Home range, movements, and activity patterns of a brown bear in Serbia

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Abstract: We present satellite telemetry data for a subadult brown bear (*Ursus arctos*) in Serbia, documenting movements and activity for 273 days (Apr 2007 to Jan 2008). Average of daily movements was 4.29 ($\pm$2.99 SD) km. The longest daily movement was recorded in June (15.62 km), while the largest home range was recorded in May–June (1,060.9 km^2). Total 95% minimum convex polygon home range was 4,366.5 km^2, which is one of the largest home ranges recorded for a brown bear in Europe. During the monitoring period the bear moved throughout the western part of Serbia, and made movements into Bosnia and Herzegovina, highlighting the necessity of international coordination in the conservation of bears in the region. We propose an increase in brown bear research, and continued monitoring and management efforts at a national level.

Key words: brown bear, Dinaric–Pindos population, home range, satellite tracking, Serbia, Ursidae, *Ursus arctos*

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Large carnivores, including brown bears (*Ursus arctos*), have made substantial population recoveries in Europe (Chapron et al. 2014, Karamanlidis et al. 2015) in recent years. Such recoveries have often been accompanied by increases in human–bear conflicts and growing concerns over how to effectively mitigate these conflicts (Can et al. 2014). Effective management and conservation actions require an in-depth understanding of a species' biology (Boersma et al. 2001).

The Dinaric–Pindos (DP) brown bear population is one of the largest (i.e., estimated to be >3,000 individuals) and most important populations in Europe (Zedrosser et al. 2001, Kaczensky et al. 2013, Chapron et al. 2014) and has been the focus of numerous scientific studies (e.g., activity patterns [Kaczensky et al. 2006], genetics [Skrbinšek et al. 2012], human–bear conflicts [Karamanlidis et al. 2011]). Despite its international importance for large-scale bear conservation in Europe (Zedrosser et al. 2001), detailed and accurate information from some DP subpopulations, such as those in Bosnia and Herzegovina, Montenegro, and Serbia, are lacking or incomplete (Kaczensky et al. 2013, Karamanlidis et al. 2014).

Brown bears in Serbia are classified as endangered, with an estimated population in 2010 of fewer than 62 $\pm$ 10 (SD), excluding the region of Kosovo and Metohija in southern Serbia for which no abundance estimates have been available since 1998 (Kaczensky et al. 2013). These bears survive in 2 geographically separated regions in the eastern and western parts of the country. Bears in eastern Serbia are connected to the Stara Planina bear population in Bulgaria and the Carpathian population in Romania and are thought to be declining (Kaczensky et al. 2013). The bear population in western Serbia belongs to the DP bear population (Zedrosser et al. 2001) and is now considered stable (Paunović et al. 2008, Kaczensky et al. 2013, Karamanlidis et al. 2014). Bear populations in Serbia hold a strategic geographic position because they represent a potential link between the DP, Carpathian and eastern Balkans bear populations. The major threats to the survival of brown bears in Serbia are poaching, habitat loss and fragmentation, and the illegal capture of wild animals for exhibition (Huber 1999, Zedrosser et al. 2001, Paunović et al. 2005). According to Serbian legislation, bears are a strictly protected species (Anonymous 2010), and studying and monitoring their populations has been identified as a national conservation priority (Paunović and Ćirović 2006, Paunović et al. 2008).

We present results of the first telemetry study of a brown bear in Serbia. We initiated this study to improve our understanding of the home range and movements of brown bears in the region, and use the results of our study to inform management and

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conservation actions that may help protect this poorly understood and endangered brown bear population.

Study area

The study was carried out in western Serbia (43°42′00″N, 19°45′00″E). This area contains mostly agricultural areas except those of Tara National Park, whose mountainous slopes are covered with dense forests and include numerous high-altitude clearings and meadows, steep cliffs, and deep ravines. Tara National Park was established in 1981, and comprises approximately 200 km^2. Bears in the area belong to the western Serbian bear subpopulation (Kaczensky et al. 2013).

Methods

We trapped the bear using an Aldrich foot-hold snare (Johnson and Pelton 1980). We tranquilized the bear with an initial intramuscular injection of 3 mL zolazepam and tiletamin (Zoletil 100; Virbac, Prague, Czech Republic; initial vol 10 mg/kg) using a dart gun (DAN-INJECT Aps Injection Rifle Model J.M. Standard, Børkop, Denmark) and a second injection by hand of 2 mL Zoletil 50 (5 mg/kg). Based on researcher experience and tooth wear (Jonkel 1993), we identified the bear as a subadult male (approx. 3–4 yr of age). We took standard body measurements, weighed the bear (84 kg) and fitted a 3-D GPS–GSM (global positioning system, global system for mobile communication) collar (GPS Plus; Vectronic Aerospace GmbH, Berlin, Germany) with a time-controlled drop-off mechanism. The collar was programmed to attempt a location every hour.

Data analysis

We estimated total and seasonal (i.e., spring = 15 Apr–14 Jun; summer = 15 Jun–14 Sep; autumn = 15 Sep–14 Dec; winter = 15 Dec–13 Jan) home ranges by calculating the 95% and 100% minimum convex polygon (MCP; Kenward 2001). To ensure equality in sample sizes, we calculated seasonal MCP home ranges using 450 randomly selected locations for each season, thus exceeding the recommended minimum of 80 locations (Belant and Follmann 2002). We also delimitated home ranges of our study animal using 99% level Brownian bridge movement models (BBMMs) and estimated habitat type (i.e., Corine land-cover) use within it using ArcGIS v. 10.1 (Environmental Systems Research Institute, Redland, California, USA). In contrast to other home-range estimators, BBMMs take into account the path travelled by an animal between successive relocations (Bullard 1999) and are considered appropriate to study home ranges, migration routes, or fine-scale resource selection (Horne et al. 2007). Calculations for σ^1 in BBMMs ($\bar{x}$ = 4.98, range = 2.72–5.31) were based on algorithms suggested by Horne et al. (2007), assuming an average error of $\pm$25 m in GPS locations (σ^2 = 25); this is a value that seems conservative according to other studies (D'Eon and Delparte 2005, Lewis et al. 2007, Stache et al. 2012). We performed all home range calculations using the package adehabitatHR for Program R 3.0.1 (Calenge 2006, R Core Team 2013).

We calculated daily distances travelled by randomly selecting 6 locations/day that were $\geq$3 hours apart from each other, using package adehabitatLT for Program R 3.0.1 (Calenge 2006, R Core Team 2013). We compared the means of seasonal distances travelled using one-way analysis of variance and post hoc Tukey´s Honestly Significant Difference tests, after $\log_{10}$ transformation to meet assumptions of normality and equal variance among groups (Sokal and Rohlf 1994).

We calculated activity patterns based on the distances between successive hourly GPS fixes; we considered a bear to be stationary when successive fixes were closer than twice the GPS average error distance (2 $\times$ 25 m = 50 m), once all 2-D locations with dilution of precision (DOP) >5 were excluded to increase precision (Lewis et al. 2007).

Results

We captured the male brown bear at 0500 hours on 15 April 2007 and fitted it with a satellite collar. We monitored the bear through 13 January 2008 (273 days) when the collar signal was abruptly lost, thus obtaining 5,409 valid locations. The overall 95% MCP home range was 4,366.5 km^2 (Fig. 1; Table 1), ranging from 8.7 km^2 in winter to 3,333.1 km^2 in spring. The overall 100% MCP was 4,567.5 km^2.

During all seasons the home range included mainly forested areas; broad-leaved and mixed forests were used most frequently. Pastures and grasslands and agricultural areas were used more frequently in spring, but were overall less frequently represented (Table 1).

The bear travelled a total distance of 1,783.5 km throughout the entire western range of the species in

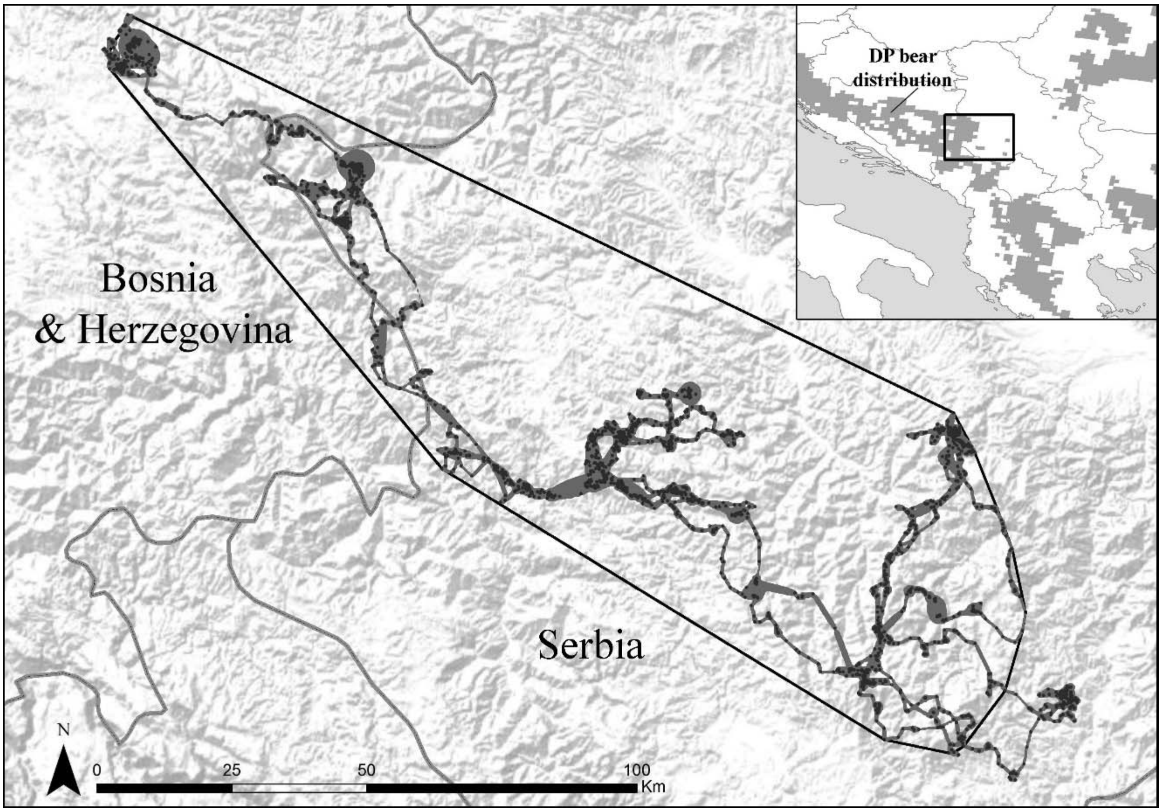

Fig. 1. Map of western Serbia, and eastern Bosnia and Herzegovina, indicating the GPS locations (dark dots) and the 95% minimum convex polygon (dark line) and Brownian bridge movement model (gray shaded area) home ranges of a subadult male brown bear monitored with satellite telemetry, April 2007–January 2008. The inset map indicates the general location of the study area in southeastern Europe, with the shaded areas indicating the distribution of the Dinaric–Pindos brown bear population.

Serbia, but also from Tara National Park to central southern Serbia and back, and then into neighboring Bosnia and Herzegovina. Average daily distance travelled varied seasonally ($F_{3,\ 244} = 9.707$, $P < 0.001$), and ranged from 1.66 km in winter to 5.09 km in spring (Table 1). The longest distance traveled in a single day was 15.62 km.

The bear was classified as moving 56.4% of the time overall, with greatest traveling activity in summer (Table 1). Movements were more frequent at night, with greater distances traveled ($F_{1,\ 4654} = 203.341$, $P < 0.001$; Fig. 2).

Discussion

Telemetry has been commonly used to study the activity and habitat selection of bears in southeastern Europe (Huber and Roth 1993, Mertzanis et al. 2005). However, because of the use of different methodology (i.e., use of very high frequency collars), some results of earlier studies (i.e., Huber and Roth 1993, Mertzanis et al. 2005, Kanellopoulos et al. 2006) are not directly comparable with this study.

The overall 95% MCP home range we estimated (4,366.5 km^2) was larger than any home range documented for male bears in the DP population. Home ranges (95% MCP) of male brown bears inside the female core area of a population in Slovenia, at the northern end of the DP population, varied from 231 to 474 km^2, while home ranges of peripheral males were larger, ranging from 851 to 1,624 km^2 (Krofel et al. 2010). Another subadult male bear ultimately poached in Austria had a home range of 3,144 km^2 in <2 months of monitoring (Kaczensky et al. 2011). At the southern end of the DP population, in northern Greece, home ranges (100% MCP) were smaller, averaging 271.1 km^2 (Mertzanis et al. 2011). The home range of the subadult male in our

Table 1. Home range (km^2), habitat use (%), average distance travelled daily (km), and percentage of time active of a subadult male brown bear tracked with satellite telemetry in western Serbia, April 2007–January 2008.

Variable	Spring	Summer	Autumn	Winter	Total
Home range (km^2)[a]					
MCP 95%	3,333.1	1,711.9	1,550.2	8.7	4,366.5
MCP 100%	3,361.9	1,766.2	1,556.6	13.9	4,567.5
BBMM 99%	323.3	199.3	198.4	12.3	586.5
Land-cover-type use (%)					
Broad-leaved forest	34.4	42.5	30.8	28.8	35.6
Mixed forest	22.9	22.1	31.8	44.5	25.4
Coniferous forest	14.9	14.2	11.7	24.0	14.0
Shrub	12.1	9.3	15.8	0.0	12.1
Pasture and grassland	6.0	4.8	4.0	2.7	5.1
Agricultural	9.6	7.1	5.8	0.0	7.8
Human settlements	0.0	0.0	0.2	0.0	0.1
Movements and activity					
Mean daily distance (km)	5.09	4.71	4.04	1.66	4.29
% time active	57.0	62.0	56.5	32.1	56.4

[a]MCP—minimum convex polygon, and BBMM—Brownian bridge movement models.

study is one of the largest home ranges reported from the European continent (Clevenger et al. 1990, Taberlet et al. 1997, Dahle and Swenson 2003a) and was rivaled only by home ranges reported from the arctic Northwest Territories (McLoughlin et al. 1999). Several studies have indicated that home range size in bears is affected by factors such as gender, reproductive status, food availability, and population density (McLoughlin et al. 1999, McLellan and Hovey 2001, Dahle and Swenson 2003a, b). Considering the increased productivity and resulting food availability typical of Mediterranean forests in this study, we suggest that the home range size we recorded is not unusual for a male subadult individual dispersing in an area with low bear density (McLellan and Hovey 2001, Proctor et al. 2004, Dahle et al. 2006).

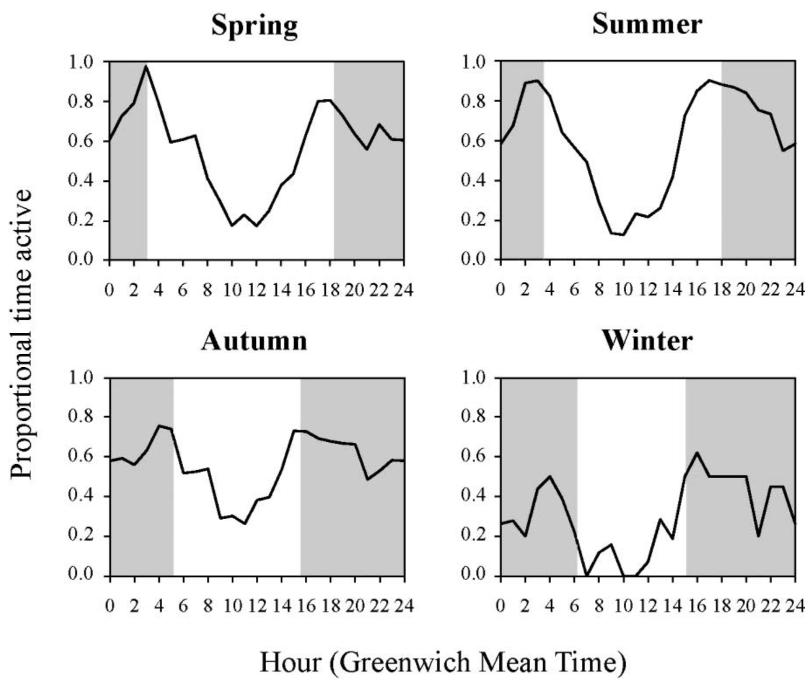

Fig. 2. Activity patterns of a subadult male bear monitored with satellite telemetry in western Serbia (Apr 2007–Jan 2008). Shaded areas indicate night-time.

The observed differences in the seasonal size of 95% MCPs are consistent with observations of bears in Greece (Kanellopoulos et al. 2006) and are probably related to food availability (Dahle and Swenson 2003b). Food availability likely also influenced habitat selection (Dahle et al. 2006, Kanellopoulos et al. 2006) because the bear generally used forested areas and rarely visited agricultural areas, pastures, and grasslands. This is in contrast with habitat selection of adult male bears in Greece; they often selected for agricultural areas (Kanellopoulos et al. 2006, Mertzanis et al. 2008).

The average daily distance traveled by the bear we monitored and the average percentage of time the bear spent actively traveling was similar to a subadult bear monitored in Bulgaria (Gavrilov 2015). Movement activity of the bear we monitored showed activity bouts during a 24-hour cycle characteristic of bears in this age group in the region (Kaczensky et al. 2006; Fig. 2).

The use of satellite telemetry to study brown bears in Serbia has provided valuable new insights into home range, habitat use, and movements of the species in the country. Because of the limited amount of information on brown bears in Serbia and the usefulness of telemetry as a research methodology (White and Garrott 2012), we suggest that efforts to study brown bears using this methodology should be intensified. This new information could be used in combination with information from other sources (i.e., genetics, ecology, human–wildlife interactions, etc.) to lead to the formulation of a bear management plan for Serbia, similar to the plans developed in neighboring countries (Huber et al. 2008).

That the subadult male bear we monitored travelled beyond the boundaries of Tara National Park and across the entire western range of the species in Serbia (i.e., an area 22 times larger than Tara National Park) highlights the necessity for coordinated species and habitat protection measures on a national level. In addition, this bear traveled beyond the national boundaries into Bosnia and Herzegovina, providing evidence of a trans-border bear population that is integral to the larger DP population. This and recent information from genetic investigations of Serbian bears (Paunović and Ćirović 2006, Karamanlidis et al. 2014) highlight the necessity for international coordination in the conservation and management of brown bears in the region.

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