

Do hole-nesting passerine birds fare well at artificial suburban forest edges?

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Urbanization and subsequent disturbance, habitat alteration and fragmentation are usually seen as major threats to biodiversity. However, habitat alterations might also create new habitat types that can be used by the local fauna. Here, we tested whether hole-nesting passerines use forest edges next to open grassland areas for reproduction by assessing five golf courses in the Helsinki region in southern Finland. We found a major effect in all species breeding at our sites (great tit, *Parus major*; blue tit, *Cyanistes caeruleus*; pied flycatcher, *Ficedula hypoleuca*): both nest occupancy and the number of offspring were significantly higher at the artificial edges than 50 m into the original forests. We conclude that man-made suburban forest edges provide suitable habitat for nesting, which could be further improved with the addition of nest boxes.

Introduction

Human-dominated environments have changed global ecosystems considerably (Vitousek *et al.* 1997). Perhaps the most significant changes are taking place in urban areas, which constitute approximately 4% of the Earth's surface, yet support more than half of the human population (Mock 2000). Urbanization has a myriad of effects on the environment, though not all of these should be perceived as negative (Niemelä *et al.* 2011). A variety of human impacts in urban areas diversify the urban environment by modifying existing ecosystems and by creating unique ones (Gilbert 1989). Many species do not

survive in urban environments, but some persist and thrive in them.

Large uniform habitat patches are usually most suitable for bird breeding (Gillihan 2000). But these large patches are rare, especially in urban areas. Therefore, small urban habitat patches often contain a considerable proportion of edge habitat, i.e. boundaries between two distinct habitats (field/forest, developed land/undisturbed habitat, etc.). The interaction between two different habitat types, when the two are separated by an abrupt transition is called the edge effect, which may alter the distribution, abundance and behaviour of organisms (Murcia 1995). Edges may offer resources from the two

surrounding habitats as well as create a new edge habitat that might in some instances show a tendency towards greater variety and density of plant and animal populations than the contrasting habitats (Ries *et al.* 2004).

Population densities of birds have been shown to increase near habitat edges long ago (e.g. Lay 1938, Good & Dambach 1943), although there is contrasting evidence that nesting success may be reduced near edges because of predation, especially in fragmented landscapes (e.g. Small & Hunter 1988, Hanski *et al.* 1996, Holt & Martin 1997). However, in his review, Lahti (2001) concluded that a majority of empirical tests have failed to support the hypothesis that avian nest predation increases near habitat edges. Despite potential negative effects, edges can be valuable in terms of biodiversity as they sometimes attract species from different environments (Gillihan 2000). McKinney (2002) refers to urban birds as “edge species”, which are adapted to forest edges and surrounding open areas.

Golf courses, if managed appropriately (Terman 1997), increase biodiversity when established in agricultural or urban landscapes (Colding & Folke 2009) or they may be at least equal to many natural habitats in terms of animal and plant diversity (Blair 1996, Terman 1997, Gange & Lindsay 2002). Many studies of birds in golf courses (Gordon *et al.* 2003, Dale 2004, White & Main 2004, Cristol & Rodewald 2005, Merola-Zwartjes & DeLong 2005, Rodewald *et al.* 2005, Cornell *et al.* 2011) have shown that a golf course can provide suitable habitats for many bird species and, in some cases, can even contain species that are of conservation concern. However, of the studies that have investigated avian responses to golf course habitats, few have used an experimental approach (Cornell *et al.* 2011). In general, experimental studies in urban environments are rare despite the frequent and replicated land transformations conducted by developers (Marzluff & Ewing 2001).

Here we studied how edges generated by artificial clearings in closed forests would affect the breeding phenology of small hole-nesting birds, especially when the open areas are intensively used for human leisure activity, which is a common occurrence in suburban areas. Based on the literature (Jones *et al.* 2005, LeClerc *et al.*

2005, Cornell *et al.* 2011), we expect such edge habitats to provide a favourable breeding habitat, because of the variable vegetation, access to prey (insects) and good thermal conditions. On the other hand, the open edge habitat might be disturbing for nesting birds and may even attract predators, reducing the reproductive success of birds nesting at forest edges (Dale 2004, Smith *et al.* 2005, Stanback & Seifert 2005). Hence, to understand the effects of suburban clearings with intense human activity on hole-breeding bird nesting, we compared the birds' nesting probability and clutch size in artificial nest boxes at forest edges and deeper into these forests at five urban and suburban golf courses in the greater Helsinki area in southern Finland. In addition, we compared the patterns between different bird species and different golf courses to examine whether local environmental conditions or species-specific attributes altered the results.

Material and methods

Data collection

We studied great tits (*Parus major*), blue tits (*Cyanistes caeruleus*) and pied flycatchers (*Ficedula hypoleuca*) during reproduction at five urban and suburban golf courses in the greater Helsinki region, southern Finland (Fig. 1). We were interested in any hole-breeding birds, but in practice these species were expected and observed. The golf courses differed in age, size and distance to the city centre (Table 1), thus representing a large variety of possible course types. Twenty wooden nest-boxes (30 cm × 15 cm × 15 cm; height, width and depth, respectively) with a hole diameter of 32 mm (+ plastic hole protectors/predator guards following Clamens & Isenmann 1989) were placed at golf-course forest edges and another 20 nest boxes 50 m into the forests at each golf course. In all cases, forests were mixed-type dominated by pine (*Pinus sylvestris*) and spruce (*Picea abies*) and a variety of deciduous trees like birch (*Betula pendula*) and rowan (*Sorbus aucuparia*). Nest boxes placed at the edge had their entrance holes facing towards the open golf course area. The nest boxes were placed 2 m high on trees, and were separated by

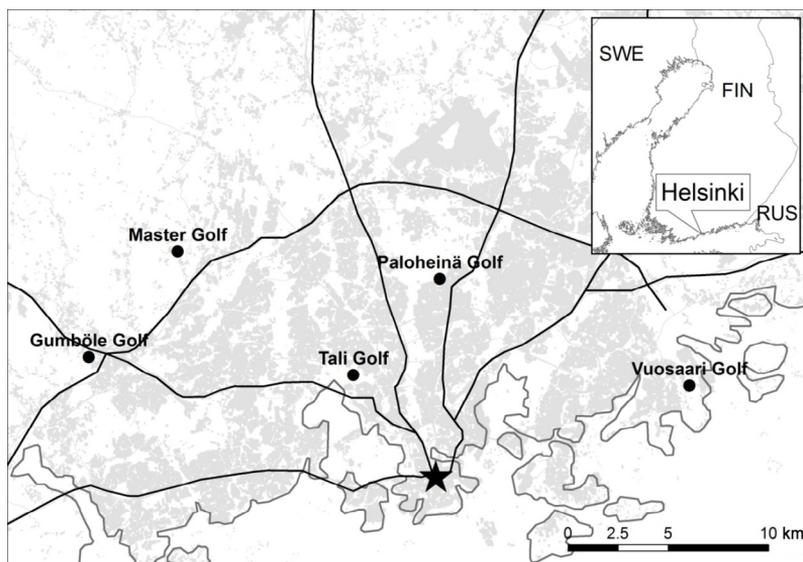


Fig. 1. Map of the study area showing the five golf courses (●). Urban areas are indicated in grey, main roads as black lines and the location of the Helsinki city centre is marked by a star.

50 m. The nest boxes were all set in April 2008, before the nesting (and golf) season started. The nest boxes were monitored weekly, with extra efforts during the incubation period. We recorded the species occupying nest-boxes and counted eggs and chicks. We believe that no nesting effort remained undetected. The nestlings were ringed before fledging.

Data analysis

The data were analysed in two steps, first focusing on the probability of occupying the nest boxes and second on the number of offspring per nest. Nesting was recorded as a binary presence/absence variable and analysed with log-linear analysis. The response variable was modelled following a binomial distribution. We entered habitat (edge or forest), course (golf course), species (great tit, blue tit, pied flycatcher) and

their two-way interactions as predictor variables.

Number of offspring was analysed with a generalised linear mixed model (GLMM) with Poisson distribution and log link. Here, number of offspring was the dependent variable, and habitat, species and their interaction the fixed effects. Because observations within a golf course were not independent, we also included course as a random factor. All analyses were performed with PASW Statistics 18 (PASW Inc. Chicago, Illinois) and SAS 9.2 (SAS institute Inc., Cary, NC, USA).

Results

Three bird species (great tit, blue tit, pied flycatcher) used our nest boxes for nesting. Nesting was significantly affected by habitat ($\chi^2 = 4.79$, $df = 1$, $p = 0.029$) and species ($\chi^2 = 7.85$, $df = 2$, $p = 0.020$), but the habitat effect did not differ

Table 1. Information of the golf courses. See Fig. 1 for course localities.

Course name	Year established	Size (ha)	Distance to city centre (km)	Surrounding forest size (km ²)
Tali	1932	55	6	0.5
Master	1987	80	22	0.5
Vuosaari	2001	50	14	0.5
Gumböle	1991	28	19	2
Paloheinä	1996	30	10	1.5

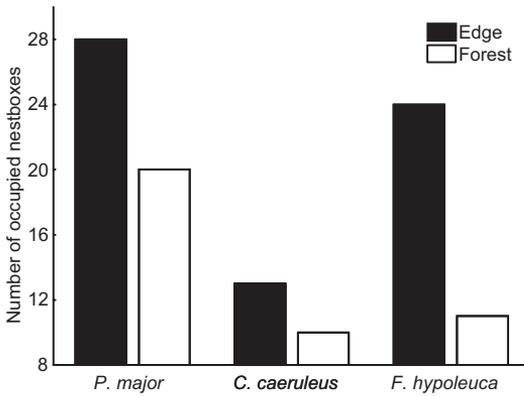


Fig. 2. Species-specific and habitat-dependent occupation of the artificial nest boxes. Note that even though both habitat and species effects were significant, their interaction was not, i.e. all species showed similar habitat-preference.

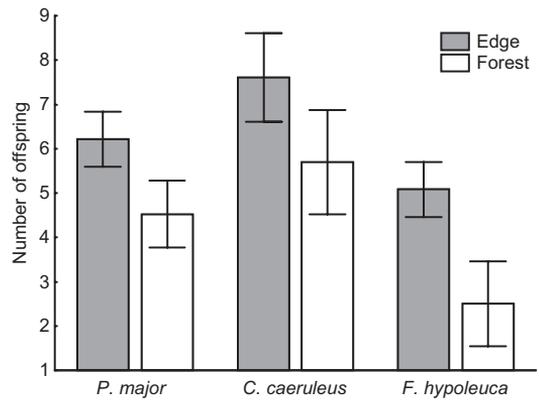


Fig. 3. Estimated species-specific and habitat-dependent reproductive output. Means \pm SEs are shown. Note that even though both habitat and species effects were significant, their interaction was not, i.e. all species showed similar patterns.

among species ($\chi^2 = 1.45$, $df = 2$, $p = 0.48$). All other predictors were non-significant (all $p > 0.39$). The habitat effect was clear: more birds nested at the edges than inside the forest, irrespective of species (Fig. 2). The species effect stemmed simply from the fact that the species were represented by different numbers (great tit: $n = 49$, blue tit: $n = 25$, pied flycatcher: $n = 44$, Fig. 2).

Number of offspring revealed a strikingly similar pattern (habitat: $F_{1,98} = 17.17$, $p < 0.0001$; species: $F_{2,98} = 9.23$, $p = 0.0002$). Birds had significantly higher numbers of offspring at the edges than in the forests, irrespective of species (Fig. 3). The species effect stemmed from the fact that pied flycatchers had fewer offspring than tits (Fig. 3). The habitat effect did not differ among species ($F_{2,98} = 1.32$, $p = 0.27$; Fig. 3).

Discussion

The most salient finding of our study is clear: the three studied bird species (great tit, blue tit and pied flycatcher) all nested more frequently at the artificial forest edges than in the surrounding forest. Further, these birds all produced more offspring per nest in the edge nests. These results show that urban and suburban edge habitats in golf courses (and possibly other similar anthropogenic structures) can provide favourable nest-

ing sites for birds that can tolerate human activity. Experimental studies of this effect are scarce at best, hence, we believe that our results provide new insights into how human disturbance can positively (at least in the short term) affect focal species.

In our study, artificial forest edges were favoured by birds as nesting sites, despite the nest-boxes being right at edges of golf course fairways. This strong edge effect indicates that the habitat mix, characteristic of edges, is attractive to species that tend to be tolerant of disturbances at their nesting habitats (Dowd 1992). Apparently, competition for edge-habitat nesting sites was evident in a few cases where we observed flycatchers ousting tits from already occupied nest-boxes. Flycatchers, in particular, seem to favour edge habitat as two times more nests were found at the edge as compared with the surrounding forest, although the distance between the edge and forest nest-boxes was only 50 m. It is possible that the quality of the edge habitat overrides the risk of increased disturbance and predation, the latter being reduced by the protective nest-boxes. Our results differ from that of Huhta *et al.* (1999), who found higher occupancy rates in interior boxes *vs.* edge boxes at forest clearings for pied flycatcher.

The number of offspring per nest box followed a similar trend; considerably more offspring were produced at the edge, irrespective

of species. Seemingly, disturbance by intense human activity on golf courses do not prevent hole-nesting passerines from nesting successfully at these sites, but the availability of the edge habitat results in increased reproductive success. It is important to note that higher preference for nesting sites at the edges alone would not provide support for the higher quality of these edges, as new human-induced habitats can act as ecological traps, where the attractiveness of the habitat does not correlate positively with the survival or reproductive success of individuals actually choosing it (Weldon & Haddad 2005). In our case, we also estimated reproductive success via the number of offspring per nest, which was also higher at the edges than in the forest, thus we can reject the hypothesis that the studied artificial forest edges acted as ecological traps. Cornell *et al.* (2011) showed that bluebirds (*Sialia sialis*) do equally well occupying nest-boxes on golf courses than at structurally similar habitats, like parks, hence, the clearly positive edge effect reported here might be true in other human made open environments than golf courses too. The open-edge habitat may provide warmer nesting conditions (Kremser & Bunnell 1999), as well as foraging areas suitable for these insectivorous species (Cornell *et al.* 2011), which overcome disturbance and predation pressures possibly attributed to the visible nesting sites (Cornell *et al.* 2011). However, increased number of offspring is not necessarily directly and only related to better habitat quality, but it is also possible that edge nesting sites were occupied by better quality/older/more experienced birds, and thus the difference in offspring number reflects parental quality. Obviously, the two sources of divergence, i.e. environmental and parental quality, might have affected the patterns together. To differentiate between these alternatives, more focussed studies, preferably by manipulating environmental and parental quality are needed.

Bird species found in urban settlements are sometimes characterized by having broader environmental tolerance (Bonier *et al.* 2007). These generalist species are capable of utilizing and exploiting resources provided by the city. Møller (2009) concludes that bird species that have adapted to life in urban surroundings are characterized by large breeding ranges, high pro-

density for dispersal, high rates of feeding innovation, short flight distances when approached by humans, high annual fecundity and high adult survival rate. Such species are often non-native or invasive (Pimentel *et al.* 2005), which contribute to the regional biodiversity of the city, making it often higher than in nearby rural areas (Marzluff 2001, Pickett *et al.* 2008). Even small greening projects within the urban matrix are valuable for biodiversity, as they show a positive response in bird diversity and thus increase the habitat value of an area (Loss *et al.* 2009, Strohbach *et al.* 2013). Our study showed that the abundance and density of native species that tolerate human activity might also increase as a result of increased environmental variability following human habitat alteration including an increase in favourable nesting sites.

However, higher probability of nesting and higher number of offspring per nest at urban-natural habitat edges does not necessarily mean that urbanization is favourable to the studied species in general. Urban birds are shown to decrease in diversity in the most densely built downtown areas, but show diversity comparable to natural environments in suburbs, that are important for providing winter habitats for seasonal species (Caula *et al.* 2008). Even though the three species of hole-nesting passerines in this study are all abundant and common, their success may vary considerably depending on the availability of nesting sites, especially in urban areas, where natural nesting sites are reduced because of a lack of dead wood and natural forest. Our study showed that areas with limited availability of naturally-occurring nesting sites could be converted to good breeding habitats only with the addition of nest boxes. It should be noted, however, that whereas nest boxes may be an effective short-term conservation tool for enhancing or maintaining some bird populations, they do not mitigate the effects of chronic habitat loss for the many species in urban or suburban areas (Fiehler *et al.* 2006).

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