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Size of home range of Tengmalm's owl (*Aegolius funereus*) males during breeding season assessed by radio-telemetry in the Jizera Mountains, Czechia

Veľkosť domovského okrsku samcov pôtika kapcavého (*Aegolius funereus*) počas hniezdnej sezóny zistená rádiotelemetriou v Jizerských horách, Česko

Marek KOUBA & Václav TOMÁŠEK

Abstract: Animal home ranges are typically characterized by their size, shape and a given time interval and can be affected by many different biotic and abiotic factors. Understanding of animal movements and assessing the size of their home ranges are essential topics in ecology and necessary for effective species protection, especially concerning birds of prey. Using radio-telemetry (VHF; 2.1 g tail-mounted tags) we studied the movements of two Tengmalm's owl (*Aegolius funereus*) males during the breeding season 2008 in a mountain area of Central Europe (the Czech Republic, the Jizera Mountains: 50˚ 50' N, 15˚ 16' E). We determined their average nocturnal hunting and diurnal roosting home range sizes. The mean hunting home range size calculated according to the 90% fixed kernel density estimator was 251.1 ± 43.2 ha (± SD). The mean roosting home range size calculated according to the 100% minimum convex polygon method was 57.9 ± 15.8 ha (± SD). The sizes of hunting home ranges during breeding in this study coincide with those previously reported by other studies focusing on Tengmalm's owl males. However, we found the roosting home ranges were smaller in size compared to those previously reported. This result was most probably connected with different habitat structure in our study area, which was severally damaged by air-pollution in the past, thus probably offering fewer suitable hiding-places, for instance from predators. We found the roosting locations were concentrated in the oldest and densest Norway spruce forest patches. We emphasize that these parts of forest stands require the highest possible protection in our study area.

Abstrakt: Domovské okrsky živočíchov sú zvyčajne charakterizované ich veľkosťou, tvarom a daným časovým úsekom a môžu byť ovplyvnené mnohými rôznymi biotickými a abiotickými faktormi. Pochopenie pohybu živočíchov a určenie veľkosti ich domovských okrskov sú základnými témami v ekológii a sú nevyhnutné pre druhovú ochranu, obzvlášť dravých vtákov. Pohyby dvoch samcov pôtika kapcavého (*Aegolius funereus*) sme študovali pomocou rádiovej telemetrie (VHF; 2.1 g na chvoste umiestnená vysielačka) počas hniezdnej sezóny 2008 v hornatom území strednej Európy (Česká republika, Jizerské hory: 50˚ 50' N, 15˚ 16' E). Určili sme ich priemerné nočné lovné a denné odpočinkové domovské okrsky. Veľkosť priemerného lovného okrsku vypočítaná pomocou 90 % jadrových odhadov hustoty bola 251,1 ± 43,2 ha (± SD). Veľkosť priemerného odpočinkového okrsku vypočítaná pomocou 100 % minimálneho konvexného polygónu bola 57,9 ± 15,8 ha (± SD). Veľkosť tu zistených lovných domovských okrskov počas hniezdenia sa zhoduje s výsledkami iných štúdií zameraných na pôtika kapcavého. Avšak, veľkosť nami zistených oddychových okrskov bola menšia v porovnaní s publikovanými údajmi. Súvisí to zrejme s odlišnou štruktúrou habitatu v nami skúmanom území, ktoré bolo v minulosti silno poškodené imisiami, a tak pravdepodobne poskytuje menej úkrytov, napr. pred predátormi. Zistili sme, že odpočinkové miesta boli koncentrované v najstarších a najhustejších častiach smrekového lesa. Tieto časti lesa vyžadujú najvyššiu možnú ochranu v študovanom území.

Key words: boreal owl, hunting, roosting, radio-tracking, bird of prey

Marek Kouba, Václav Tomášek, Department of Ethology and Companion Animal Science, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague, Czech Republic. E-mail: marekkouba8@gmail.com.
Václav Tomášek, Department of Ecology, Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic.

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Introduction

As early as Darwin (1861) it was noted that the primary characteristic of animal movement is that most animals use the same areas repeatedly over time. Movements of this type in fairly well-defined areas within which animals perform their daily activities are often referred to using the "home range" concept (Powell 2000). The first definition of home range (hereafter HR) was provided by Burt (1943) as: "Area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered part of the home range. Although this basic construct has been retained within the concept of HR to this day, it is usually refined to include clear specification of the time frame involved in a given home range analysis (e.g. daily, seasonal, annual, life-time) and in more formal statistical analysis of HR size (e.g. White & Garrott 1990, Seaman & Powell 1996, Hansteen et al. 1997). The HR is characterized typically with descriptors of its size, shape and structure (Kenward 2001), and to be fully defined the relevant time interval must be specified (Harris et al. 1990, Powell 2000, Laver & Kelly 2008).

Various biotic and abiotic factors (intrinsic and/or extrinsic) are likely to affect the size, use and spatial configuration of individual HRs, and all these factors interact within a hierarchical pattern according to various spatial and temporal scales (Mace & Harvey 1983; McLoughlin & Ferguson 2000; Adams 2001). Using hierarchy theory (Allen & Starr 1982), McLoughlin & Ferguson (2000) offer a review of the limiting factors which are likely to determine HR size on three spatial levels (among species, populations and individuals), identifying the critical factors as including (inter alia): body size, climate, abundance and distribution of food, social organisation, population density and risk of predation.

Tengmalm's owl (*Aegolius funereus*) is a small, nocturnal, cavity-nesting owl (male body mass approx. 100 g), living in coniferous forests in the boreal zone and in alpine forests further south in Eurasia (Cramp 1985), and feeding mainly on small mammals (Korpimäki 1981, König & Weick 2008, Korpimäki & Hakkarainen 2012). The young stay in the nest for 27–38 days after hatching (Kouba et al. 2015), and reach independence 5–9 weeks after fledging (Eldegard & Sonerud 2009, 2010, 2012, Kouba et al. 2013). The great majority of prey brought to the young throughout the late nestling and post-fledging dependence period, in this particular species, is delivered by the male (Eldegard & Sonerud 2010, 2012). Tengmalm's owl searches for prey using the pause-travel mode, and locates it by sound (Norberg 1970, Andersson 1981, Bye et al. 1992).

Studies of the hunting HRs of Tengmalm's owl males during breeding essentially agree on their having an average size of approx. 2 km^2. Older studies which established HRs using the minimum convex polygon method (Mohr 1947) give the size of the hunting range as 205 ha (Sonerud et al. 1986), 181 ± 48 ha (mean ± SD; Jacobsen & Sonerud 1987) and 100–300 ha (Sorbi 2003); the studies by Santangeli et al. (2012) and Kouba et al. (2017) which determined the size of the male owls' hunting range using the kernel density estimator (Silverman 1986) suggested range sizes of 114 ± 20 ha (mean ± SE) and 191 ± 66 ha (mean ± SD) respectively. Hakkarainen et al. (2003) noticed that in the low phase of the vole cycle males hunted up to 4 km from the nest, whereas in good vole years hunting trips were about one-third of that distance. Kouba et al. (2017) found that the HR size was affected by prey abundance, the presence or absence of polygyny, the number of fledglings, and weather conditions. Specifically, HR size increased with decreasing prey abundance. Polygynous males had overall larger HRs than those mated monogamously, and individuals with more fledged young possessed larger HRs compared to those with fewer raised fledglings. Finally, HRs recorded during harsh weather were smaller in size than those registered during better weather (Kouba et al. 2017).

Studies of the roosting HRs of Tengmalm's owl males during breeding are scarce. Jacobsen & Sonerud (1987) described three roosting HRs of breeding males. These ranges were 142 ± 73 ha (± SD) on average. Bondrup-Nielsen (1978) also followed three breeding males and found HR sizes of 100, 250 and 500 ha. Palmer (1986) published a finding of mean HR size of 296 ha for two non-breeding males. Other authors have combined locations/fixes of diurnal roosting and nocturnal hunting for assessing HR sizes (e.g. Lane 1997, Belmonte 2005).

In this paper we describe the sizes of hunting and roosting HRs during the breeding season for two Tengmalm's owl males, and discuss them in a broader context.

Materials and methods

Study area

This study was carried out during the 2008 breeding season in an area close to the Souš reservoir in the Jizera Mountains, Czech Republic (50° 50' N, 15° 16' E). This area was severely damaged by air-pollution in the 1970s, with most coniferous trees above the altitude of

500 m a. s. l. dying out as a result; the study area (269 km^2, 280–1110 m a. s. l.) has been artificially replanted, with the predominant species being Norway spruce (*Picea abies*, 79%), European beech (*Fagus sylvatica*, 10%), blue spruce (*Picea pungens*, 3%) and European larch (*Larix decidua*, 3%). To compensate for the lack of natural tree cavities, 523 wooden nest boxes (with base 25 × 25 cm, height 40 cm and an entrance hole 8 cm in diameter) have gradually been installed in the area since 2000.

Field procedures

In the study year 2008, two nests were found early in the season. The nesting dates were backdated to 1st and 7th June based on the hatching dates. There were five and four eggs from which four nestlings hatched in both nests. The number of fledglings was not recorded. At the time of radio-tracking, the nestlings were approx. 3–13 days old in both nests. The males from these two nests were captured during the nestling phase using a mist net placed in front of the nest box. This was done during the night when the males were bringing prey items to the nest. The captured males were fitted with tail-mount transmitters of type TW-4 (Biotrack Ltd., UK). These transmitters weighed 2.1 g (lifespan ± 10 weeks), following the welfare recommendation not to exceed 3% of the body weight of tagged individuals (e.g. Withey et al. 2001). At least five days were left after the marked birds were released, before telemetry recordings were made towards assessment of their hunting and roosting ranges, so that the data recorded would not be influenced by any direct effect of tagging (White & Garrott 1990, Kenward 2001, Withey et al. 2001).

We radio-tracked both males for five nights and for the complete night-time period, i.e. from dusk till dawn, to determine the sizes of their nocturnal hunting HR during the breeding season. During the tracking nights, two observers (MK and VT) continuously followed each male, recording locations/fixes every 10 minutes (if possible). The observers were connected via walkie-talkie, and they recorded the exact time of every single fix, their own positions, the direction to the tag/male using a compass, and the strength of the signal received using MVT-9000 receivers (Yupiteru Industries Co. Ltd., Japan) and 3-element Yagi antennas. Afterwards, each individual location was confirmed by triangulation in ArcGIS 9.3 software. Experimental calibrations in the field suggested that location accuracy was approximately 100 m, and whenever we were not sure about their sufficient precision, the fixes were discarded from the analysis.

During daylight the two monitored males were located once every day (both individuals nine times in total) either using the ‘homing-in’ method (Kenward 2001), i.e. we followed the signal to a particular tree or until we saw the individual, or by triangulation (as described above) to determine the sizes of their diurnal roosting HR during the breeding season.

Hunting HR size was estimated using the 100% minimum convex polygon method (MCP; Mohr 1947, Hayne 1949) and the kernel density estimator (KDE; Silverman 1986, Worton 1989), with fixed smoothing parameter *h* established by the least squares cross-validation method (LSCV; Seaman & Powell 1996, Seaman et al. 1999, Börger et al. 2006); HRs were calculated for both 90% and 95% isopleths. Roosting HR size was estimated using the 100% MCP method only due to the limited number of locations/fixes for both individuals. Both types of HR estimates (MCP and KDE) were calculated with Home Range Tools and Hawth’s Tools (Rodgers et al. 2007, Rodgers & Kie 2011), which are freeware extensions for the ArcGIS 9.x software. Following De Solla et al. (1999) and others (e.g. Cushman et al. 2005, Börger et al. 2006), we used the fixed time interval of recording during night monitoring to maximize the number of observations included in our HR estimations; for our purposes in estimating HRs, locational fixes did not require serial independence of observations (Hurlbert 1984).

Results

The mean size of hunting HRs during the breeding season for Tengmalm’s owl males (n = 2) calculated according to the 90% kernel density estimator was 251.1 ± 43.2 ha (± SD), and according to the 95% KDE it was 307.9 ± 50.1 ha; the MCP method offered a range estimate of 315.4 ± 32.7 ha (100% MCP). These ranges were based on 125 ± 9 (± SD) locations/fixes of nocturnal hunting on average. Specifically, the ranges were 294.3 ha (MALE 1, Fig. 1; 90% KDE) and 207.9 ha (MALE 2, Fig. 1; 90% KDE), 358.0 and 257.7 ha (95% KDE), and 348.1 and 282.7 ha (100% MCP) in area, based on 116 and 134 locations/fixes, and were recorded during the nights from 8–9th to 12–13th July and from 13–14th to 17–18th July respectively.

The mean size of one-night ranges (n = 5 nights) calculated using the 100% MCP method was 121.8 ± 83.7 ha for the first male (MALE 1) and 109.2 ± 31.8 ha (± SD) for the second male (MALE 2). These one-night

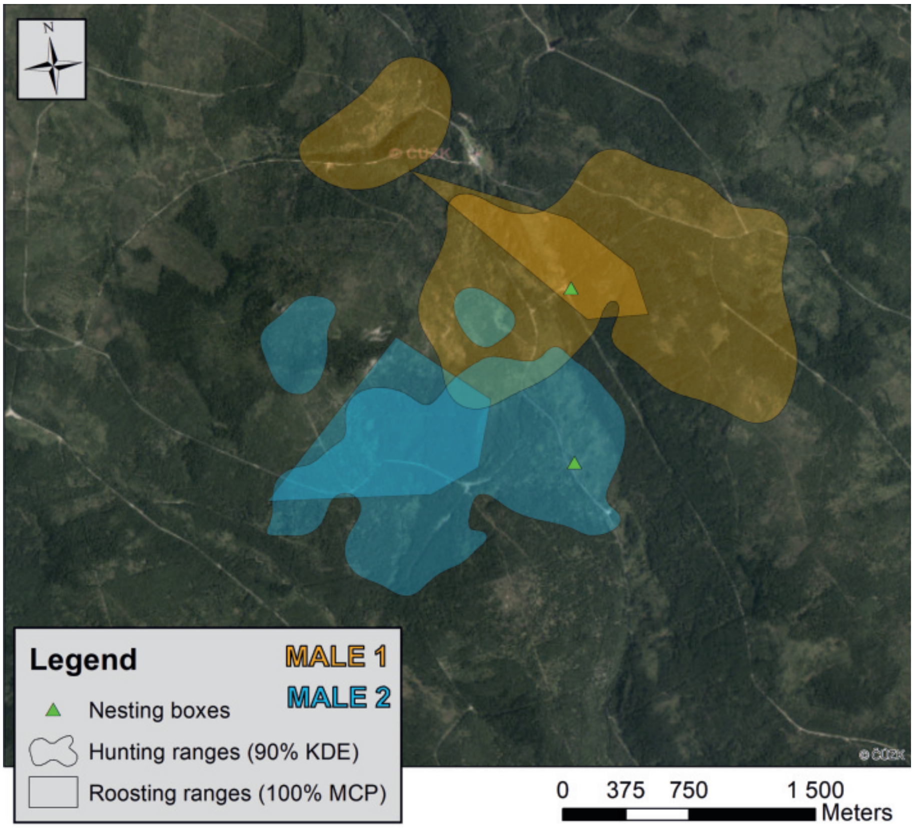

Fig. 1. Hunting home ranges (established using the 90% kernel density estimator method), roosting home ranges (established using the 100% minimum convex polygon method) and nesting boxes of two Tengmalm's owl males recorded during the breeding season 2008 in the Jizera Mountains.
Obr. 1. Lovné domovské okrsky (vylíšené pomocou 90% jadrových odhadov hustoty), odpočinkové okrsky (vylíšené pomocou 100% minimálneho konvexného polygónu) a hniezdne búdky dvoch samcov pôtika kapcavého sledovaných počas hniezdnej sezóny 2008 v Jizerských horách.

ranges were based on 23.2 ± 0.7 and 26.8 ± 5.5 (± SD) locations/fixes of nocturnal hunting on average respectively.

The mean distances of recorded nocturnal hunting locations/fixes from nesting boxes were 781 ± 393 m (maximum 1805 m) for the first male and 707 ± 515 m (± SD, maximum 1965 m) for the second male.

The mean size of roosting HRs during the breeding season for Tengmalm's owl males (n = 2) calculated using the 100% MCP method was 57.9 ± 15.8 ha (± SD). Both these ranges were based on 9 locations/fixes of diurnal roosting. Specifically, the ranges were 42.1 and 73.6 ha (100% MCP; Fig. 1) in area.

The mean overlap of the two types of ranges (hunting and roosting) was 31.5 ± 8.1% (± SD, n = 2). Specifically, the overlap of the ranges was 21.6% for the first male and 41.3% for the second male.

Discussion

The size of nocturnal hunting HRs of male Tengmalm's owls during the breeding season reported in this study is consistent with results from previous studies by other authors (Sonerud et al. 1986, Jacobsen & Sonerud 1987, Sorbi 2003, Santangeli et al. 2012, Kouba et al. 2017), who reported range sizes between 100 and 300 ha. The two males in this study were radio-tracked in 2008, and during the same year Kouba et al. (2017) followed via radio-telemetry four Tengmalm's owl males in the Ore Mountains (these two study areas are located in neighbouring mountain ranges and are approx. 140 km distant from each other), which allows a unique comparison. The two study sites are very similar regarding both their environment and their history, because both were previously severely damaged by air pollution. Moreover, both studies followed the males using exactly the same methodology regarding radio-tracking. Kouba et al. (2017) reported mean hunting HR size of 212 ± 36 ha (± SD) based on 90% KDE for the four males in 2008, and overall hunting HR size of 154 ± 54 ha (± SD; n = 5 years and 20 males). We found hunting HR size of 251 ± 43 ha (± SD; 90% KDE) on average. Thus the findings are very similar from both study areas; however, it should be noted that the hunting HR sizes found in both studies would probably have been larger if the males had been tracked during the whole breeding period compared to only five nights, as was actually done. Although prey abundance was not determined in our study area in the Jizera Mountains, and we can only speculate about its amount, it is theoretically possible that prey abundance was quite similar and relatively low in both areas based on the mean number of eggs and hatchlings, which are always significantly connected with the amount of available prey (e.g. Korpimäki & Hakkarainen 2012). In the Ore Mountains there were 3.8 ± 1.1 eggs (± SD) and 3.5 ± 1.1 hatchlings on average (Kouba et al. 2017), and 4.5 ± 0.5 eggs on average and 4 hatchlings in both nests in this study.

We also found that the hunting HRs of Tengmalm's owl males during breeding season may partly overlap (Fig. 1). A similar finding was previously reported by Sorbi (2003) and may be further supported by observations of fledglings from different nest boxes in the same places during the post-fledging dependence period (Kouba, unpublished data). This suggests the degree of territoriality is probably relatively weak for Tengmalm's owls during this time period, and that their territory may be restricted only to the close surroundings of the nesting box, compared to larger owl species for which the sense of territoriality is usually stronger (Mikkola 1983, Cramp 1985).

Roosting HR sizes reported by Jacobsen & Sonerud (1987) were 226, 94 and 106 ha in area and were based on 29, 21 and 9 locations/fixes respectively. These roosting ranges were larger than those found in our study (42 and 74 ha). From the comparison it is clear that the number of locations/fixes may have played some role, because our ranges were based on 9 locations/fixes only; however, this is probably not the main reason explaining the difference. The current mosaic forest stand structure in our study area, which was damaged by serious air pollution in the past, probably did not offer sufficient roosting places. The roosting locations were concentrated in relatively small patches of forest, usually the oldest and densest forest stands in the study area. In our opinion, this could better explain why the roosting HRs were smaller in comparison with other studies on Tengmalm's owl roosting HRs, because the forest stand structures in these study areas were different and unaffected by air-pollution damage (Bondrup-Nielsen 1978, Palmer 1986, Jacobsen & Sonerud 1987). This explanation could be further supported by findings from the Ore Mountains, where the males of the species in question also had relatively small roosting HRs (similar in size to those recorded in this study), and where males also roosted repeatedly in small, old and dense forest patches (Kouba and Tomášek, unpublished data).

In contrast to our results, Sorbi (2003) found that the males in his study area roosted only in very young Norway spruce stands (15 – 25 years old). A similar result was also reported by Lane (1997). He found roosting sites in thick coniferous growths with high tree density. We suggest that high density of forest stands is most important for the roosting of Tengmalm's owl, regardless of how old the forest is. Such forest stands most probably offer the best hiding places against diurnal avian predators as well as mobbing by passerine birds.

A similar difference as in the case of roosting HR size was also found in the amount of overlap between hunting and roosting HRs for individual males. In Norway, Jacobsen & Sonerud (1987) found that the overlap of hunting and roosting HRs was 56 ± 9% on average. We found an overlap of 32 ± 8%. This result is clearly connected with the small size of roosting HRs in our study area and the habitat use affected by forest stand composition and distribution.

Our sample size (two males) was very small, although comparable with some other older studies (e.g. Sonerud et al. 1986, Jacobsen & Sonerud 1987); however, we were not able to test whether the HRs reported in this one-year study were affected by variables such as prey abundance, presence or absence of polygyny, number of fledglings, and/or weather conditions as reported previously by Kouba et al. (2017). On the other hand, we may speculate that prey abundance was theoretically similar to that in the Ore Mountains in 2008 based on the mean number of eggs and hatchlings found in both studies. In that case our results would be in accordance with other studies on birds of prey which reported larger HRs during poor food years and *vice versa* (Newton 1986, Zabel et al. 1995, Pfeiffer & Meyburg 2015). Our results regarding diurnal roosting HR sizes suggest the great importance of the oldest and densest Norway spruce stands for Tengmalm's owls as roosting habitat in our study area, and we emphasize that these specific forest patches require the highest possible degree of protection.

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