control, but numbers and species in intensive agricultural cultivation have repeatedly been shown to be low (Kromp, 1999). An interesting finding made by Lindsay (2003) is that these beetles were never recorded crossing fairways on golf courses, indicating that these are major barriers for some invertebrate species. Incorporating natural buffer zones within the golf course and between adjoining sites, as suggested by Terman (2000), could provide wildlife with natural corridors. It is a fact that between 40 and 70% of a golf course is non-play areas of varying habitats (Anonymous, 1989; Terman, 1997) which has the potential to act as corridors within the course. More studies such as that of Gange et al. (2003) are required so that management of golf course habitats can be better informed by ecological research.

There is growing concern about the decline in the natural populations of several species of bumblebee in Europe, and only six of Britain's 19 species are now regularly found in the countryside (Carvell, 2002). Declines in populations have been attributed to habitat loss and agriculture intensification (Saville et al., 1997). We found that the species richness and abundance of bumblebees was higher on the golf course habitats than the adjacent habitats. Nest site availability, abundant flowering herbaceous species and low management intensity (in the rough) are possible explanations for the higher numbers and species of bumblebees found on the courses. Often golf courses have a varied ground surface with exposed banks, which are ideal nesting sites for some bee species (Gange and Lindsay, 2002). Such heterogeneous habitats with uneven, exposed ground are much less common on farmland and pasture. Our data suggest that the presence of a golf course in a landscape could have a positive effect on bumblebee populations, though as yet we do not know if courses can act as reservoirs of these insects. If golf courses can act as source habitats for bees, then they could greatly enhance crop pollination and production in nearby areas.

We are aware that our data only cover one season. Future studies in golf course ecology should include multi-species sampling and large sample sizes, performed over longer periods of time. Recording species movements within golf courses (and between golf course and adjacent sites) is vital, so that green keepers and ecologists can formulate biological action plans, which target specific endangered species and promote their existence with the course. These problems are the subject of our current research.

5. Conclusion

In the current age of golf expansion, the most meaningful question to address is whether construction of a golf course can enhance local biodiversity, compared with the farmland from which it is invariably formed. This study has shown that golf courses can enhance the diversity of three indicator groups (birds, ground beetles and bumblebees), relative to adjacent pasture farmland. More studies are needed to determine if golf courses act as source or sink habitats for beneficial insects and rare species, or conversely, whether they can act as refuges for pest species too. Different forms of farmland, involving varying intensities of agriculture also need to be considered.

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