Urbanization and nest-site selection of the Black-billed Magpie (Pica pica) populations in two Finnish cities

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Abstract

Urbanization is an important ecological factor that modifies the living conditions of species at multiple levels. Urbanization is also influenced by human-animal relationships. We studied the effects of human-related factors on nest site selection of the Eurasian Magpie (Pica pica) by using both historical and contemporary data on the nest sites of the Magpie both at landscape and micro-habitat levels in Finland. The nest site data on the Magpie were collected by searching old nest site data as well as by collecting data from current nest sites in two Finnish towns. Our results indicate that the population densities of the Magpie have increased in both study areas during 1950-2010, and that the actual adjustment to urban conditions began around 1980. The relative nest height of Magpies has decreased in urban, but no in rural habitats. The Magpie preferred breeding sites with great green area cover and less built-up areas. Moreover, Magpies preferred ever-green coniferous trees over deciduous tree species as their nest sites. The Magpie made its nest in the upper parts of the tree canopies, regardless of the tree species. Our results give support that urbanization by the Magpie is related to both changes in human disturbance, and in the species-specific habitat needs. Planting coniferous trees may promote the breeding of the Magpie in urban environments in northern area. We suggest that, the Magpie, as a common and well-known species, may be a good candidate to monitor the state of the urban environment.

Introduction

Currently, more people live in urban than in rural areas, and urban built-up areas are increasing at an even greater rate than the urban population (UN, 2014). Urbanization involves one of the most extreme forms of land-use alteration, and generally leads to a nearly complete restructuring of vegetation and species composition (Francis & Chadwic, 2013). Urban areas differ in many ways from natural environments. For example, urban environments are characterized by a high level of predictable anthropogenic food resources, high levels of human-caused disturbances, a milder microclimate, and with only remnants of the original habitat persisting (Francis & Chadwic, 2012, 2013). Despite these challenging conditions, several species have been able to colonize urban environments (e.g. Bezzel, 1985; Erz, 1966; Fey et al., 2015; Kövér et al., 2015; Shochat et al., 2006; Vuorisalo et al., 1992, 2003, 2014).

Urbanization has created a number of new ecological niches (Erz, 1966), which benefit some bird species possessing specific traits (Croci et al., 2008; Jokimäki et al., 2014; Kark et al., 2007). Because urbanization may act as a filter on species' traits, urbanized bird species may share a suite of biological traits that explain their success in tolerating the impact of humans (Croci et al., 2008; Kark et al., 2007). In general, bird species have been shown to have wider environmental niches and greater tolerance of disturbance factors in urban centers than in non-urban areas (Blair, 1996; Chace & Walch, 2006).

Evans et al. (2010) identified three successive stages in the species' urbanization process: (i) arrival, (ii) adjustment, and (iii) spread. *Arrival* refers to the initial dispersal to an urban area, *adjustment* refers to the processes whereby individuals manage to cope with a markedly different new environment, and *spread* refers to the colonization of new urban areas by populations already adjusted to the urban environment. Particularly human attitudes and species´ ecological traits influence the rate of progress through each stage (Clucas & Marzluff, 2012; Evans et al., 2010). Different factors may operate in different phases of the urbanization process. For example, a high population density in original habitat and good dispersal ability of species are important factors during the arrival phase, whereas ecological and behavioral plasticity of species play important role during the adjustment phase, and lastly, high reproductive success is one key factor for the further spread of the species (Evans et al., 2010).

The Black-billed Magpie (Corvidae; *Pica;* hereafter Magpie) populations have grown dramatically in urban areas in Europe during the last 50 years (Jerzak, 2001; Luniak, 2004). The Magpie has several traits, such as generalist habitat choice and omnivorous diet, that have been found to promote bird species urbanization (e.g. Croci et al., 2008; Evans et al., 2010; Jokimäki et al., 2014; Kark et al., 2007; see review Chace & Walsh, 2006). Generally, finding a suitable nest site is a major factor for birds to be able to settle and reproduce successfully, especially in urban environments where suitable nesting sites are usually reduced (Antonov & Atanasova, 2002; Kövér et al., 2015; Tatner, 1982). Tree nesters, like the Magpie, would find nest sites in urban woodlots, parks, and private gardens as well as in rows of trees along the streets.
In addition to the possible changes in habitat structure in the course of urbanization, also changes in human behavior (e.g. hunting pressure) may impact on species' occurrence in urban areas. Species considered harmful may be directly or indirectly persecuted. This has been the case with the Feral Pigeon in many cities worldwide (Johnston & Janiga, 1995). According to Tatner (1982) and Cramp and Perrins (1994), the colonization of suburban and urban habitats, and the reoccupation of areas of former occurrence by the Magpie may have resulted from a decrease in persecution by humans. However, this topic has been almost totally ignored in earlier studies related to landscape and urban planning (but see Vuorisalo et al., 2003, 2014).

The Magpie usually breeds in association to human activities in Finland (von Haartman et al., 1963-1972; Mela, 1882; Palmgren, 1935). The Magpie was classified as a pest species in Finland already in the Imperial Hunting Decree of 1898 (Hunting Decree, 1898), and was therefore persecuted by hunters. The relative late onset of urbanization during late 1950´ and 1960's was probably due to its persecution in densely populated areas (Tenovuo, 1967). The most probable reason for the widespread persecution was the questionable reputation of the Magpie as nest predator of songbirds and game birds (Renwall, 1896). The situation with regard to persecution has probably been rather similar elsewhere in Europe (e.g. Tatner, 1982).

Eden (1985) suggested that hatching success of urban Magpies might be higher in urban than in rural areas because of the reduced human persecution. In some areas, Magpies prefer coniferous trees over deciduous trees in their nest placement (Antonov & Atanasova, 2002; Dhindsa et al., 1989; von Haartman, 1969), whereas in some other areas, deciduous trees are favored over conifers (Dulisz, 2005; Meissner & Żółkoś, 2010; Tatner, 1982; Zbyryt & Banach, 2014). Antonov and Atanasova (2002) indicated that the breeding of urban Magpies starts earlier in conifers than in deciduous trees, because of permanent and thick foliage cover in coniferous trees during the starting phase of the breeding. Several studies have also indicated that the nest height of Magpie increased with urbanization (Antonov & Atanasova, 2002; Dhindsa et al., 1989; Mérő, et al., 2010; Wang et al., 2008; Zbyryt & Banach, 2014) probably because the greater nest height in urban environments might decrease the probability that the nest will be destroyed by humans or nest predators. According to Antonov and Atanosova (2002) Magpie nests located in preferred tree species and nests located higher above the ground are more successful (hatching and fledging success) than nests located in avoided tree species and lower part of the tree.

In this paper, we investigate the urban colonization processes and nest site selection of the Magpie in Finland during the period 1950-2010 using both historical and current data sets. Considering the rapid global urbanization process, large-scale temporal analyses are needed to understand species' colonization and habitat selection patterns in urban environments (Marzluff et al., 2001; Vuorisalo, 2010). However, long-term studies in urban environments are extremely rare (Marzluff et al., 2001; Parlange, 1998; Vuorisalo et el., 2003).

We assumed that the adjustment phase of urban colonization (*sensu* Evans et al., 2010) of Magpies should be reflected to its nesting habits in trees and shrubs (Cramp & Perrins, 1994; von Haartman et al., 1963-1972). Thus, as it occurs for corvids (Antanov & Atanasova, 2002; Dhindsa et al., 1989; Kövér et al., 2015; Vuorisalo et al., 1992; Wang et al., 2008), characteristics of trees (e.g. tree species, height of tree) would influence nest site selection of Magpies and, therefore, the urbanization process. Our main aim was to analyze human influence on the Magpie abundance and nest site selection (nest tree species, height of nest in tree) in two Finnish towns, Rovaniemi and Turku, across a long time period.

We tested the following three main hypotheses: a) as changes in persecution (e.g. number of killed Magpies by the hunters) influence occurrence of species within urban areas, we predicted that a decrease of persecution might allow Magpies to breed nowadays more often in town centers; b) as both nest tree availability and access to sheltered nesting sites influence nest site selection, we predicted that Magpies would favor coniferous trees over deciduous trees in urban environments due to the better shelter against human persecution or nest predation provided by coniferous trees, and c) as human persecution is now less common than earlier, we predicted that Magpies nowadays less frequently place their nests in the upper canopies of the trees to avoid persecution.

2. Methods

2.1. Study areas and data sets

We studied the nest site selection of the Magpie in the towns of Turku (60° 27'N, 22° 15'E) and Rovaniemi (66° 230'N, 25° 42'E). Turku is located in southern Finland, and Rovaniemi in northern Finland. Turku was founded ca. 1300 A.D., making it the oldest town in Finland. The current human population is about 184,000 inhabitants. The surrounding landscape of Turku is dominated by agricultural areas. The town of Rovaniemi, on the other hand, is the one of the northernmost towns in Finland. The town was almost totally destroyed at the end of the Second World War. The current human population is about 61,600 inhabitants. The surrounding landscape of Rovaniemi is dominated by forested areas. Partly because of the much larger municipality area of Rovaniemi (8,016 km^2) compared to that of Turku (249 km^2), the human population density in Turku (727 inhabitants per km^2) is far greater than in Rovaniemi (8 inhabitants per km^2; Environment Statistics, 2014).

The study areas covered only the urban core areas (i.e. the most urbanized areas), if not otherwise mentioned, with their densely built block-of-flats areas, parking lots, traffic areas and small patches of managed urban parks (Turku 480 ha; Rovaniemi 81 ha). The human population density in the urban core area of Rovaniemi is 86 persons/km^2 and in Turku 999 persons/km^2. The proportion of built-up areas (block-of flats, parking areas, and roads) in the urban core areas exceeds 50% in both towns. These areas thus fulfil the criteria set for urban areas as suggested by Marzluff et al. (2001). Maps of the study areas are available from Jokimäki (1992; Rovaniemi) and Vuorisalo et al. (1993; Turku).

Historical sources made it possible to describe breeding occurrence and nest tree selection during the course of the Magpie urbanization process in our study towns. Old data on nests were extracted from the Finnish nest-card database (data before 1980; the Finnish Museum of Natural History, Helsinki, Finland). These data sets included 48 nest records from the Turku area and 14 nest records from the Rovaniemi area. Additionally, 23 old nest records from Rovaniemi were extracted from Aimo Komonen´s “nest card” archive located at the Arctic Centre, Rovaniemi, Finland. These data sets contain nests from the urban core areas and surrounding rural areas (within 50 km from the town core area located agricultural-dominated landscapes; proportion of built-up area 5-20 %, residential human density <100/km²; *sensu* Marzluff et al, 2001) from the both study towns. Rural data were used only in comparison of the nest height change between urban and rural Magpies. The data bases include both the information about the nesting tree species as well as the nest height, but no data about the tree height.

More recent data about the numbers of nests located in urban core areas of both towns were extracted from the literature (1967-1990; Rovaniemi, Jokimäki, 1992; Turku, Kunttu & Laine, 2002; Vuorisalo et al., 1992, 1993) and collected by our own field surveys conducted in Turku (1991, 1999, 2001) and in Rovaniemi (1999-2000, 2010-2012). The data sets of these studies are based on intensive nest surveys. Regional densities of rural and urban Magpies and their trends were extracted from the Finnish National Bird Monitoring Program. Both old and more recent data sets were used to identify the number of occupied nests in the town core areas of Turku and Rovaniemi.

Our field survey data from urban core areas from the period 1999-2001 were used for a nesting habitat choice study. Nest tree choice related to the availability of trees (within 50 m radius around the Magpie nest) was studied using the data covering the years 1999-2000 in Rovaniemi, and the years 1999 and 2001 in Turku. The temporal changes in nest tree selection (conifers vs. deciduous trees) and nest height in urban core areas were analyzed by means of the nest-card data (data before 1963; von Haartman, 1969) and our own data (data after 1980).

We used the Finnish nest card data from 1986-2012 to estimate the possible difference and changes in nest site selection of the Magpie between the rural (percent of built-up area 5-20; residential human density maximum 10/ha; dominant land use type agricultural) and urban core (see definition above) habitats. Urban core areas cover exactly the same areas as in our other analyses. We divided this data into two parts, before and after the year 1990. This year corresponds to the time, when the nesting Magpie populations increased heavily in urban core areas of both study towns. This data set contained information of the nest height, nest tree height and nest habitat in all parts of Finland. Unfortunately, nest card data before the year 1986 were not appropriated from our purposes, because the height of tree and nesting habitat were not mentioned in that dataset.

To estimate persecution levels, we extracted data on killed Magpies by the hunters in Southwest Finland (Turku region) and Southern Lapland (Rovaniemi region) during 1996-2014. The Finnish Game and Fisheries Research Institute (presently Natural Resources Institute Finland) has surveyed the annual game bag during 1996-2014 with a standard questionnaire which is based on a sample of about 5000 hunters (e.g. Finnish Game and Fisheries Research Institute 2014). Unfortunately, no older data were available. In addition, we did not have any quantitative data about the changes of human behavior (e.g. numbers of Magpie nests destroyed by schoolboys).

2.2. Field methods

2.1.1. Nesting Magpies

We conducted systematic searches for the nests of the Magpie in the urban areas of Turku and Rovaniemi. These surveys were conducted in Turku in 1991, 1999, and 2001, and in Rovaniemi in 1999-2000 and 2010-2012. They were conducted by walking every street within the centers of both towns (Rovaniemi, 81 ha; Turku 480 ha) from late April to early May, before leaf-flush of deciduous trees. We registered active/occupied nests, which meant that Magpies were observed in and around the nests. We also identified nest trees to the species/genus level, and estimated the height of tree and the height of the nest bottom from the ground by hypsometer. In addition, we calculated number of each tree species/genus around (within 50 m) each Magpie nest.

We also estimated the breeding density of the Magpie in suburban and rural areas of Rovaniemi. Suburban Magpies were surveyed by the 5-visit mapping method (Bibby, 2000) during the years 1967-1969, 1983, 1985, 1999-2001 and 2010 within a 149 ha survey plot (2966 inhabitants). Rural Magpies were surveyed in 10 villages (93-1369 inhabitants) by the one-visit plot method (Bibby, 2000) during the years 1988 and 2011 within a 10 ha study plots. More detailed description about study sites and methods are given in Jokimäki and Kaisanlahti-Jokimäki (2012).

2.3. Habitat availability

We analyzed the habitat use by the Magpie in the urban core areas of Turku (18 nests) and Rovaniemi (10 nests) in 1999-2000. We used up-to-date (2014) aerial photographs to estimate the percent cover of four habitat variables; i.e. (i) proportion of buildings, (ii) proportion of asphalt, rocks and sand, (iii) proportion of green areas, which included parks, woodlots, and open green areas, and (iv) open water, around (within 75 m) each Magpie nest site to assess the variability of the habitat features. A corresponding number of randomly selected points (with 75 m radius; and which did not overlap with each other's) that did not overlap with the nest site description circles of the Magpie was included in the analyses. We used 75 m radius around the nest because the Magpie usually collects food items for its nestlings no further than 75 m away from the nest site (Högstedt, 1980). The year of air photos did not correspond exactly to our survey years. However, city planning documents show that changes in urban core areas have been very small during 1999-2014. Therefore, we assume that these up-to-date photos provide valid information. We also measured the habitat heterogeneity around Magpie nests and at random points by means of the Simpson index. The Simpson index is $1- \Sigma p_i^2$ where p_i is the proportion of habitat type (buildings, asphalt, green area, and open water) in the study area (Krebs, 1999).

2.4. Data analyses

In habitat availability study (field survey data 1999-2000) we followed the *used* (nests) *vs unused* (random points; without nests) study design for resource selection functions (Boyce et al., 2002). In this logistic regression analysis, habitat variables (proportion of different habitat types) were continuous covariates and towns were categorical covariates. In total, we had 28 Magpie nest points (value 1 in the logistic regression analysis) and 28 random points (value 0). We presented only the best of the tree logistic models using the Akaike information criteria (AICc; Andersson et al., 2000). The best model selected was based on the results of logistic regression analyses and on which variable(s) had the lowest AICs value fits the nesting habitat selection data.

The relationship between the year and number of Magpie nests was studied by the Spearman rank correlation coefficient. We tested selection of nesting tree species using the analysis of covariance (ANCOVA), in which the dependent variable was proportion (%) of nests in each tree species and the categorical independent variables were numbers of coniferous and deciduous tree species. The covariate was proportion (%) of each species within 50 m radius from the Magpie nest. If the covariate was statistically significant, the Magpie selects common tree species as its nesting sites. The Fisher's exact test was used for comparison of coniferous and deciduous trees as nest sites of the Magpie between the towns of Turku and Rovaniemi. We used the Chi Square test for testing the temporal shift in nest tree choice between coniferous and deciduous trees.

Finally, we analyzed the temporal change in nest heights (in meters) in Turku and Rovaniemi, before and after colonization by the Magpie within these areas, using the analysis of variance (ANOVA). We firstly checked that the claims of the ANOVA analyses were fulfilled. We further analyzed the temporal change in nest heights before-and-after urban colonization by the Magpie with the ANCOVA. For this analysis, we divided the post-colonization period a single variable with the information of period (earlier and later), and used these periods as independent variables. The interval between these post-colonization periods was about 10 years in both towns. In Turku, the early period was the year 1991 and the later period consisted of the years 1999 and 2001. In Rovaniemi the early period was 1999-2000 and the later period 2010-2012. In this analysis, we used tree height as a covariate.

We tested temporal changes of the height of Magpie nest between urban and rural habitats with the ANCOVA by using the Finnish nest card data from 1986 to 2012. These data sets had 2,619 nest records with the information of the nest height, nest tree height and nest habitat around Finland. For this analysis we divided the data for two periods, before and after year 1990, because based on our earlier analyses, the Magpie has increased heavily in both study towns after 1980. We had data on 2066 nests from rural areas and 151 nests from urban areas before 1990.

Correspondingly, we had data on 331 nests from rural and 71 nests from urban areas after 1990. In this analysis we used two periods (before and after 1990) and two habitat types (urban and rural) as fixed factors and the height of tree as a covariate. Unfortunately the data did not allow us to separate study regions (Turku and Rovaniemi) from each other because of the small sample sizes. All statistical tests were performed by the IMB-SPPS Statistics 22.

3. Results

3.*1. Historical urbanization and persecution chronologies of the Magpie in Turku and Rovaniemi*

The first Magpie nests were found from suburban areas of Turku in the 1960s and from Rovaniemi in 1954. The first nests were found from the urban core area of Turku in 1952 (Fig 1a) and in 1983 in Rovaniemi (Fig. 1b). The number of nesting Magpies increased from 1980 to 2010 in both urban core areas (Turku: $r_s = 0.89$, $n = 7$, $p = 0.007$; Fig. 1a; and Rovaniemi: $r_s = 0.91$, $n = 9$, $p = 0.001$; Fig. 1b). In Rovaniemi (no corresponding data from Turku), the number of nesting Magpies increased in suburban areas during the 1967-2010 ($r_s = 0.86$, $n = 9$, $p = 0.003$). However, the number of breeding Magpies did not differ in the rural villages of Rovaniemi between the two study years 1988 (mean = 1.1, $sd = 0.88$, $n = 10$) and 2011 (mean = 1.4, $sd = 1.07$, $n = 10$; Mann-Whithney U-test, U = 42.0, $p = 0.579$)

The numbers of killed Magpies have decreased in Turku area ($r_S = -0.62$, $p = 0.004$, $n = 19$), Rovaniemi area ($r_S = -0.50$, $p = 0.030$, $n = 19$) and the whole Finland ($r_S = -0.60$, $p = 0.006$, $n = 19$) during 1996-2014.

3.2. Choice of nesting habitat

According to the aerial photo analyses, Magpie nest surroundings contained more green and less built-up areas than the surrounding of random points without nests in both towns (Table 1). The proportions of open areas (asphalt, rocky and sand habitats) around the nests and the random points were almost equal (Table 1). Two nests in Turku and one nest in Rovaniemi were located near a river (Table 1). Habitat heterogeneity was higher around the nests (0.58 ± 0.8) than around the randomly selected points without nests (0.52 ± 0.13) (t-test, $t = 2.33$, $df = 54$, $p = 0.024$). The probability of Magpie nesting decreased with increasing proportion of built-up areas around study points (logistic regression, $\chi^2 = 6.22$, $df = 1$, $p = 0.013$, $AICc = 45.06$; Fig. 2), and increased with habitat heterogeneity (logistic regression, $\chi^2 = 5.59$, $df = 1$, $p = 0.018$, $AICc = 60.60$), and with co-occurrence of both factors (logistic regression, $\chi 2 = 14.51$, $df = 2$, $p = 0.001$, $AICc = 61.84$).

3.3. Choice of nesting tree species

Species richness of nest trees was much greater in the southern town, Turku (16 species or taxa), than in the northern town, Rovaniemi (7 species or taxa; Table 2). The availability of tree species around (within 50 m) the nest tree also differed between the southern and the northern study areas. A total of 34 tree species (or taxa) were found in Turku and 14 tree species (or taxa) in Rovaniemi. The Magpie selected more often a common tree species for nesting than a rare species both in Turku (ANCOVA, $F_{1,31} = 20.56$, $p < 0.001$; Fig. 3a) and in Rovaniemi (ANCOVA, $F_{1,11} = 37.22$, $p < 0.001$; Fig. 3b).

In both towns, more Magpie nests were found in conifers than in deciduous trees when the availability of trees was taken into account (Turku, ANCOVA, $F_{1,31}$= 5.27, p = 0.029; Fig. 3a; Rovaniemi, ANCOVA, $F_{1,11}$= 7.57, p = 0.019; Fig. 3b). We found no differences in coniferous and deciduous tree species preference between Turku and Rovaniemi (Fisher's exact test, p = 0.065). We therefore pooled the data from Turku and Rovaniemi for further analyses.

There was a temporal shift in the preference for coniferous vs deciduous tree species as nesting sites (Fig. 4). Earlier most Magpie nests (over 90%) were found in coniferous trees (Fig. 4), whereas later, the proportion of Magpie nest in deciduous trees was almost equal to the proportion of nest located in coniferous trees (χ^2 = 84.66, df = 1, p < 0.001; Fig. 4).

3.4. Nest height

The average height of nest from the ground was 7.4 m (SD = 3.4 m; range 1.7 – 17.5 m, n = 115; Fig. 5) in urban core areas. This corresponded to a relative nest height ((nest height from the ground/nest tree height)*100)) of 72% (SD = 13.5), indicating that the Magpie usually builds its nest in the top part of the tree crown. There was a temporal shift in nest height (Fig. 5). In Rovaniemi, the nest height was lower before Magpie colonization than after colonization. Such a temporal difference in nest height was not observed in Turku (ANOVA, between cities $F_{1,311}$ = 5.69, p = 0.018, before and after $F_{1,311}$ = 27.84, p < 0.001 and interaction $F_{1,311}$ = 28.95, p < 0.001; Fig. 5).

In the post-colonization period, the average height of Magpie nests increased by 0.7 m during the ten-year interval (ANCOVA, $F_{1,218}$ = 7.59, p = 0.006), when the height of tree was used as a covariate (ANCOVA, $F_{1,218}$ = 853.41, p < 0.001). The estimated marginal means was in the early post-colonization period 7.3 m (SE = 0.1), and in the later post-colonization period 8.0 m (SE =

0.1). However, there was no difference between the towns (ANCOVA, $F_{1,218} = 0.78$, $p = 0.378$), nor between coniferous and deciduous trees (ANCOVA, $F_{1,218} = 0.27$, $p = 0.606$). Neither were the interactions statistically significant ($p > 0.108$ in all cases).

Because number of nesting Magpies increased heavily after 1989 in both towns, we analyzed if there were changes in nest height between rural and urban habitats before and after the year 1990. The Magpie nest height increased with increasing tree height during the years 1986-2012 (Table 3). However, the mean nest height decreased from 5.2 m (SE = 0.2) to 4.5 m (SE = 0.17) in urban habitats, but remained at about the same level in the rural habitats (correspondingly; 4.5 m (se =0.1) vs. 4.8 m (0.8)) when tree height was controlled for (Table 3; Fig 6).

4. Discussion

4.1. Changes in urban Magpie populations

Our results indicate that the arrival phase (sensu Evans et al, 2010) of Magpies to urban areas started via suburban areas during early 1950s in Turku and mid-1950s in Rovaniemi. Although a couple of nesting's were discovered in the Turku grid-plan area already in the 1950s, both in Turku and Rovaniemi the actual colonization of urban core areas took place since the 1980s. Adjustment phase, when the abundance of breeding Magpies increased considerably in urban core areas, started in both towns during the late 1980's. These time periods fit well into the time frame of urban colonization and adjustment phases of Magpies in other parts of Finland (Jokimäki & Kaisanlahti, 1999) and elsewhere (Jerak, 2001; Luniak, 2004; Nakahara et al., 2015; Snow & Perrins, 1998). Currently, the density of the Magpie in urban core area of Rovaniemi is about 13 pairs per square kilometer (Jokimäki, unpublished) and in urban core area of Turku 5 pairs per square kilometer (Vuorisalo, unpublished). However, these densities are much lower than the maximum densities (17-57 pairs per square kilometer) observed in Central European towns (Antonov & Atanasova, 2002; Jerzak, 2001; Luniak, 2004). Indeed, it seems that Magpie densities have reached their upper-limit at least in urban core areas of Rovaniemi, where the population density has been relatively stable already for a long time (1999-2015; 6-9 pairs/81 ha; Jokimäki, unpublished), whereas suburban population seems to still increase (1967-1985; 4-9 pairs; and 1999-2010; 13-18 pairs per 149 ha; Jokimäki, unpublished).

There are several, not mutually exclusive, explanations for the spread of the urban Magpie. One reason for urbanization of the Magpie in Finland, and probably in other parts of the world as well, is the decrease in its persecution by humans. Unlike before, the Magpie's nests nowadays usually remain unmolested in urban areas. The main reasons for this lies in the changes in attitudes adopted by people regarding wild animals (Vuorisalo et al., 2001) and changes in legislation. The European Union's Bird Directive (1979) prohibits disturbing of the Magpie during its breeding season, and the same ban is included in the Finnish Hunting Act (2011). Concurrently with this, the traditional hobby of Finnish schoolboys to collect birds' eggs and to destroy their nests in the vicinity of inhabited areas has more or less become history (Vuorisalo et al., 2001, 2003). Our results also indicated that the number of Magpies killed by hunters have markedly decreased around our study sites, and Finland in general, during the last decades. Due to the decrease in persecution levels, the Magpie has habituated to the constant presence of humans and traffic in urban areas (Jerzak, 2001). At the same time, the flight escape distance of Magpies has decreased in many areas, being currently about double in rural as compared to urban areas in Europe (Diaz et al., 2013; Møller, 2008).

A possible explanation for the increase in urban population could be an increase in the size of surrounding rural populations. However, this seems unlikely since the number of breeding Magpies did not change in rural areas of Rovaniemi during 1988-2011. Also, the national breeding Magpie population in Finland remained quite stable during 1975-2012 (Väisänen & Lehikoinen, 2013), and no changes in breeding rural Magpie population has been observed during the period 2001-2008 in Finland. (Valkama et al., 2011). According to the results of the Finnish national winter-bird monitoring program, the Magpie population increased significantly during the 1970s and early 1980s (Väisänen & Solonen, 1997), but after that (1987-2014) wintering populations have been very stable both in rural and urban areas (Lehikoinen & Väisänen, 2014). In Poland, breeding abundance of Magpies increased three times faster in urban than rural settings and the breeding success of urban Magpies have been higher than in rural Magpies (Jerzak, 2001). Therefore, population pressure from rural to urban environments is not a plausible explanation for the increase of urban Magpie populations.

Winter feeding of birds has become more common in suburban as well as urban areas, and being an opportunistic species, the Magpie has undoubtedly benefited from this extra food source provided by humans (Väisänen, 2008). According to the Finnish winter feeding sites monitoring program, the occurrence and abundance of the Magpie on feeding sites increased markedly during the period 1989-2007 in Finland (Väisänen, 2008). Winter feeding facilitates overwintering of omnivorous and feeding-table species such as the Magpie (Jerzak, 2001; Jokimäki & Kaisanlahti-Jokimäki, 2012; Jokimäki & Suhonen, 1998; Luniak, 2004). Winter feeding may also promote colonization of urban habitats as is demonstrated by the case of the Raven (*Corvus corax*, Baltensperger et al., 2013), Mallard (*Anas platyrhynchos*, Pulliainen, 1963), the Greenfinch (*Carduelis chloris*; Väisänen, 2008; Väisänen & Solonen, 1997) the Blue

Tit (*Parus caeruleus*; Väisänen, 2008; Väisänen & Solonen, 1997), and the Blackbird (*Turdus merula*; Møller et al., 2014). During the late 1940s, the whole wintering Magpie population in urban area of Rovaniemi was about 200 individuals (Komonen, 1950). According to intensive winter bird surveys conducted during 1976/77-1981/82 in the Rovaniemi area, the Magpie was more abundant as a wintering species in urban areas (31 individuals/10 km survey route) than in the surrounding villages (10 individuals/10 km survey route) or in the more natural areas (3 individuals/10 km survey route; Jokimäki, 1982).

4.2. Choice of nesting habitat

In both towns, Magpie nest surroundings contained more green areas and fewer built-up areas than non-breeding random sites. A preference of green areas might be related to availability of nesting trees (Nakahara et al., 2015). However, the avoidance of built-up areas might also be related to human disturbance. Jokimäki (1999) showed that the Magpie in northern Finland breeds more often in unmanaged than in managed parks. This may be related to the fact that even in urban areas Magpies still need shelter against predators such as humans, or that they prefer to forage in unmanaged park areas with a lower level of human disturbance. However, the Magpie is a species that is able to breed in very small parks, less than 2 ha in area, as far as suitable nesting trees/shrubs are available (Jokimäki, 1999; Suhonen & Jokimäki, 1988).

4.3. Choice of nest tree

According to our results, the Magpie selects more often common tree species than rare tree species for their nest sites in Finland. Earlier studies, taking also account the availability of different tree species, from the more southern parts of the Europe have reported that the Magpie prefers deciduous tree species belonging to genera such as *Ilex*, *Ulmus*, *Populus* and *Prunus*, and avoid conifers (Jerzak, 2001; Snow & Perrins, 1998; Tatner, 1982; but see Antonov & Atanasova, 2002; Dhindsa et al., 1989). Our results are, thus, not consistent with patterns observed in Southern and Central Europe. An obvious reason for the difference is that deciduous trees lack leaf cover during the early nest building phase in northern areas, leaving nests exposed to predators as well as human disturbance. The preference for conifers as nest sites may thus be an antipredator behavior against species such as the Hooded Crow and therefore the results gained across different areas may not be generalized for the other areas.

4.4. Relative nest height

In Rovaniemi and Turku, the Magpie builds its nests usually in the top part of the tree, on average at the relative height of 72% of tree height. This result corresponds well with earlier results from the other parts of the world (Antonov & Atanasova, 2002; Dhindsa et al., 1989; Nakahara et al., 2015; Wang et al., 2008). Naturally, the height of the nest above the ground may depend on the tree species (Antonov & Atanasova, 2002; Birkhead 1991). However, even after taking this factor into account in our analyses, the preference for the upper parts of trees was statistically significant. There are two likely reasons for this. One reason may be related to the purpose of avoiding ground-dwelling predators like the cats and humans, and the other may be related to the architectural constraints of trees. A nest located in the upper parts of the tree may be more difficult for ground-dwelling predators to reach. It may be also related to it being technically easier to build a proper nest in the upper parts of tree canopies than among the lower branches of trees. Our results indicate that relative nest height has remained the same in rural, but decreased in urban areas during the years 1986-2012. This result indirectly indicates that persecution pressure towards urban nest sites has decreased especially in urban environments.

Conclusions

Our results show that urbanization and nest site selection by the Magpie are scale-dependent processes. We observed increase in nest numbers within the urban core areas during the sixty study years. At the habitat level, the Magpie builds its nest in areas with a low proportion of built-up areas, probably to avoid human disturbance. At the tree level, the Magpie in Finland prefers coniferous trees and builds its nest in the upper parts of tree canopies. Also these results support the possible role of human disturbance on the Magpie nest selection patterns. As regards nesting tree species selection, our and earlier results from elsewhere, indicate that nest tree selection is site-specific and depends on the latitude.

Therefore, tree species selection should be considered when making decisions concerning tree planting in urban green areas. In northern latitudes, Magpies prefer coniferous over deciduous trees, and to attract Magpies also to the urban areas, using conifers in urban park management is a good option. However, our results indicate that after the colonization phase in urban habitats, the Magpie has increasingly started to nest in deciduous trees. It is possible that, although conifers are preferred, their limited availability in urban centers forces some pairs to build their nests in the less-preferred deciduous trees. In addition, it is also important to consider human attitudes towards birds in urban planning (Clucas & Marzluff, 2012; Fernández- Juricic & Jokimäki, 2001; Lepczyk et al. 2008). More ecological research about the breeding success of urban Magpies are needed.

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List of tables

Table 1. Percent of habitat variables within 75 m buffers around random points (without nests) and around Magpie nest sites (used) in the towns of Turku and Rovaniemi

	n	Habitats							
		Buildings		Open areas		Green areas		Water	
Turku		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nests	18	26	16	41	14	31	15	2	7
Random	18	36	21	43	29	21	26	0	0
Rovaniemi									
Nests	10	23	13	45	17	31	24	1	3
Random	10	36	16	47	16	18	20	0	0

Table 2. Tree species used for Magpie nests in the town of Turku and Rovaniemi and in pooled data. *n* is number of nests found per tree species and % is percent of nests in each tree species.

	Turku		Rovaniemi		Pooled data	
Species	*n*	%	*n*	%	*n*	%
Abies sp.	1	2			1	1
Acer platanoides	7	14			7	6
Aesculus hippocastanum	1	2			1	1
Betula sp.	1	2	22	32	23	19
Crataegus sp.	3	6	1	1	4	3
Malus domestica	5	10			5	4
Picea abies	2	4	4	6	6	5
Picea pungens	4	8			4	3
Pinus cembra	7	14	8	12	15	13
Pinus sylvestris	8	16	30	43	38	32
Populus sp.	2	4			2	2
Salix sp.			1	1	1	1
Salix alba	1	2			1	1
Salix caprea	3	6			3	3
Salix fragilis	2	4			2	2
Sorbus aucuparia		0	3	4	3	3
Tilia x vulgaris	2	4			2	2
Ulmus glabra	2	4			2	2
Total	51	100	69	100	120	100

Table 3. Final results of an ANCOVA model, which predicted mean nest height of magpie in habitat type (urban area and rural area) and between two time periods (before and 1990 and after that) in Finland. The table includes model test statistics. Habitat type (urban vs rural area) and time period (before and 1990 and after 1990) were fixed factors. Tree height was a continuous covariate in the model.

Source of variation	F	df_1, df_2	*p*
Intercept	0.76	1, 827	0.384
Habitat type	2.21	1, 827	0.138
Time period	2.87	1, 827	0.091
Habitat type x Time period	13.17	1, 827	<0.001
Tree height	1874.12	1, 827	<0.001

Legends for figures

Figure 1. Number of nesting Magpies in the town centers of Turku (a; 480 ha) during 1950- 2010 and Rovaniemi (b; 81 ha) during 1966-2010.

Figure 2. The proportion of buildings (%) within 75 m radius in relation to the predicted probability (%) that the Magpie nests occurred in the town center (*n* = 56; some dots are overlapping each other's). The symbols denote the Magpie nest (open dot) and the random point (filled dot).

Figure 3. Nest tree species (%) choice by the Magpie in relation tree species available (%) within a 50 m radius from the nest tree in the towns of (a) Turku and (b) Rovaniemi. An open dot denotes a deciduous tree species and a filled dot denotes a coniferous tree species. In Turku, there were 34 tree species or taxa available within a 50 m radius from the Magpie nests. In Rovaniemi, there were 14 tree species or taxa available within a 50 m radius from the Magpie nest. The continuous line indicates that the proportion was the same for the available tree species and the Magpie's choice of nesting tree species. The two most common nesting tree species of the Magpie were coniferous tree species Scots pine (*Pinus syslvetris*) and Swiss Pine (*P. cembra*), which were added to the figure.

Figure 4. The temporal change in the proportion (%) of coniferous (black) and deciduous (grey) trees by the Magpie for nesting before (earlier than 1980) and after (1980 or later) urban colonization.

Figure 5. The temporal change in the mean nest height (m) (upper bound of 95% interval) of the Magpie's nest in a tree. The change in nest height was divided into two groups: before (before than 1980) and after (later than 1980) urban colonization in Turku (black) and in Rovaniemi (grey) area.

Figure 6. The temporal changes in the nest height of the Magpie's nest in relation to tree height in urban (grey bars) and rural (black bars) environments before (-1990) and after (1991-) the heavy increase of the urban Magpie populations in Turku and Rovaniemi.

Figure 1

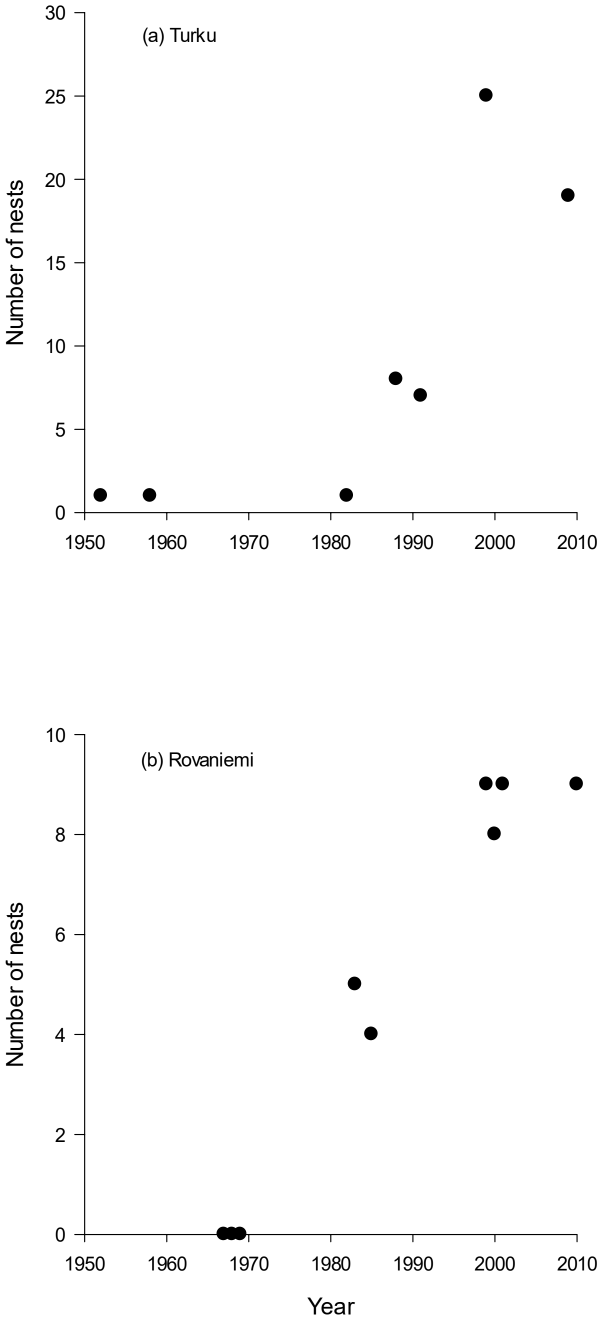

(a) Turku
Number of nests
30
25
20
15
10
5
0
1950
1960
1970
1980
1990
2000
2010
(b) Rovaniemi
Number of nests
10
8
6
4
2
0
1950
1960
1970
1980
1990
2000
2010
Year

Figure 2

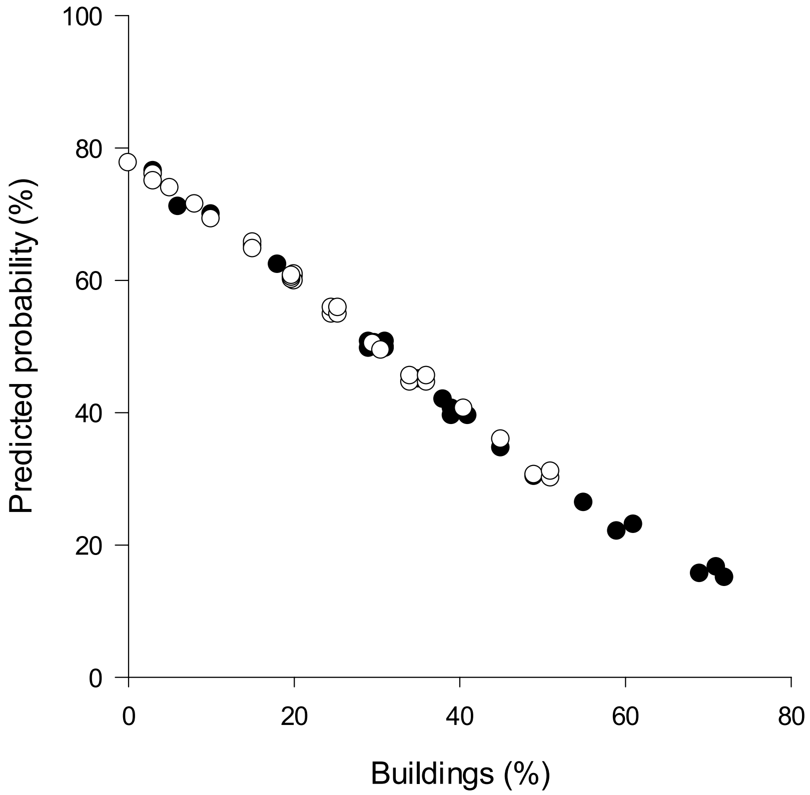
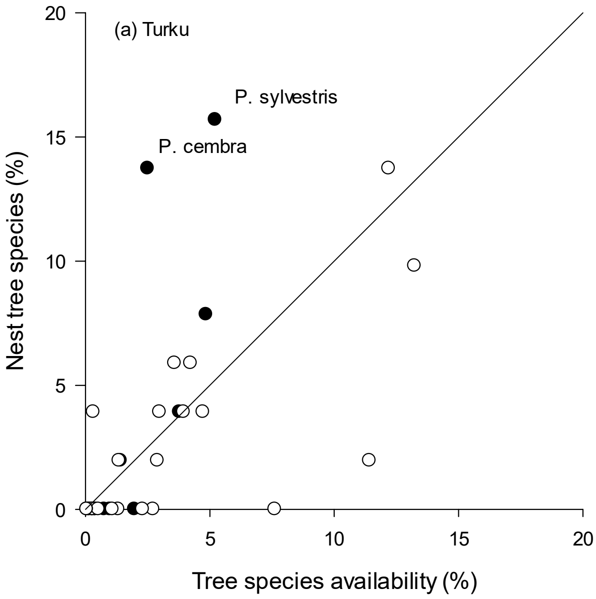


Figure 3


(a) Turku
P. sylvestris
P. cembra
Nest tree species (%)
Tree species availability (%)
0
5
10
15
20

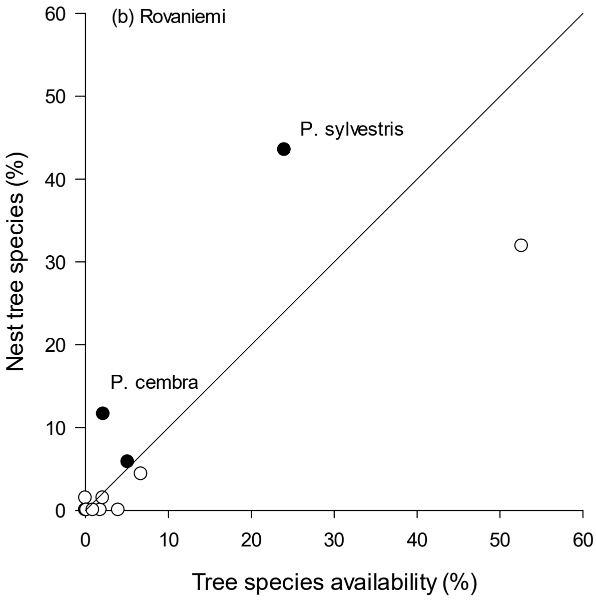
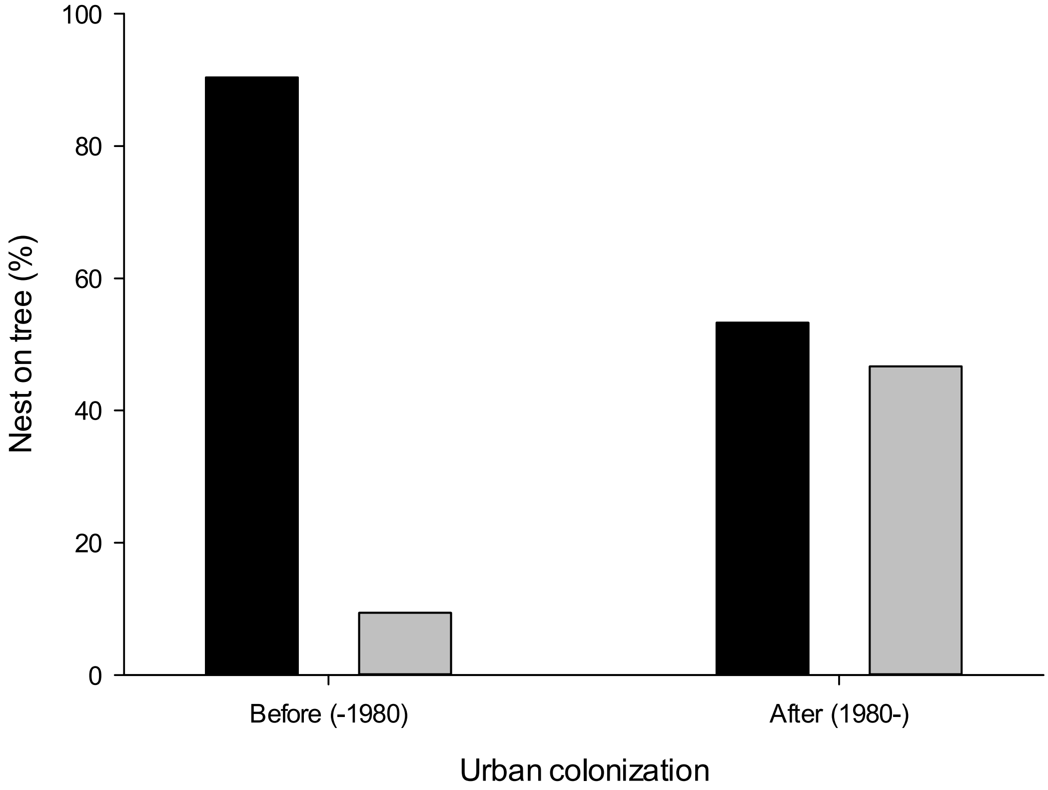

(b) Rovaniemi
P. sylvestris
P. cembra
Nest tree species (%)
Tree species availability (%)
0
10
20
30
40
50
60

Figure 4



100
80
60
40
20
0
Nest on tree (%)
Before (-1980)
After (1980-)
Urban colonization

Figure 5

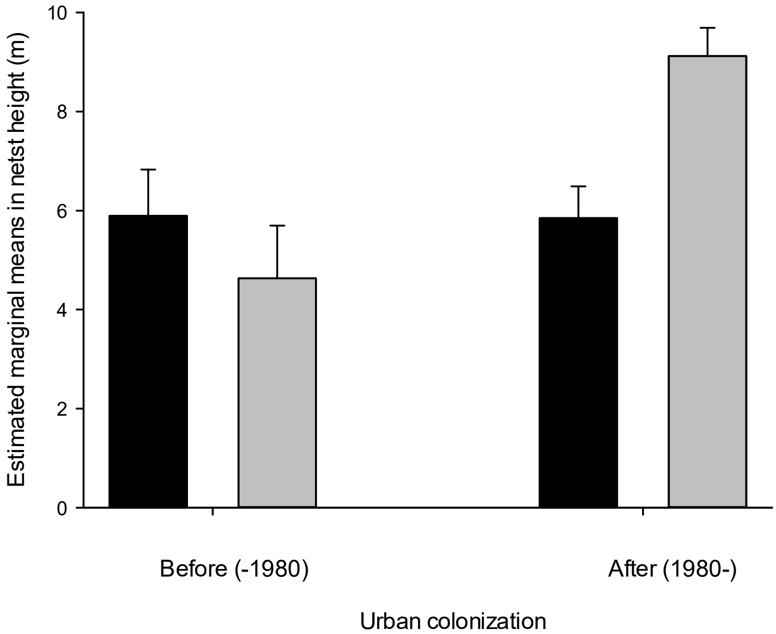
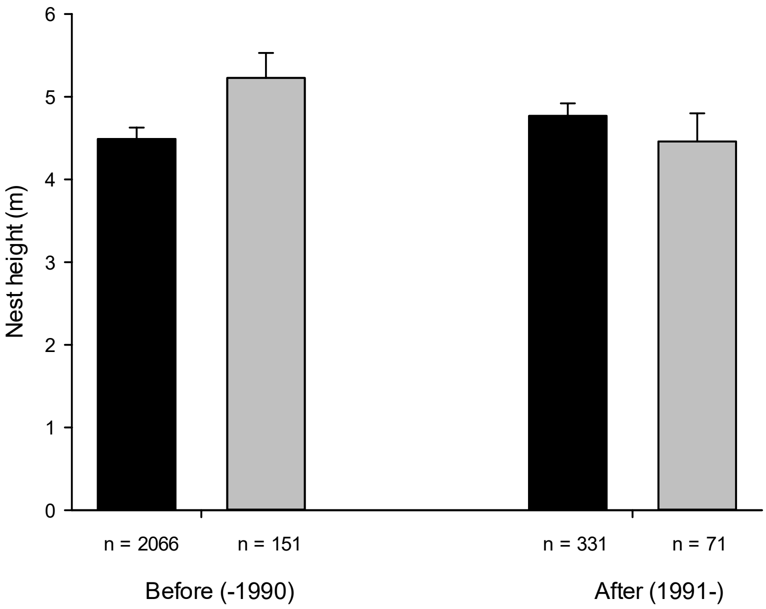

10
8
6
4
2
0
Estimated marginal means in netst height (m)
Before (-1980)
After (1980-)
Urban colonization

Figure. 6


6
5
4
3
2
1
0
Nest height (m)
n = 2066
n = 151
n = 331
n = 71
Before (-1990)
After (1991-)