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HOME RANGE, DAILY AND SEASONAL ACTIVITY OF BROWN BEAR (*URSUS ARCTOS*) IN SOUTH-EASTERN CARPATHIANS – A GPS/GSM TELEMETRY STUDY

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Abstract: *Approximately 35% of the European population of brown bears (Ursus arctos) is located in Romania, thus representing the largest stable population. Here, we analyzed 11 brown bears in the Romanian Carpathians for determining a series of eco-ethological characteristics of the species, such as: i) the size of territories; ii) daily routes and iii) an average value of intensity of bear activity for day/night/seasons and periods, information that can be used for conservation planning. The dataset was collected across eighteen months, thus the individuals were captured, tranquilized and set up with GPS Collars. The total number of monitoring days was 2.235, thereby hourly locations (24 locations per day) for each monitored individual obtaining a total of 30,004 valid locations.The longest distance registered was 1,912 kilometers in 391 days, with highest daily average at 4.9 km/day for ID 2271 Predeal (male, 2 years). The largest home range was 127,358 ha (MCP Method) / 38.165 ha (Kernel Bivariate Method 95%) by ID 2271 Predeal (male, 2 years). Moreover, for determining daily and seasonal activity, two individuals whose activity was at least one cycle of four seasons were chosen: a dominant adult male (ID 2278, male, 9 years) and an adult female with a cub in second year (ID 2274, female, 7 years). While autumn seasonal movement is correlated with both northern and southern aspect and is influenced by the fructification of forest species and food availability in orchards, the occurrence of significant agglomerations of individuals results in damages and human - bear conflicts. Our results may contribute to a better knowledge of brown bear eco – ethology and territories characteristics.*

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Key words: *Ursus arctos*, brown bear, home range, GPS Telemetry, activity sensors, GPS/GSM collars, Carpathians.

1. Introduction

Large carnivores, including brown bears (*Ursus arctos*), are top of the food chain species and are considered key species in regulating herbivores populations and consequently in maintaining ecological communities’ equilibrium [3].

Romanian Carpathians, although represent less than 2% of Europe's surface, sustain viable and stable populations of large carnivores, moreover about 35% of the entire European population of brown bears is located in Romania, representing largest stable population. This population has an important role in the ecosystem by "top-down" controlling the huge territories on prey populations [3].

There is a permanent concern for knowledge of wildlife populations ecology existing in a certain area [1], for determining the habitat where they can be found at different times of year or day and as well as finding methods for maintaining a large number of animals and places for movement (wildlife corridors), with applicability on ecological management of populations [7].

In Romania there are few scientific datasets regarding the influence of infrastructure development on eco-ethological characteristics of large carnivores and interconnectivity of habitats across time. Brasov area which represents a major transport junction will be crossed by some important highways that are currently planned to be executed. Consideration for creating a wildlife database correlated with ecological network was recommended prior to infrastructure development [2]. A harmonious development of infrastructure should consider the basic principles of conservation and protection of natural environment and biodiversity [6].

Regarding other studies across Europe, low densities of brown bears are registered in Northern Europe (approx. 5 bears/100 km^2) [8] comparing with very high densities in Romania (approx. 20 bears/ 100 km^2). These high densities are highly correlated with home ranges and territories overlapping, which can vary depending on food availability and population density [5].

However, to determine more precisely density intervals requires a better understanding of the size of the territory species, which can be determined using GPS/GSM Telemetry [4].

One of the specific objectives of this research was to monitor brown bears individuals in relevant population segments, using advanced systems Radio/GPS/GSM. Further we decided to determine for monitored bears a series of eco-ethological characteristics such as: the size of territories, daily route, average value of intensity of bear activity for day/night/seasons periods.

We consider that this study is particularly important for determining the above described parameters with very good accuracy (using GPS/GSM technology), a novelty in the last decade implemented in studies regarding brown bear movement in Romania.

2. Material and methods

The study was conducted on 11 brown bear individuals, which were captured and tranquilized. For those bears we set up GPS 8000 Collars, purchased from Lotek Wireless (Canada). These collars are suitable for midsize and large mammals and are using two remote communication options – a high speed UHF modem and a GSM modem, to provide users with more convenience when downloading the collar's data records.

The collars provide the following information: GPS location (GPS fix), temperature and activity status of subjects (activity/inactivity/mortality). One of the important characteristics is "on demand" - two ways communications that provide user the possibility of upload and download data. Also "on demand" the drop-down system is included, in order to recover the collar.

In addition to radio transmitter, the collar is equipped with a GSM modem which can send information in SMS format. In there isn't GSM coverage, data is stored and will be sent when the bear enters in the GSM coverage area. The sensors that equip the collar are: temperature sensor for monitoring the ambient temperature with 1°C precision, the activity sensor that measure the animal acceleration of movement 6-8 times/second, inactivity/mortality sensor (can store up to 132 events) and hibernation sensor which can determine the collar to switch on stand-by mode when the individual has low activity. When the activity rate increases the collar starts to function normally.

The data acquired by collars can be downloaded using GPS Total Host (Lotek Wireless) software, in this interface data can be easily managed, in order to view or export information (Appendix A3).

The GPS fixes were analyzed using GIS software ArcGIS v.10.2.1 (ESRI) and we generate the maps regarding the home ranges in the study period (Appendix A1).

The home range mapping was done using two methods: Minimum Convex Polygons (MCP) and Kernel with bivariate density estimation (Hawths Tools for ArcGIS extension v.3.27).

Statistical analyses of activity data was processed with Activity Pattern v.1.2.3 (Lotek Wireless) software.

3. Results

The monitoring period of the 11 bear individuals bear totalized 18 months (539 days). The whole period was covered by the bear with ID 2274 (female, 7 years), the smallest monitoring period was for ID 2276 (female, 17 years), which was captured before entering at denning winter sleep. We have managed to recover the collar after leaving the den, meanwhile the female gave birth.

The total number of monitoring days was 2235, in this period we collected hourly locations (24 per day) for each monitored individual, in total 30004 valid locations were obtained (Appendix A4).

The longest distance traveled per unit of time was 1912 kilometers in 391 days and represents the highest daily average, at 4.9 km/day, probably due to the fact that this bear was is dispersion movement for ID 2271 Predeal (male, 2 years). The shortest distance traveled per unit of time was 10 km in 33 days, with daily average of 0.3 km/day that might be due to the fact that the female was captured a few days before going to winter for the ID 2276 Lăptici (female, 17 years). Average daily distances traveled by the monitored individuals was 4.3 km for adult males, 4.1 km for young males and 1.6 km for females (Table 1).

Table 1

The resulted home ranges of monitored bears

No	Bear ID	Home Ranges							
		MCP Method		KDE Method					
		P [km]	S [ha]	95%		50%		5%	
				P [km]	S [ha]	P [km]	S [ha]	P [km]	S [ha]
1	2270	89.7	43617.8	128.9	21167.3	63.5	3585.4	4.2	139.2
2	2271	147.7	127358.2	238.9	38165.6	66.4	4872.0	5.7	258.7
3	2272	39.5	7757.2	51.0	7572.5	19.2	1519.6	4.7	173.3
4	2273	91.3	28548.3	72.6	10308.5	25.1	1904.0	4.7	175.4
5	2274	36.3	6860.4	23.2	3879.2	19.0	1128.3	5.4	155.0
6	22751	28.7	5362.2	37.6	5045.1	12.0	763.5	3.1	78.1
7	22752	17.5	1904.6	20.7	2948.7	10.4	737.2	3.8	107.5
8	2276	8.5	265.5	14.9	1607.1	7.3	376.5	2.7	54.1
9	2277	53.9	10112.4	58.5	6790.1	15.6	1064.8	3.9	118.1
10	2278	59.4	15804.0	67.5	10428.1	37.1	2320.8	5.3	225.4
11	2279	41.6	9096.3	46.6	7206.8	26.4	1498.1	6.9	184.2

The largest home range was 127358 ha (MCP) / 38.165 ha (Kernel 95%), registered by ID 2271 Predeal (male, 2 years), this might occur due to the fact that this young male was monitored shortly after its mother left him and searched for establishing a territory. The average values of home ranges for studied bears can be consulted in Table 2.

The detailed maps for studied bear individuals are presented in Appendix A1.

Table 2

The home range of studied bears (average)

Males	Method	Home range [ha]
< 2 years	Minimum Convex Polygon method (MCP)	85.488
	Kernel Bivariate Method	29.667
> 2 years	Minimum Convex Polygon method (MCP)	9.505
	Kernel Density Estimation Model Method (KDE)	7.563
Females	Minimum Convex Polygon method (MCP)	9.538
	Kernel Density Estimation Model Method (KDE)	5.107

4. Statistics - Daily and Seasonal Activities

GPS monitoring system from collars contains activity and temperature sensors, these sensors provides information about daily and seasonal activity. Thus, we chose two bear individuals whose activity were at least one cycle of four seasons: a dominant adult male (ID 2278, male, 9 years) and an adult female with a cub in second year (ID 2274, female, 7 years).

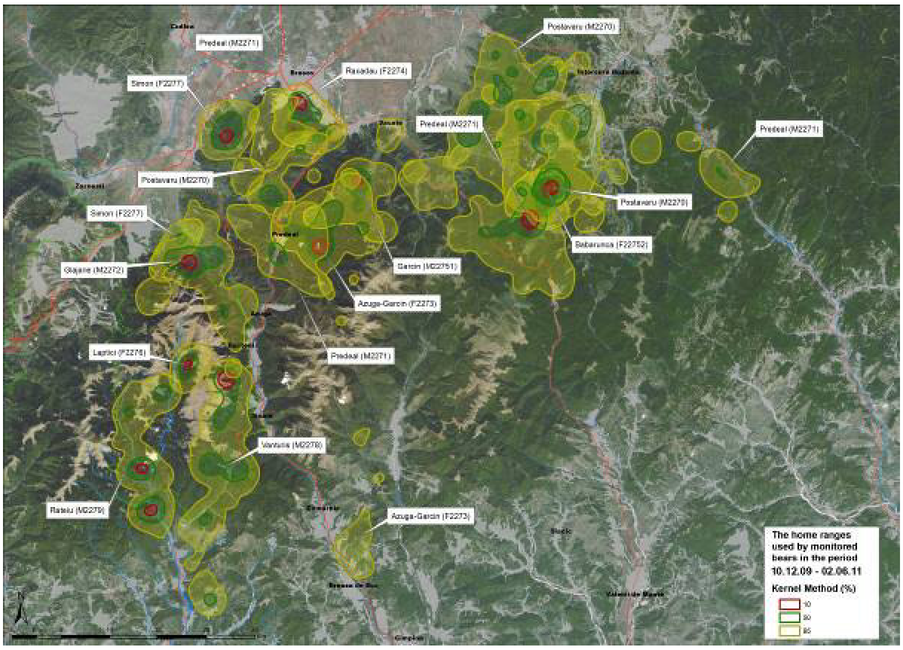

Fig. 3. The home ranges of monitored bears (KDE)

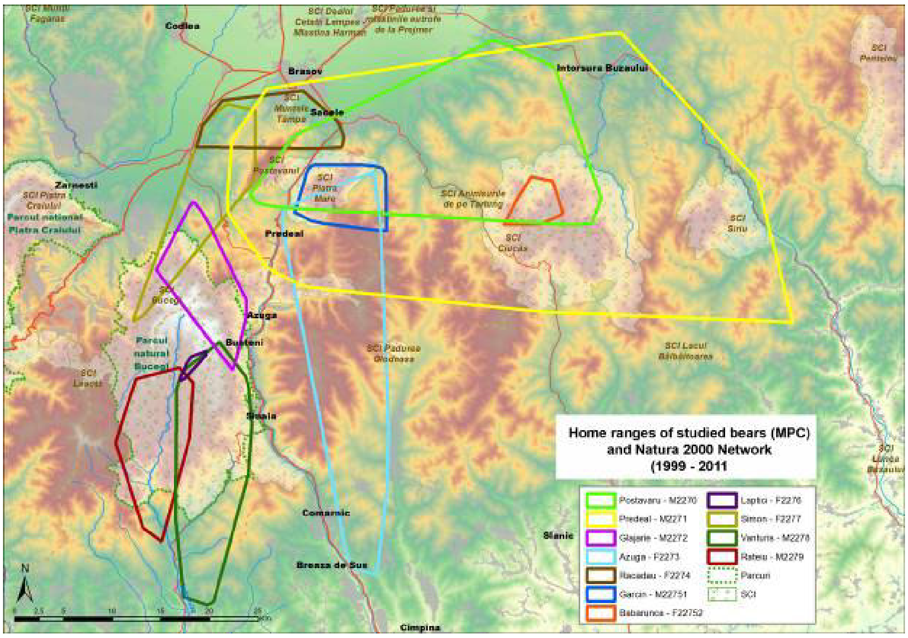

Fig. 4. The home ranges of monitored bears (MCP)

To access and download activity data, the operator should identify the individual in the field using a UHF radio receiver. The range of data connection is quite small

(100-500 m), so it requires physical effort to follow the animal in the field and to get close to him.

For generating the charts below, we have used a number of 90.000 activity information from bear ID 2278 and 160.000 activity information from bear ID 2274.

These analyzes were performed based on the activity diagrams that are presented in Annex A2.

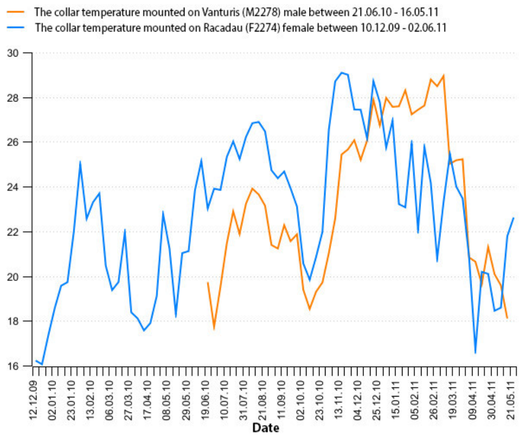

Fig. 5. Seasonal statistical variation of collars temperatures

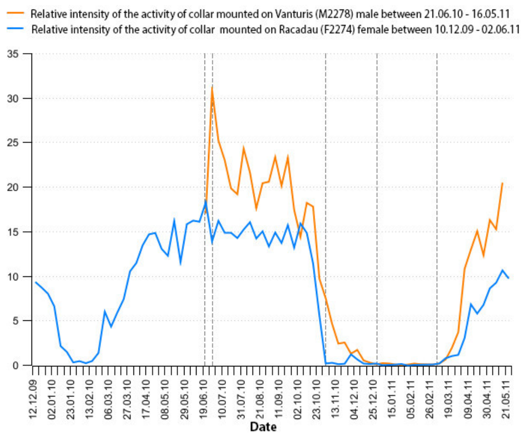

Fig. 6. Seasonal statistical variation of bears relative intensity of activity

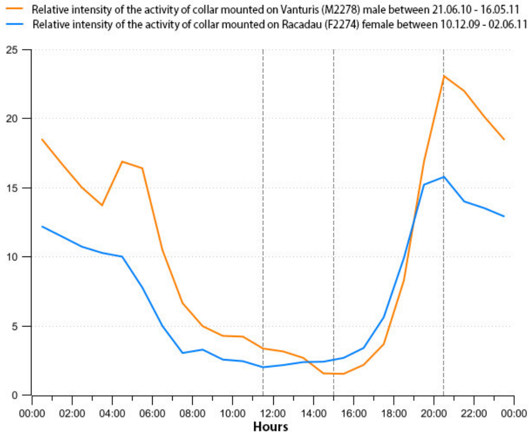

Fig. 7. Statistical variation of bears relative intensity of activity per periods of the day

5. Discussion

Using **satellite radio-telemetry**, we collected very high information quantitatively and qualitatively. We consider that satellite radio-telemetry compared with classic telemetry provide better results regarding the home ranges used by studied individuals.

The total area resulted from 11 monitored home ranges with GPS/GSM system is 256686 ha, some young males individual’s territories overlaps. In home ranges of the three dominant males doesn't exist overlapping areas.

Analysis of the maps resulted, indicated that bears spring movements are correlated with the grass species availability, while in the summer period individuals are moving in the areas where berries are available. In the autumn brown bears are using as main source of food trees fructification or/and fruit trees.

Autumn seasonal movement is correlated with both northern and southern expositions, being influenced by the fructification of forest species and availability of food from fruit tree orchards. The existence of orchards can determine the occurrence of significant agglomerations of individuals and will result in damages and conflicts with human communities.

Given the expected development of the transport system in Romania it is foreseeable that restrictions of species movement to be increasingly higher. High-capacity transport infrastructure will cross large areas of important habitat of the brown bear. This can result in fragmentation and connectivity loss of species favorable habitat. Moreover, in a 10 km buffer area from highway significant noise occurs with a negative impact on the existence of individuals, if not proper mitigation measures are implemented.

Regarding **activity analysis** based on obtained data, we consider that according to statistical variations of activity and collar temperature the seasonal temperature is higher for female specimens, as determined by differences in altitude home range. The male has predominant activity at altitudes of 900-1900 m and the female has activity at an altitude of 600-1400 m. Temperature variations are about the same, except the period of winter sleep, when the male variation is reducing. On the seasonal periods there is a similar activity in terms of variations of both.

We found an interesting fact that on the same day (06.09.2010), both bear individuals had an abnormal increase in activity variation and then returned to normal.

Another observed fact is the female who went denning earlier and went out later than the male bear individual.

Statistical variance of bear activity during a day peaks between the hours 20-21 and then reaches the minimum value between the hours 11-15.

Also, analyzes of activity diagrams reveals that daily activity is closely related to sunrise and sunset, so it begins 1-2 hours before sunset and ends at 2-3 hours after the sunrise. The exception is during the fall, immediately before entering denning and in spring immediately after exit denning, when activity time is longer during the day. During winter sleep occasionally bears are still active, but brief, which proves that the bear is not idle throughout the winter.

The female with ID 2274 which was found in the second year of study have had 2 young cubs of 3-5 months. The first 2 months after winter sleep end she has the predominant activity during the day, up to 2-3 hours after sunset.

6. Conclusions

Our data suggest that the bear monitoring method based on GPS/GSM Telemetry is more convenient than radio telemetry classical method in terms of economic aspect but particularly in terms of quantity and quality of information obtained. We consider that the downsides of the method based by GPS collars is a relative limited duration of collar batteries of 12-18 months (depending on the environmental temperature and activity of individual which the equipment was set up) and of course a larger acquisition price. Moreover, the batteries in “classical” collars without GPS/GSM/UHF technology implemented can last tree times longer.

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Appendix list

A1. Maps of home rages and tracks for studied bears: MCP and KDE Methods

Figure 1: Home Range of F2274 - Minimum Convex Polygon Method (MCP)
Figure 2: Home Range of F2274 - Kernel Density Estimation Model Method (KDE)
Figure 3: Home Range of M2278 - Minimum Convex Polygon Method (MCP)
Figure 4: Home Range of M2278 - Kernel Density Estimation Model Method (KDE)

A2. Activity patterns chart

Figure 5: Activity patterns chart for M2278 (21.06.2010–16.05.2011)
Figure 6: Collar Temperature Variation chart for M2278 (21.06.2010–16.05.2011)
Figure 7: Activity patterns chart for F2274 (10.12.2009–02.06.2011)
Figure 8: Collar Temperature Variation chart for F2274 (10.12.2009–02.06.2011)

A3. Database structure

Table 1: Database structure

A4. The monitoring – bears information and resulted routes

Table 2: The monitoring – bears information and resulted tracks

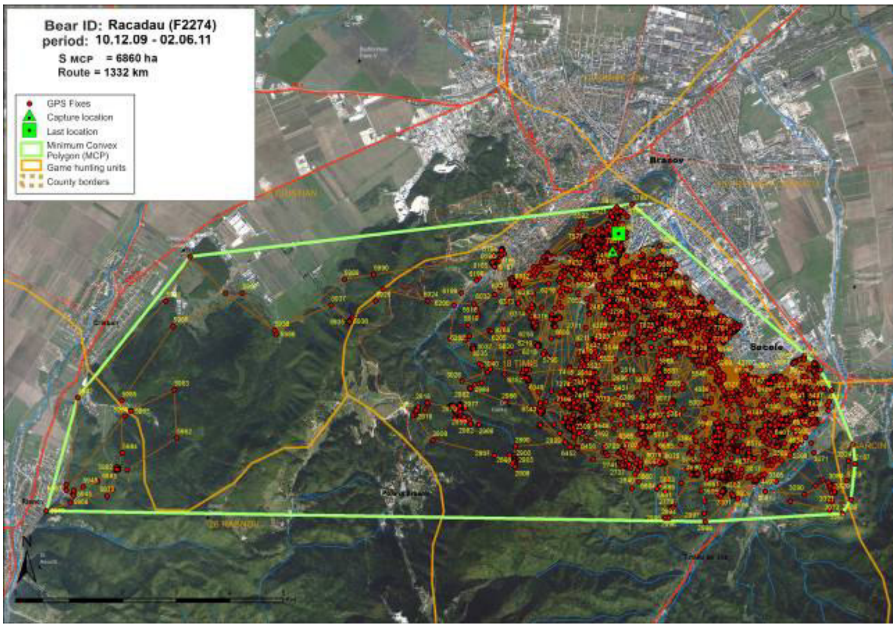

Fig. 1.Home Range of F2274 - Minimum Convex Polygon Method (MCP)

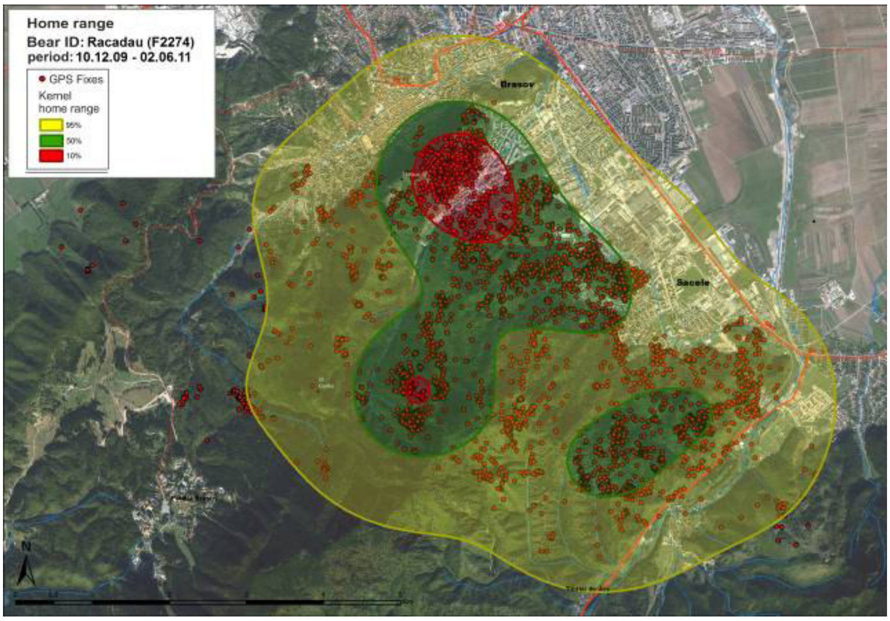

Fig. 2. Home Range of F2274 - Kernel Density Estimation Model Method (KDE)

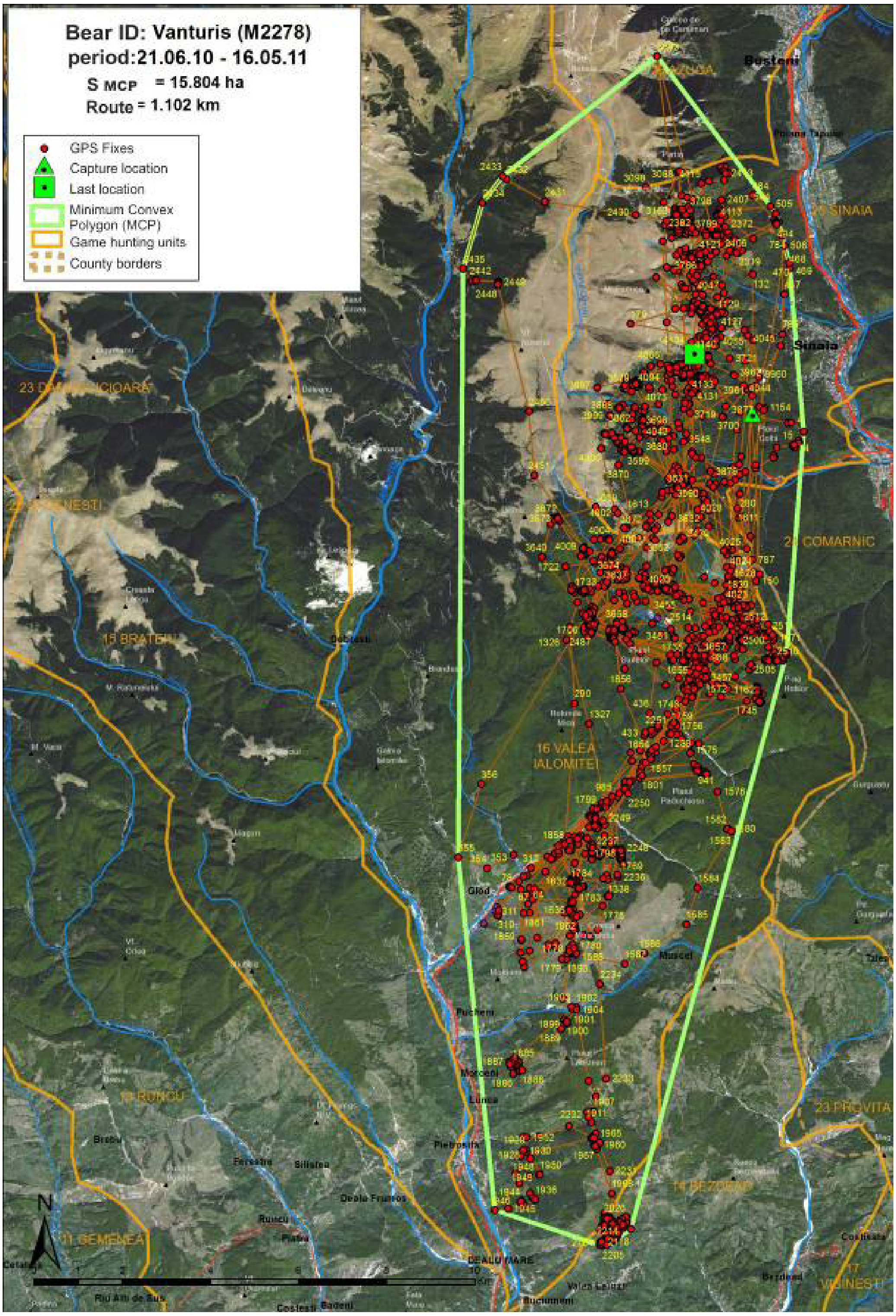

Fig. 3. Home Range of M2278 - Minimum Convex Polygon Method (MCP)

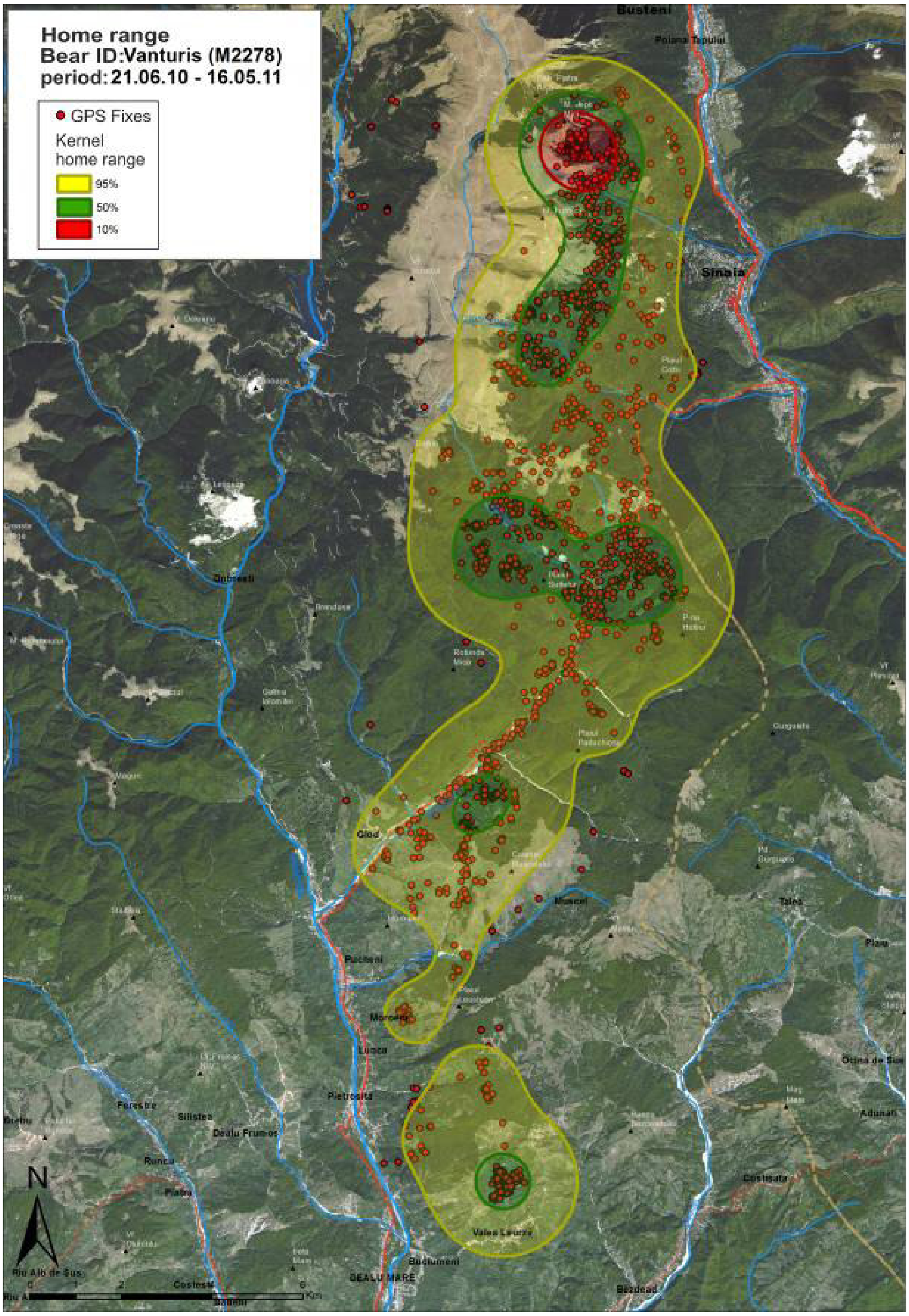

Fig. 4. Home Range of M2278 - Kernel Density Estimation Model Method (KDE)

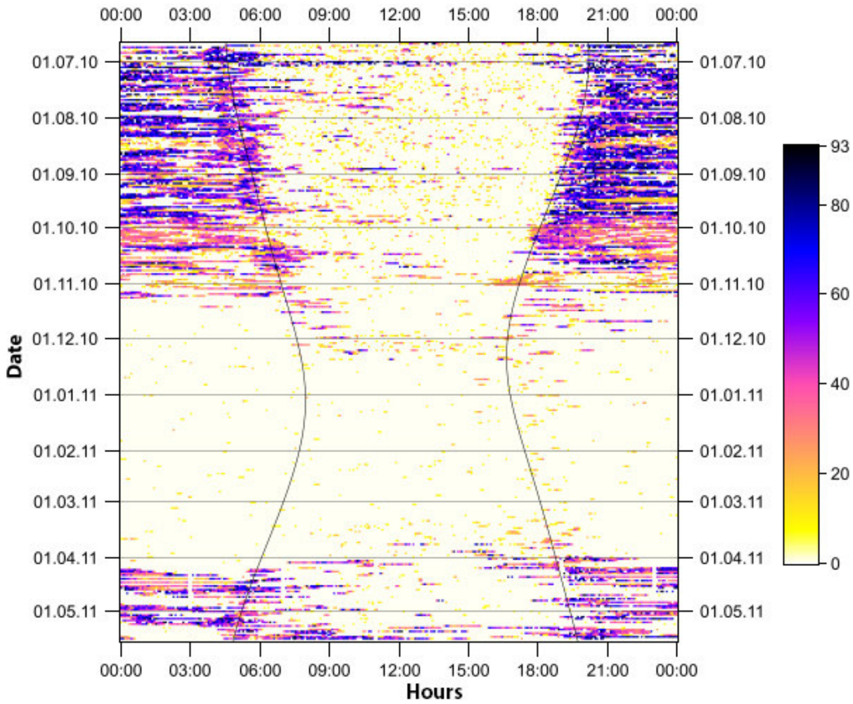

Fig. 5. Activity patterns chart for M2278 (21.06.2010–16.05.2011)

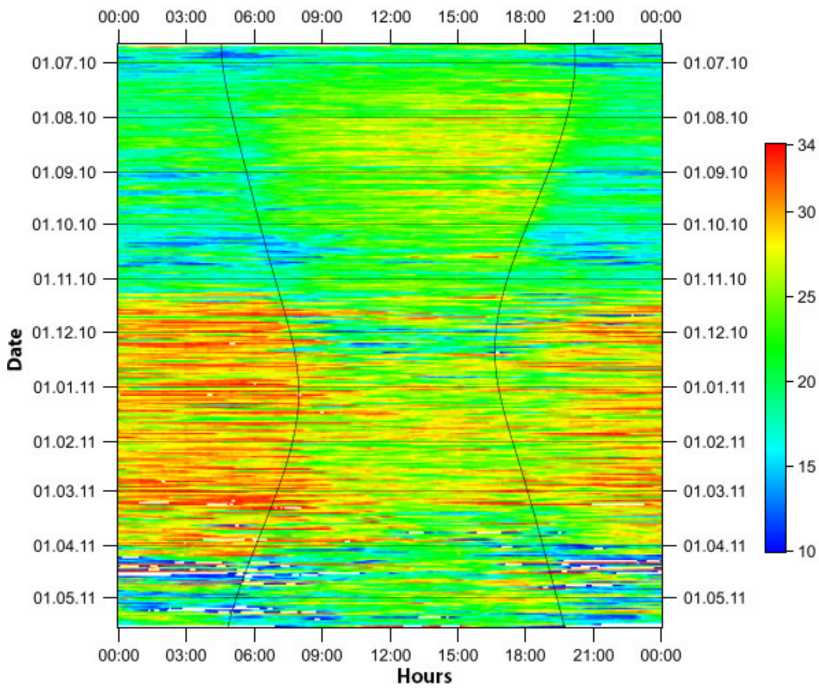

Fig. 6. Collar Temperature Variation chart for M2278 (21.06.2010–16.05.2011)

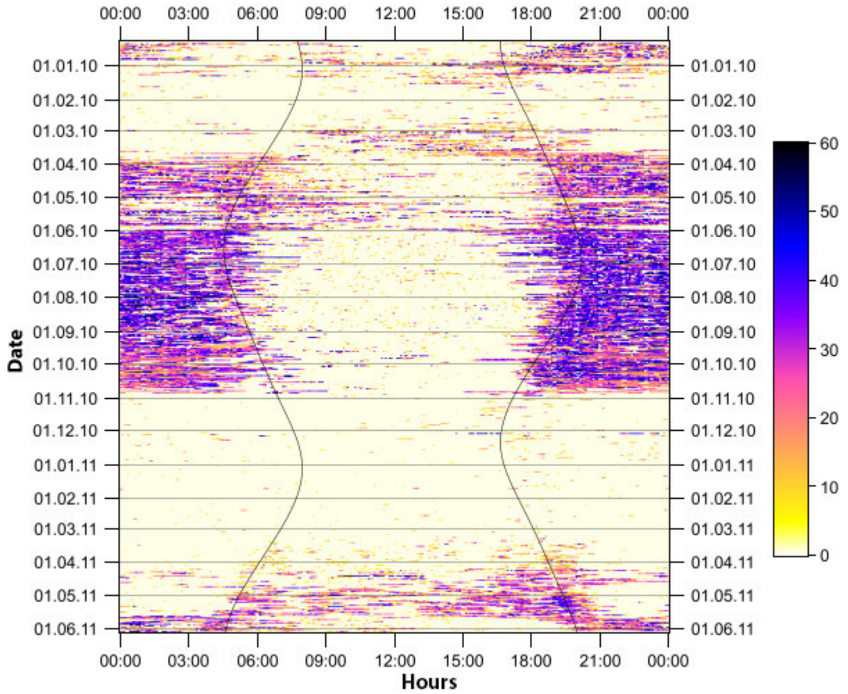

Fig. 7. Activity patterns chart for F2274 (10.12.2009–02.06.2011)

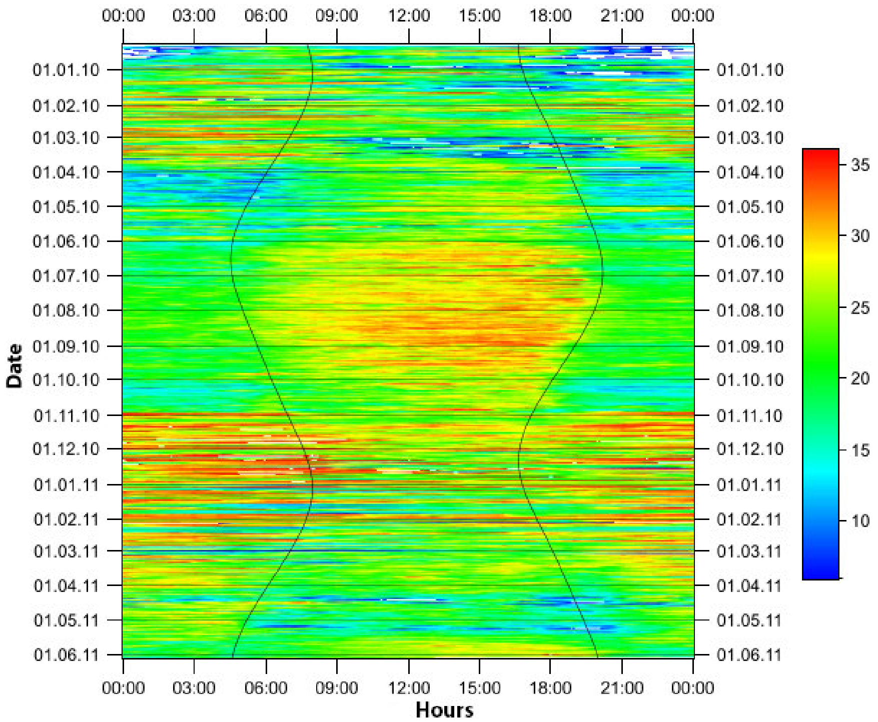

Fig. 8. Collar Temperature Variation chart for F2274 (10.12.2009–02.06.2011)

Database structure Table 1

No	Date	Time	Latitude	Longitude	Altitude [m]	Dilution of precision (DOP)	Navigation	No of satellites used	Temp [Celsius]
1	10.07. 2012	17:30:20	52.43075	13.52548	89.12	1.4	3D	8	28
…	…	…	…	…	…	…	…	…	…

The monitoring – bears information and resulted tracks Table 2

No	Bear ID	Sex	Name	Esti-mated age	Capture date	Last location date	Days of moni-toring	Loca-tion	Total track [km]	Average length of tracks [km/day]
1	2270	M	Postavaru	2	19.04.2010	16.09.2010	150	2.390	557	3.7
2	2271	M	Predeal	2	07.05.2010	02.06.2011	391	7.823	1.912	4.9
3	2272	M	Glajarie	21	22.04.2010	28.05.2010	36	548	169	4.7
4	2273	F	Azuga-Garcin	8	27.05.2010	02.05.2011	340	3.184	1.168	3.4
5	2274	F	Racadau	7	10.12.2009	02.06.2011	539	7.860	1.332	2.5
6	22751	M	Garcin	6	22.03.2010	07.05.2010	46	1.061	149	3.2
7	22752	F	Babarunca	11	13.06.2010	14.11.2010	154	538	91	0.6
8	2276	F	Laptici	17	13.10.2010	15.11.2010	33	160	10	0.3
9	2277	F	Simon	6	11.12.2010	02.06.2011	173	1.548	237	1.4
10	2278	M	Vanturis	9	21.06.2010	16.05.2011	329	4.140	1.102	3.3
11	2279	M	Rateiu	10	08.07.2010	21.08.2010	44	752	226	5.1