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Land use and behavioral patterns of brown bears in the South-Eastern Romanian Carpathian Mountains: A case study of relocated and rehabilitated individuals

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Abstract

Although brown bears are not drastically threatened by habitat loss and fragmentation at the present, the socio-economic development in Romania is proceeding rapidly and already came along with noticeable changes in landscape. Human-bear conflicts though exist for decades, requiring proper management and related research findings. We analyzed the habitat use on landscape level of 8 GPS-collared bears between 2008 and 2011. According to the type of human intervention we grouped our study animals into four classes: (1) non-relocated, non-rehabilitated; (2) relocated, non-rehabilitated; (3) non-relocated, rehabilitated; (4) relocated, rehabilitated. We tried to respond if bear types exhibit varied responses to landscape level habitat use by examining home range sizes and occurrence in the proximity of human settlements, defined as High Potential Conflict Areas (HPCA). We tested the effect of age and sex on presence versus absence and on the time spent in this buffer area. Home rang sizes calculated with the minimum convex polygon varied substantially among bears and types but less for the 95% kernel estimators. Between 50.9% and 94.7% of all bear locations were in forest areas and shrubland. Agricultural fields were frequented moderately, urban areas were practically avoided. But bear presence remarkably increased within the HPCA, in bear type 1 up to 70%. There was no significant difference between relocated and rehabilitated bears (type 2 and 3), both being more present outside the buffer area. Bears of type 4 behaved wary and approached urban areas less frequently. Females tend to stay further away from human activities, whereas males did not have a special preference. Adults frequented more often and remained longer inside the buffer zone than subadults, which were four rehabilitated animals out of total five.

Keywords: *Ursus arctos*; habitat use; conflict area; home range; Romania.

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1. Introduction

Romania still provides natural and semi-natural ecosystems supporting a high level of biodiversity. Landscape elements that disappeared from many parts of Europe are still well represented in Romania, including meadows rich in species and pastures, extensively managed semi-natural woodlands, traditionally maintained orchards, wood pastures and wetlands [1] and unspoiled large-scaled mountain ranges (66 303 km^2 total Carpathian Range) [2]. Practices of traditional land use in this part of Europe maintained over centuries, creating small-scale patchiness in the landscape and increasing landscape heterogeneity [3]. As one result, Romania still provides suitable habitat in quantity and quality, including unfragmented habitat for large carnivores like the brown bear (*Ursus arctos*) [1]. Forest clear-cutting though was recently identified as a significant source of disturbance with regard to the distribution of large carnivores in the Eastern and Western Carpathians of Romania [4]. Besides historical aspects regarding national bear management the biogeographical conditions may explain the Carpathian Mountain range sustaining 6 000 individuals [5], being potentially overestimated due to the inventorying procedure [6]. Other population data state a more realistic value of approximately 4 350 bears which refer to 35 % of the total European brown bear population [2]. Nevertheless, wildlife habitats are threatened by rapid socio-economic development that inevitably proceeds to keep up with the economic activities within the European Union [2]. The expansion of settlements (especially cities and suburban villages) and of agricultural fields into wildlife habitat as well as the quickly evolving (transport) infrastructure [1] may affect the behaviour of the brown bear in Romania on a large scale. Human caused habitat fragmentation and loss already led to altered behavioural pattern in species, particularly in large carnivores in Canada [7] and North America [8].

The human factors can cause avoidance of urban areas and/or an adaptation of the animals′activity to human encroachment, like e.g. becoming more night active [9]. Besides the potential risk of habitat fragmentation and degradation that result in a minor habitat quality for the animal, anthropogenic activity can generate a large spectrum of attractants for bears, as the access to garbage, orchards, agricultural products and livestock.

Understanding the spatial use of bear populations is mandatory to address conservation issues like human-bear conflicts, which are a persistent problem in Romania. It needs to be administered directly in managing human-habituated and food-conditioned individuals on the one hand, on the other by adapting land use to the requirements of the species′ habitat. A preferred management tool to mitigate such conflicts is the relocation which is defined as a non-lethal procedure to remove so called ‛problem animals′ from areas of conflict [10, 11] and to transport them to more remote environments, outside of their estimated home range, hoping that they will remain in wild habitats and stay problem-free [12]. Relocation has turned out to be a short-time solution as high rates of return are common [13,14]. There is evidence that trapping causes some bears to avoid an area [15], but most food-conditioned bears do return [16]. Rehabilitation as a conservation tool is defined by Bereczky [17] as the raising of an orphaned bear cub to self-sufficiency [18] targeting its reintroduction into natural habitats without developing nuisance behavior.

The goal of this study was to describe bear movements and behaviour patterns in an economically developing landscape in Romania with the purpose to highlight factors that could affect human-bear-conflicts. Therefore our objectives were (*a*) to describe relationships between landscape use patterns of brown bears and landscape features and (*b*) to examine their home ranges, (*c*) particularly their presence close to human settlements. Moreover, we tried to respond (*d*) if individuals exhibit varied responses to habitat use if they received a “human intervention” like relocation and/or rehabilitation before they were back-released into the wild.

2. Methodology

2.1. Study area

Our study area of 15 822 km^2 which covers approximately 23% of the estimated total bear distribution area in Romania (69 000 km^2) [19], is located in the Central and Southern part of the Eastern Romanian Carpathians between 45° - 47°N and 24° - 27°E. The study site is mainly overlapping four counties: Covasna, Harghita, Vrancea and Mures [20]. The size of the study area was determined according to the movements of the collared bears, their home ranges estimated with the minimum convex polygon (Fig. 1). Within the study site the urban areas, defined by us as all categories of human settlements (cities and villages), cover 670 km^2 (4%). The landforms vary from mountainous zones to lowlands, with altitudes between 200 and 2 100 m, including the Eastern part of the Transylvanian hills. The area consists of approximately 50% forest, dominated by broad-leaved tree communities, like different oak species (*Quercus* ssp.) below 800 m and beech trees (*Fagus sylvatica*) between 800 - 1 200 m. Mixed and coniferous forests include mainly spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and silver fir (*Abies alba*) covering altogether almost the same surface as the broad-leaved forests [17]. The sub-alpine belt (> 1 650 m) is mainly composed of *Pinus mugo*, *Alnus viridis* and *Rhododendron myrtifolium* shrubs [21]. We selected this study site for several reasons: (1) high density of brown bears (4.3 per 10 km^2), (2) high number of damages reported (352 damages were reported between May 2007 and September 2011) [20, 22], (3) great variety of land-use, (4) presence of orphan bear cub rehabilitation center.

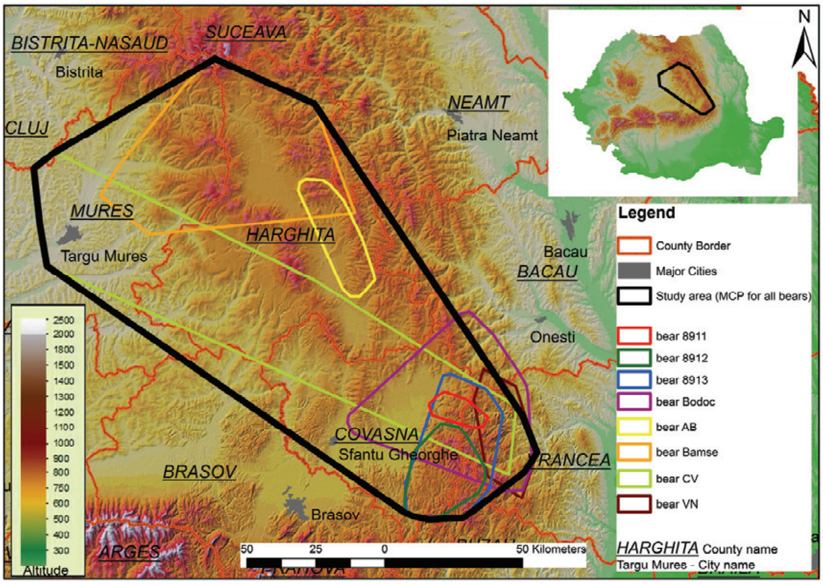

Fig.1. Location of the study site in the Eastern Carpathians with minimum convex polygons (MCP) for eight GPS-collared bears

2.2. Equipment and handling

We analyzed data of 8 bears that were equipped with GPS Pro Light – collars (GPS/GSM-System, Vectronic Aerospace GmbH, Berlin, Germany) covering the period between 2008 and 2011. The GPS units fixed the position at different time intervals (see Table 1). According to human intervention we grouped the tagged bears into four categories: (1) non-relocated, non-rehabilitated; (2) relocated, non-rehabilitated; (3) non-relocated, rehabilitated; (4) relocated, rehabilitated. Four of our investigated bears were classified as human-habituated (bear 8911, 8912, 8913, Bodoc) due to reported damages and/or to the frequency they haunted settlements including waste disposal sites. Relocated bears were released > 100 km (bear 8913, CV, VN) and > 60 km (bear Bodoc) away from their capture site.

2.3. Rehabilitation methods

The orphan bear rehabilitation centre is located in Balan, Harghita County (see Fig.1), in the Eastern Carpathians. It is a pilot project which aims to reintroduce orphan bear cubs into natural habitat after a professionally conducted rehabilitation process [17]. Poorly organized hunting and winter den disturbance can be mentioned as main reasons for cubs becoming orphan. The bears that undergo such a process are offered relatively large enclosures with natural habitat, food resources (forest fruits, grass and ants) and minimal human contact. Natural food is provided additionally and found by the cubs randomly, since it is placed in absence of the bears. The rehab period lasts maximum two years, the time of release depending on the animal′s physical condition and behavioural development. There are two implemented methods of release: (1) relocation including capture and transport to a release site and (2) release through an open gate of the facility that allows the cubs to leave and to come back [17].

2.4. Home range analysis

We used Hawth´s Analysis Tools for ArcGIS 9.3 [23] to calculate the minimum convex polygon (MCP) and the fixed kernel home ranges for our collared bears. Home range sizes were displayed with the MCP (see Fig.1) to show overall bear movements, but analyses regarding habitat use within the home range were conducted with the fixed kernel estimators. For the classification of different land types in our research we used Corine Land Cover (CLC 2006) with a 100 m resolution, compiled by the European Environment Agency (EEA). The land-use classes included several detailed codes for artificial surfaces (CLC code = 111-142), agricultural areas (CLC code = 211-242), forest and semi-natural areas (CLC code = 311-333) as well as wetlands (CLC code = 411, 412) and water bodies (CLC code = 511–523). We merged the telemetry locations of bears in forested areas with the few ones obtained in wetlands and at water bodies. For comparison among our study animals, we calculated the percentage of each surface.

A buffer zone with a perimeter of 1.5 km was created around the urban areas. We consider this zone an area where conflicts between man and bear occur with high potential (HPCA = High Potential Conflict Area). We assume this value to be appropriate and realistic to display bear presence near residential areas in Romania. Former findings [24, 25] revealed that bedding/resting sites in Romania tend to be at least at a 1.5 km distance from streets or homesteads. Pop [22] stated that 65% of damages appeared at a distance less than 1.5 km to human settlements.

2.5. Data editing and statistical analyses

We computed the ʽtotal hours spent per dayʼ (THD) for seven of our study animals in their buffer zone. Since bear AB was monitored in an eight hour interval, we decided to exclude it for further analyses related to time, avoiding potential bias. Because of an incomplete data base, we defined a system with dummy variables that allowed us to estimate the period of time in which a bear was present within its buffer zone. In the case that the GPS fixes appeared consecutively, the variable 1 was assigned between two GPS fixes for intervals of one hour, the variable 2 for intervals of two hours and accordingly the variable 3 for intervals of three hours. The value 0 was referring to GPS locations that had no following fixes within the mentioned intervals. The time point ‘0:00’ started with the variable 0. By applying this method, we could compensate ‘lost’ values due to be assessed as 0, despite an animal’s presence, with the abode time that might be overestimated if the animal did not remain over the entire hour(s). Having the information about the THD-value and the total number of days, we obtained the ‘mean hours spent per day’ (M-THD) within the buffer zone for all seven bears. The THD/M-THD values were categorized by: (1) type of human interference: non-relocated, non-rehabilitated; relocated, non-rehabilitated; non-relocated, rehabilitated; relocated, rehabilitated; (2) age: adult (≥ 4 years) and subadult; (3) sex.

Statistical analyses were performed in IBM SPSS Statistics 19. Data were first subjected to a Kolmogorov-Smirnov test for normality and to a Levene test for homogeneity of variance. Our data displayed non-normally distributed values and inhomogeneity of variance, even after transforming it into a natural log or square-root function. Accordingly we applied the non-parametric chi-square test for testing whether bear types differ in the frequency of being present versus absent in the buffer zone. The same analysis was carried out for the variables sex and age of the study animals. For further comparisons among the bears and between individuals, we tested the effect of type, age, and sex on the THD values in the buffer zone with the Kruskal-Wallis and respectively by applying the Mann-Whitney-U test. We assumed statistical significance at $P < 0.05$.

3. Results

The monitoring period was restricted to mortality (CV, VN) and poor collar performance (8913, Bodoc). Due to dense forest coverage in the habitat and thus partly restricted signal transmission, the GPS location data base was not complete. Overall, 50% of location attempts were successful (range 20-80%). Bear profiles in our study are summarized in the Table 1.

Table 1. Monitoring settings and individual bear characteristics

Bear ID	Monitoring period	GPS fix interval	# of locations	Gender	Age	Relocation	Rehabilitation
8911	08/2011 - 11/2011	1h	1 869	M	4	No	No
8912	09/2011 - 11/2011	1h	1 364	M	4	No	No
8913	05/2011 - 07/2011	1h	929	F	6	Yes	No
Bodoc	06/2010 - 10/2011	2h	1 089	M	2	Yes	No
AB	06/2008 - 08/2009	8h	716	F	2	No	Yes
Bamse	07/2009 - 12/2009	3h	926	M	2	No	Yes
CV	06/2009 - 11/2009	3h	541	M	2	Yes	Yes
VN	06/2009 - 12/2009	3h	667	F	2	Yes	Yes

3.1. Home range and landscape level habitat-use

Home ranges were estimated on the basis of different sample sizes (total nr. of locations) and in disregard of the season due to different monitoring periods (Table 2; Fig. 2). The home ranges of bears (n = 8) with a total of 8 101 locations (range = 541 – 1 869) varied considerably for MCP (range = 165.7 – 6 390.0 km^2) but less for 95% kernel estimators (range = 39.6 – 392.0 km^2). The total mean calculated using fixed kernel ($\bar{x}$ = 212.9 km^2, SD = 132.1) was approximately 10% of the MCP mean ($\bar{x}$ = 2021.0 km2, SD = 213.2).

Table 2. Home range sizes based on minimum convex polygon (MCP) and 95% kernel

	Bear ID												
Home range	8911	8912	8913	Bodoc	AB	Bamse	CV	VN	Mean	SD	Median	Median males	Median females
MCP [km^2]	165.7	709.3	1302.6	2615.5	571.8	3737.2	6390.0	676.1	2021.0	213.2	1005.9	2615.5	676.1
95% Kernel [km^2]	39.6	150.8	380.0	230.3	148.6	285.3	392.0	76.5	212.9	132.1	190.6	230.3	148.6

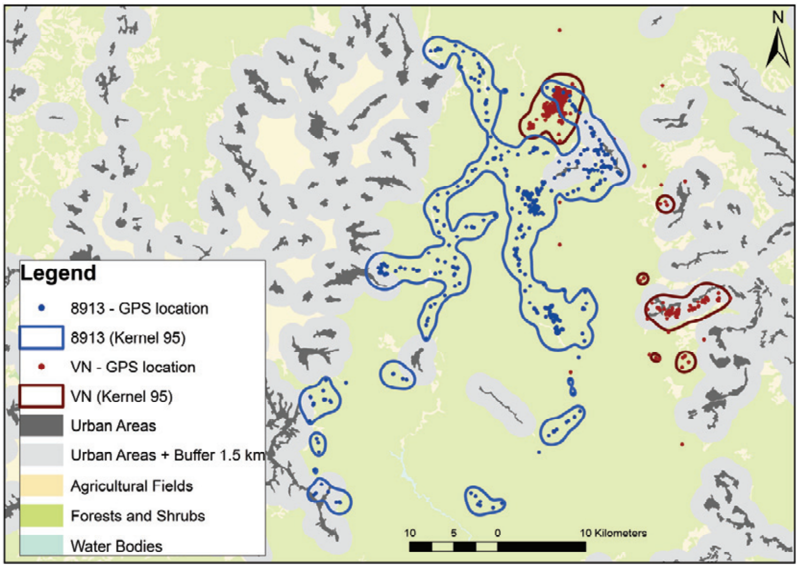

Fig. 2. Home range and land use of bear 8913 (type 2, female, adult) and bear VN (type 4, female, subadult)

The main land use within the home ranges of all bears was represented by forest and shrubland (FS) (range = 50.9% – 94.7%). Our study bears frequented urban areas (UA) in a small percentage compared to the HPCA that represents human settlements, partially agricultural fields (AF) and woodlands (e.g. for bear Bodoc: the UA surface is 7.2 km^2 and the HPCA is 91.7 km^2). The landscape categories differed substantially between the mean values ($\bar{x}_{UA}$ = 5.9 km^2, SD = 3.38; $\bar{x}_{AF}$ = 46.9 km^2, SD = 37.29; $\bar{x}_{FS}$ = 160.1 km^2, SD = 104.92) and among individual bears (Table 3).

Table 3. Land use in different landscape classes (UA, AF, FS) and HPCA use for individual bears

Bear ID Land use (km^2)	8911	8912	8913	Bodoc	AB	Bamse	CV	VN
Urban Areas (UA)	3.2	3.8	4.0	7.2	5.4	7.7	13.6	2.6
Agricultural Fields (AF)	12.4	16.1	16.2	59.2	67.5	63.9	125.2	14.4
Forest and shrubs (FS)	24.0	130.9	359.9	163.9	75.7	213.7	253.1	59.5
Total	39.6	150.8	380.0	230.3	148.6	285.3	392.0	76.5
HPCA (km^2)	27.6	32.2	67.9	91.7	60.1	97.9	162.3	28.2

3.2. Bear presence in the buffer zone (HPCA)

Bear types highly varied in frequencies for being present inside or outside the buffer zone (n = 8 101; χ^2 = 1 440.024; d.f. = 3; P < 0.001) (Fig. 3). Bears grouped to type 1 that were neither relocated nor rehabilitated were present more frequently inside the buffer area than outside among any other bear types. The absolute frequencies for occurrence inside and outside the buffer almost displayed a 2:1 ratio (n_{in} = 2 166; n_{out} = 1 067). The results for type 2 (n_{in} = 501; n_{out} = 1 517) and 3 (n_{in} = 462; n_{out} = 1 180) that were either relocated or rehabilitated bears showed a similar behaviour pattern in relation to presence and absence in the HPCA. The fourth group with both direct human interventions, had approximately three times more locations outside than inside the HPCA (n_{in} = 245; n_{out} = 963). Moreover, the value for "outside the buffer" was approximately the same as for the group 1, whereas the HPCA values varied highly (n = 4 441; χ^2 = 773.349; $P < 0.001$). Figure (4) illustrates the presence and home ranges of bear 8911 (type 1) and bear VN (type 4) with different percentages of overlap with the buffer area.

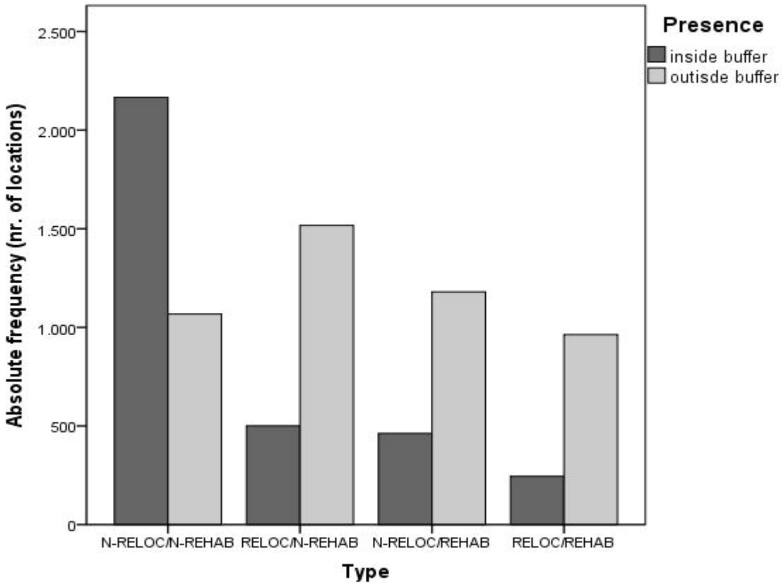

Fig. 3. Presence (absolute frequencies for GPS locations) inside and outside the buffer zone for different bear types

A difference among sex (χ^2 = 331.673; P < 0.001) and age (χ^2 = 690.049; P < 0.001) was recorded. Absolute frequencies of locations regarding sex, in both, males (n_{in} = 2 904; n_{out} = 3 013) and females (n_{in} = 598; n_{out} = 1 714), revealed higher values for occurrence outside the buffer. The distribution of locations in males was evidently more balanced than in females. Adults (n_{in} = 2 316; n_{out} = 1 846) frequented the buffer zone more often than subadults (n_{in} = 1 058; n_{out} = 2 881) which besides preferred to stay more frequently outside the HPCA.

3.3. 'Daily time spent' in the HPCA

The values of type 1 ($\bar{x}_{8911}$ = 14.38 h, SD = 7.21; $\bar{x}_{8912}$ = 13.11 h, SD = 5.33) and of type 4 ($\bar{x}_{CV}$ = 9.43 h, SD = 8.19; $\bar{x}_{VN}$ = 9.18 h, SD = 8.16) differed substantially but were similar within the groups. Bear Bodoc (type 2) spent less time in average ($\bar{x}$ = 4.65 h) in HPCA than all other bears. Type 3 is represented only by bear Bamse that reached the second lowest value ($\bar{x}$ = 6.25 h) in the row. For further comparison, we analyzed the median values for each bear and type. The non-parametric Kruskal-Wallis test revealed highly significant differences in both cases, between the individuals (n = 381; χ^2 = 118.436; d.f. = 6; $P <$ 0.001) as well as between the types (n = 381; χ^2 = 112.801; d.f. = 3; $P < 0.001$). The total median amounts to the value 8.00 h, which is 1.5 h less than the total mean value ($\bar{x}$ = 9.31 h¸ SD = 7.63). Generally, the median values (Fig. 5) showed similar patterns and distributions among the bears as the mean values.

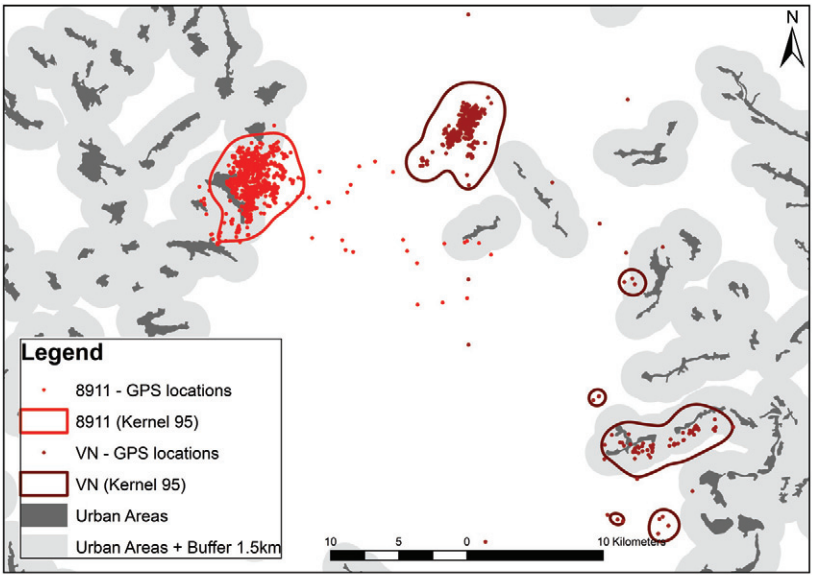

Fig.4. Home ranges and buffer areas (HPCAs) of bear 8911 (type 1, male, adult) and bear VN (type 4, female, subadult)

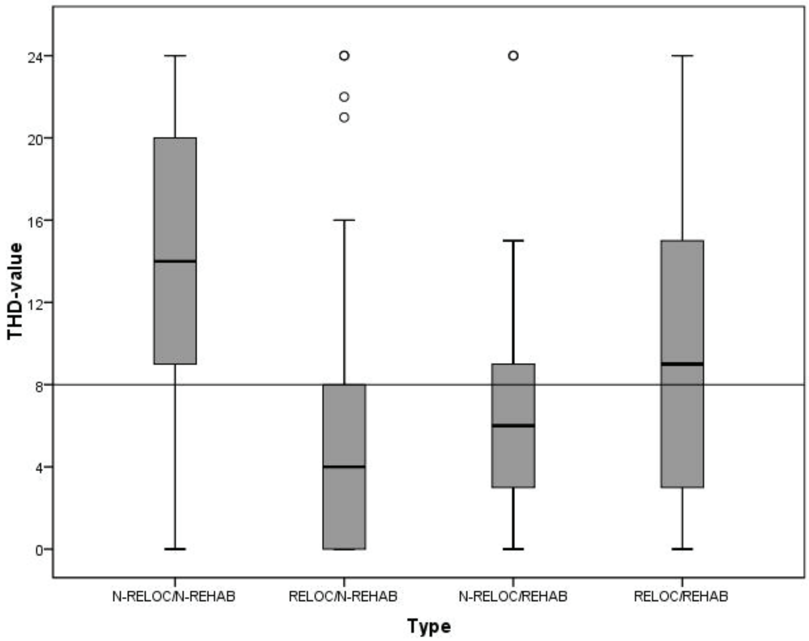

Fig. 5. Median hours spent by types (1-4) in the HPCA; bar (grey), whisker (vertical line), outlier (circle), total median (horizontal line)

The Mann-Whitney-U-analysis revealed a significance between type 1 and type 4 (U = 2 946.5; $P <$ 0.001), but no difference between type 3 and 4 (U = 1 198; $P = 0.077$).

The variable sex had no effect on the THD-value ($n_f = 49$, $n_m = 332$; U = 7 882.5; $P = 0.73$), but age had a highly significant impact ($n_a = 164$, $n_{sa} = 217$; U = 7 471; $P < 0.001$). Adults remained longer in the HPCA than subadults.

4. Discussion and conclusion

In regard of our study animals, home range sizes could be strongly affected by the previous experience of the individual bear with humans. According to a study of Beckmann and Berger [9] urban black bears experience a 70 to 90 % reduction in home range size in comparison to wildland individuals (referred by the author as non-human-habituated). Home range sizes of type 1 were 90% and 62% smaller than CV`s home range (type 4). In type 2, also classified as human-habituated, the reduction amounted only to 3% and 41%. Taking into consideration that type 2 bears were relocated and monitored longer, the large sizes could be explained by wide post-release movements. In general, bears verify thoroughly the unknown site after release and in most cases return to their former home range [14]. Subadults, likely representing exploratory dispersing individuals [26], might feature large home range sizes (bear Bodoc, Bamse, CV). There was evidently no relation between home range size and sex.

Although the estimated home-range area increases as the number of animal locations collected increases [27, 28, 29], the total number of locations did not correspondingly evoke larger or smaller home range sizes in our study (Table 1). The monitoring period regarding length and season might have influenced the size remarkably. Home ranges in our study noticeably overlapped with each other: because of different monitoring periods may be not exclusively in the same time. The amount of intraspecific variation in home range overlap may be associated with the abundance and predictability of food [30] indicating a high quality habitat for bears in the study area [20].

Our results revealed that forest and shrubs was the most preferred habitat for both male and female bears in the study area that in total exhibits 45% forest coverage. Shrubland played a minor role, therefore the few GPS locations for each bear were assigned to forest areas. However, shrubland seemed to be negatively correlated with bear presence [31]. Rugged terrain may provide particular benefits to bears [26]: the availability of denning sites [32], food plants and the abundance of ant hills [33]. Forests also provide better cover and lower human access [34]. Bear presence in agricultural fields could be moderately detected, varying quite intensively among the bears. Subadults seemed to frequent cultivated land more often, probably in search of food that are easy to access and provide manifold sources. Another reason could be based on the avoidance-theory stating that older bears that are more abundant in the more remote area may pose risk to sub-adults by predation [35]. Among the adults, only bear 8911 haunted agricultural fields to the same extent than subadults.

Urban areas were generally avoided by bears. On the contrary, the percentage of land use in the HPCA increased remarkably, in some cases up to almost 70%. The median value of 38.3% displays the crucial role of the HPCA for bear presence. Creating the buffer zone with a 1.5 km perimeter around the urban areas matched our expectations of high habitat use by bears. In contrary, findings from North America and Europe revealed avoidance and low use by bears of areas surrounding major roads and human settlements [36, 37, 38]. However, the strong presence in the proximity of urban areas is not surprising since human-habituated and food-conditioned bears pose huge problems to the public and authorities in Romania for decades. In this context, we could conclude that type 1 was present most frequently in the HPCA. This assumption was evident for bear 8911, but not for bear 8912. By analyzing group 2 and 3, we compared relocation versus rehabilitation: there appeared no relevant difference between the types, relocated bears frequenting in average the buffer zone less due to the low value of bear 8913. Bear 8912 had the second lowest value. It should be taken into consideration that these two bears were monitored for only two months. Consequently, if we compare type 1, excluding bear 8912, with type 2, 3 and 4, that represent relocated and/or rehabilitated animals, we can conclude that those human interventions might mitigate bears frequenting the proximity of urban areas.

In opposition to the descriptive discussion about land-use, our statistical tests based on frequency data regarding the presence and absence in the HPCA identified distinct results between the types (Fig. 3). Type 1, regarded as our control group with no previous human intervention, was the single group that revealed more locations inside than outside the HPCA. Type 4 with both 'human treatments' was present least inside the buffer zone. There was no difference between relocated and rehabilitated bears, indicating that both treatments have the same positive effect regarding the avoidance of human areas. Likewise, the same results were obtained by using the THD-method which was based on time estimation (Fig. 5). Bereczky's [17] study about the suitability for the reintroduction of rehabilitated bears in the Carpathian Mountains of Romania revealed no significant differences regarding the ecological and behavioural characteristics of rehabilitated and free-ranging brown bears.

The distance at which bears are potentially disturbed by human activities is likely depended upon age and sex [26]. The distribution of locations in males was evidently more balanced for inside and outside the HPCA than in females. Females chose to remain more time outside the buffer zone. One explanation might be that females are more wary, selecting areas with a high degree of security for raising cubs [39], involving the avoidance of males in some cases [7]. Researchers from Norway [26] reported as well a strong tendency in females to avoid habitats closer to towns. Our analyses regarding the THD-values in the HPCA did not confirm significance between sexes. Subadults in Norway [26] and in Canada [7] could be located closer to settlements than adults. As opposed to our initial expectation, the actual distribution for adults attached more value to the locations inside than outside the buffer. Adults significantly frequented the HPCA more often than subadults, which preferred to stay away from human areas. This finding was once more strongly affirmed by testing the THD-values among ages. The effect of rehabilitation on the subadults (4 out of total 5) probably made them behave wary.

Relocation could be an effective management tool for mitigating human-bear conflicts, at least as a short-term solution in dealing with nuisance animals. Based on our results, relocation on rehabilitated individuals had no additional impact. Therefore we consider that it is not crucial to relocate bears after rehabilitation process. It could be sufficient to use the soft-release methods. Rehabilitated individuals did not frequent the proximity of urban areas as often as human-habituated bears did.

Land use changes and development in the rural areas should seriously take the presence and movements of the brown bears into consideration to avoid future human-bear conflicts. In this context the impact of human activities, land use management and natural resource exploitations should be assessed adequately for areas at local level with the goal of maintaining the natural food availability and habitat quality for bears. We strongly recommend to manage properly potential attractants and to stop the feeding of bears, which represents a popular hunting management tool in Romania, inside the High Potential Conflict Area. Further, efficient waste management should be conducted and agricultural attractants protected by setting up electrical fences and implementing other effective measures.

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