Lesn. Cas. For. J. 61 (2015) 12–18 DE GRUYTER OPEN DOI: 10.1515/forj-2015-0009

PÔVODNÁ PRÁCA – ORIGINAL PAPER

Lesnícky časopis - Forestry Journal
http://www.nlcsk.sk/fj/

Differences in evaluation of three different approaches in home range sizes of red deer *Cervus elaphus* in Western Carpathians

Rozdiely vo vyhodnotení veľkosti domovských okrskov jeleňa lesného *Cervus elaphus* v Západných Karpatoch tromi rôznymi prístupmi

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Abstract

The aim of this study was to evaluate differences using three different approaches in home range sizes of selected male individuals of red deer (*Cervus elaphus*). This study was conducted in the Kremnica Mountains (the Western Carpathians) located in central Slovakia. The study included data from three individuals, collared and tracked by using the VHF (Very High Frequency) telemetry. The data were evaluated within three different seasons (winter, summer and rut). For the measuring of home range sizes three methods were used: Minimum Convex Polygon (MCP), Kernel Home Range (KHR) and Local Convex Hull (LoCoH). The seasonal effect on home range size was analyzed by using the analysis of variance (ANOVA) two and three main effects. The study showed differences in home range sizes and core areas in red deer population. The migrant individual had a lager home range size with used methods. The differences occurred between total seasonal home ranges, but statistically not significant. The home range created by Local Convex Hull was significantly smaller than the home range created by Kernel Home Range.

Key words: *Cervus elaphus*; home range size; core area; VHF telemetry

Abstrakt

Cieľom tohto príspevku bolo porovnať rozdiely v aplikácií troch rôznych prístupov k vyhodnocovaniu veľkosti domovských okrskov vybraných samčích jedincov jeleňa lesného (*Cervus elaphus*) v Západných Karpatoch. Výskum bol vykonaný v Kremnických vrchoch, situovaných v centrálnej časti Slovenska na vzorke troch jedincov sledovaných VHF (Very High Frequency) rádiotelemetriou. Údaje boli vyhodnocované v rámci troch sezón (zima, leto a ruja). Na odhad veľkosti domovských okrskov boli použité tri metódy: Minimum Convex Polygon (MCP), Kernel Home Range (KHR) and Local Convex Hull (LoCoH). Sezónne rozdiely vo veľkosti domovských okrskov boli analyzované použitím analýzy variancie (ANOVA). Výsledky poukázali na rozdiely vo veľkosti domovských okrskov a jadrových zón v populácii jelenej zveri. Migračný typ jedinca mal väčší okrsok v porovnaní s ostatnými, tento rozdiel však nebol štatisticky významný. Metóda LoCoH s použitím malej vzorky dát významne podhodnocuje odhady veľkosti domovských okrskov.

Kľúčové slová: *Cervus elaphus*; veľkosť domovského okrsku; jadrová zóna; VHF telemetria

1. Introduction

The spatial behaviour of mammals is influenced by several factors: metabolic needs, body mass, feeding habits, and mating system (Cameron & Spencer 1985; Clutton-Brock 1989; Sandell & Liberg 1992). The size of the home range (HR) is also related to the combination of other parameters such as age (Cederlund & Sand 1992), population density (Vincent et al. 1995), predation and human disturbance (Van Dyke & Klein 1996). Ungulate use of space and home range size is the end result of a combination of phenotypic plasticity and natural selection that reflects successful strategies to maximize individual fitness (White & Garrott 2005). Habitat structure and the distribution and quality of food exert an important influence on the extent of home range. In this context, among ungulates in the temperate climates of the northern hemisphere, metabolic rate and food intake decline during the winter, a period associated with weight loss (Clutton-Brock et al. 1982). In these areas ungulates conserve energy during the winter by reducing activity and movements within a restricted home range (Lieb 1981a, b; Clutton-Brock et al. 1982; Georgii & Schröder 1983). Mountain environment emphasizes the need to preserve energy during the winter and to compensate winter food intake lost during summer. A relevant factor in determining food availability is snow cover that strongly reduces food availability and accessibility during winter time. Consequently, during winter, snow cover and temperature are regarded as important factors determining spatial behaviour in many mountain ungulate species. In addition, food reduction and snow cover can also reduce winter mobility as observed in Siberian ibex (*Capra ibex sibirica*) (Fox et al. 1992), reindeer (*Rangifer tarandus*) and wapiti (*Cervus elaphus canadensis*), red deer (*Cervus elaphus elaphus*) (Georgii & Schröder 1983), roe deer (*Capreolus capreolus*) (Hewison et al. 1998) and European bison (*Bison bonasus*) (Krasinska et al. 2000). Regarding the last mentioned species, winter home range sizes were inversely related to the number of days with snow cover and to the mean daily temperature.

The red deer is one of the most widespread, and both ecologically and economically most important large ungulate

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species in Europe. Understanding its requirements such as habitats, distribution and spatial strategies of behaviour is considered to be a base for successful management of population at the present time and, in principle, of sustainability for next generations. Data in this study confirmed that migration is a very important component of resilient and sustainable ecosystems and its understanding is the key to a future successful management (Kropil et al. 2015).

The objective of this study was to evaluate spatial distribution (home range sizes in particular) of red deer (*C. elaphus*) on the basis of telemetry data and to evaluate differences using three different approaches in home range sizes.

2. Material and methods

2.1. Study area

The research was conducted in the model territory of the Kremnica Mountains (48°39'60.00"N, 19°0'0.00"E) located in central Slovakia, in the districts of Banská Bystrica and Žilina, in the regions of Turčianske Teplice, Banská Bystrica, Zvolen, and Žiar nad Hronom. The total area is 62,725 ha, including 39,925 ha forest (64.5%), (Fig. 1).

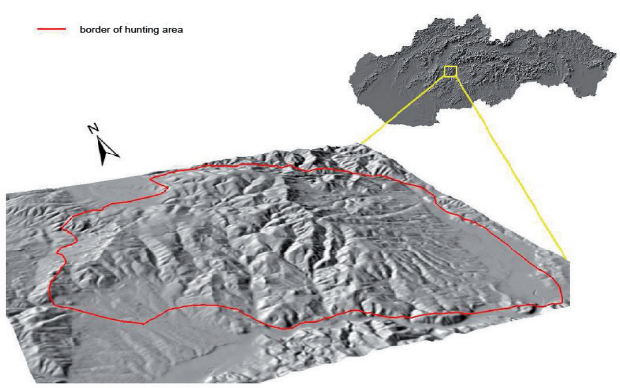

Fig. 1. The digital model of the terrain of the Kremnica Mts.

Big altitudinal zonation and differences in elevation offer a possibility to distinguish several climatic and geographical types or subtypes in the described area. The major mountain part of the described area has a mountain climate. Žiarska, Hornonitrianska and Turčianska kotlina basins represent a characteristic basin type of climate.

The higher parts of the Kremnica Mountains belong to the subtype of the cold mountain climate. This subtype is characterized by January temperatures from −7 up to −6 °C and average July temperatures are in the range of 11.5–13.5 °C. The average annual precipitation amount is from 1,000 up to 1,400 mm. the frost-free period lasts approximately 80 days, the period with average daily temperature below 0 °C lasts 180–200 days. Snow cover during a year keeps about 160 days. The southern foothills of the Kremnica Mountains sloping down to Žiarska and Zvolenská kotlina basins belong to the subtype of the temperate warm mountain climate. Average January temperature ranges from −6 up to −3.5 °C, July temperature from 17 to 18 °C. The annual precipitation amount is 650–850 mm. The period with an average daily air temperature below 0 °C lasts 80–100 days. Snow cover occurs 100–120 days a year (Ostrihoň 2010).

The area has a mosaic structure with 65% of forests (73% deciduous, 27% coniferous), meadows and agricultural land surrounding human settlements. The area is dominated by beech (*Fagus sylvatica*, 37%), followed by oak (*Quercus spp*., 19%), spruce (*Picea abies*, 11%), hornbeam (*Caprinus betulus*, 10%), pine (*Pinus sylvestris*, 7%) and fir (*Abies alba*, 7%). The area is intensively managed from a forestry and hunting perspective; however, there are several natural preserves within the area with restricted management. Red deer is the main game species in the Kremnica Mountains, and during this study, its population was estimated to be 2200 individuals in the area. Other wild ungulates living in the area are roe deer (*Capreolus capreolus*) with a population reaching 2100 individuals and wild boar (*Sus scrofa*) with 1100 individuals. There is also the constant presence of three large carnivores, namely brown bear (*Ursus arctos*), wolf (*Canis lupus*) and lynx (*Lynx lynx*) (Kropil et al. 2015).

2.2. Home range

For home range size evaluation three methods were used: Minimum Convex Polygon (MCP), Kernel Home Range (KHR) and Local Convex Hull (LoCoH). Use of all three methods ensure better understanding of spatial behaviour of animals and provide as sufficient amount of information for evaluation of home range size as each of methods has some disadvantages.

Kernel home range is frequently used method due to its ability to evaluate utilization distribution within dataset and use particular percentage of locations. We used 90% of locations instead generally used 95% because according Borger et al. (2006) bias in dataset with small amount of points is significantly smaller with use of 90% of locations. Use less than 100% locations is advantageous because we avoid extreme edge values. Use of 50% of locations is considered as a core area of the home range, it means the area most frequently used by an animal within its whole home range.

We created LoCoH total home ranges with use of 100, 90 and 50% of locations due to ability to compare these results with outputs of other methods (MCP 100%, KHR 90 and 50%).

The study of behavioural strategies includes VHF (Very High Frequency) telemetry data of three red deer male individuals (ID 172, 714, and 353) in the area of the Kremnica Mountains. The ID number represents the radio frequency of a particular animal.

ID 172 was immobilized and collared on 16/04/2008 at the age of 3 years and was radio tracked until 21/09/2011 when it was probably poached. A total number of 102 locations were collected within the tracking period. In terms of spatial strategy, ID 172 is considered as a resident individual.

ID 714 was collared on 10/04/2008 at the age of 3 years, then radio-tracking of the individual continued, but for the purpose of this study the data are evaluated up to 14/12/2011. A number of evaluated locations are 104. In relation to the spatial strategy, ID 714 is considered as an intermediate migrant individual.

ID 353 was immobilized and collared in 15/02/2005 as 4 years old and tracked until 12/04/2006. Totally, 114 locations were collected during the tracking period. In this individual the third type of spatial strategy occurred, which is the third type of spatial strategy typical of its long migration distances occurred.

The data were analyzed through the analysis of variance (ANOVA); we used ANOVA two main effects to compare the total home range size between the methods (Local Convex Hull and Kernel Home Range method) and three main effects to compare between the seasons as well as the individuals. Our study is mainly focus on comparing the home range sizes within observed individuals and seasons in terms of size (ha), with the using of different methods.

The data in this study were divided into three seasons from animal's perspective:

– Winter season: December – April
– Summer season: May – August
– Rut season: September – November

November is not generally considered as a rut season in European deer but our data show (clear clusters of locations especially in ID 353) that animals stay at the same locations after rut (during November) until the first snow, respectively 20–25 cm of snow cover (trigger of winter migration). From this reason November locations were added to rut season as the same type of spatial behaviour.

3. Results

3.1. Minimum Convex Polygon (MCP)

There are some clearly noticeable differences in terms of spatial distribution and size of seasonal and total home ranges across the individuals.

The summer HR of the individual 172 (1896.89 ha) dominate in size, but in 714 and 353 (761.08 and 602.55 ha, respectively) are smaller than winter HR (Table 1; Figs. 2–4). As opposed to 172, in 714 and 353 winter HR is noticeable greater. The 714 is a typical by two clusters of locations with summer and winter HRs in each cluster (Fig. 3). Rut HRs are relatively smaller compared with the summer and winter HR except 353, but the difference is only 76 ha (Table 1).

Table 1. Minimum Convex Polygon 100% home range sizes (ha) of radio-tracked individuals.

Individual ID	Summer MCP	Winter MCP	Rut MCP	Total MCP
172	1896.89	1153.65	956.37	2451.20
714	761.08	802.09	495.55	2463.61
353	602.55	3281.63	678.53	9135.70

Total sizes of home ranges provide overall insight of spatial behaviour of our animals. Home range size of 353 (9135.70 ha) is apparently greater compared to other animals (Table 1). In 172 and 714 is HR size relatively equal despite their different distributions and sizes of seasonal home ranges (Figs. 3 and 4; Table 1). There are differences among total of seasonal home ranges occurred, but statistically not significant (Fig. 5).

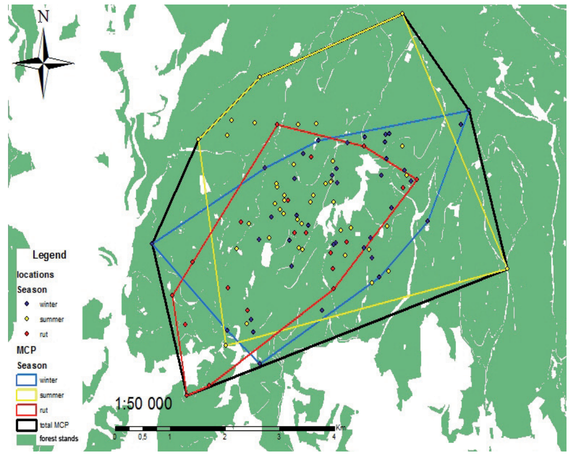

Fig. 2. Total and seasonal home ranges of the individual 172 by the Minimum Convex Polygon.

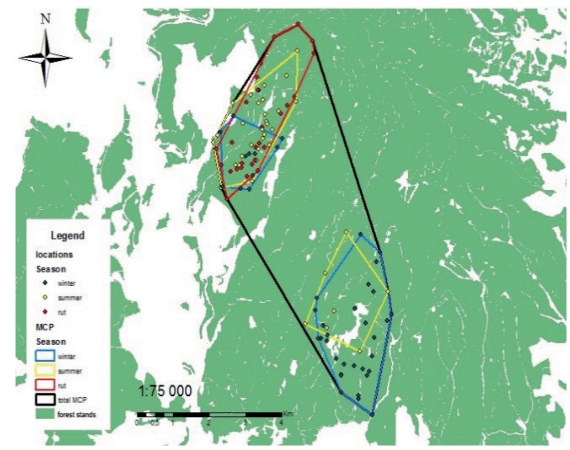

Fig. 3. Total and seasonal home ranges of the individual 714 by the Minimum Convex Polygon.

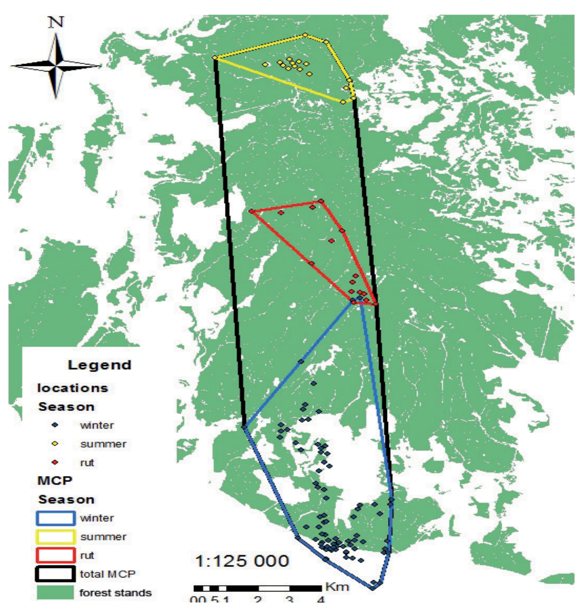

Fig. 4. Total and seasonal home ranges of the individual 353 by the Minimum Convex Polygon.

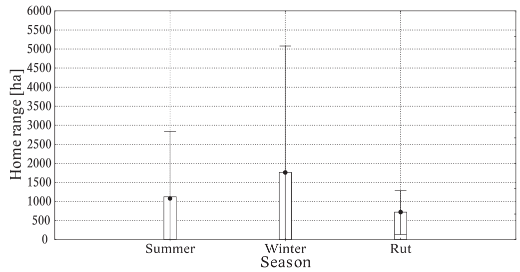

Fig. 5. Mean of home range sizes (ha) by Minimum Convex Polygon 100% among summer, winter, and rut seasons.

3.2. Kernel Home Range (KHR)

We generated seasonal and total KHR for our tracked animals (Figs. 6–8). The sizes of the summer HR are relatively equal to the winter ones except animal 353 where the winter HR is twice greater than the summer HR (Table 2). Summer HR of 353 is also relatively small compared to other animals. Rut HRs by KHR 90%, which vary between 1157.65–1690.64 ha are smaller than HRs of other seasons except summer HR of the 353 (1077.97 ha).

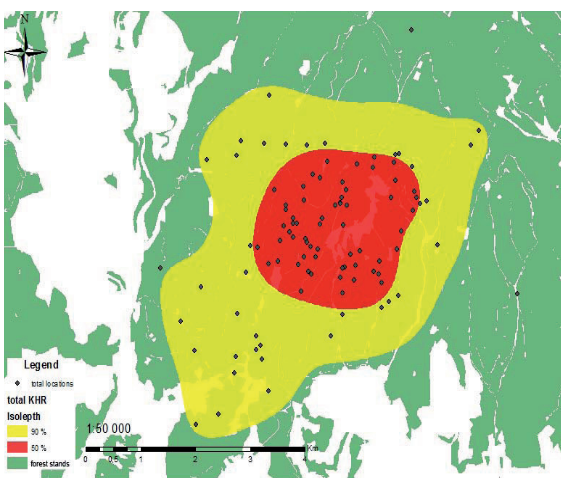

Fig. 6. Total Kernel Home Range (90 and 50%) of the individual 172.

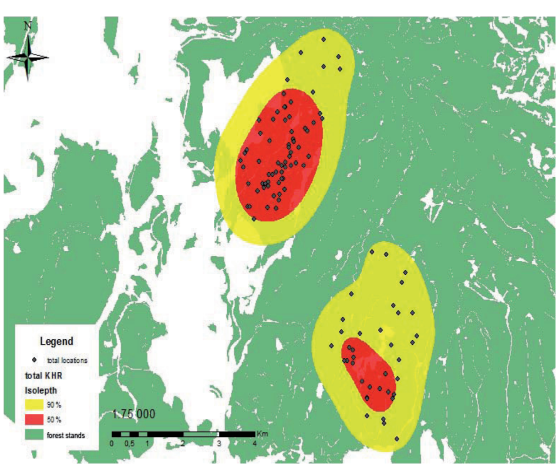

Fig. 7. Total Kernel Home Range (90 and 50%) of the individual 714.

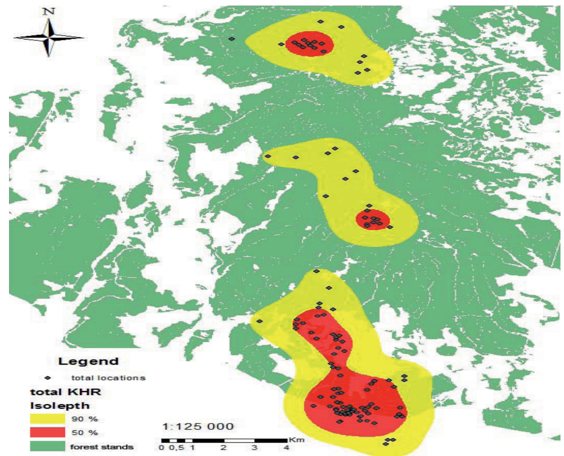

Fig. 8. Total the Kernel Home Range (90 and 50%) of the individual 353.

Core areas are stable in relation to proportion from 90% across seasons in 172 and 714. In 353 is noticeable great disproportion of core areas across seasons (Table 2).

Table 2. Kernel Home Range 90 and 50% home range sizes (ha) of the radio-tracked individuals.

Individual	Isopleth	Summer KHR	Winter KHR	Rut KHR	Total KHR
172	90%	1322.67	1202.56	1157.65	1550.26
	50%	464.71	571.77	662.64	592.57
714	90%	2048.96	2025.85	1690,64	2059.63
	50%	442.09	659.07	533.20	744.21
353	90%	1077.97	2267,98	1364.07	4709.99
	50%	174.66	1328.35	101.07	1608.08

The total home range sizes are differed across the seasons and the individuals in relation to the spatial strategy of a particular animal, without showing significant differences (Figs. 9 and 10).

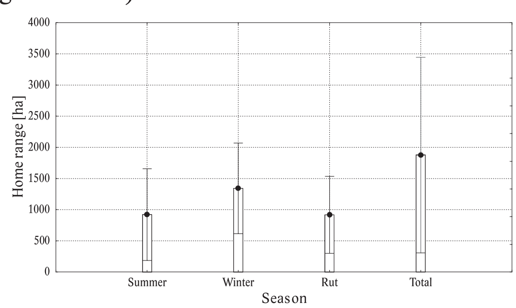

Fig. 9. Mean of total home range size (ha) by Kernel Home Range (90% and 50%) of tracked individuals.

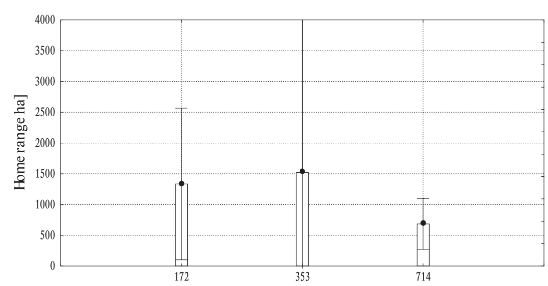

Fig. 10. Mean of seasonal and total home ranges (ha) by Kernel Home Range (90% and 50%) among the seasons.

3.3. Local Convex Hull (LoCoH)

There are some remarkable differences in HR sizes across individuals depending on spatial strategy of particular animal (Table 3).

Table 3. Local Convex Hull (100, 90 and 50%) home range sizes (ha) of radio-tracked individuals.

Individual	Isopleth	HR size
	100%	2285.52
172	90%	1213.46
	50%	294.19
	100%	1254.17
714	90%	874.42
	50 %	292.48
	100%	5333.83
353	90%	2201.49
	50%	708.29

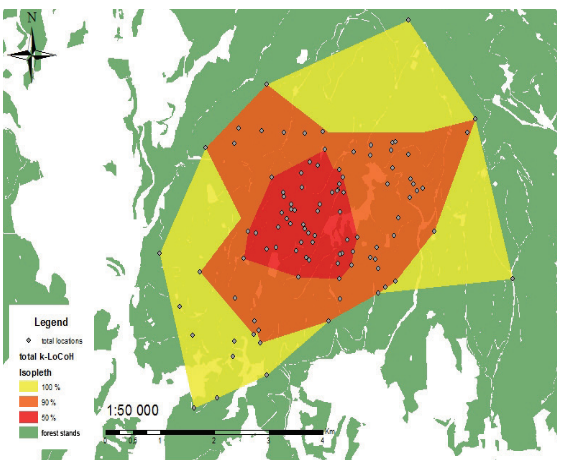

Fig. 11. Total home range sizes of the individual 172 by the Local Convex Hull.

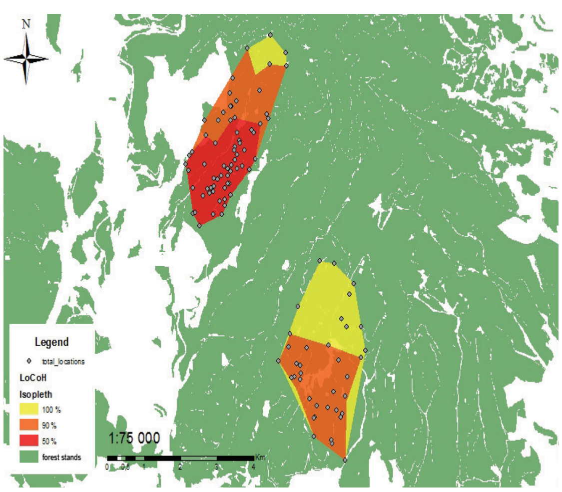

Fig. 12. Total home range sizes of the individual 714 by the Local Convex Hull.

Comparing the outputs of MCP 100% with LoCoH 100% location, the differences are varied between them. Generally MCP 100% recorded larger home range size than LoCoH 100% between all individuals. Exceptionally, individual 172 which MCP 100% is relatively greater than LoCoH 100%, the home range sizes of the other individuals (714 and 353) according to MCP 100% equal two times home range size by LoCoH 100% (Tables 2 and 3). We also compared between KHR 90% and LoCoH 90% location. ID 172 by KHR 90% larger than LoCoH 90%, otherwise we found that the individuals 714 and 353 have home range size according to KHR 90% (2059.63 and 4709.99 ha, respectively) larger twice than by LoCoH 90% (874.42 and 2201.49 ha). LoCoH is smaller because this method demands large sample size and in small samples tends to underestimate a home range. Statistically, the difference between LocoH and KHR is significant (Fig. 14).

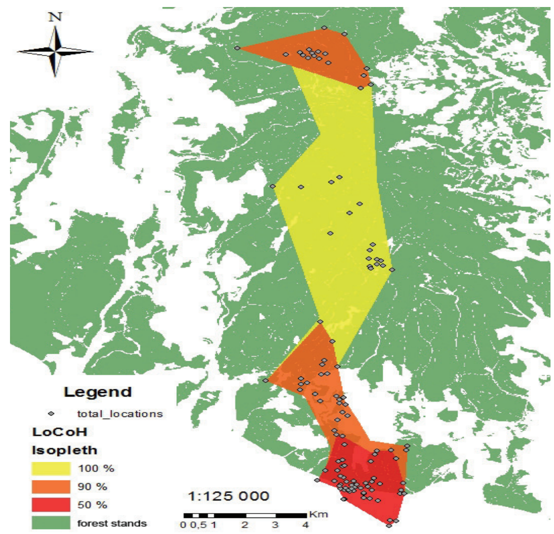

Fig. 13. Total home range sizes of the individual 353 by the Local Convex Hull.

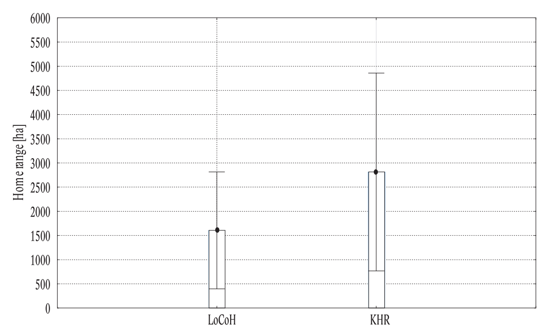

Fig. 14. Mean of total home range size (ha) by the Local Convex Hull (90% & 50%) compared with the Kernel Home Range (90% & 50%).

4. Discussion

Our study which was conducted in the Kremnica Mts. clearly noticed the differences in terms of spatial distribution and size of seasonal and total home ranges across the examined individuals (resident, intermediate migrant, and migrant).

Our findings showed that by the using MCP 100%, the summer home range in animal 172 dominate in size, but in 714 and 353 are smaller than winter HR. Beier & McCullough (1990) showed that animals are expected to reduce activity (and movement) at a high temperatures during summer and a low temperature during winter. In reverse, Rivrud et al. (2010) mentioned that home range size increase with temperature during winter and decrease with temperature during summer, with the largest effects of short temporal scales.

MCP 100% total home range size in 353 is apparently greater compared with other individuals (ID 172 and ID 714). The first study of home range in Slovakia was conducted in the territory of the Low Tatras Mountains and Poľana; and the study found that home range size of migrant individual ranging from 2980 ha to 8660 ha, for the resident individual was from 840 ha to 1315 ha (Finďo 2002). Annual home range sizes of migratory red deer in the Italian Alps were significantly larger than those recorded for stationary ones (Luccarini 2006). In 172 and 714 the total HR size by MCP 100% is relatively equal, despite their different distributions and sizes of seasonal home ranges. Szemethy et al. (1994) confirmed that similar home range sizes were found in a preliminary study on a hilly area of Hungary.

Evaluating of total home range size by using KHR (Kernel Home Range) noticed that summer home range of the individual 353 smaller twice than winter home range (2267.98 ha), also relatively smaller compared with even summer HR of the other individuals. The size of home range could be determined by some factors; especially a movement of animals in summer may be restricted by accessing forage and food availability. A summer time is considered to be the richest season of the year so animals have access to needed food in small area. However, on the other hand, enlargement of the winter home range size of the animal 353, may be driven by several factors such as supplementary winter feeding or human disturbance (logging, antlers collecting). Greater winter home ranges were also recorded in intensively managed red deer populations in Hungary (Nahlik et al. 2009). Individuals with less forage-rich habitat types dominating their home range, have usually larger home ranges than individuals with forage rich habitats dominating their home range, as they are able to cover their nutritional needs within a smaller area (Rivrud et al. 2010). Van Dyke & Klein (1996) found that red deer home range size also related to predation and human disturbance. Deer home ranges were enlarged as a reaction to human disturbance in the Oksbøl area in Denmark. Hinds fled out of their home ranges to "refuge areas" where they stayed for some days free from repeated disturbances (Jeppesen, 1987).

KHR and LoCoH 50% location, considered as core area of home range (the area most frequently used by an animal within its whole home range). The animal 714 moves between two core areas North and South core areas, irregularly moves between them because of its spatial strategy as intermediate individual. Core area of the 353 according to KHR 50% location relatively larger compared with 172 and 714. Harris et al. (1990) concluded that core areas (if they exist in an animal's home range) may be useful in understanding the behaviour of the animal, by providing a clearer interpretation of shifting patterns of use within a home range, and allowing better insight into intraspecific and interspecific patterns of area use. Also they suggested that in some cases total home ranges might overlap, while the core areas may be mutually exclusive. Powell (2000) described how core areas may indicate higher concentrations of important resources, and is thus more important to us in understanding an animal's life requisites than are peripheral areas. Borger et al. (2006) showed how the effects of local climate on home range size of roe deer (*Capreolus capreolus* L.) differed between total home range area and the core home range area. Similarly, the effect of home range determinants can change across temporal scales. The complex study of red deer population in the Western Carpathians from 2005–2013 which included 20 male individuals was conducted by (Kropil et al. 2015) who found that the differences in annual home range sizes between migrant and resident were significant and seasonal changes in the size and altitude of the home ranges were also proven. While MCP and KHR gave comparable results, LoCoH significantly differed from both, probably as consequence of small sample size. Cores should reflect biologically important areas in a range, rather than arbitrary probability cut-offs. In home range analyses, core areas are often reported simply as percentage use areas at some arbitrarily defined probability (Powell, 2000).

5. Conclusion

In this study using of different methods (MCP, KHR and LoCoH) with several Isopleths (100%, 90%, and 50%) showed variations in seasonal and total home range sizes and core areas among the tracked individuals, but statistically the differences in total home range sizes are not significant. Interestingly, the study confirms that by using KHR the summer home range size of the migrant individual is smaller twice than its winter home range size, also relatively smaller compared with even summer HR of the other individuals. The size of home range could be determined by some factors, especially movement of animals in summer may be restricted by accessing forage and food availability. Summer time is considered to be the richest season of the year so animals have access to needed food in small area. Otherwise, enlargement of the winter home range size of migrant individual, may be driven by several factors such as higher density on wintering areas cause higher exploitation of the food resources and animals tend to larger areas for satisfying its nutritional demands. Core areas of animal home range that determined by animals is most important rather than arbitrary probability cut-offs.

Total home range sizes created by LoCoH (50% and 90%) were significantly smaller than KHR (50% and 90%), because LoCoH demands lager sample size. I tis not recommended to use this approach in small telemetry data sets. There are three different movement strategies in the population (resident, intermediate, and migrant), which may substantially affect the effectivity of hunting management. If not taken into account, these differences may lead to overexploitation of migrants as indicated by Jarnemo (2008). Also supplementary winter feeding can influence movement behaviour of red deer and cause browsing deterioration in forests, although feeding experiments under controlled conditions indicate that properly designed supplementary winter feeding could be used as a tool for effective game damage control (Rajský et al. 2008).

Considering the minimum extent of the hunting ground in Slovakia to be 2000 ha (Garaj & Kropil 2013), there is a logical demand of more complex approach in order to take into account migratory animals occupying multiple size of this area. The Hunting Act 274/2009 for the first time established large-scale game management in Slovakia, establishing hierarchical coordination of hunting units over the geographic ranges considered as compact hunting areas with identical management objectives (Kropil et al. 2015).

Acknowledgements

This paper was prepared within the projects "Centre of Excellence: Adaptive Forest Ecosystems" (ITMS 26220120006) and "Completing the Centre of Excellence: Adaptive Forest Ecosystems" (ITMS 26220120049) supported by the Operational Programme Research and Development within European Regional Development Fund. The authors gratefully thank Dr. Peter Smolko for his assistance with field and technical work, the thanks extended to Assoc. Prof. Erika Gömöryová for her advice, encouragement, and contributions.

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