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AN EVALUATION OF STONE MARTEN (*MARTES FOINA*) RECORDS IN THE CITY OF BUDAPEST, HUNGARY

TÓTH, M., BÁRÁNY, A. and KIS, R.

[1]*Department of Systematic Zoology and Ecology, Eötvös Loránd University*
1117 Budapest, Pázmány Péter s. 1/c, Hungary, E-mail: toth.maria@gmail.com
[2]*Hungarian National Museum, 1088 Budapest, Múzeum körút 14–16, Hungary*
[3]*DHISTECH Kft., 1121 Budapest, Konkoly -Thege út 29–33, Hungary*

A multi-scale investigation into the urbanization process of the stone marten in Budapest was initiated in 1996. Topographic records (n = 214) of stone martens were gathered within the city's administrative area (525 km^2) on the basis of questionnaires, correspondence and phone-calls. Earlier studies had pointed out that the occurrence and the diversity of the food-basis of this species does not show a significant relation to the greenness of habitats in Budapest. The aim of our analysis was to search for connections between confirmed records of stone martens and the habitat and structure of patches where they were located. Two main types of patches were defined: green habitat had >50% green covering, desert habitat ≤ 50%. Overall, the green patches were preferred (67%), although certain desert patches had a relatively high density of sightings. The reason for this might come from compensating factors, such as the structure of buildings, the type of roof or gutter. The multi-storey, old and often neglected houses, sometimes with inner gardens, appear to be excellent hideouts that also provide some nutritive sources. No similar analysis appears to have been carried out to date neither in Budapest nor elsewhere.

Key words: building, Budapest, occurrence, stone marten, urban

INTRODUCTION

The urbanisation of animals has shown an accelerating tendency in recent years both in the number of species and the expansion of their habitats. Cities are the most densely urbanized human settlements. They often have variable structure and history and may provide a variety of resources, such as food, shelter and migration corridors for various species. Through historical times, the growing cities encroached upon or surrounded adjacent natural habitats. While the impact of urbanization on the surrounding landscape has been widely studied, a lot less is usually known about the animals that inhabit cities.

The stone marten's colonization of urban habitats started in the 1950's in most of the Central and Western Continental European countries (BISSONETTE & BROEKHUIZEN 1995). This process cannot be attributed to diminishing natural habitats. Rather, the stone marten's successful urban settlement and integration into the urban food web is attributed to its flexibility: they are known to be dietary opportunists, generalists and fairly skilled predators (GENOVESI & BOITANI 1997, LANSZKI 2003, TÓTH 2003). Their body shape and size enables them to move briskly across all terrains. Urban stone martens live practically side by side with humans, using attics, roofs and suspended ceilings as den-sites (TÓTH & SZENCZI 2004, HERR *et al*. 2009*b*). Their ingenuity seems to be limitless: they create holes between tiles, use guttering and plumbing, climb on lightning conductors, use staircases to access well insulated safe attics, roofing, thatched roofs, neglected rooms, suspended ceilings, or church towers, etc. (TÓTH & SZENCZI 2004). Other factors contributing to their success may be the absence of larger predators and a low density of competitors (VAN DRUFF *et al*. 1996). At the same time, they might cause significant financial and sanitary problems (TÓTH *et al*. 2007*a*, SZŐCS *et al*. 2008, HERR 2008). Unlike other countries, where stone martens have been known to enter and damage cars since the late 1970s (reviewed in HERR 2008), this is knew phenomenon in Hungary.

In Hungary, the stone marten is currently a widespread and common carnivore. Consequently, its status was changed from protected to hunted game in 1996 (SZEMETHY & HELTAI 1996, TÓTH *et al*. 2007*b*). It is also frequent in urban environments.

There have been some studies indicating the generalist, opportunistic features and the high degree of adaptability of the stone marten in Budapest (TÓTH 1998, TÓTH 2003, SZENCZI 2005, BÁRÁNY 2006). They demonstrated a high diversity and seasonal changes of food composition. This diversity did not correlate with the greenness of habitats and the stone martens appeared to prefer the patchy but dense food sources (TÓTH & SZENCZI 2004, TÓTH *et al*. 2007).

However, it is still not well understood what exactly makes highly disturbed urban areas attractive for stone martens. In addition to food, the cover effect is believed to constitute an important factor. Thus the structural characteristics of old buildings may facilitate the stone marten's (and probably other urban vertebrates') colonisation of the inner districts of Budapest. The data was collected through visiting a wide range of buildings.

The question is how these ecological factors (i.e. food availability, green spaces, cover) rank in terms of priority. The aims of our analysis were to use data from a 13-year monitoring program of stone marten presence in Budapest 1) to map the extent of its occurrence through the city; 2) to test the quality (in terms of greenness) of the habitat patches visited by martens; 3) to highlight characteristics of used patches and define the preferred type of buildings.

METHODS

Study area

Budapest has an administrative area of 525 km² consisting of 23 districts (Fig. 1) with a population of about 1.8 million residents (Hungarian Central Statistical Office 2001). The city is split into two parts by the Danube river. The Buda side (west of Danube) represents the green part of the city, occupying the surrounding hills, while Pest (east of Danube) forms a densely developed basin, with a highly fragmented landscape. Both parts have undergone intensive redevelopment during the last few years, resulting in significant changes in the structural, sociological and ecological aspects of the city.

Data collection and analysis

Between 1996 and 2008 the presence of stone martens was recorded through field work, phone calls, email correspondence or a questionnaire that was available through the webpage of our research group. An attempt was made to confirm all records, other than sightings of living or dead specimens, through the presence of hair, scats, or footprints.

Fig. 1. Numbering and location of the 23 districts in Budapest. The striped patches represent the DESERT (≤ 50% green) and the grey patches represent the GREEN (≥ 50% green) type districts. There were no topographical data available for districts 6 and 10 until 2008

Table 1. Basic data for the evaluation of stone marten records in Budapest (1996–2008). C: Code of districts, TR: No. of topographic records included the GIS database (n = 214), AR: No. of all records between 1996–2008 (n = 303), A: Area of the districts (km^2)

C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
TR	6	55	20	5	1	0	4	6	16	0	25	28	11	10	2	1	4	5	3	1	1	9	1
AR	11	65	31	7	2	3	4	7	21	2	34	42	14	17	4	5	4	12	4	3	1	9	1
A	3.4	36.3	39.7	18.8	2.6	2.4	2.1	6.8	12.5	32.5	33.5	26.7	13.4	18.1	26.9	33.5	54.8	38.6	9.4	12.2	25.8	34.3	40.8

The topographical records were marked on a map using a Geographical Information System (ArcView GIS 3.2). Following conversion from WGS-84 to EOV (Standard National Projection Grid of Hungary), the maximum coordinate error was 0.17 m. The following additional data was recorded for each report: year of sighting, district code, type of damages caused by the animals, and presence of progeny. The latest investigations have indicated that urban stone martens use relatively small home ranges of between 4 to 122 ha in size (BISSONETTE & BROEKHUIZEN 1995, ESKREYS-WÓJCIK *et al.* 2008, HERR *et al.* 2009*a*), depending on sex, age and density. Based on the findings it was decided to use a 25 ha square (hereafter also referred to as 'patch') as a possible, average "urban" home range (SZENCZI 2005, BÁRÁNY 2006, TÓTH *et al.* 2007*a*). The GPS records of stone martens were marked on a map in Google Earth and overlaid with a 500 m × 500 m (25 ha) grid. The ratio of the green areas (e.g., gardens, parks, cemeteries, sports grounds, etc.) to built-up environment (buildings, railways, roads, etc.) within a patch was expressed as the ratio of the different coloured pixels (Adobe Photoshop CS2). Each 25 ha-quadrate was characterised based on the ratio of green areas and the main type of buildings that were located within it.

Two greenness categories defined as GREEN (> 50%) and DESERT (≤ 50%) on the basis of the proportion of green pixels. Based on visual analysis of Google Earth aerial photos on field work, three building categories were defined: AB = predominantly family houses with gardens; BB = predominantly multi-storey, old houses with a quadrangle, often with a circular gallery; CB = all the other built-up environments, such as modern buildings, panels (blocks of multi-storey houses), roads, railways and industrial areas.

Due to the data not being normally distributed, the Spearman's Rank correlation (Statistica 6.0) was used to assess the correlation between the density of stone marten records and greenness of patches.

An evaluation was carried out of the completed online questionnaires (n = 42). Source data for this pilot project included a wide range of information regarding the stone marten's occurrence (date, place), habitat, behaviour, potential food sources, progeny and conflict with human interest.

RESULTS

Over the course of the 13-year monitoring program, 415 reports of stone marten presence were received. Of those, 303 topographical records contained all background data. There was an overall trend for the yearly number of records increasing over the study period (Fig. 2). Due to the observers' request only 214 records were represented as habitat patches in the GIS database (Table 1). A further 112 records presented essential information but lacked exact addresses of sightings. Thus, only 21 one of the 23 three districts of Budapest were represented in the statistical analysis, as no topographical records existed for districts 6 and 10. Most of the 415 observations (approx. 90%) were the result of noise, large amounts of scats or damaged roof insulation in attics. Only a few records (10%) were actual sightings of live or dead specimen.

Districts

The highest numbers of marten reports were recorded for districts 2, 3, 9, 11 and 12 (Table 1).

Density of marten records was calculated for each district on the basis of the area of the given districts and the number of local records (Fig. 3). The highest density occurred in the 1st, 2nd, 7th, 9th and 12th districts with more than 1 record /km^2. Only the 1st and the 2nd districts belonged to the so called green districts (Fig. 4), with more parks and family houses with gardens, etc. There was a weak negative correlation between the greenness of districts and the density of marten records Spearman's $r_s = -0.43636$ ($p = 0.048$) (Statistica 6.0). The results indicated that the density of stone marten records did not correlate positively with the greenness of patches (Fig. 5).

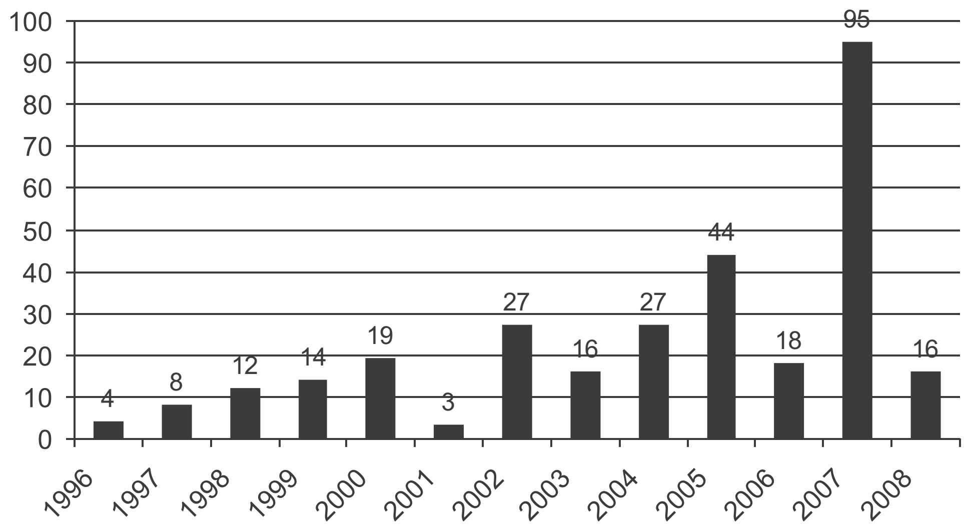

Fig. 2. The number of yearly topographical records of stone martens in Budapest (n = 303) during the 13 years of monitoring

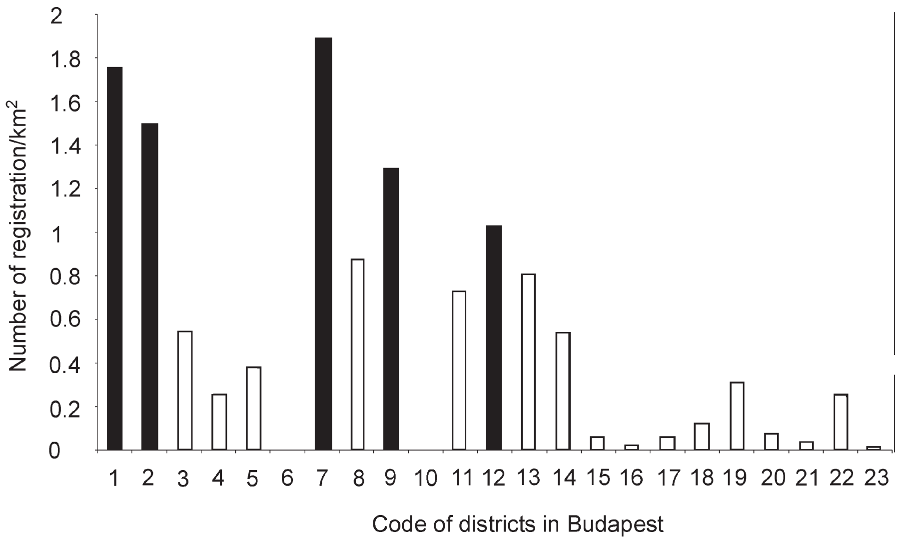

Fig. 3. Density of stone marten records (n = 214) in Budapest districts (n = 23) between 1996 and 2008. The black coloured columns represent the districts with at least one or more registrations per km^2

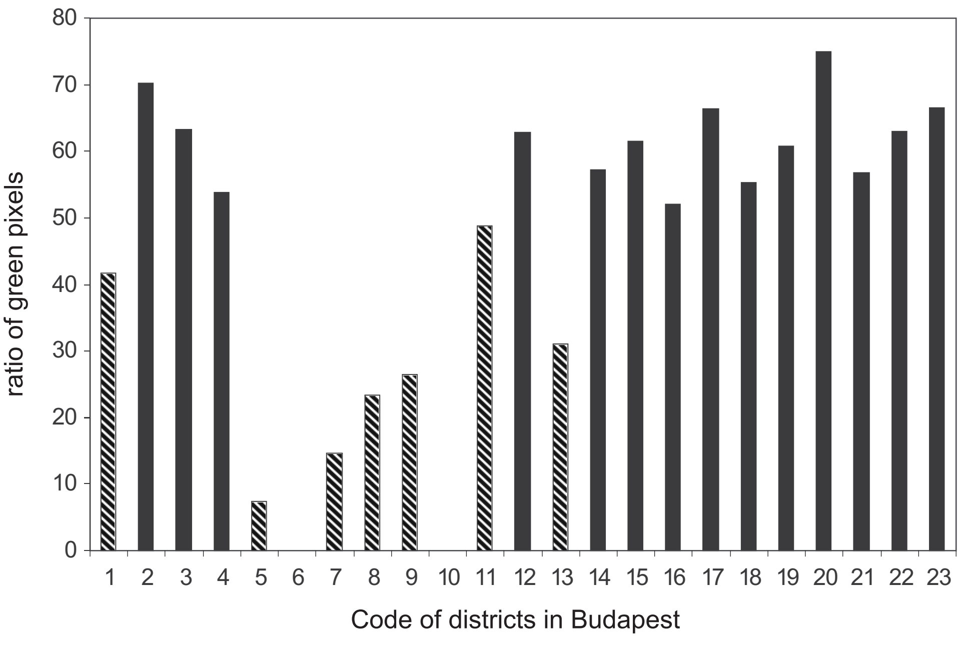

Fig. 4. Average greenness (%) of those 25 ha patches (n = 225) within each districts that contained at least one marten record. Green (> 50%) districts are highlighted in grey

Habitat patches

Martens appeared to show a preference for GREEN habitats as the majority (67.7%) of records were located in green type of habitat patches. Nevertheless, in some cases marten record densities were actually higher in DESERT type habitats than in the GREEN patches. For example, all records on Üllői street (districts 8 and 9), which is situated in the central part of Pest, a highly built-up, disturbed and crowded part of Budapest were located in DESERT type patches. Sightings in these DESERT patches were frequent (up to 10 records / patch), whereas, several GREEN patches had only one or two records during the long-term observation period.

Stone martens showed a strong preference for old multi- storey buildings with a quadrangle. There were 69 DESERT patches among the 214 topographical detections. Thirty-nine of those were identified as having extremely small green coverage (proportion of green pixels 5–30%), with 30 patches being classed as multi-storey buildings with quadrangles (BB), 3 as family houses (AB) and 6 as others (CB).

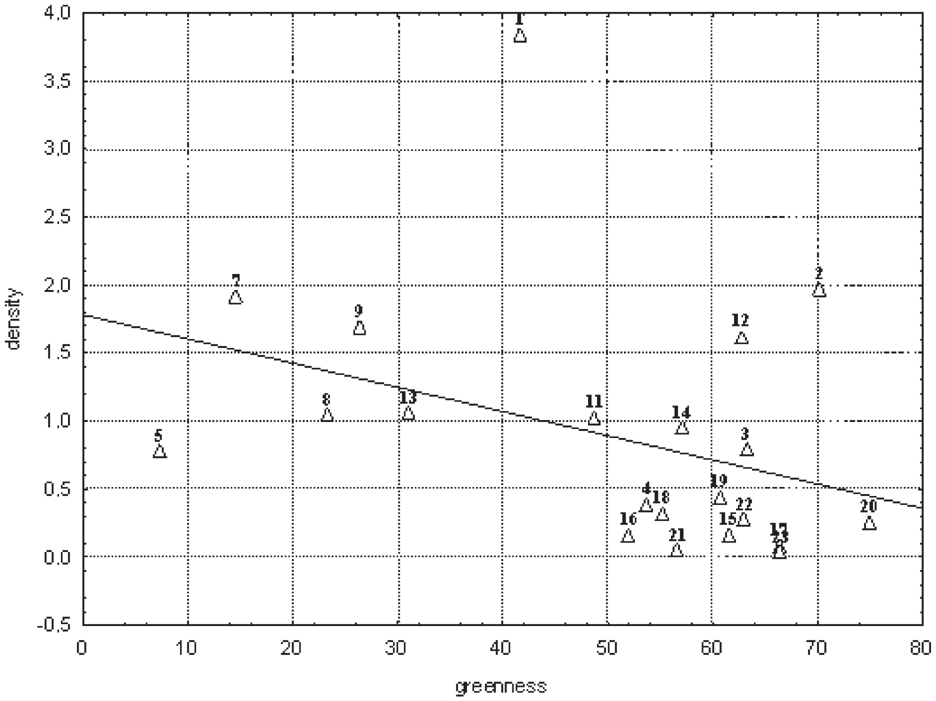

Fig. 5. Scatterplot diagram representing of the “greenness” (% of green cover) of districts and the density (records/km²) of records within them (Statistica 6.0)

Based on the questionnaires (n = 42) it appeared that stone martens inhabited areas where they could find diverse food-sources. They favoured habitats with fruit trees (78%), and resident, nesting birds (84%) as well as habitats where cats and/or birds were regularly fed (76%) and where garbage was available on a daily basis from free standing rubbish bins (65%). Reports about marten-related car damage made up only 4% of the 415 registrations. In these cases martens had chewed electrical wires and cables, damaged the body works or the insulation in the engine compartment to use it for food storage.

DISCUSSION

The study found the stone marten to have occupied the inner suburbs of Budapest and integrated into the city's unique and largely unexplored food network (TÓTH 1998, TÓTH 2003, SZENCZI 2005, BÁRÁNY 2006). The dynamic spread is evidenced in Budapest by the increasing number of sightings, tracks and human-marten conflicts. The number of records (from sightings, direct or phone correspondences, or questionnaires) was growing year by year but did not necessarily correlate directly with the population size or the directions of the urban colonization process of this species. Similarly, the number and ratio of records in the different habitat types and different years were treated carefully, too. There are no definitive tendencies or answers for the high density of records in some DESERT patches (districts 7 and 9), but it might be in close connection with the better detectability, in comparison with the lush vegetation of gardens, parks. The high number of records in 2007 (n = 95) might be the consequence of appearance of questionnaires on our homepage in 2007. This kind of data collection is usually prone to error, despite the fact that all records were verified on-site (hair samples, scats, carcasses, footprints). The main problem was the heterogeneous information content of the records: it depended on the knowledge, the intention and the permission of the announcer.

Nevertheless, a multidimensional, progressive GIS database was set up as part of this work and is anticipated to be continuously updated in order to support further multi-scale analyses.

The high fragmentation and low ratio of green areas in Budapest do not present barriers for the stone marten. It is understood that even the narrow strips and small patches of greenness can serve as corridors, temporary hideouts or, in particular, foraging areas.

For instance, martens show seasonal preference for the trees that bear berries and fruits growing along the avenues and in the parks, such as *Celtis* spp. (sugarberry), *Taxus* spp. (yew), *Morus* spp. (mulberry), *Prunus* spp. (cherry, plum), *Vitis* spp. (grape) (TÓTH & SZENCZI 2004, SZENCZI 2005, BÁRÁNY 2006; TÓTH *et al.* 2007*a*).

VIRGÓS and GARCÍA (2002) pointed out the sensitivity of stone marten to forest fragmentation. Their study was based on forest fragments larger than 50 ha and emphasized the importance of the structure as fragments were surrounded by greater forests. In their study, in Spain, the small forest fragments were surrounded by structureless agricultural areas offering little to martens, whereas in Budapest small green fragments are surrounded by areas with a large structural diversity (i.e. buildings). Nonetheless, the preference for green patches remains in the stressed, overcrowded cities, like Budapest.

The desert type areas, highlighted by the low ratio of green coverage, and high ratio of roads, industrial parks and railways, were found to be successfully colonised areas. In particular, the multi-storey, older houses of Classicist, Eclectic or Secession style with quadrangles, small gardens and circular galleries, appear to be excellent hideouts that also provide nutritive resources such as regular household waste and /or birds and small mammals. The registered occurrences of martens were correlated strongly with the presence of these buildings in the inner districts of Budapest.

One of the main results of this study appears to be that the presence of the stone marten depends mainly on the quality, number and continuous availability of hideouts. The availability of safe and warm hideouts in buildings seems to be the main factor driving the stone marten's urban-rural integration (GENOVESI & BOITANI 1997, MICHELET *et al.* 2001, HERR 2008). Stone martens often prefer the suburbs and the old city centre (BROEKHUIZEN & MÜSKENS 2000). Therefore the structure of a building might be a so- called cover effect (FRY 1947) as far as the urbanization ecology of this species is concerned. It means that the structure of a building (e.g. type of roof and gutter) and the high number of artificial hideouts (attic, church roof, abandoned or ruined buildings) can compensate for a lack of the natural GREEN habitats.

Arguably, the stone marten is a successful urban adapter species (HERR 2008, TÓTH *et al.* 2007). The key to its success in urban areas lies in its unique adaptability to anthropogenic environments and to humans. This process can expand rapidly as the young learn advantageous behaviour patterns from mothers and may then make their own adjustments to urban circumstances.

However, just as other *Martes* species function as indicators for changes in their natural habitat (BISSONETTE & BROEKHUIZEN 1995), the stone marten may be seen as an indicator of the changes in the fabric of the City. Reports of this species, constituted a daily event until recently. Public opinion on the presence of this species is ambivalent, some trying to keep it as a pet, others fearing that the coexistence would result in economical and health problems (TÓTH *et al*. 2007*a*, SZŐCS *et al.* 2007). Furthermore, habitants probably tend to solve the emerging problems themselves, which could explain why in 2008 there were fewer registrations of sightings as in earlier (Fig. 2).

However, the prevailing evolutional trend of Budapest seems to be resulting in an intensive shrinking of parks and in a dramatic modernisation of buildings. This process is thought to drive the urban- adapted, but building-dependent stone martens out of the central districts, as happened to other creatures – such as bats, birds, etc., which strive to share habitat with us. It is our view that town planning needs to take a new approach to urban ecology, where due consideration is given to the needs and significance of the natural environment.

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