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Although golf courses are not substitutes for naturally occurring habitats, landscaping characteristics of golf courses may provide several benefits for wildlife. In this study, researchers investigated the value of golf courses for butterfly conservation using six golf courses within a 50-kilometer radius of Cincinnati, Ohio.

Volume 3, Number 14
July 15, 2004

PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of \$25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
904 Highland Drive
Lawrence, KS 66044
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

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Assessing the Conservation Value of Golf Courses for Butterflies

Eric E. Porter, Derric N. Pennington, Jason Bulluck, and Robert B. Blair

SUMMARY

Golf courses are prime examples of partially developed areas that may serve as valuable habitat refuges for many wildlife species. In this study butterfly communities were used to investigate the value of golf courses for conservation.

- Six golf courses surrounded by landscapes of varying degrees of land-use intensity were identified and butterfly communities were examined within these courses to identify factors that promote diverse butterfly assemblages. GIS and aerial photography were used to estimate percentages of different land-cover types surrounding each golf course using buffers at scales of 100-1000 meters. On-site vegetation characteristics were recorded.

- Butterfly species composition varied among all courses with only the two most developed courses missing substantial numbers of species.

- Abundance, species richness, and diversity measures decreased as the surrounding land uses of the courses became more urban. Butterfly abundance was significantly related to the land-cover characteristics measured in buffers surrounding the courses and natural land-cover had the strongest relationship with all of these measures.

- These findings suggest that a golf course with both a small buffer, free of development, along with a larger buffer comprised of patches of natural area improves its conservation value.

On a global scale, the conversion of natural landscapes to urban and suburban land uses is a primary threat to biodiversity (26, 37). As settlement has progressed, land cover has changed from natural vegetation to suburban and urban areas characterized by the introduction of exotic vegetation used in landscaping and by progressively more impervious surfaces in the form of roads,

ERIC E. PORTER, Ph.D., Carlsbad Fish & Wildlife Office, Carlsbad, CA; DERRIC N. PENNINGTON, Ph.D., Department of Fisheries, Wildlife & Conservation Biology, University of Minnesota, St. Paul MN; JASON BULLUCK, 2317 Fair Drive, Knoxville, TN; and ROBERT B. BLAIR, Ph.D., Department of Fisheries, Wildlife & Conservation Biology, University of Minnesota, St. Paul MN

parking lots, sidewalks, and buildings. The remaining natural vegetation within human settlements is becoming increasingly important for many species of wildlife (8). Identifying the value of partially developed areas for wildlife conservation is important if we hope to sustain healthy populations of species of wildlife now dependent on such areas (8, 22, 23).

Golf courses are prime examples of partially developed areas that may serve as valuable habitat refuges for many wildlife species (35). Previous work on urbanization gradients in two bioregions, coastal California and southwest Ohio, suggested that golf courses contain relatively high species richness and Shannon diversity (2, 4). Golf courses are not substitutes for naturally occurring habitats, but the landscaping characteristics of golf courses may provide several benefits for wildlife (10, 35). In this study, we use butterfly assemblages to investigate the value of golf courses for wildlife conservation.

The conservation value of golf courses has



One of the most common skipper species in southwest Ohio, the Silver-spotted Skipper (*Epargyreus clarus*) can be found in a wide variety of habitats. Common hostplants for larvae include tree and herb Leguminosae. The favored species, Black Locust (*Robinia pseudoacacia*), is an early successional native species in southwest Ohio.

been subject to debate (15,16, 20). While golf courses tend to be small compared to most nature reserves, even small patches can make important contributions to conservation efforts in a "sea of urban development" (36). For aesthetic reasons and to delineate boundaries, most golf courses contain large trees and forest patches. While greens and fairways are often monocultures of grass mowed frequently, roughs, grassy areas surrounding greens and fairways that are mowed only rarely may provide less disturbed habitat for butterflies.

Butterfly assemblages are strongly associated with vegetation change because they have short generation times and often depend on one or a few species of larval host plants. Additionally,



An exotic species, the Cabbage White (*Pieris rapae*) was introduced into North America in the mid 1800s and has become our most widespread species. Cabbage Whites were the most abundant species across all golf courses for our study. Many crucifers (*Brassicaceae spp.*), as well as nasturtiums (*Tropaeolaceae spp.*) found in gardens, cities, and disturbed areas are food sources for butterfly larvae.

butterflies have important functional roles as selective herbivores and pollinators and as prey for a variety of bird species. These characteristics, coupled with the relative ease of butterfly identification, have led workers to develop ecological indexes of habitat quality based on butterflies (17). These characteristics make butterflies common subjects for studies of human-altered ecosystems (3, 18, 29). Typically, researchers working in urban areas find that butterfly species composition changes along gradients of land-use intensity because urbanization tolerant species invade altered landscapes (3, 4, 29, 31).

Previous work on urban gradients in both southwestern Ohio and coastal central California showed that butterfly richness and diversity are quite high in golf courses (3, 4). These results are in agreement with previous work suggesting that golf courses can serve as important wildlife habitat within altered ecosystems (10, 35).

While our previous work treated golf courses as one type of land use within a spectrum of urban and suburban land uses, we realize that golf courses can be found in a variety of surroundings, and can vary in landscaping practices. We initiated this study in order to assess the variation among golf courses in terms of their ability to support diverse butterfly assemblages. We used this approach because we hoped to identify factors that can promote wildlife diversity within golf courses.

Recently, researchers have begun to evaluate the importance of both on-site and surrounding landscape characteristics in determining species distributions among fragmented and degraded habitats. Results have varied with some researchers finding strong effects of surrounding landscape matrices (32) and others finding negligible effects of the surroundings (19). Results of studies that have examined the influence of surrounding landscapes matrices on butterfly and moth assemblages have been mixed as well.

Ricketts et al. (28) found little difference in species richness of moths among areas subject to different agricultural practices; however, they showed that the amount of forest cover within 1.0 and 1.4 km of their study areas significantly influ-

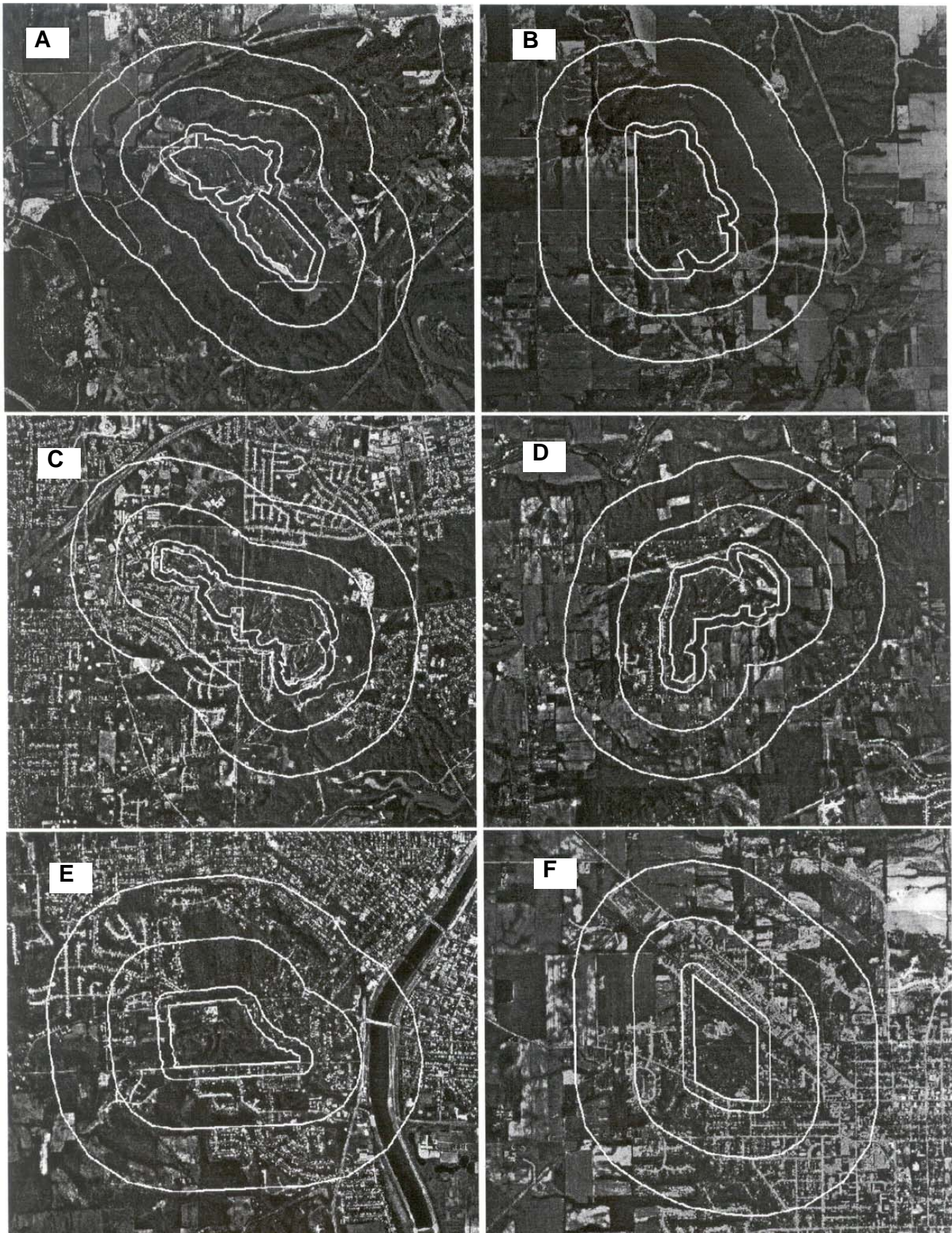


Figure 1. Aerial photographs of each golf course arranged in order from lowest to highest land-use intensity: (A) Miami Whitewater, (B) Hueston Woods, (C) Winton Woods, (D) Twin Run, (E) Potter's Park, and (F) Oxford Country Club. These photographs were used to generate land-cover categories within 100-meter, 500-meter, and 1-kilometer buffers surrounding each course. White lines indicate the outer limits of each buffer size.

enced moth richness. In a similar landscape, Horner-Devine et al. (13) found that the correlation between forest cover and both species richness and abundance of butterflies decreased with distance from the sample point. Collinge et al. (6) reported no significant influence of landscape surroundings on butterfly diversity in grassland patches. Instead, the grassland type and degree of habitat degradation were the primary influences on butterfly diversity.

Due to the high variability in land cover surrounding golf courses, we used aerial photography and Geographic Information Systems (GIS) to quantify characteristics of the landscape surrounding each golf course in our study. Using this approach we estimated percent cover of various land uses in buffers of 100 - 1000 m surrounding each golf course. We compared the influence of on-site land cover and tree biomass versus surrounding landscape characteristics on butterfly assemblages.

Methodology

Field Sites

We sampled 6 golf courses within a 50 km radius of Cincinnati, Ohio in the Eastern Broadleaf Forest (1). We specifically selected the courses to represent a gradient of land-use intensity (Figure 1). We arranged the courses along the intensity gradient using landscape-level characteristics of buffers around each course as well as on-site environmental characteristics at butterfly sampling points. We sampled the following golf courses arranged in order of increasing land-use intensity:

1) Miami Whitewater- This course lies within the Miami Whitewater Forest near Harrison, Ohio, under the management of the Hamilton County Park District. The course covers 80.6 hectares (199 acres) and is largely surrounded by second growth forests and a lake.

2) Hueston Woods- This course is managed by Hueston Woods State Park near Oxford, Ohio. The course covers 106.4 hectares (263

acres) and is surrounded by virgin and second growth forests, agricultural fields, and old field plots.

3) The Mill Course at Winton Woods- This course lies within the Winton Woods Forest near Cincinnati, Ohio, under the management of the Hamilton County Park District. The course covers 84.3 hectares (208 acres) surrounded by second growth forest and residential areas.

4) Twin Run- This municipal course is located on the outskirts of Hamilton, Ohio. The course covers 57.2 hectares (141 acres) and is surrounded by old field, active agriculture, and residential developments.

5) Potter's Park- This municipal course is located within Hamilton, Ohio. The course covers 39.7 hectares (98 acres) and is surrounded by high-density residential development.

6) Oxford Country Club- This private course is located within Oxford, Ohio. The course covers 22.9 hectares (57 acres) and is surrounded by agriculture, residential areas, and urban development.

Survey Methods

We surveyed each site 3 to 5 times during the summers of both 2000 (July 17 - August 2) and 2001 (July 11 - August 15) for a total of 8 sampling periods. July and August are within the flight period peaks for many butterflies in Ohio (14). Each site was divided into 8 areas of approximately 2 hectares (5 acres) which we walked for 15 minutes each between 10:00 a.m. and 4:00 p.m.. We sampled only on cloudless days with minimal breezes. We noted all species that were seen during each 15-minute sampling period and captured voucher specimens of the species that were difficult to identify. This method results in a measure of relative abundance of each species for each sampling period, which ranges from 0 (no individuals of that species seen during that sampling period at that site) to 8 (at least one individual of that species seen in each area during the sampling period at that site). When all eight sampling periods were combined, the measure of relative abundance of each species in each site ranged from 0 to 64.

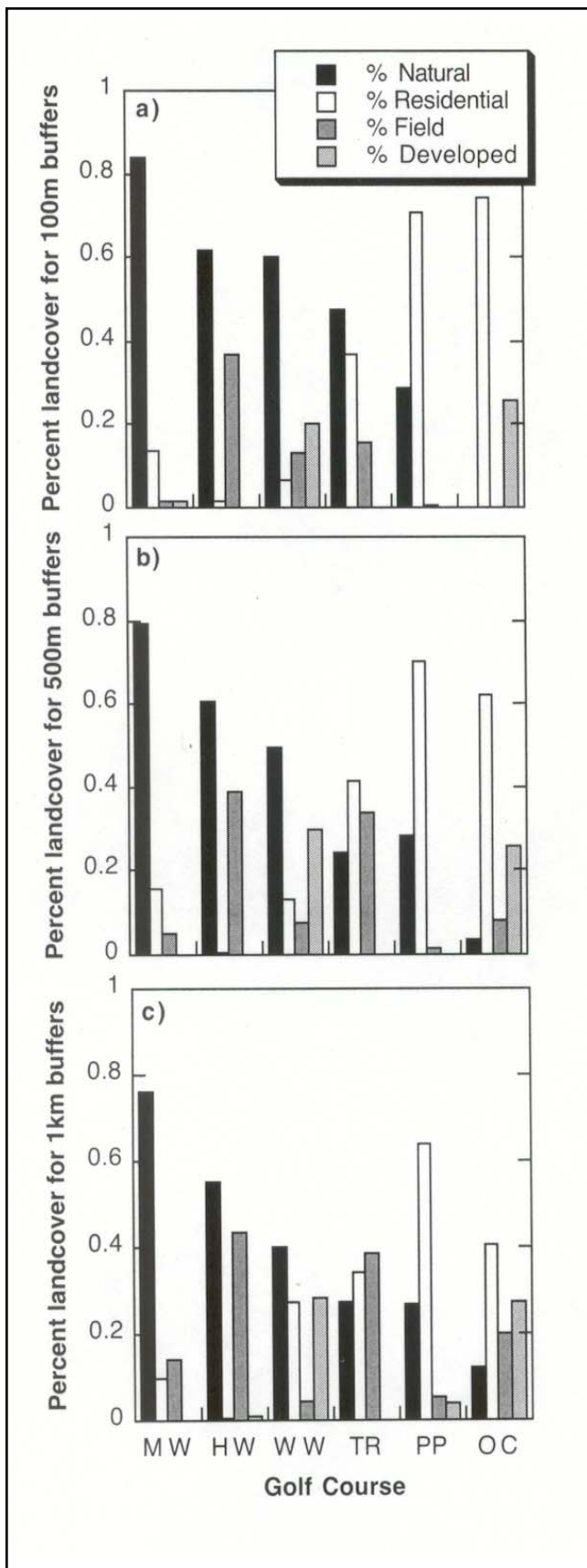


Figure 2. Percent cover of land-cover categories in (a) 100-meter, (b) 500-meter, and (c) 1-kilometer buffers surrounding each golf courses

Buffers around golf courses

We quantified characteristics of the landscape surrounding each golf course using remotely sensed data and ArcView 3.2 GIS Software. One-kilometer buffers were constructed around each golf course. Throughout the 1 km buffers for all courses, we described the landscape as any of four land-cover types or patches: (1) developed (50-100% impervious), (2) residential (2-49% impervious), (3) field (both agricultural and old field), and (4) natural (including forested upland and forested riparian areas). We used percent land-cover of each of these four classes for statistical analyses.

We digitized and identified each land-cover patch within the 1-km buffer as one of the nine land-cover classifications. The first buffer was established at the edge of the actively maintained portion of the course. We then constructed nine additional 100-meter buffers around each golf course perimeter starting at 100 meters and ending at 1 kilometer. We quantified the percent cover of each land-cover type within each buffer. For simplicity, we only present results from 100, 500 and 1000 m buffers. Finally, we digitized the perimeter of the golf courses to quantify the area of each golf course proper.

On-site independent variables

We measured vegetation characteristics within two 50-meter radius circular plots within each butterfly sampling patch. We combined the plots for each transect leaving a total of 8 vegetation samples for each course.

We followed guidelines outlined by Noon (24) to characterize plant biomass and composition within courses. We measured diameter at breast height (DBH) for all plants with DBH greater than 10 cm (trees) within sample circles. Each tree was identified to species and categorized as native or introduced and deciduous or evergreen according to Braun (5). We used total diameter at breast height (the sum DBH of all trees) as a measure of tree biomass. We used percent native DBH to characterize the degree to which native species had been replaced by golf course designers. We classified tree origin as

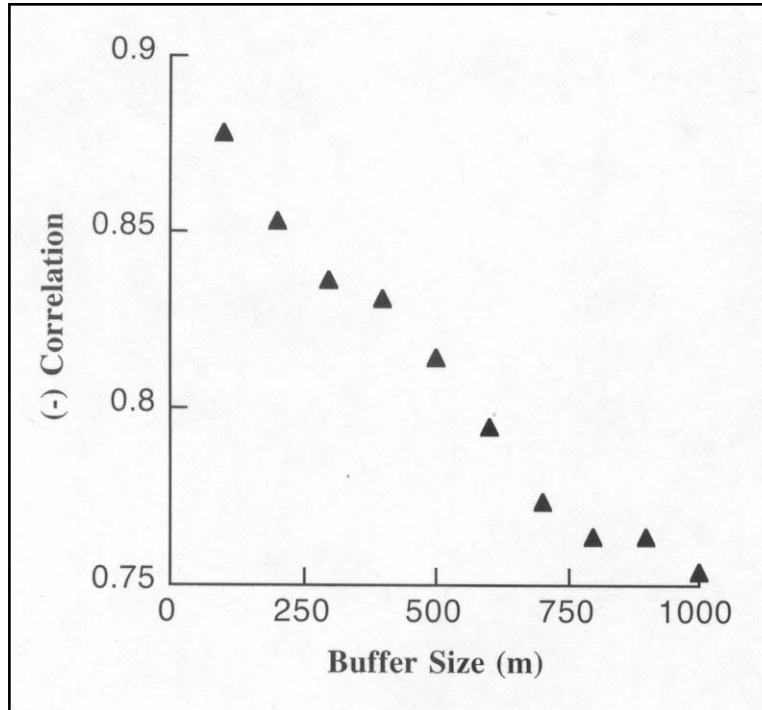


Figure 3. Correlation coefficients between percent natural cover and percent residential cover across lanscape buffer measures

unknown for individuals that we could not identify to species. Because the native forest is almost exclusively deciduous, we used percent deciduous DBH as another measure of the degree of replacement of native species.

We also measured on-site land cover categories within the vegetation sampling plots. In each plot we estimated percent cover of greens, tees, fairways, rough, unmarked rough, impervious structures (buildings and pavement), and water. Grass height varies among golf courses, but grass in greens and tees is always relatively short compared to fairways. For the courses included in this study, unmarked rough usually indicates areas with trees. We grouped land cover into four categories for analysis: mowed (green, tee and fairway), rough, unmarked rough, and impervious (built structures and pavement).

Data Analysis

We used Analysis of Variance (ANOVA)

on total diameter at breast height (DBH) and the dominant cover types (mowed, rough, unmarked rough, impervious surface, and open water) to evaluate whether significant variation existed in on-site environmental characteristics among golf courses. We did not do the same at the larger spatial scale with the land cover data because GIS buffers are complete measures rather than samples and statistical comparisons among sites are inappropriate and unnecessary.

We estimated butterfly abundance (N) at each site by summing the relative abundance of all species. For example, if the relative abundance of *Pieris rapae* was two and the relative abundance of *Colias eurytheme* was one, then the butterfly abundance was three. We calculated species richness (S) as the number of species seen at each site. We also estimated total richness (7) and calculated Shannon diversity (H') and evenness (E) using the number of species within a site and the relative abundance of each species (11, 21).

We used two separate approaches to identify factors most closely related to measures of butterfly diversity. First, we performed simple linear regressions between each land-cover variable and butterfly diversity measures of butterfly abundance (N), species richness (S), Shannon diversity (H'), and evenness (E). We performed Canonical Correspondence Analysis (CCA) to evaluate effects of land cover (1-kilometer buffer) on butterfly abundance in each course. CCA is a technique that can be used to measure the influence of environmental variables on assemblages. We chose to include only natural, residential, and field cover in the CCA. We used cluster analysis to identify butterfly life history characteristics associated with patterns in species composition among courses. We looked for patterns in species composition based on taxonomy, vagility, number of broods per year in Ohio, host plant type, and host plant specificity (Table 1, references 9, 14, and 30).

Results

Gradient of Courses

At the 1-km buffer, percent natural cover generally decreased along the land-use intensity gradient (Figure 2). Percent residential cover generally increased along the same gradient. Field and developed cover did not vary predictably along the gradient. Within each land-cover type, all values were significantly correlated to the next largest scale (e.g. 100 m % natural was correlated with 500 m % natural, and 500 m % natural was correlated with 1 km % natural, etc.). Percent natural cover was significantly related to % residential cover except in the 1-km buffers (Figure 3).

There was no significant variation in either mowed or rough cover among golf courses (Figure 4a). There was significant variation in total diameter at breast height (DBH) among golf courses, and native deciduous trees dominated each course (Figure 4b,c). Variation in diameter at breast height (DBH) did not correspond to the land use gradient. With the exception of Hueston Woods, diameter at breast height (DBH) tended to

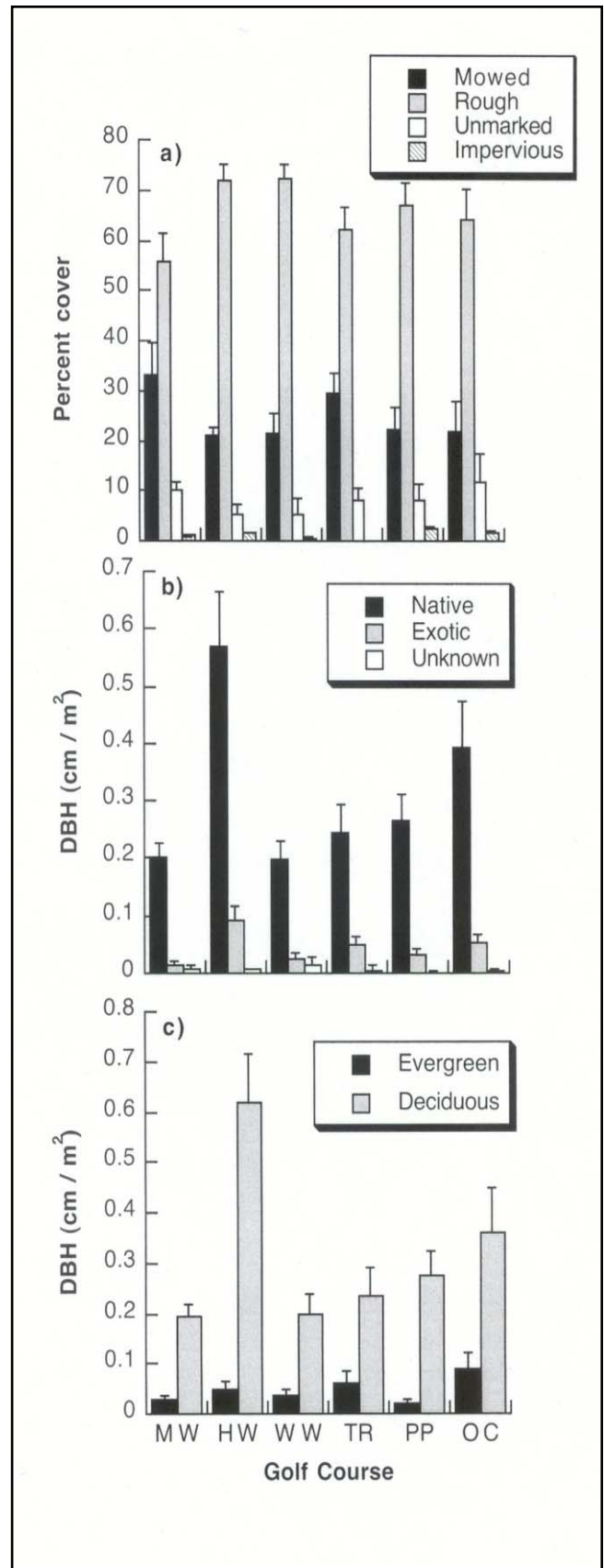


Figure 4. On-site habitat characteristics measure for each golf course.

be higher in smaller courses though the relationship was not statistically significant. Course area was positively related to percent natural cover in 100- and 500-meter buffers, and negatively related to percent residential cover for all buffer sizes. No other on-site variables showed significant relationships.

The Influence of Environmental Variables on Butterfly Community Measures

We recorded a total of 33 species of butterflies. Ten species were present at all six courses

and 17 species were present at five of the six courses (Table 1). While species composition and abundance varied among courses, there were no obvious patterns in species distributions among courses. The cluster analysis revealed no patterns in butterfly species distributions in relation to any life history characteristic. All assemblage / diversity measures (butterfly abundance, species richness, Shannon diversity, and evenness) generally decreased along the gradient of land-use intensity.

Butterfly abundance was significantly related to species richness and Shannon diversity

Family	Species	Common name	Broods	Host plants
Papilionidae	<i>Battus philenor</i>	Pipevine Swallowtail	3-Feb	<i>Aristolchia spp.</i>
Papilionidae	<i>Eurytides marcellus</i>	Zebra Swallowtail	3-Feb	<i>Asimina spp.</i>
Papilionidae	<i>Papilio cresphontes</i>	Giant Swallowtail	2	Rutaceae
Papilionidae	<i>Papilio glaucus</i>	Eastern Tiger Swallowtail	2	trees and shrubs
Papilionidae	<i>Papilio polyxenes</i>	Black Swallowtail	2	herbs and shrubs
Papilionidae	<i>Papilio troilus</i>	Spicebush Swallowtail	2	Lauraceae
Pieridae	<i>Colias eurytheme</i>	Orange Sulfur	5-Mar	Legumes
Pieridae	<i>Colias philodice</i>	Clouded Sulfur	5-Mar	Legumes
Pieridae	<i>Pieris rapae</i>	Cabbage White	5-Mar	Crucifers
Nymphalidae	<i>Asterocampa celtis</i>	Hackberry Emperor	2	<i>Celtis spp.</i>
Nymphalidae	<i>Asterocampa clyton</i>	Tawny Emperor	1	<i>Celtis spp.</i>
Nymphalidae	<i>Boloria bellona</i>	Meadow Fritillary	3-Feb	Viola spp.
Nymphalidae	<i>Cercyonis pegala</i>	Common Wood-nymph	1	Grasses
Nymphalidae	<i>Danaus plexippus</i>	Monarch	4-Feb	Asclepiadaceae
Nymphalidae	<i>Junonia coenia</i>	Common Buckeye	2-Jan	Plantaginaceae
Nymphalidae	<i>Limenitis arthemis</i>	Red-spotted Purple	2	trees
Nymphalidae	<i>Megisto cymela</i>	Little Wood-satyr	1	Grasses
Nymphalidae	<i>Nymphalis antiopa</i>	Mourning Cloak	1	trees
Nymphalidae	<i>Phyciodes tharos</i>	Pearl Crescent	4-Mar	<i>Aster spp.</i>
Nymphalidae	<i>Polygonia interrogationis</i>	Question Mark	2	trees and vines
Nymphalidae	<i>Spyeria cybele</i>	Great Spangled Fritillary	1	<i>Viola spp.</i>
Nymphalidae	<i>Vanessa atlanta</i>	Red Admiral	2	herbs
Nymphalidae	<i>Vanessa cardui</i>	Painted Lady	3-Jan	herbs
Lycaenidae	<i>Celastina ladon ladon</i>	Spring Azure	3-Feb	trees and shrubs
Lycaenidae	<i>Everes comyntas</i>	Eastern Tailed-blue	5-Mar	Legumes
Lycaenidae	<i>Mitoura gryneus gryneus</i>	Juniper Hairstreak	2	<i>Juniperus spp.</i>
Lycaenidae	<i>Strymon melinus</i>	Gray Hairstreak	3	Herbs
Hesperiidae	<i>Ancyloxypha numitor</i>	Least Skipper	3	Grasses
Hesperiidae	<i>Epargyreus clarus</i>	Silver-spotted Skipper	3-Feb	Legumes
Hesperiidae	<i>Polites peckius</i>	Peck's Skipper	2	Grasses
Hesperiidae	<i>Polites mystic</i>	Long Dash	1	Grasses
Hesperiidae	<i>Pompeius verna</i>	Little Glassywing	1	<i>Tridens flavus</i>
Hesperiidae	<i>Thorybes pylades</i>	Northern Cloudywing	1	Legumes

Table 1. Butterfly life history characteristics used in cluster analysis to identify patterns common in assemblages among golf courses (9, 14, 30).

and marginally related to evenness. Abundance and Shannon diversity were significantly related to both natural and residential land-cover in at least some buffer sizes. Evenness was related to natural land-cover at all buffer sizes, and it was related to residential land-cover in only the smallest buffers. The CCA revealed a significant relationship between butterfly distributions and land cover within 1 kilometer of the golf course..

Discussion

For this study, we purposely selected golf courses located within a variety of surrounding landscapes, from natural areas composed primarily of forest, fields, and open water to primarily residential and business areas. This variation is clearly illustrated by the buffer data derived from aerial photography for each golf course. In general, various measurements of land cover in the 100-meter buffers confirm the land-use intensity gradient, and this pattern carried through the 500-meter and 1-kilometer buffers.

On-site vegetation characteristics and land cover did not vary along the land-use intensity gradient in the same pattern. Golf courses surrounded by the most intense development tended to have high tree biomass. This pattern is likely due to the spatial constraints of designing small golf courses. Courses surrounded by more intense development were smaller than courses in more natural settings. Due to the use of wooded areas to delineate holes, trees were generally closer to greens and fairways in smaller courses. Therefore, trees were more frequently encountered in vegetation sampling on smaller courses.

Butterfly species composition varied among all courses, with only the two most developed courses, Potter's Park and Oxford Country Club, apparently missing substantial numbers of species. In general, abundance, species richness and diversity measures decreased along the gradient from natural to more urban golf courses. Abundance was significantly related to land-cover characteristics measured by buffers.

In general, natural land-cover had the strongest relationship with all measures, illustrat-



The Zebra Swallowtail (*Eurytides marcellus*) was one of the most habitat-sensitive species observed in the study. Pawpaw (*Asimina triloba*) is the only species of the tropical hostplant family Annonaceae found in the Midwest for Zebra Swallowtail larvae. Pawpaws grow wild in the understory of rich, mesic hardwood forests. Large wooded areas adjacent and surrounding golf courses can provide important habitats for our most distinctive swallowtail butterfly.

ing that golf courses surrounded by a higher proportion of undeveloped areas support higher butterfly diversity. Earlier work by Blair and Launer (3) showed that low levels of human alteration can increase butterfly diversity, but diversity decreases with more intense alteration. Our results suggest that any increase in land-use intensity beyond the creation of a golf course -- such as increased manipulation of vegetation, increased number and size of structures and increased area covered with impervious surfaces -- reduces butterfly diversity.

Because some of our earlier work showed that species composition of butterflies is sensitive to habitat alteration (3), we expected that occurrence of butterflies with fewer broods per year, and high host-plant specificity would decrease along an increasing gradient of land-use intensity. However, while there was clear variation in butterfly abundance and diversity among courses, we could discern no clear pattern of change in species composition based on life history characteristics.

These results might suggest that the range of habitat change measured in this study was not enough to create a clear signal with respect to but-

terfly community composition or, alternatively, that sensitive species have already been eliminated from the landscape at the level of development of a golf course. However, we did sample a wide range of golf course types. Consequently, this suggests that land cover within a course has little effect on species composition of butterflies. Given the limited sample size of our study ($n = 6$), the CCA including all butterfly species suggested a significant relationship between landscape buffers and butterfly abundance and distribution.

Overall, the results of CCA were similar to regressions, suggesting that the features of the landscape surrounding golf courses do influence the butterfly assemblage. Although we failed to detect significant changes in butterfly composition among courses, it appeared that species with greater host-plant specificity (e.g., Zebra Swallowtail, Spicebush Swallowtail, Meadow Fritillary, Great Spangled Fritillary, Juniper Hairstreak) were associated with the amount of surrounding natural habitat represented by open fields and forests. This mirrors the results of other studies of butterflies and land use that suggested adjacent land cover influences Lepidopteran abundance and diversity (13, 28). Consequently, this suggests that butterfly composition from site



Associated wooded areas surrounding fairways of golf courses can provide valuable habitat refuges for conserving butterfly diversity. This is a photo of the 18-hole Hueston Woods Golf Course.

to site may have varied because of the land-cover composition (e.g. trees, open water and fields) in the landscape surrounding each golf course.

Course area was correlated with the proportion of natural land-cover in surrounding buffers in this study. Consequently, we could not separate the influences of golf course size and surrounding land use. However, it appears that large courses tend to be found in landscapes that are less densely developed and that smaller courses are found in more highly developed, site restricted landscapes. This suggests that larger courses have greater diversity of butterflies for two different reasons: 1) they may have more habitat within the golf course and 2) the surrounding land uses promote butterfly diversity and abundance.

One other study has demonstrated that larger golf courses offer quality habitat for more species independent of surrounding landscape (12). In this study, abundance was correlated with richness/diversity which suggests that more natural surroundings simply offer habitat for more individuals, and number of species is likely to be correlated with number of individuals.

While landscape measures explained the most variation in butterfly diversity among golf courses, there was a difference in the scale at which natural and residential land-cover influenced community composition. In this study, natural land cover surrounding a golf course was probably the single most important factor determining butterfly community structure. In general, small buffers (100 meters) of natural area were most strongly associated with increases in butterfly diversity. Residential development was negatively associated with butterfly diversity across all scales. This relationship may be due to the benefits from surrounding natural habitat in providing a greater diversity of host plants and shelter beyond what is provided by the golf course itself.

Findings from other studies have suggested that the amount and proximity of fragments of natural habitat in the surrounding landscape can increase Lepidopteran diversity (28, 33). These findings suggest that surrounding a golf course with both a small buffer that is free of development and a larger buffer containing patches of nat-

ural vegetation improves its conservation value. Unfortunately, the trend towards the development of residential "golf communities" is increasing, placing houses directly abutting and surrounding golf courses, leaving very little buffer. We suggest future researchers incorporate both small (100 meters) and large buffers (500-1000 meters) into their analyses in order to identify subtle changes in relationships because of scale.

On-site golf course characteristics had very little influence on butterfly assemblages. Therefore, from the results of our study we cannot recommend any specific landscape practices within golf courses to promote butterfly diversity or conservation. We should note, however, that none of the courses used in this study were designated as "links" golf courses, which are designed to target wildlife diversity. While our study could not address the importance of on-site habitat, other studies that have measured diversity of trees and herbaceous vegetation in other land-use contexts concluded that habitat quality is important in maintaining lepidopteran community structure (6, 34). This suggests that local habitat restoration may be as important as increasing habitat area.

In general, a comparison across taxa between butterfly and bird diversity illustrates similar responses to land-use alteration around golf courses. Earlier research by Porter et al. (in press) examined the role of landscape and on-site characteristics on bird communities at the same golf courses concluding that bird diversity increased with the amount of natural land-cover and decreased with residential development in small buffers immediately surrounding the course. Compared to highly mobile birds, many butterflies tend to have much smaller movements away from their origin, being more influenced by the availability of suitable host plant species immediately around the site. Therefore, smaller buffers of natural habitat can greatly increase butterfly diversity found on golf courses.

Our conservation suggestions are only relevant for golf courses in similar ecoregions. It is important to note that similar courses in other regions, such as the arid southwest, may not act as complementary to surrounding natural habitat. In

the Eastern Broadleaf Forest, we conclude that golf courses offer important habitats for many butterfly species, and the landscape surrounding courses has a significant influence on their ability to support diverse butterfly communities.

Acknowledgements

We thank N. Crosby for assistance in site selection and butterfly sampling. C. Dieckhoner, H. Daltabuit, N. Compton, and J. Minturn assisted in butterfly and vegetation sampling. This project was funded through a grant to RBB from the United States Golf Association Wildlife Links program and the National Fish and Wildlife Foundation.

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