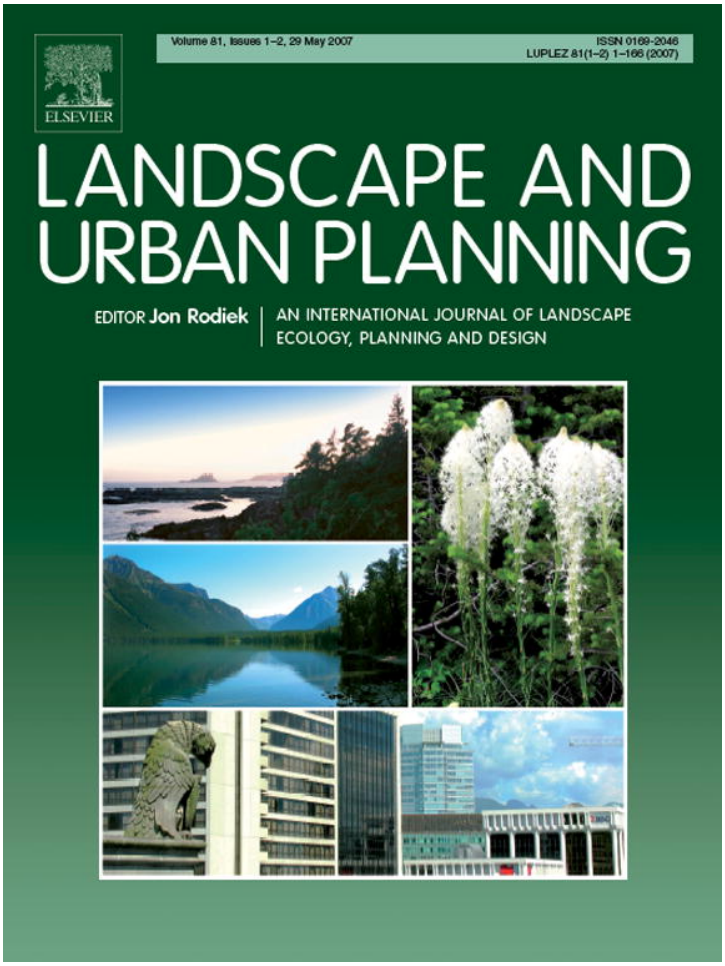

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Avian diversity on golf courses and surrounding landscapes in Italy

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Abstract

Golf courses are increasingly occupying land worldwide. This study investigates whether golf courses can contribute to wildlife conservation and to the enrichment of the local biodiversity. In 23 Italian golf courses, the presence of species of conservation concern was related to land use. In addition, censuses of birds and predators were conducted in three golf courses and the immediate surrounding urban–agricultural areas. Similarity between the 23 golf courses and Italian urban–agricultural territory was complete for the groups of generalist species and minimum for the species of conservation concern belonging to the groups of specialists. In the 23 golf courses, the proportion of forested area was positively related to the richness of species and to the number of species sensitive to forest fragmentation. In two of the three golf courses where censuses were conducted, the proportion of forested area, the number of species of conservation concern and those sensitive to forest fragmentation, were higher than in the surrounding areas. All groups of nest predators were more abundant in the two above golf courses than in the surrounding areas. Golf courses play a minor role in the conservation of specialist species. However, a good amount of forested area in golf courses that are located in urban and agricultural areas can positively affect wildlife. Predation pressure upon nests might be higher in some golf courses than in the relative surrounding areas. This source of concern requires future investigation.

Keywords: Golf courses in Italy; Birds; Species richness; Predator densities; Wildlife conservation; Land cover

1. Introduction

Urbanization and intensive agriculture have created habitats where opportunistic species are mostly found (e.g., O'Connor and Shrubb, 1986; BirdLife International, 2004; Palomino and Carrascal, 2006). The preservation, recovery, and creation of natural patches in highly disturbed areas might provide a first step towards the conservation of wildlife and natural corridors. Species richness may be at its peak in moderately disturbed areas (Jokimäki and Suhonen, 1993; Blair, 2001). Small protected areas and private land have a considerable potential for the preservation of wildlife, and may provide stepping-stones linking larger natural areas (Shafer, 1995).

Golf courses occupy large green areas and their numbers are growing worldwide (Priestley, 1995; Kunimatsu et al., 1999; Tanner and Gange, 2005). For example, almost one golf course a day has been opened in the USA over the last 10 years (Smith et al., 2005). In Europe, there are 5200 golf courses and over 31,500 worldwide (Tanner and Gange, 2005). In Italy, about 300 golf courses cover roughly 7500 ha, and their numbers have been increasing in recent years (Caggiati et al., 1999).

The growing number of golf courses raises concern about their possible negative effects on ecosystems due to pesticide application and alteration of water sources (e.g., Miles et al., 1992; Cohen et al., 1999; Davis and Lidy, 2002), and possible alteration of the air quality (Koerner and Klopatek, 2002). However, if managed in a naturalistic way, golf courses could have a potentially positive role for wildlife conservation (Pearce, 1993; Terman, 1997; Tanner and Gange, 2005).

On the Sefton Coast (United Kingdom), 20% of the dune system is protected by the presence of golf courses (Simpson, 2000). Some threatened species are even more abundant in golf courses than in native habitats (Green and Marshall, 1987; Rodewald et al., 2005; Smith et al., 2005). However, Platt (1994) pointed out that many hectares of forest are lost annually to golf course development (e.g., 5000 ha in Japan). Natural areas are likely

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to lose many bird species if golf courses are created on that site (Blair, 1996; Terman, 1997; see also LeClerc and Cristol, 2005).

An accepted strategy by many national golf federations is to avoid setting up golf courses where they would compromise the original habitats (www.committedtogreen.org/foundation.html, www.golfecology.co.uk/articles/valdec.html). However, the effectiveness of placing a golf course in highly-disturbed areas to promote wildlife conservation was scarcely tested in the past. This requires comparing wildlife living in the golf courses with that living in the surrounding disturbed territory (Jones et al., 2005; LeClerc and Cristol, 2005; Tanner and Gange, 2005; Yasuda and Koike, 2006).

The first aim of this paper was to evaluate the similarity between the avian community in the 23 Italian golf courses and that in the Italian agricultural and urban territories. In these golf courses, we investigated whether the proportions of natural patches positively affected the richness of species and the number of species of conservation concern or sensitive to habitat fragmentation. The second aim of the paper was to compare bird community parameters of three golf courses with the immediate surrounding areas to evaluate whether golf courses can lead to an enrichment of the local biodiversity. The three courses were representative of the main type of land cover where golf courses are usually located namely urban areas, intensively cultivated areas, or extensively cultivated areas.

We focused on bird species due to their sensitivity to environmental change and habitat fragmentation, reduced costs of sampling, broad distribution, and relative independence by sample size (e.g., Noss, 1990; Croonquist and Brooks, 1991; Francl and Schnell, 2002). We also estimated predator abundance, based on the assumption that possible observed benefits from golf course creation to wildlife might be lost in case of increased predation pressure.

2. Study area

The study was undertaken in 23 golf courses (Table 1) characterized by the use of registered and authorized non-toxic chemical products for turf grass preservation (applied once a year). The golf courses are located in the Italian lowlands and hilly territories (below 400 m a.s.l.) (Fig. 1). According to the Corine Land Cover database (see Krynitz, 2000), they are located in areas with dominant agricultural and urban land use. Several golf courses show intermediate aspects going from the 'Scottish style links' golf courses to the Japanese/American courses with little rough; other golf courses are more similar to the latter. In general, some houses (2–7) are close to the golf courses.

The percentage of forest and other land cover in each golf area was estimated by means of local maps analysed using Arcview software (Table 1). In 20 out of the 23 golf courses, we only investigated the occurrence of different bird species (qualitative assessment). In the remaining three golf courses (Olgiata, Verona, Le Querce), we also estimated species abundance (quantitative assessment). For these three golf courses a more detailed description is included below.

Table 1
Proportion of different habitat types in the 23 study golf courses

	Turf grass[a]	Forest[b]	Uncultivated area[c]	Wetland[d]	Area size[e] (ha)
Antognolla	40	20	30	10	80
Casentino	79	20	0	1	20
Cà della Nave	79	6	1	14	70
Cosmopolitan	47	20	8	25	70
Fioranello	60	30	8	2	50
Fiordalisi	30	30	20	20	60
Frassanelle	55	15	15	15	50
Fiuggi	75	20	0	5	70
Is Arenas	41	50	6	3	100
La Margherita	87	5	6	2	70
La Montecchia	75	5	5	15	85
Le Querce	39	31	21	9	70
Olgiata	35	51	11	3	100
Padova	90	10	0	0	85
Parco di Firenze	90	5	0	5	7
Poggio dei Medici	40	30	25	5	70
San Michele	30	30	38	2	44
Terme di Galzignano	82	5	3	10	13
Tirrenia	30	70	0	0	60
Ugolino	40	50	8	2	80
Venezia	45	50	0	5	56
Verona	48	43	8	1	40
Vicenza	74	5	2	19	25

[a] Turf grass includes tee, fairway, green and semi-rough.
[b] Forest category includes tree rows and bushes.
[c] Uncultivated area includes the rough, i.e., the scarcely managed semi-natural belt around turf grass.
[d] Wetlands includes small lakes, ponds and small streams.
[e] The area size is the area managed by each golf course club.

Fig. 1. Geographical location of the 23 study golf courses. OL: Olgiata golf course; LQ: Le Querce golf course; VE: Verona golf course.

Olgiata is located on the northern part of the Rome urban area, the most populated Italian town. This golf course was created in an area where there are meadows, cultivated land, small woods (mostly oak), and bushes. Most of the surrounding territory is residential with individual family houses. The golf course has 27 holes. **Verona** is at the northern part of the Po Plain (north-east Italy), the most intensive agricultural area in Italy. This golf course was established in an area where there are rows of trees, meadows, and a small oak wood. Outside the golf course area, there is an area where intensive agriculture is carried out (with orchards and wheat fields). The course comprises 18 holes. **Le Querce** is located at the northern end of the Latium region (Central Italy) and it was created in an agricultural area characterized by a 10 m deep ditch where there are woods and bushes including uncultivated meadows and hedges. The golf course is surrounded by a varied landscape including agricultural patches, pastures, country houses, gardens, hedges, small woods, and ditches. The golf course is made up of 18 holes.

3. Methods

3.1. Qualitative assessment

Data were collected by the two authors (both authors having 15–25 years of experience censusing birds) between 15 May and 21 June 2000 and between 18 May and 23 June 2001. The study period strongly reduced the possibility of recording the non-breeding migrants (Macchio et al., 1999). When faced by doubtful cases, we took into account only those birds that performed territorial behaviour (e.g., song broadcasting).

For every golf course, we established a series of transects at least 200 m apart throughout the whole area. Transects were straight lines cutting through forest, rough and green. In each study year, during a 1-day visit, the observer recorded all species present along the transects of the golf course. Observations along the transects were carried out from 30 min after the dawn, walking slowly (1–1.5 km/h), with stops of less than 1 min to solve doubtful bird identification. The kilometres covered by transects increased with the area size (about 1 km per 7–15 ha) as for the time for bird censusing in different golf courses (1–6 h). The presence of aquatic or nocturnal breeding species was not investigated.

Interviews with local birdwatchers that had repeatedly visited some of our study golf courses (Fiordalisi, Is Arenas, S. Michele, Le Querce, Parco di Firenze, Ugolino) confirmed that we had recorded most of the breeding species in these courses. Thus we are confident that our surveys were sufficiently accurate to detect the majority of breeding species.

As species of conservation concern (see Appendix A) we considered those birds included in: Italian Birds Red List (LIPU and WWF, 1999); Annex I of EC Directive 79/409/CEE on wild bird conservation; categories 1–3 of the Species of European Conservation Concern (SPEC) (BirdLife International, 2004). Species were subdivided in the following ecological groups (e.g., Helle, 1985; Matthysen et al., 1995; Bellamy et al., 1996; Boulinier et al., 1998; Hinsley et al., 1995; Frank and Battisti, 2005): field-edge/anthropophilous species, forest sensu latu species, species sensitive to forest fragmentation, open habitat species, Mediterranean species, raptors (see Appendix A). Mediterranean species include the species living exclusively in steppe and scrub habitats of the Mediterranean basin (Hagemeijer and Blair, 1997).

From the Atlas of Italian Breeding Birds (Meschini and Frugis, 1993) we obtained the list of the species breeding in the Italian hills and plain territories (below 400 m a.s.l.), where there is predominant urban and agricultural land use (see Appendix A). We then evaluated the similarity of ecological groups between the golf courses and the Italian territory by means of the Sorensen similarity index (SI) = $2c/(a+b)$ where c is the number of species shared by the two samples and a and b are the total number of species in each sample. We multiplied SI by 100 to obtain a percentage similarity value. The index is designed to equal 100 in the case of complete similarity.

We performed simple linear regressions between each variable used to describe land use (i.e., the proportion of area occupied by turf grass, forest, uncultivated land, or the area size) and bird community parameters (i.e., total number of species, number of species of conservation concern, number of species belonging to different ecological groups). However, autocorrelation between variables might complicate the correct interpretation of results. Therefore, when more than one variable describing land use was significantly related to one bird community parameter, a multiple regression analysis (backward stepwise) was carried out to confirm or exclude the significant relationships.

3.2. Quantitative assessment

Bird recording was carried out between 15 May and 5 June 2001 by means of 50-m-radius point counts (Verner, 1985). In the golf courses, point counts were placed on the green or at the tees of the different holes. In the areas surrounding the golf courses, point counts were randomly selected in a 500 m wide belt immediately around the golf course. Point counts were about 200 m apart (Blondel et al., 1970) both in the golf course and surrounding area. The number of point counts changed among golf courses basically in proportion to the number of holes in the course: 14 point counts in the Verona golf course, 15 point counts in Le Querce golf course, 20 point counts in the Olgiata golf course. The same sample of point counts was performed in the relative surrounding areas.

During a 5 min visit to each point count (Sorace et al., 2000), the observer recorded the species of all birds identifiable by sight or song. Over-flying birds that did not land or forage in the study area were excluded. Point counts were carried out in each golf course and relative surrounding area by the same observer, from 30 min after dawn to about 10:00–10:30 h, on sunny and calm days. The point counts were alternated between the golf course and the surrounding area by groups of 3–5 point counts. It took two mornings to complete the census in each golf course and relative surrounding area.

We recorded the number of predators (snakes, raptors, crows, feral cats and dogs, foxes and mustelids) per point count. We included observations collected both during the 5 min point counts used to census birds (50 m radius) and after these 5 min along a 200 m transect (50 m belt). We walked along the transect at a steady pace (100 m/5 min) from each point count towards the next. One point was attributed to one recorded individual or predator sign (faeces, exuvia, tracks, etc.; see Sorace, 2001). We raised big stones and logs that were encountered along the transects and directly close by (5 m belt) to check for the presence of snakes. However, information on snake or mustelid presence has not been reported since we obtained only few data on these two groups. In June, owl species living in the study areas, i.e., *Strix aluco*, *Athene noctua* and *Otus scops* were censused by means of playback recording techniques in seven nocturnal point counts both in the golf courses and surrounding areas whereas recordings of individual or spontaneous *T. alba* song were counted during the point counts arranged to census the other owl species (see Sorace, 2001).

In each 50 m radius point count used for the bird sampling, we visually estimated (e.g., Porter et al., 2005; Rodewald et al., 2005) percent cover of urban area (i.e., buildings and paved roads), forest (including single trees over 2.0 m in height), bush (including single trees under 2.0 m in height), uncultivated areas (including pastures and grassland), and cultivated areas (including turf grass).

For each point count, the following parameters were calculated: species richness (S); abundance (A), i.e., number of recorded individuals (ind./point count); number of species of conservation concern; number of individuals and species belonging to different ecological groups (see above). For each golf course and relative surrounding area, we calculated: (1) the diversity index (H'): $-\sum \mathrm{fr} \ln(\mathrm{fr})$ where fr is the relative frequency of each species (Shannon and Weaver, 1963); and (2) the Eveness index: $H'/H'_{\max}$ where $H'_{\max} = \ln(S)$ (Lloyd and Ghelardi, 1964).

We evaluated whether there was significant variation between the golf course and surrounding territory within each study area regarding the values of bird community parameters, predator abundance, and percentages of different land cover. With this aim, we conducted several two-way ANOVAs with location (i.e., golf course or surrounding area) as random effect and study area (i.e., Olgiata, Verona, Le Querce) as fixed effect. The normality of variables was checked by means of Kolmogorov–Smirnov test and data were either natural log ($x+1$), square root, or arcsine transformed where appropriate (Fowler and Cohen, 1995). When data for one variable violated the assumptions required by ANOVA, we tested for the differences between the golf course and surrounding territory using the non-parametric Mann–Whitney test. Values presented throughout are means ± S.E. Statistical analysis was performed with Statistica software package (StatSoft Inc., 1984–2000).

4. Results

4.1. Qualitative assessment

We found 59 species in the 23 study golf courses. Among them, 19 species were of conservation concern, 10 sensitive to forest fragmentation and 5 typical of Mediterranean habitats (Appendix A). Similarity between golf courses and Italian territory was complete for the field-edge/anthropophilous species and forest sensu latu species (Table 2). Whereas, similarity was lower for the open habitat species, the species sensitive to forest fragmentation, and above all, the Mediterranean and raptor

Table 2
Similarity between the Italian territory and the 23 study golf courses for the composition of some ecological groups[a]

	Number of species		Similarity[b] (%)
	Golf courses	Italian territory	
Field-edge	21	21	100.0
Field-edge CC	4	4	100.0
Forest species	12	12	100.0
Forest species CC	1	1	100.0
Forest fragmentation sensitive species	10	13	87.0
Forest fragmentation sensitive species CC	3	6	66.7
Open habitat species	9	14	78.3
Open habitat species CC	6	9	80.0
Mediterranean species	5	12	58.8
Mediterranean species CC	3	9	50.0
Raptor species	3	6	66.7
Raptor species CC	1	4	40.0

[a] The species belonging to each group (field-edge/anthropophilous species, forest sensu latu species, species sensitive to forest fragmentation, open habitat species, Mediterranean species and raptor species) are listed in Appendix A. CC = of conservation concern.
[b] Values of Sorensen similarity index (see Section 3).

Table 3
Significant linear regressions between each variable used to describe land use (i.e., the proportions of area occupied by turf grass, forest, uncultivated land, or the area size[a]) and bird community parameters (i.e., total number of species, number of species of conservation concern, and number of species belonging to different ecological groups)

Regression analysis					
Dependent variable	Independent variable	r	T	P	n
Total number of species	Turf grass	−0.65	3.87	0.0009	23
Total number of species	Forest	0.59	3.32	0.003	23
Total number of species	Uncultivated area	0.42	2.13	0.045	23
Total number of species	Area size	0.42	2.10	0.048	23
Number of species of conservation concern	Turf grass	−0.49	2.59	0.017	23
Number of species of conservation concern	Area size	0.60	3.41	0.003	23
Number of field-edge/anthropophilous species	Area size	0.43	2.16	0.042	23
Number of forest species	Turf grass	−0.63	3.78	0.001	23
Number of forest species	Forest	0.65	3.90	0.0008	23
Number of species sensitive to forest fragmentation	Turf grass	−0.43	2.20	0.039	23
Number of species sensitive to forest fragmentation	Forest	0.58	3.27	0.003	23
Number of species sensitive to forest fragmentation CC	Forest	0.42	2.12	0.046	23
Number of species of open habitat	Uncultivated area	0.46	2.38	0.027	23
Number of species of open habitat CC	Area size	0.43	2.19	0.040	23

[a] The area size is the area managed by each golf course club.

species. Minimum similarity was observed for the species of conservation concern of the last three groups (Table 2).

The total number of species was significantly related to all considered independent variables (Table 3), but only the positive relationship with the proportion of forested area was significant in the multiple regression analysis ($t_{21} = 3.33$, $P = 0.003$). The number of species sensitive to forest fragmentation was negatively related to the proportion of area occupied by turf grass and positively related to the forested area (Table 3). However, only the latter relationship was significant in the multiple regression analysis ($t_{21} = 3.27$, $P = 0.004$). Similar results were obtained for the forest species (Table 3; multiple regression analysis: $t_{21} = 3.90$, $P = 0.0008$) and the number of species of conservation concern among those sensitive to forest fragmentation (Table 3). The total number of species of conservation concern was related negatively to the proportion of area occupied by turf grass and positively to the area size (Table 3). However, only the latter relationship was significant in the multiple regression analysis ($t_{21} = 3.41$, $P = 0.002$). Also the number of both field-edge/anthropophilous species and open habitat species of conservation concern were positively related to the area size (Table 3). The number of open habitat species was positively related to the proportion of uncultivated areas (Table 3). No significant correlations were observed for Mediterranean and raptor species (data not shown).

4.2. Quantitative assessment

The percentage of area occupied by forest was higher in the golf course than in surrounding territory of the three study areas (location effects: $F_{1, 92} = 7.9$, $P = 0.0007$); in the pairwise comparisons the differences were significant only for Olgiata (39.4 ± 1.1 versus 19.3 ± 1.9; $P < 0.01$) and Verona areas (29.3 ± 2.3 versus 10.1 ± 1.8; $P < 0.01$). In the Olgiata area, the percentage of area occupied by buildings was lower in the golf courses than in surrounding territories (4.0 ± 1.2 versus 46.6 ± 1.5; $Z = 4.8$, $P = 0.00001$, N_1 and $N_2 = 16$). The percentage of cultivated area (including turf grass) in the golf courses of Le Querce (40.7 ± 1.8) and Verona (42.1 ± 2.5) areas was lower than in relative surrounding territory (respectively, 51.1 ± 2.9 and 65.1 ± 2.4), the opposite occurred in the Olgiata area (35.4 ± 0.6 versus 10.9 ± 0.7; study area × location effects: $F_{2, 92} = 93.8$, $P \leq 0.000001$). Other significant differences for the land use variables were not observed (data not shown).

The total number of bird species, the number of species of conservation concern, the number of forest species and the number of species sensitive to forest fragmentation were higher in the golf courses than in relative surrounding territories (Table 4). In pairwise comparisons, there were maximum differences for Olgiata area and secondly for Verona area, while no significant differences were observed for Le Querce area (Fig. 2). The val-

Table 4
Results of the ANOVA analysis for the values of bird community parameters[a] obtained in the three study areas (Olgiata, Verona, and Le Querce) where the species abundance was surveyed

Parameter	Study area effect	Location effect	Study area × location effect
Number of species	$F_{2, 2} = 0.8$, $P = 0.55$	$F_{1, 92} = 24.0$, $\mathbf{P = 0.0000004}$	$F_{2, 92} = 3.5$, $\mathbf{P = 0.03}$
Number of species of conservation concern	$F_{2, 2} = 1.2$, $P = 0.45$	$F_{1, 92} = 4.0$, $\mathbf{P = 0.048}$	$F_{2, 92} = 2.6$, $P = 0.08$
Number of fragmentation sensitive species[b]	$F_{2, 2} = 0.6$, $P = 0.64$	$F_{1, 92} = 15.6$, $\mathbf{P = 0.0002}$	$F_{2, 92} = 1.4$, $P = 0.25$
Number of forest species	$F_{2, 2} = 42.5$, $\mathbf{P = 0.02}$	$F_{1, 92} = 16.9$, $\mathbf{P = 0.00001}$	$F_{2, 92} = 0.1$, $P = 0.86$

[a] Results are reported only when a significant location effect (i.e., differences between golf course and surrounding area) was observed. Significant effects are highlighted in bold. Mean values for the parameters are reported in Fig. 2.
[b] Species sensitive to forest fragmentation.

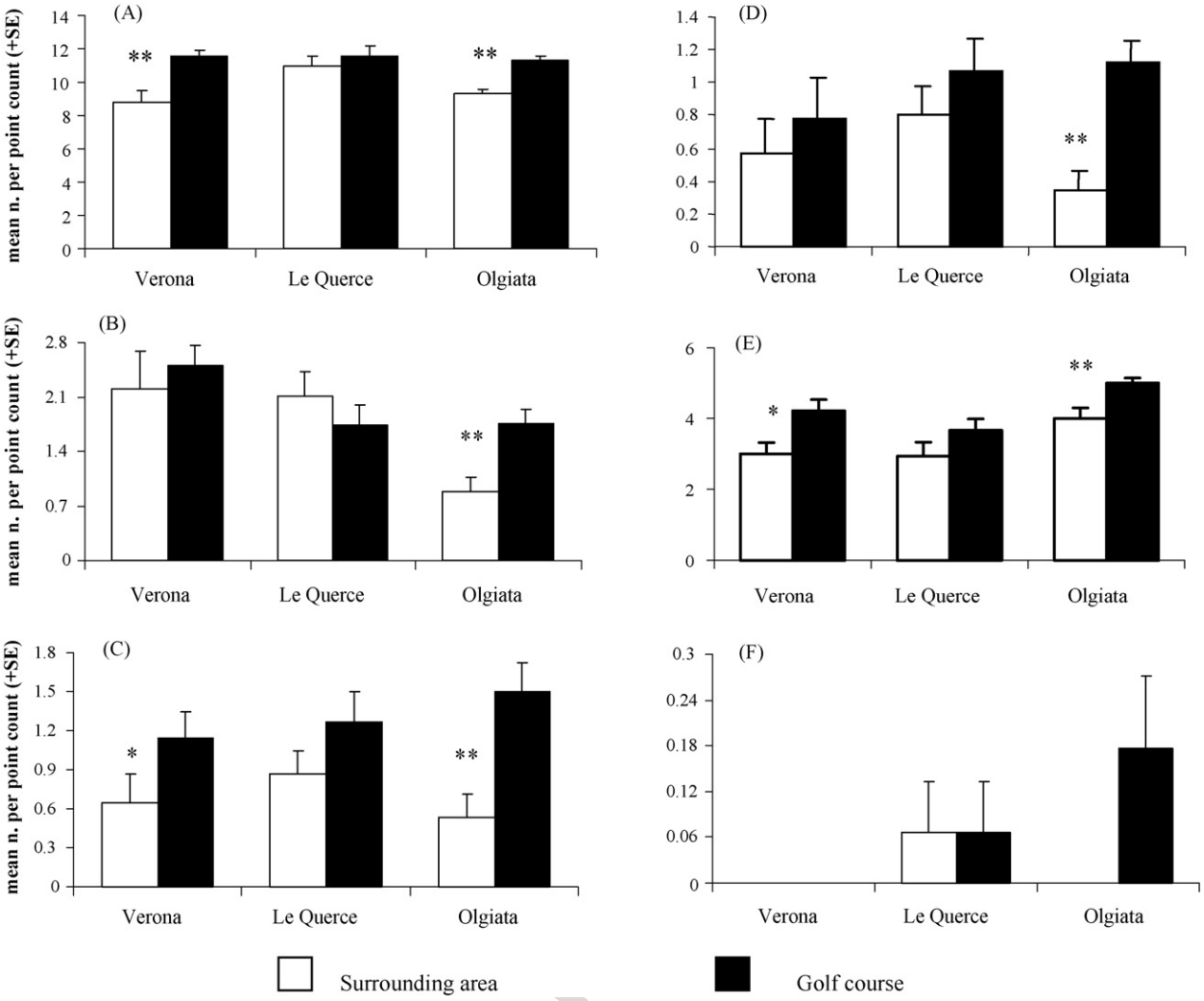

Fig. 2. Mean value per point count (±S.E.) of the bird community parameters that resulted significantly different in the comparison between golf course and relative surrounding territory in the three study areas (Olgiata, Verona, Le Querce). (A) Number of species; (B) number of species of conservation concern; (C) number of species sensitive to forest fragmentation; (D) number of species of conservation concern sensitive to forest fragmentation (CC); (E) forest species; (F) forest species of conservation concern (see Section 3). Results of ANOVA analysis for each parameter are reported in Table 4. Post hoc tests, $^{*}P<0.05$, $^{**}P<0.01$. For the data reported in graphs (D and F), the differences were analysed by means of Mann–Whitney test.

ues of diversity index and evenness index were higher in the golf courses than in surrounding territories in all study areas; minimum differences were observed for Le Querce area (Table 5).

Except for dogs and cats, the numbers of different predators were higher in the golf courses of Olgiata and Verona areas than in the relative surrounding territories (Fig. 3). In particular, the number of *Picoides major* was significantly higher in the Verona golf course than in the surrounding territory (Fig. 3C), while the numbers of crows and foxes were significantly higher in the Olgiata golf course than in the surrounding territory (Fig. 3D and F). In Le Querce area, the numbers of different predators were usually lower in the golf course than in the surrounding territory, but the differences were not statistically significant (Fig. 3).

Table 5
Values of diversity index and evenness index obtained for the bird communities of golf course and relative surrounding territory in the three study areas (Olgiata, Verona, and Le Querce)

Study area	Diversity index[a]		Evenness index[b]	
	Golf course	Surrounding area	Golf course	Surrounding area
Olgiata	2.79	2.54	0.88	0.82
Verona	2.95	2.39	0.88	0.74
Le Querce	2.74	2.63	0.84	0.80

[a] Shannon and Weaver (1963).
[b] Lloyd and Ghelardi (1964).

5. Discussion

Although golf courses located in the Italian agricultural and urban territories host several species of conservation concern and some Mediterranean and fragmentation sensitive species, the results suggest that in general golf courses play a minor role for the conservation of specialist birds. The avifauna of the golf courses showed the maximum similarity with the component of generalist species of the Italian avifauna and the minimum

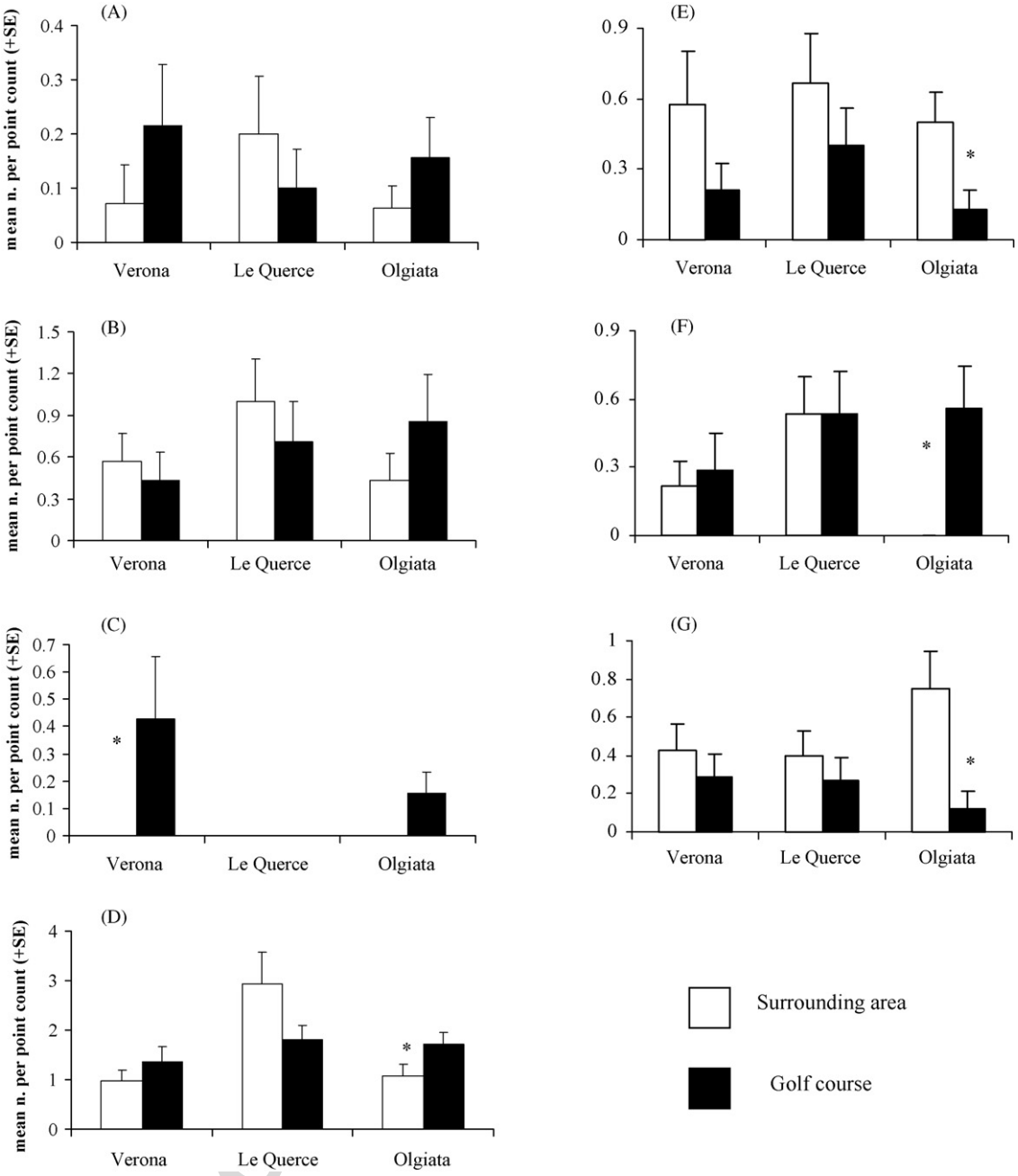

Fig. 3. Abundance of different predators in the golf course and relative surrounding territory (mean number per point count ± S.E.) of the three study areas (Olgiata, Verona, and Le Querce). (A) Diurnal raptors; (B) owls; (C) *Picoides major*; (D) crows; (E) dogs; (F) foxes; (G) cats. Mann–Whitney test, $^{*}P < 0.05$.

similarity with the groups of species of conservation concern belonging to the three groups of species with more restrictive habitat needs and low tolerance levels for disturbance (i.e., Mediterranean species, species sensitive to forest fragmentation, and raptors). LeClerc and Cristol (2005) reported that typical golf courses in Virginia do not provide more habitat for birds of conservation concern than alternative land uses, including residential or agricultural uses.

In the Italian golf courses, the total number of species and the number of species sensitive to fragmentation increased with the proportion of forest in the course area. Therefore, a higher availability of forested area in the golf courses of Olgiata and Verona as compared to the surrounding areas is the likely cause of the higher diversity and higher number of species, including those of conservation concern and sensitive to forest fragmentation, that were observed in these two golf courses. Likewise, in American golf courses an increased proportion of forested patches promoted the richness of species and the presence of species of conservation concern (Hostetler and Knowles-Yanez, 2003; Jones et al., 2005; LeClerc and Cristol, 2005). In urban and agricultural areas, golf courses with widely forested areas may enrich the local bird community (Sorace and Visentin, 2002; Tanner and Gange, 2005; Yasuda and Koike, 2006) similarly to the role played by urban parks in residential areas (Fernández-Juricic and Jokimäki, 2001; White et al., 2005; Chace and Walsh, 2006; Sandström et al., 2006), with the possible further advan-

tage, in comparison to such parks, of limited human activity disturbance. Analogously to urban green areas (Park and Lee, 2000; Cornelis and Hermy, 2004; Fernández-Juricic, 2004), species richness might be positively affected by an increased size of the golf course (see also Porter et al., 2005). However, the results from Le Querce area indicate that where a golf course does not include proportions of natural patches larger than those of the surrounding territory its fauna keeps the characteristics of the original territory.

It is important to notice that an increase of forested areas due to golf course development can bring a negative change when it occurs in areas with particular climatic and environmental conditions. For example, in a desert environment, golf courses might be detrimental for the specialists of such habitats, even if advantageous for species of riparian habitats (Merola-Zwartjes and DeLong, 2005). We observed an increase of forest species but a reduction of Mediterranean species in the open habitats of Is Arenas golf course with respect to the surrounding semiarid pastures (data not showed).

Our observations that generalist predators such as crows and foxes were more abundant in the golf courses than in the surrounding urban and agricultural areas (for foxes, see also Adkins and Stott, 1998) may suggest higher predation risks for birds living in the golf courses. It might be argued that predation rates cannot be directly related to the number of predators, but to their diversity and behaviour (Reitsma et al., 1990; Söderström et al., 1998; Chalfoun et al., 2002). However, since all groups of nest predators (*Picoides major*, crows, foxes) were more abundant in Olgiata and Verona golf courses as compared to the surrounding territories, a high predation pressure upon nests in some golf courses can be correctly hypothesized. Thus, a golf course might act as an ecological trap (Gates and Gysel, 1978; Saunders et al., 1991; Terman, 1997). Many anthropogenic habitats have been found to function as ecological 'sinks' even though they are used by high number of birds (Pulliam, 1988; Vierling, 2000). Unfortunately, data comparing breeding performance of birds living in the golf courses or nearby areas are currently scarce and the results are not univocal to draw conclusive statements (LeClerc et al., 2005; Rodewald et al., 2005; Smith et al., 2005; Stanback and Seifert, 2005).

6. Conclusions

Golf courses seem to play a minor role for the presence of species of conservation concern that have more restrictive habitat needs and a low tolerances for disturbance. However, a high proportion of forest cover in the golf course may increase the richness of such species in particular those sensitive to forest fragmentation. Therefore, the designers of golf courses can enhance the conservation value of courses by preserving and increasing the amount of natural patches, and decreasing the amount of managed turf grass. In particular, in areas deeply transformed by human activities such as highly urbanized or intensively cultivated areas, the creation of golf courses with wide forested areas may be effective for the local enrichment of bird communities.

To our knowledge, studies on the impact of predation in golf courses and surrounding areas have never been conducted. We showed that the number of some generalist predators may be higher in golf courses than in surrounding territories. If such a high abundance of predators translates in high levels of predation, it would be an important source of concern for the wildlife living in the golf courses. Future studies should investigate these aspects to identify, if necessary, the appropriate management responses.

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Appendix A

Bird species present in the Italian urban and agricultural territory were subdivided in ecological groups. The species recorded in the 23 study golf courses are highlighted in bold.

Species of Italian plain and hilly territory characterized by urban and agricultural land use

Field-edge/anthropophilous species

Phasianus colchicus, ***Columba livia dom.***, ***Streptopelia decaocto***, ***Galerida cristata***, ***Hirundo rustica****, ***Delichon urbica****, ***Motacilla alba***, ***Saxicola torquata***, ***Cettia cetti***, ***Pica pica***, ***Corvus monedula***, ***C. corone***, ***Sturnus vulgaris****, ***Passer italiae***, ***P. hispaniolensis***, ***P. montanus****, ***Serinus serinus***, ***Carduelis chloris***, ***C. carduelis***, ***Emberiza cirlus***

Forest species

Cuculus canorus, ***Troglodytes troglodytes***, ***Erithacus rubecula***, ***Luscinia megarhynchos***, ***Turdus merula***, ***Sylvia atricapilla***, ***Regulus ignicapillus***, ***Muscicapa striata****, ***Parus caeruleus***, ***P. major***, ***Oriolus oriolus***, ***Fringilla coelebs***

Species sensitive to forest fragmentation

Streptopelia turtur*, ***Columba palumbus***, ***Upupa epops****, ***Jynx torquilla****, ***Picus viridis****, ***Picoides major***, *P. minor**, *Parus ater*, *P. palustris**, ***Aegithalos caudatus***, ***Sitta europaea***, ***Certhia brachydactyla***, ***Garrulus glandarius***

Open habitat species

*Perdix perdix**, ***Coturnix coturnix****, ***Merops apiaster****, ***Lullula arborea****, ***Alauda arvensis****, ***Motacilla flava***, *Monticola solitarius**, *Phoenicurus ochruros*, ***Cisticola juncidis***, ***Hippolais polyglotta***, *Lanius collurio**, ***Petronia petronia***, ***Carduelis cannabina****, ***Miliaria calandra****

Mediterranean species

Alectoris barbara*, *Coracias garrulus**, *Melanocorypha calandra**, *Calandrella brachydactyla**, ***Oenanthe hispanica****, ***Sylvia cantillans***, *S. conspicillata*, *S. sarda**, ***S. melanocephala,*** *Lanius minor**, ***L. senator****, *E. melanocephala**

Diurnal raptors

*Milvus migrans**, *Circus pygargus**, ***Buteo buteo***, ***Accipiter nisus***, *Falco subuteo**, ***F. tinnunculus****

*Species of conservation concern (see Section 3).

References

Adkins, C.A., Stott, P., 1998. Home ranges, movements and habitat associations of red foxes *Vulpes vulpes* in suburban Toronto, Ontario, Canada. J. Zool. 244, 335–346.

Bellamy, P.E., Hinsley, S.A., Newton, I., 1996. Factors influencing bird species number in small woods in south-east England. J. Appl. Ecol. 33, 249–262.

BirdLife International, 2004. Birds in Europe: Population Estimates, Trends and Conservation Status. BirdLife Conservation Series No. 12. BirdLife International, Cambridge.

Blair, R.B., 1996. Land use and avian species diversity along an urban gradient. Ecol. Appl. 6, 506–519.

Blair, R.B., 2001. Creating a homogeneous avifauna. In: Marzluff, J.M., Bowman, R., Donnelly, R. (Eds.), Avian Ecology and Conservation in an Urbanizing World. Kluwer Academic Publishers, Boston, pp. 459–486.

Blondel, J., Ferry, C., Frochot, B., 1970. Le methode des Indices Ponctuels d'Abondance (I.P.A.) ou des relevés d'avifaune pour "stations d'ecoute". Alauda 38, 55–71.

Boulinier, T., Nichols, J.D., Hines, J.E., Sauer, J.R., Flather, C.H., Pollock, K.H., 1998. Higher temporal variability of forest breeding communities in fragmented landscapes. Proc. Natl. Acad. Sci. U.S.A. 95, 7497–7501.

Caggiati, P., Di Pasquale, S., Gallerani, V., Viaggi, V., Zanni, G., 1999. Gli Effetti Ambientali Delle Attività Ricreative Sul Territorio-Il Caso Del Golf in Italia. GeSTA-CNR, Roma.

Chace, J.F., Walsh, J.J., 2006. Urban effects on native avifauna: a review. Landsc. Urban Plann. 74, 46–69.

Chalfoun, A.D., Ratnaswamy, M.J., Thompson, F.R., 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecol. Appl. 12, 858–867.

Cohen, S., Svrjcek, A., Durborow, T., Barnes, N.L., 1999. Water quality impacts by golf courses. J. Environ. Qual. 28, 798–809.

Cornelis, J., Hermy, M., 2004. Biodiversity relationships in urban and suburban parks in Flanders. Landsc. Urban Plann. 69, 385–401.

Croonquist, M.J., Brooks, R.P., 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. Environ. Manage. 15, 701–714.

Davis, N.M., Lidy, M.J., 2002. Evaluating best management practices at an urban golf course. Environ. Toxicol. Chem. 5, 1076–1084.

Fernández-Juricic, E., 2004. Spatial and temporal analysis of the distribution of forest specialists in an urban-fragmented landscape (Madrid, Spain). Implications for local and regional bird conservation. Landsc. Urban Plann. 69, 17–32.

Fernández-Juricic, E., Jokimäki, J., 2001. An habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. Biodivers. Conserv. 10, 2023–2043.

Fowler, J., Cohen, L., 1995. Statistics for ornithologists. BTO Guide, vol. 22, Tring.

Francl, K.E., Schnell, G.D., 2002. Relationships of human disturbance, bird communities, and plant communities along the land–water interface of a large reservoir. Environ. Monit. Assess. 73, 67–93.

Frank, B., Battisti, C., 2005. Area effect on bird communities, guilds and species in a highly fragmented forest landscape of Central Italy. Ital. J. Zool. 72, 297–304.

Gates, J.E., Gysel, L.W., 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59, 871–883.

Green, B.H., Marshall, I.C., 1987. An assessment of the role of golf courses in Kent, England, in protecting wildlife and landscapes. Landsc. Urban Plann. 14, 143–154.

Hagemeijer, E.J.M., Blair, M.J. (Eds.), 1997. The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance. T. and A. Poyser, London.

Helle, P., 1985. Effects of forest fragmentation on bird densities in northern boreal forests. Ornis Fenn. 62, 35–41.

Hinsley, S.A., Bellamy, P.E., Newton, I., Sparks, T.H., 1995. Bird species turnover and stochastic extinction in woodland fragments. Ecography 18, 41–50.

Hostetler, M., Knowles-Yanez, K., 2003. Land use, scale, and bird distributions in the Phoenix metropolitan area. Landsc. Urban Plann. 62, 55–68.

Jokimäki, J., Suhonen, J., 1993. Effects of urbanization on the breeding bird species richness in Finland: a biogeographical comparison. Ornis Fenn. 70, 71–77.

Jones, S.G., Gordon, D.H., Phillips, G.M., Richardson, B.R.D., 2005. Avian community response to a golf-course landscape unit gradient. Wildl. Soc. Bull. 33, 422–434.

Koerner, B., Klopatek, J., 2002. Anthropogenic and natural CO_2 emission sources in an arid urban environment. Environ. Pollut. 116 (Supp. 1), S45–S51.

Krynitz, M., 2000. Land Cover. Annual Topic Update 1999. European Environment Agency, Copenhagen.

Kunimatsu, T., Sudo, M., Kawachi, T., 1999. Loading rates of nutrients discharging from a golf course and neighboring forested basin. Water Sci. Technol. 39, 99–107.

LeClerc, J.E., Che, J.P.K., Swaddle, J.P., Cristol, D.A., 2005. Reproductive success and developmental stability of eastern bluebird (*Sialia sialis*) on golf courses: evidence that golf courses can be productive. Wildl. Soc. Bull. 33, 483–493.

LeClerc, J.E., Cristol, D.A., 2005. Are golf courses providing habitat for birds of conservation concern in Virginia? Wildl. Soc. Bull. 33, 463–470.

LIPU, WWF, 1999. Nuova Lista Rossa degli uccelli nidificanti in Italia. Riv. Ital. Orn. 69, 3–43.

Lloyd, M., Ghelardi, R.J., 1964. A table for calculating the equitability component of species diversity. J. Anim. Ecol. 33, 217–225.

Macchio, S., Messineo, A., Licheri, D., Spina, F., 1999. Atlante della distribuzione geografica e stagionale degli uccelli inanellati in Italia negli anni 1980–1994. Biol. Conserv. Fauna 103, 1–276.

Matthysen, E., Lens, L., Van Dongen, S., Verheyen, G.R., Wauters, L.A., Adriaensen, F., Dhondt, A.A., 1995. Diverse effects of forest fragmentation on a number of animal species. Belg. J. Zool. 125, 175–183.

Merola-Zwartjes, M., DeLong, J.P., 2005. Avian species assemblages on New Mexico golf courses: surrogate riparian habitat for birds? Wildl. Soc. Bull. 33, 435–447.

Meschini, E., Frugis, S. (Eds.), 1993. Atlante degli uccelli nidificanti in Italia. Supp. Ricerche Biol. Selvaggina 20, 1–344.

Miles, C.J., Leong, G., Dollar, S., 1992. Pesticides in marine sediments associated with golf course runoff. Bull. Environ. Contam. Toxicol. 49, 179–185.

Noss, R.F., 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conserv. Biol. 4, 355–364.

O'Connor, R.J., Shrubb, M., 1986. Farming and Birds. Cambridge University Press, Cambridge.

Palomino, D., Carrascal, L.M., 2006. Urban influence on birds at a regional scale: a case study with the avifauna of northern Madrid province. Landsc. Urban Plann. 77, 276–290.

Park, C.-R., Lee, W.-S., 2000. Relationship between species composition and area in breeding birds of urban woods in Seoul, Korea. Landsc. Urban Plann. 51, 29–36.

Pearce, F., 1993. How green is your golf? New Scientist 139, 30–35.

Platt, A.E., 1994. Toxic Green: The Trouble With Golf. Worldwatch Institute, Washington.

Porter, E.E., Bulluck, J., Blair, R.B., 2005. Multiple spatial-scale assessment of the conservation value of golf courses for breeding birds in southwestern Ohio. Wildl. Soc. Bull. 33, 494–506.

Priestley, G.K., 1995. Sports tourism: the case of golf. In: Ashworth, G.J., Dietvorst, A.G.J. (Eds.), Tourism and Spatial Transformations. CAB International, Wallingford, pp. 205–224.

Pulliam, H.R., 1988. Sources, sinks, and population regulation. Am. Nat. 132, 652–661.

Reitsma, L.R., Holmes, R.T., Sherry, T.W., 1990. Effects of removal of red squirrels, *Tamiasciurus hudsonicus*, and eastern chipmunk, *Tamais striatus*, on nest predation in a northern hardwood forest: an artificial nest experiment. Oikos 57, 375–380.

Rodewald, P.G., Santiago, M.J., Rodewald, A.D., 2005. Habitat use of breeding red-headed woodpeckers on golf courses in Ohio. Wildl. Soc. Bull. 33, 448–453.

Sandström, U.G., Angelstam, P., Mikusiński, G., 2006. Ecological diversity of birds in relation to the structure of urban green space. Landsc. Urban Plann. 77, 39–53.

Saunders, D.A., Hobbs, R.J., Margules, C.R., 1991. Biological consequences of ecosystem fragmentation: a review. Conserv. Biol. 5, 18–32.
Shafer, C.L., 1995. Values and shortcomings of small reserves. Bio Science 45, 80–88.
Shannon, C.E., Weaver, W., 1963. The Mathematical Theory of Communication. University of Illinois Press, Urbana.
Simpson, D., 2000. Links for wildlife. Enact—Managing Land for Wildlife 8, 1.
Smith, M.D., Conway, C.J., Ellis, L.A., 2005. Use of artificial nesting burrows on golf courses by burrowing owls. Wildl. Soc. Bull. 33, 454–462.
Söderström, B., Pärt, T., Ryden, J., 1998. Different nest predator faunas and nest predation risk on ground and shrub nests at forest ecotones: an experiment and a review. Oecologia 117, 108–118.
Sorace, A., 2001. Value to wildlife of agricultural urban parks: a case study from Rome urban area. Environ. Manage. 28, 547–560.
Sorace, A., Gustin, M., Calvario, E., Ianniello, L., Sarrocco, S., Carere, C., 2000. Assessing bird communities by point counts: repeated sessions and their duration. Acta ornithol. 35, 197–202.
Sorace, A., Visentin, M., 2002. Importanza di due campi da golf in Italia centrale per le specie ornitiche. Alula 9, 46–55.
Stanback, M.T., Seifert, M.L., 2005. A comparison of eastern bluebird reproductive parameters in golf and rural habitats. Wildl. Soc. Bull. 33, 471–482, StatSoft, Inc. 1984-2000. Statistica (data analysis software system), version 5.5. StatSoft, Inc, Tulsa.
Tanner, R.A., Gange, A.C., 2005. Effects of golf courses on local biodiversity. Landsc. Urban Plann. 71, 137–146.
Terman, M.R., 1997. Natural links: naturalistic golf courses as wildlife habitat. Landsc. Urban Plann. 38, 183–197.
Verner, J., 1985. Assessment of counting techniques. Curr. Ornithol. 2, 247–302.
Vierling, K.T., 2000. Source and sink habitats of red-winged blackbirds in a rural/suburban landscape. Ecol. Appl. 10, 1211–1218.
White, J.G., Antos, M.J., Fitzsimons, J.A., Palmer, G.C., 2005. Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. Landsc. Urban Plann. 71, 123–135.
Yasuda, M., Koike, F., 2006. Do golf courses provide a refuge for flora and fauna in Japanese urban landscapes? Landsc. Urban Plann. 75, 58–68.