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FOCAL BIRD SPECIES AND RISK ASSESSMENT APPROACH FOR NONAGRICULTURAL GRASSLAND SCENARIOS IN CENTRAL EUROPE

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Abstract: The European Food Safety Authority (EFSA) guideline on risk assessment identifies pesticide exposure scenarios for nontarget wildlife; however, this scheme is not applicable to nonagricultural grassland. For example, different habitats and human utilization on golf courses attract bird communities that differ from those found in agricultural fields with annual crop cycles. The present study determined focal bird species for amenity grasslands such as golf courses following the EFSA guideline. Based on published data and bird surveys, a total of 102 species were found on 13 golf courses in Central Europe. Approximately 58% of the species were recorded on >20% of the golf course and were classified as focal species candidates. Common kestrel (*Falco tinnunculus*), common linnet (*Carduelis cannabina*), wood pigeon (*Columba palumbus*), yellowhammer (*Emberiza citrinella*), white wagtail (*Motacilla alba*), and gray heron (*Ardea cinerea*) are the most adequate candidate focal species for exposure scenarios of carnivorous, granivorous, herbivorous, omnivorous, insectivorous, and piscivorous birds, respectively. Candidate species were verified on 3 golf courses in southwestern Germany in spring 2012. Observations on feeding behavior identified the main foraging areas of focal species. The results of the field work combined with data from the literature identified reliable exposure scenarios to assess the risk of pesticides to birds found on golf courses. *Environ Toxicol Chem* 2014;33:2055–2061. © 2014 SETAC

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INTRODUCTION

In terms of their impact on the environment, some golf courses have been historically criticized for their excessive use of water, pesticides, and fertilizers [1–4]. However, it has now been recognized that golf courses can provide important habitat for wildlife, including many species of birds. This recognition of the value of golf courses to conservation has resulted in the publication of a comprehensive guidance document offering advice on how to manage these recreational areas as sanctuaries for threatened birds and other wildlife species [5]. Thus, in accordance with European Union legislation, golf courses will need to be assessed for any risks posed to their associated birdlife arising from the use of pesticides.

Within the European Union, it is the task of the European Food Safety Authority (EFSA) to assess and communicate on all risks associated with the food chain. This includes the assessment of risks to wildlife posed by the use of pesticides and other chemicals on agricultural land. Current EFSA guidance includes data on bird species relevant to specific crop types as an aid to the assessment of risk for a range of agricultural exposure scenarios [6]. The identification of appropriate focal species for a given exposure scenario is considered a key factor in this process. Accordingly, a number of recent publications have identified candidate focal species for most arable crops [7–9].

The grassland exposure scenarios defined in the current EFSA guidance document address the potential risks to birds following the application of pesticides to pasture, meadows, and other grazing land [6]. Birds from 4 different feeding guilds have been proposed as representatives for assessing potential risks resulting from the ingestion of contaminated food items associated with agricultural grasslands. Typically, the species selected as representatives for these exposure scenarios are the house sparrow (*Passer domesticus*, a small ganivore potentially exposed via treated grass seeds), common linnet (*Carduelis cannabina*, a small ganivore potentially exposed via treated seed heads), pink-footed goose (*Anser brachyrhynchus*, a large herbivore potentially exposed via treated plant shoots), and the yellow wagtail (*Motacilla flava*, a small insectivore potentially exposed via contaminated insects). The exposure scenarios used in the assessment of pesticide risk to birds on agricultural grasslands are therefore well defined, and appropriate focal species have been identified.

In contrast, candidate focal species data are not currently available for nonagricultural grassland scenarios such as ornamental, domestic, and amenity grasslands that include golf courses. Unlike the agricultural landscape, where extensive uniform areas of crops are treated with pesticides and human activity is relatively low, pesticide applications to golf courses are usually restricted to specific areas (greens, teeing grounds, fairways) where levels of human activity are relatively high. The agricultural practice of crop rotation usually results in different crops being planted in individual fields on consecutive years, and thus the range of bird species utilizing a particular field or group of fields is likely to change annually. However, the layout of greens, tees, fairways, and rough areas of a golf course usually remains unchanged and provides a relatively stable habitat for the local bird community. Moreover, the trees, hedges, streams, lakes, flower beds, and buildings associated with many golf courses provide additional breeding and foraging habitat for a wide range of bird species. Candidate focal bird species for the assessment of pesticides on golf courses are therefore likely to be different from those used for agricultural grassland scenarios. The aim of the present study was to combine data available from the literature with field observations to compile a list of bird species utilizing golf course habitats in Central Europe and from

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this list propose candidate species for assessing the risk posed by pesticides to birds using these areas.

MATERIALS AND METHODS

Literature review

Our approach to compiling a list of candidate focal species for avian risk assessment on Central European golf courses was to combine published data with our own field observations. Literature searches revealed a total of 11 studies and surveys of birds associated with golf courses in Central Europe (Germany and Switzerland) [10–20]. Each of these surveys was conducted to investigate the environmental impact of golf courses, including their construction or renovation, on local avifauna. These investigations usually took the form of breeding bird surveys, and in each case the reported data were assessed for quality, suitability, and relevance to risk assessment.

Field surveys

Field surveys were conducted on 3 golf courses in southwestern Germany during spring 2012. The courses surveyed were: 1) Heidelberg-Lobenfeld (49°22′00″N, 8°52′00″E), an 18-hole course of approximately 77 ha; 2) Golfpark Kurpfalz (49°22′25″N, 8°22′50″E), a 27-hole course of approximately 110 ha; and 3) Pforzheim Karlshäuser Hof (48°57′25″N, 8°44′00″E), an 18-hole course of approximately 80 ha.

These golf courses are typical of the region, comprising tees, greens fairways, rough areas, and a diverse range of other structural elements including trees, bushes, water bodies, flower beds, parking lots, and buildings. The Heidelberg-Lobenfeld course is situated adjacent to woodland, and the remaining 2 courses (Golfpark Kurpfalz and Pforzheim Karlshäuser Hof) are sited in agricultural land. Each of these courses is mainly composed of rough areas (60%–70%) and fairways (25%–35%) with tees and greens together making up less than 3% of their respective totals. Similar compositions are reported for other golf courses in Central Europe [14,21].

The composition of the avifauna on each golf course was recorded using standardized line transect ($n = 12$) and scan sampling ($n = 11$) survey methods, previously described in detail [7]. Line transect and scan sampling surveys were conducted a minimum of 3 times on each of 3 visits (late March, mid-to-late April, and early May, 2012) coinciding with the start of the reproductive season for birds in Central Europe. All line transects were predefined with lengths and widths varying according to the constraints of the individual courses. The avifauna present on each golf course was recorded by a trained observer walking slowly along the transect line, identifying the bird species present on the course, and recording their numbers and locations. Birds flying at heights ≤5 m above the golf courses (e.g., hunting swallows, Hirundinidae) were included in the surveys. Any birds flying >5 m over the golf courses (e.g., migrating species) were deemed to be outside the survey area, and were not recorded.

Scan sampling surveys were conducted by trained observers from specific locations on each golf course. In all cases, the observer remained static while observing, identifying, and recording the locations and numbers of any birds present. A scan sampling survey consisted of a minimum of 15 sampling sessions conducted for 2-min periods. A scan sampling session was paused if human activity (e.g., from green keepers or players) caused any disturbance and continued only when the disturbance had ceased.

All birds recorded during transect and scan surveys were assigned to a behavioral category (either foraging or nonforaging) and a specific golf course microhabitat (fairway, green/tee, rough, trees/bushes) surrounding area. The surface areas of the respective microhabitats on each course were calculated with the aid of Google Earth Pro. The microhabitat preferences of individual species were then determined by relating habitat usage to habitat availability (normalized to 1 ha). The Mann–Whitney U test was used to determine any significant differences in the preferences of individual species for specific microhabitat types (i.e., areas of high vs areas of low pesticide treatment). Values given for these analyses have been rounded to 1 significant figure.

Data analysis

A list of bird species utilizing golf courses was compiled by combining data from the literature with data from our own field studies. Candidate focal species were identified from this list using the frequency of occurrence criterion previously described in Dietzel et al. [7] Briefly, frequency of occurrence values for birds were calculated by dividing the number of golf courses on which a species was observed by the total number of golf courses surveyed (literature plus field data). Using this approach, a species found on all golf courses would have a frequency of occurrence value of 100%. As proposed by the EFSA, species from individual diet guilds with frequency of occurrence values ≥ 20% were considered candidate focal species for their respective guilds [6]. Because our focus is on those species potentially exposed to the pesticides applied to golf course grasslands, we then excluded any species primarily associated with nongrassland habitat (i.e., trees and hedges). Bird species with lower body weights are at greater risk than those with higher body weights [6]. We therefore compiled a final list of candidate focal species for each diet guild (carnivorous, granivorous, herbivorous, omnivorous, insectivorous, and piscivorous) according to body weight. Candidate focal species on the final list for each diet guild were then ranked according to foraging stratum (either ground or canopies of trees and bushes), frequency of occurrence value, and body weight. Where seasonal variation in diet meant that a species could be assigned to more than 1 diet guild, the dominant food source was the primary determinant in guild assignment.

RESULTS

Focal bird species on golf courses

The 13 golf courses used to provide data for the present study are distributed from Germany's North Sea coast through its western regions into Switzerland (Figure 1). Accordingly, our analysis includes data from coastal, inland, and alpine courses.

A total of 102 bird species were recorded on the 13 golf courses included in the present study. With the exception of some species restricted to coastal areas (e.g., the oystercatcher, *Haematopus ostralegus*, and the curlew, *Numenius arquata*), the golf courses we investigated attracted broadly similar bird communities. A number of typical grassland species that could have been expected to occur because of their habitat requirements [21] were not recorded on any of the courses. These included the meadow pipit (*Anthus pratensis*), whinchat (*Saxicola ruberta*), and stonechat (*Saxicola rubicola*).

The blackbird (*Turdus merula*), white wagtail (*Motacilla alba*), great tit (*Parus major*), and blue tit (*Cyanistes caeruleus*) were the most common species on all golf courses, each with a frequency of occurrence value of 100%. In total, 60 bird species comprising 4 carnivores, 3 granivores, 4 herbivores, 17 omnivores, 31

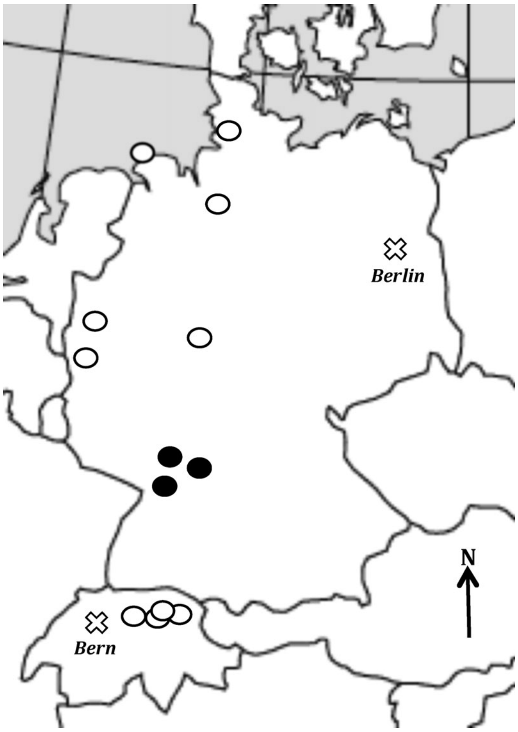

Figure 1. Distribution of study areas: white dots are golf courses where data was taken from published literature [10,13,15–20] and black dots are golf courses where data was collected during the field work for the present study.

insectivores, and 1 piscivore were found to have frequency of occurrence values exceeding the 20% threshold recommended for focal species by the EFSA [6]. Each of these species was therefore included in our initial list of candidate focal species. Although carnivorous birds are not currently considered by the EFSA as appropriate for risk assessment, these species were included in our initial list for completeness.

From the initial list of candidate focal species, we selected the 34 species observed to have fed on the ground and therefore most likely to be exposed to pesticides applied to golf course grasslands. These species are given in Table 1, where they have been categorized according to diet guild and ranked according to frequency of occurrence value.

Carnivorous species. Four species of carnivorous birds were recorded feeding on golf course grassland. Of these, the common buzzard (*Buteo buteo*, body wt 781 g) and kestrel (*Falco tinnunculus*, body wt 186 g) were the most frequently recorded, with frequency of occurrence values of 64% and 55%, respectively. Both species are therefore considered to be candidate focal species for use in risk assessment.

Granivorous species. Three granivorous species, the goldfinch (*Carduelis carduelis*, body wt 15.6 g) linnet (body wt 15.3 g), and serin (*Serinus serinus*, body wt 11.2 g) were frequently recorded feeding on golf course grasslands. All 3 species regularly feed either on the ground or in foliage. Of these 3 candidate focal granivores, the goldfinch and linnet were found to have the highest frequency of occurrence values at 64% and 55%, respectively.

Herbivorous species. Three herbivorous species, the wood pigeon (*Columba palumbus*, body wt 490.0 g), Eurasian coot (*Fulica atra*, body wt 770.0 g), and Egyptian goose (*Alopochen aegyptiacus*, body wt 2040.0 g) were regularly recorded feeding on golf course grasslands and all 3 are exclusively ground feeders. Of the herbivores, the wood pigeon and Eurasian coot were found to have the highest frequency of occurrence values, at 73% and 64%, respectively.

Omnivorous species. A total of 15 omnivorous species were regularly recorded feeding on golf course grasslands. Of these 15 species, 5 are exclusively ground feeders with the remainder feeding both on the ground and in foliage. The frequency of occurrence values for the omnivores ranged from 100% for the blackbird (body wt, 113 g) to 27% for the jay (*Garrulus glandarius*; body wt, 161.0 g). Several small omnivores such as the chaffinch (*Fringilla coelebs*; body wt, 20.9 g), yellowhammer (*Emberiza citronella*; body wt, 26.5 g), and greenfinch (*Carduelis chloris*; body wt, 27.8 g) were frequently present on the golf course grasslands, each with a frequency of occurrence value of 82%. Two larger omnivorous species, the carrion crow (*Corvus corone*, body wt 570 g) and starling (*Sturnus vulgaris*, body wt 79.9 g) were also frequently present, with the same frequency of occurrence value (82%).

Insectivorous species. Of the 29 insectivorous species regularly recorded on golf courses (i.e., frequency of occurrence $\geq$ 20%), 20 are known to forage predominantly either in the canopies of trees or in flight. The 9 remaining species are either exclusively ground feeders or, in 3 cases, feed both on the ground and in foliage. Each of these 9 species was therefore considered to be a candidate focal species. The frequency of occurrence values for the 9 ground-feeding candidate focal insectivores ranged between 27% for the tree pippet (*Anthus trivialis*; body wt, 21.7 g), and 100% for both the white wagtail (body wt, 21 g) and great tit (body wt, 19 g). Other ground feeding insectivores with high frequency of occurrence values included the black redstart (*Phoenicurus ochruros*; body wt, 16.5 g) and robin (*Erithacus rubecula*; body wt, 18.2 g).

Piscivorous species. Although probably not directly exposed to pesticides on golf course grasslands, piscivorous species are considered to be relevant to risk assessment because of their potential to be affected by secondary poisoning via the food chain [6]. The grey heron (*Ardea cinerea*; body wt, 1443 g) was the most frequently recorded piscivorous species on golf courses, with an frequency of occurrence value of 27%.

Use of microhabitats

Golf courses comprise various grassland types that are subjected to different management practices. In particular, greens, tees, and fairways are mown more frequently than rough areas. This has the effect of creating distinct grassland microhabitats in terms of both sward height and associated fauna and flora. Rough areas also receive fewer pesticide treatments than the more frequently mown areas, giving rise to differences in the grassland microhabitat that can be categorized as either low treatment (rough) or high treatment (greens, tees, and fairways).

In the present study, the dominant forms of behavior displayed by birds using golf courses were found to be foraging and feeding (combined hereafter as *feeding*). A few species, such as the mallard (*Anas platyrynchos*), were observed resting on golf course grassland. However, the vast majority of bird species used the various grassland microhabitats as feeding grounds. The extent to which ground-feeding birds are exposed to pesticides therefore depends very much on which grassland microhabitats they prefer to use as feeding areas.

Several species, including wagtails and thrushes, were found to spend extended periods feeding in grassland microhabitats subjected to both high and low pesticide treatment regimes. Other species, such as the tits and the robin, made only brief visits to the ground and these were often in areas adjacent to bushes and trees situated in roughs (i.e., areas subjected to low pesticide treatment regimes).

Table 1. Frequency of occurrence on golf courses values for focal species candidates (categorized according to diet guild and ranked according to Frequency of occurrence value) (published breeding bird surveys and field surveys).

Species	Scientific name	Stratum use	Body weight (g)	Frequency of occurrence golf course (%)
Carnivorous				
Common buzzard	*Buteo buteo*	Ground	781.0	64
Kestrel	*Falco tinnunculus*	Ground	186.0	55
Red kite	*Milvus milvus*	Ground	1080.0	36
Long-eared owl	*Asio otus*	Ground	350	27
Granivorous				
Goldfinch	*Carduelis carduelis*	Ground/foliage	15.6	64
Linnet	*Carduelis cannabina*	Ground/foliage	15.3	55
Serin	*Serinus serinus*	Ground/foliage	11.2	27
Herbivorous				
Wood pigeon	*Columba palumbus*	Ground	490.0	73
Eurasian coot	*Fulica atra*	Ground	770.0	64
Egyptian goose	*Alopochen aegyptiacus*	Ground	2040.0	27
Omnivorous				
Blackbird	*Turdus merula*	Ground/foliage	113.0	100
Chaffinch	*Fringilla coelebs*	Ground/foliage	20.9	82
Yellowhammer	*Emberiza citronella*	Ground	26.5	82
Greenfinch	*Carduelis chloris*	Ground/foliage	27.8	82
Carrion crow	*Corvus corone*	Ground	570.0	82
Starling	*Sturnus vulgaris*	Ground/foliage	79.9	82
Magpie	*Pica pica*	Ground/foliage	166.0	73
Fieldfare	*Turdus pilaris*	Ground/foliage	104.0	73
Song thrush	*Turdus philomelos*	Ground/foliage	66.6	64
Tree sparrow	*Passer montanus*	Ground/foliage	22.0	55
House sparrow	*Passer domesticus*	Ground/foliage	27.4	55
Skylark	*Alauda arvensis*	Ground	37.2	45
Reed bunting	*Emberiza schoeniclus*	Ground	18.3	45
Pheasant	*Phasianus colchicus*	Ground	953.0	36
Jay	*Garrulus glandarius*	Ground/foliage	161.0	27
Insectivorous				
White wagtail	*Motacilla alba*	Ground	21.0	100
Great tit	*Parus major*	Ground/foliage	19.0	100
Black redstart	*Phoenicurus ochruros*	Ground	16.5	73
Robin	*Erithacus rubecula*	Ground	18.2	55
Redstart	*Phoenicurus phoenicurus*	Ground	14.6	45
Dunnock	*Prunella modularis*	Ground/foliage	19.7	45
Green woodpecker	*Picus viridis*	Ground/foliage	176.0	36
Red-backed shrike	*Lanius collurio*	Ground	29.9	36
Tree pipit	*Anthus trivialis*	Ground	21.7	27

Sufficient data were available for the blackbird, starling, fieldfare (*Turdus pilaris*), carrion crow, and white wagtail to allow a more detailed evaluation of their use of golf course grassland microhabitats. The preference indices were compared across the various microhabitats to reveal species preferences for areas of high or low pesticide treatment. None of the species for which a preference index was calculated was found to feed exclusively in grassland microhabitats subjected to either high (greens, tees, and fairways) or low (roughs) pesticide treatment. Furthermore, no significant differences were found between the preference indices calculated for areas of high and low treatment for any species (Mann-Whitney U test, Figure 2). However, white wagtails and carrion crows were observed feeding in microhabitats subjected to high levels of pesticide treatment (greens, tees, and fairways) twice as often as in areas of low pesticide treatment (rough). These findings suggest that a preference for high treatment areas may exist for both of these species. Conversely, data for the blackbird indicate a possible preference for feeding in areas of low pesticide treatment (rough).

DISCUSSION

It has been suggested that both the diversity of bird species and the numbers of individuals found on many golf courses are lower compared with the surrounding habitat [10,11,13,15,16]. Activities such as routine maintenance of the course (daily mowing and raking of bunkers, top dressing, the application of insecticides and herbicides, turf irrigation, scarification, and aeration) and players searching for mishit balls in the rough were thought to cause enough disturbance to deter many bird species [10,11,13,15,16]. However, recent studies indicate that golf courses play an important role in biodiversity conservation and ecosystem management [22,23]. For example, a recent quantitative synthesis of studies comparing the biota associated with golf courses with that of adjacent areas indicated that when constructed in areas with high levels of anthropogenic impact (e.g., agricultural and urban areas) they can exhibit greater biodiversity than their surroundings [22]. The range of microhabitats and other structural elements found on many golf courses appears to make these recreational grassland areas particularly attractive to wild birds. However, the routine maintenance of their grasslands often requires application of various pesticides, some of which have the potential to adversely affect birds. An assessment of the risks posed by pesticides to wild birds foraging on the various grassland microhabitats provided by golf courses is therefore an important aspect of their conservation management.

Within the European Union, guidance on assessing the risks posed by pesticides to wildlife is provided by the EFSA [6] and is based on the use of appropriate focal species for various exposure scenarios. Nevertheless, despite increasing recognition

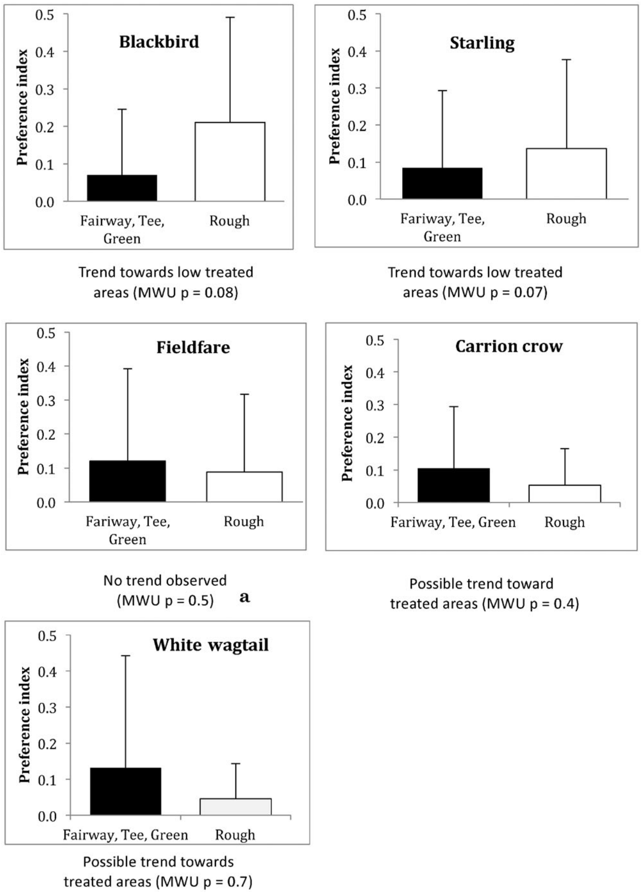

Figure 2. Preferences of habitat use by birds in treated areas (greens, tees, and fairways) versus untreated areas (rough) on golf courses. MWU = Mann–Whitney U test.

that golf courses are potentially important for biodiversity conservation, to date no focal bird species have been proposed for these areas. The primary aim of the present study was to propose relevant focal species for assessing the risks posed by pesticides to wild birds using golf courses as feeding and breeding habitat. A secondary aim was to identify the golf course microhabitats most frequently used by foraging birds to gain an insight into any potential for exposure to pesticides used in these areas.

Focal species

Calculated frequency of occurrence values for more than half of all species recorded (59%) were greater than the 20% frequency of occurrence threshold considered by the EFSA to be a requirement for focal species candidature. Of the 5 focal species suggested by the EFSA for agricultural grasslands, only 2, the house sparrow and linnet, were frequently found on the golf courses included in the present study, both with a frequency of occurrence value of 55%. With a relatively low body weight of 15.3 g, the linnet is considered a relevant candidate focal granivore for golf courses. However, with a frequency of occurrence value of 64%, we found the goldfinch to occur more frequently on golf courses. Although slightly heavier than the linnet, the goldfinch (body wt 15.6 g) may therefore also be an appropriate focal granivore for use in risk assessment on Central European golf courses. The absence of some typical grassland species (e.g., the meadow pipit, whinchat, and stonechat) can be explained by their requirement for specific habitats not normally found on golf courses [21].

The EFSA recommends that the house sparrow (body wt, 27.4 g) be used as the small focal omnivore for agricultural grasslands. Although we found that the house sparrow was often present on golf courses (frequency of occurrence, 55%), a number of other small omnivores with lower or similar body weights occurred far more frequently. These were the chaffinch (body wt, 20.9 g), yellowhammer (body wt, 26.5 g), and greenfinch (body wt, 27.8 g) each with a frequency of occurrence value of 82%. Each of these species could therefore be considered a more appropriate small focal omnivore than the house sparrow for avian risk assessment on golf courses in Central Europe. However, because of its small body weight, the chaffinch is potentially the most susceptible to the adverse effects of pesticides and is therefore the most suitable focal species for risk assessment.

With a calculated frequency of occurrence value of only 9% on the golf courses included in the present study, the yellow wagtail (body wt, 17.6), a small insectivore recommended by the EFSA as a focal insectivore for agricultural grasslands, failed to meet the 20% frequency of occurrence criteria for focal candidates. Of the 9 ground-feeding insectivores with frequency of occurrence values greater than 20%, by far the most frequently occurring were the white wagtail (body wt 21.0 g) and the great tit (body wt 19.0 g). Both of these species were found on all golf courses during each survey, with a resulting frequency of occurrence value of 100%. However, in terms of focal species candidature, despite being slightly heavier, the exclusively ground-feeding white wagtail is a more appropriate focal insectivore for golf courses than the ground- and foliage-feeding great tit.

The pink-footed goose, recommended by the EFSA as a large focal herbivore for agricultural grasslands, was not recorded on any of the golf courses included in the present study. However, 3 other herbivores were frequently present. These were the wood pigeon (body wt, 490.0 g), Eurasian coot (body wt, 770.0 g), and Egyptian goose (body wt, 2040.0 g). Of these 3 species the wood pigeon had both the highest frequency of occurrence value (73%) and the lowest body weight, making it the most suitable candidate focal herbivore.

Taken together, the results clearly show that rather than using the default focal species recommended by the EFSA for agricultural grasslands, any focal species–based assessment of the risks posed by pesticides to wild birds on golf courses should use more relevant alternative species. Based on their frequency of occurrence on golf courses, feeding stratum, and body weight, we suggest that in Central Europe the linnet and the goldfinch are the most relevant focal granivores, with the chaffinch, white wagtail, and wood pigeon representing the most relevant focal omnivore, insectivore, and herbivore, respectively. We also suggest that if required for risk assessment purposes, on Central European golf courses, the grey heron (body wt, 1443 g) is the most relevant focal piscivore and the kestrel (body wt, 186 g) the most relevant focal carnivore.

Microhabitats

The various grassland microhabitats found on golf courses are subject to widely varying degrees of management and maintenance. Grass height on putting greens is kept to approximately 5 mm, requiring these areas to be mown every second day [11,22,23]. Tees and fairways are usually mown 2 to 3 times per week to keep grass heights to 8 mm to 12 mm and 10 mm to 15 mm, respectively [11,22,23]. Rough areas are mown according to the degree of difficulty required by the course. Semirough areas generally make up approximately 37% of a total course area and are usually mown once every 7 d to 14 d to keep grass height from 5 cm to 8 cm. Deep rough areas, comprising approximately 20% of the total course area, are mown only once or twice per year [11]. With the exception of deep rough areas, the majority of golf course grassland microhabitats are too frequently disturbed to provide vegetative cover for ground nesting birds [11].

Pesticides are used to various degrees on all golf course grassland microhabitats to maintain the health and appearance of the turf [24]. The average pesticide treatment rate of golf courses in the United Kingdom is 0.5 kg/ha of total active substance per application over the entirety of a golf course (~8550 kg of active substance per year) [25]. However, the patterns of pesticide use differ markedly from those on agricultural land. When used for agricultural purposes, specific pesticides are usually applied uniformly to 1 or more individual fields containing the same crop at the same growth stage. However, golf courses are larger than most arable fields, and more diverse in terms of both overall structure and pesticide use. Pesticides are most frequently applied to greens and tees, less frequently to fairways, and only infrequently to rough areas [24–27].

Pesticide application rates differ markedly on the various golf course microhabitats, with the highest rates applied to putting greens and tees (up to 15 kg/ha per year) [25]. The average yearly application to fairways is much less (approximately 0.4 kg/ha) [25]. Roughs are left mainly untreated. Fungicides are typically applied to greens and tees where the grass is kept short and is therefore susceptible to infection. Once courses have been established and any postconstruction surge in colonization by invasive weed species suppressed, herbicides tend to be applied mostly to specific areas on fairways where mosses and weeds (e.g., clover) can occasionally cause problems [24–26]. The application of pesticides to golf courses is therefore unlike that on agricultural fields (e.g., some small areas receive relatively frequent applications at high rates, whereas the vast majority of the course receives little or no treatment). Clearly, any attempt to assess the risks posed by pesticides to birds foraging on golf courses should take this pesticide use pattern into account.

According to a report by the Austrian Federal Environment Agency [24], fungicides are the most frequently used class of pesticides on golf course grasslands, (e.g., against snow mold, *Microdochium nivale*). Herbicides tend to be used mainly in the early years following the golf course construction to prevent the growth of invasive weeds (e.g., clover) on putting greens and tees. Insecticides are required occasionally to combat turf-damaging insects such as leatherjackets (Tipulidae larvae). Moss killers are only applied locally. Birds foraging on golf course grasslands are therefore potentially most frequently exposed to fungicides and herbicides. Exposure to insecticides can be expected to occur much less frequently.

The degree to which birds foraging on golf courses are exposed to pesticides depends on the particular grassland microhabitats they use and the type of management to which those habitats are subjected. Any estimation of avian exposure to pesticides should therefore take into account preferences for feeding in a particular microhabitat. Statistical analysis of our data revealed that most species failed to display a preference for any specific golf course microhabitat. Possible exceptions were the blackbird, starling, white wagtail, and carrion crow (Figure 2). Although not statistically significant, data for the blackbird and starling suggest a preference for foraging in rough areas infrequently treated with pesticides. Conversely, but again not statistically significant, data for the white wagtail and carrion crow suggest that both of these species have a slight preference for foraging on greens and tees, (i.e., areas more frequently treated with pesticides). These observations suggest that the white wagtail and carrion crow therefore represent primary candidate focal species for avian risk assessment on golf courses in Central Europe. Nevertheless, species such as the fieldfare (Figure 2), which were frequently present on golf courses but showed no preference for, or avoidance of, any particular microhabitat, could also be considered candidate focal species. However, given that only a small area (~5%, greens and tees) of a golf course receives regular and relatively high pesticide treatments, our results indicate that it is unlikely that any bird species will obtain all of its diet from these regularly/highly treated areas.

CONCLUSIONS

Current EFSA guidance on risk assessment [6] for wild birds potentially exposed to pesticides uses a tiered approach. In the initial tiers, worst-case default assumptions based on the feeding habits of recommended focal species are used to model exposure and gain insight into the degree of risk posed by a specific pesticide. If a potential risk is indicated, in higher tiers both the focal species and its feeding habits can be refined to provide a more realistic and environmentally relevant exposure scenario. The results of the present study indicate that bird species other than those recommended by the EFSA for agricultural grasslands should be used for assessing the risk posed by pesticides on golf courses in Central Europe. Our results also suggest that it is unlikely that any of the candidate focal bird species we propose for higher tier risk assessment on golf courses will obtain all of its food from an area highly and/or regularly treated with pesticides.

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