

Bear footprints and their use for monitoring and estimating numbers of brown bears (*Ursus arctos* L.) in Bulgaria

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Abstract: We present an improved table of the footprint dimensions of the Bulgarian/ Eastern European brown bear (*Ursus arctos* L.). Our results demonstrated congruence between the length of the hind paw footprint and the width of the fore one, as well as correlation between footprint size, age, and sex of the individuals. Six categories of bear fore paw and respectively hind paw footprints were identified according to their dimensions, which are related to their body sizes (influenced also by sex and age). The table could be useful for identification of the individuals by their footprints and could be utilised in the National monitoring of the bear in Bulgaria. Examples are given to demonstrate the effectiveness of using size parameters of footprints for determination of local population numbers and structure.

Key words: *Ursus arctos*, Bulgaria, bear monitoring, bear footprints

Monitoring of the bear in Bulgaria and field identification of the individuals by their footprints

The brown bear (*Ursus arctos* L.) is of high importance in terms of conservation in Europe and its Bulgarian population is among the few national populations in the EU amount to more than 500 individuals. It is an endangered and protected species at the same time (SPIRIDONOV, SPASSOV, 2015). The monitoring of the brown bear in Bulgaria, aiming to evaluate the status of the species has been initialised several years ago. It is funded within the frame of the project of the Executive Agency of the Environment (EAE) "Development of National System of Monitoring of the Biodiversity and the Protected Areas in Bulgaria" – PPA03/BG/715 (2004). The regular national monitoring of the species was planned as per the concepts of the National action plan for the brown bear in Bulgaria (2008). The improved methods of this monitoring were accepted officially by the Ministry of Environment and Waters (MOEW) in 2016. As the brown bear inhabits the mountain regions in Bulgaria and due to the difficult logistics and the expensive methods, up to now only the method of the individualised bear footprints has been used in Bulgaria. The data collected by using this method were considered sufficiently suitable for statistical analysis giving the

opportunity for extrapolation of the results for larger territories (GUROV et al., 2014). That is why the methods applied in the national monitoring of the bear are based on the identification of signs of life activities of bears (especially footprints) and the statistical analysis of these data.

Different modern methods are used globally and in Europe in order to estimate local numbers and densities of bear populations (see: SOLBERG et al., 2006 and references therein; KENDALL et al. 2009; SWENSON et al., 2011; JERINA et al., 2013). At the same time, the "traditional" method of the measurement and identification of the footprints is widely used in field studies of carnivores, and the methods of their analysis have become more precise. Several recent studies advocate the use of footprints for sex and individual identification (see in: GARCIA et al., 2010; SINGH et al., 2014). Some comparisons between the radio-tracking method and the one based on measuring footprints and following the tracks of carnivores by walking show that both methods have advantages and disadvantages and could be successfully applied together (MATJUSHKIN, 2000). The significant

amount of data collected through permanent observations provided by large number of field experts in Russia allowed defining the number and structure of the bear populations (see: GUBAR, 1990; PAJETNOV 1990; DANILOV et al. 1993; PAJETNOV & PAJETNOV, 2002). In the eighties of the 20th century studies on the number and the structure of the bear population using sustained observations, the transect method and identification of individual animals by their footprints had been in use also in Bulgaria (GUNCHEV RAYCHEV, 1989; 1990; SPIRIDONOV & MILEVA, 1987). Until now, the identification of footprints and the assessment of the bear population structure based on the size of the footprints, and carried out for the purposes of the national monitoring, was based on the scheme proposed by GUNCHEV RAYCHEV (1989). This scheme considers the correlation between the size/ weight parameters of the bears recorded through observation and measurements (done on a large number of killed individuals during the bear hunting) and the footprints (of the killed bears incl.) measured on the terrain (GUNCHEV RAYCHEV, 1989). The explanation of how to apply it for differentiating the individuals with similar footprints is presented in SPASSOV et al. (2000).

The main goal of the present study is to amend and improve the method for field identification of bear individuals by using their footprints. This would help the better assessment of the numbers and status of the species, and could be used for monitoring purposes.

Material and Methods

The proposed new correlation table for field identification of the age, size and sex of the bears (Table 1) is based on the comparison and analysis on data from previous studies, as well as on our new data accumulated during field trips. Data show a direct dependence between mass/ size category (related to age and sex), and the size and proportions of the footprint. The basic studies used herein are the one conducted by GUNCHEV RAYCHEV (1989) in the Central Balkan Mountains (Bulgaria) and those, conducted in European Russia (GUBAR, 1990). The summarised significant amount of data regarding the size and proportions of the footprints collected from the European territories of Russia show significant resemblance to the data concerning the size of the footprints collected in our country. Therefore, the Russian data were considered for the development of the present new correlation table covering the size of the footprints, the sex and the age of the individuals. Data from Bulgaria on the correla-

tion of the individual size, age and sex mainly with the size of the footprint of the hind paw (according GUNCHEV & RAYCHEV, 1989) and data from the European part of Russia regarding the same correlation with the footprint of the fore paw (according GUBAR, 1990; PAJETNOV & PAJETNOV, 2002), have been taken into account. All these studies provide specific information on the correspondence of particular dimension of the footprint with the body size/ weight, as well as with the related individual age and sex. Further, an attempt for relating the size of the footprint of the fore paw to the hind one was done in this study, taking into account some correlations established by SPASSOV et al. (2000), and especially the significant new accumulation of measured footprints with identified age and sex. During our field observations (1997-2015), in the frame of several projects, more than 300 footprints were measured from the entire bear habitat in the country. These data and comparisons were used to specify six categories of footprint size (Table 1). The measurement of the footprints in the field was done following the scheme presented in Fig. 1. While interpreting the data from the correlative table of footprints given below, it should be taken into consideration that the differences in the size of the footprints could reach and even exceed 10% (GUBAR, 1990), affecting especially the length of the posterior footprint. These differences could be affected by the solidity and inclination of the terrain, and depend on the speed of movement of each animal. Therefore, based on our experience and to ensure measurement accuracy below 0.5 cm, double and triple measuring of each footprint (by means of compasses) has been necessary, as well as measuring of several footprints of the same animal. Measurements taken in mud are the most precise. The size may appear a little bit smaller than the actual one when measurements are done on solid ground, and a little bit bigger when in snow. Usually the footprint of the anterior paw is turned towards the body in an oblique way (FORMOZOV, 1952) which facilitates the identification of the left and right footprint. When the front footprints are completely clear, the interior part of the palmar pad is well visible and shows that it is considerably shorter than the external one in males (Fig. 1; PAJETNOV & PAJETNOV, 2002). In case the animal is moving fast, the footprint of the hind paw could be placed in front of the forelimb paw, as the animal moved its hind leg before its front one. In some cases, the anterior part of the hind paw steps on/overlaps the footprint of the front paw (Fig 2). This could lead to imprecise measurements of the posterior footprint if

Table 1. Size of the footprints of the brown bear from Bulgaria and Eastern Europe. Congruence between the length of the footprint of the hind paw, the width of the fore one, and the size, the sex and the age of the bear.

Feature	Category bear	Width of the fore paw footprint	Width of the hind paw footprint	Length of the hind paw footprint
1. A bear cub – 1 st year		5-7 cm	-	6-11 cm
2. A bear cub – 2 nd year, up to ~ 50 kg.		~ 8-9 \ 10	0-0.5 cm Narrower than the anterior one	12-15
3. Young females (3 and 4 year) and young males ~ three-years old (small bear: ~ 50-100 kg)		10/11-12 cm. (Most frequent in the field). The young individuals with 12 cm are probably young males as 12 cm is normal size for a mature female)	0-0.5 cm. Narrower than the anterior	16-19/20
4. Adult females and subadult (four- or five-year old) males (average-sized bear – 100 ~ 200 kg.)		12/13-13.5/14; (Extremely rarely 14 cm – for a female but most frequently for a young male)	~ 0.5-1 cm Narrower than the anterior	19/20-23/24 cm; (23/24 – only male individuals)
5. Mature males more than 5 years old (large bear ~ 200-250 kg)		14.5-17	It could be up to 1-1.5 cm narrower	24-26/27
6. Very big, old males, usually more than 10 years old and more than 250 kg (records – above 350 kg)		17 and more	Up to 1-2 cm narrower	27-30 (31?) cm

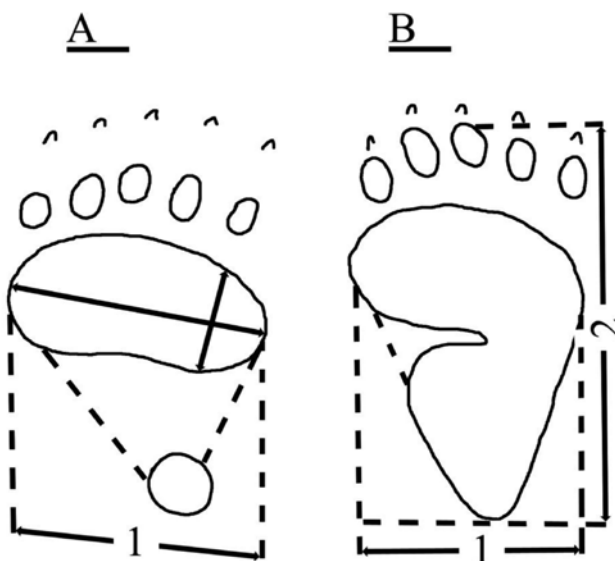


Fig. 1. Measurement of bear footprints. A – footprint of the left forepaw. B – footprint of the right hind paw. The length of the traces is measured without the claws; the width is measured in the main pad behind the toes (in the area of the metapodials).

the researcher is not aware of the fact that the measured width is that of the front paw, rather than that of the hind paw, which is narrower.

Development of the method for identification of the individuals by footprints

The improved table of the footprints size categories (Table 1) proposes more precise criteria for evaluation of size/ weight, sex and age of the individuals, based on the size and proportions of specimens' footprints. In size categories 1-2, the sex ratio of the

discovered footprints could be 1:1, and our experience shows that the footprints in categories 5-6 are only of adult males (M). Therefore, in the discovered in the field footprints of the size category 3 the female individuals seem to prevail (probable proportion F : M = ~1.5 :). Our results suggest that they should prevail especially in category 4 (probable proportion F : M = ~ 3:1). We agree with experts who consider the fore paw footprint more reliable for individual identification (GUBAR, 1990). The disadvantage of measuring the posterior footprint arises from the fact that the posterior paw does not leave always a complete print. The regression analysis showed a significant relation between the width of the anterior footprint and the weight of the animal ($r = 0.8 \pm 0.07$; $P > 0.99$, coefficient of regression 18.5 according DANILOV et al. (1993). Our experience (see also GUBAR, 1990 and SPASSOV et al., 2000: appl. 6) shows that the width of the footprint from the anterior foot of adult animals is usually bigger by 0.5 to 1 cm as compared to the footprint of the posterior foot. It is important to note that the growth of the foot and, therefore, the size of the footprints, is accelerated until the end of the intensive growth of the young animal. This growth ends around the sixth year. Then the total size of the foot can increase only insignificantly (GUNCHEV, 1990), and mainly in males.

Evaluation of the reliability of the field method for identification of bear individuals by footprint measurements.

The census of bears by detected footprints in Adjilarska Reka Hunting Husbandry at the village



Fig. 2. A footprint from the hind paw of a very large male bear (width 17.5 cm), Rakitovo State Forestry, the Rhodope Mountains. The anterior part of the hind paw overlaps the fore paw, which is slightly rotated inward, that is why the footprint seems slightly arched (photo by N. Spassov, 2011).

of Kojari, Western Rhodope Mountains (biotope: 80-100-year old spruce forest), is given here as an example of the evaluation of the reliability of the presented above correlation table of the footprints. This territory was suitable for testing the method because of the: concentration of individuals (due to the game feeding points) in a relatively small territory; (ii) good knowledge of the foresters on the present individual bears due to regular observations from game watch-towers and camera-traps; (iii) concentration of bears due to availability of points for supplementary game-feeding; (iv) and the small size of the territory.

According to the reports of the foresters R. Radulov and M. Bukovski in 2012, the presence of the following individuals has been known: female with one-year-old cub; another mother with a two-year-old cub, a young already corpulent male (in the surroundings of the villages of Bujново and Kozhari), and as it seems, one more bear (adult female/sub-adult bear?) in the region of the village of Kesten.

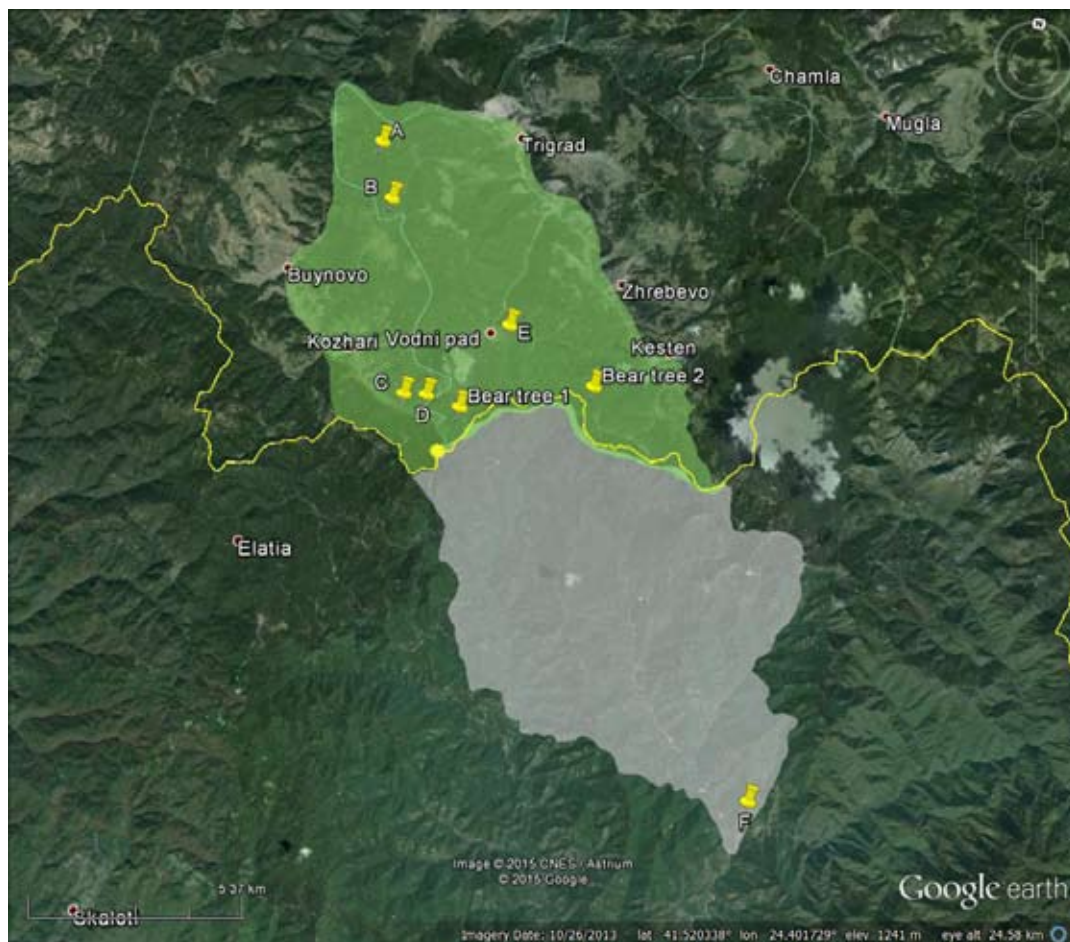


Fig. 3. The approximate minimum individual territory of a dominant male in the region of the Bulgarian/Greek border, Western Rhodope Mountains. The marked points (A-F) refers to places where the old male had been seen, or traces of its activity were observed; the star – the place of a mark tree on the Bulgarian-Greek border. The bear marking trees are marked by nails at 2.40 till 2.50 m. of height. (The boundaries of the individual territory in Greece are provisional).

A very large male which had seriously wounded a pack-horse 6 years ago inhabits the whole territory and spends considerable part of its time on Greek territory (SPASSOV & IVANOV, 2016).

After two-day field study (1.10 – 2.10.2012), we (N.S. & V.I.) were able to identify six of the seven mentioned bears, using the comparative table of measurements (Table 1). We identified the following bear individuals in the region, in close proximity to the game-feeding point: mature ~ 5 year--old male (width of the anterior footprint – 14.2 cm, length of the posterior one – 23 cm); one-year-old cub with its mother, identified close to it by scats; see SPASSOV et al. 2015 (width of anterior footprint 7 cm); a second mother with a two-year-old cub (width of the anterior footprint of the cub – 9 cm, length of the posterior one up to 15 cm). The width of the anterior footprint of the mother was 12.5-13 cm and the length of the posterior one was 20.5 cm. Another bear (most probably a subadult from category 3, Table 1) was identified in the periphery of the studied area, along a dusty road following the Bulgaria/Greece border from Kesten Village to Vodni pad Village (anterior footprint width – 11-11.5 cm, posterior one – 11 x 18 cm). The mentioned huge old male (with 18-19 cm width of the front footprint) was not recorded in the region during this short field study in 2012, probably due to its movement range within a very large area. Its first recording at the mentioned feeding stations occurred on 17 Mar 2014 using camera-trap and later the same year – by tracks (SPASSOV & IVANOV, 2016). According our observations the large diameter of the home range of the above-mentioned old dominant male exceeds considerably 20 km (probably reaching 30 km). Its minimum home range, calculated based on witnesses' and our observations, is ca. 140-150 km² in spring (core territory?) (SPASSOV & IVANOV, 2016; Fig. 3). The younger male (in 2015 already most probably 8 years old) visited the feeding stations when the old one was not there, according to the observations of M. Bukovski. The footprint width of the forelimb that was close to 16 cm and was found in the same place probably belonged to him.

Bear density in limited territories. Results after individualization of the signs of bear life activities, especially footprints.

During November 2015 (in mild weather) the following bears were identified in Adjilarska Reka Hunting Husbandry and the adjacent territories on a surface of ca. 70 km² (using footprints detections and the camera-trap visual information; Fig. 4): a female



Fig 4. Bear density in Adjilarska Reka Hunting Husbandry (November, 2015). Bears detected in different points: at Point Feeding station 1: all bears visited this place (game supplementary feeding station); at P. Feeding station 2 (game supplementary feeding station): the younger male and the female with three cubs from this year were identified; at P. 37 (a GPS-localised point): the dominant male; at P. 40: the female with two cubs from last year (2014); at P. 55 – the same female with two cubs; at Point named dominant male track: the track of the dominant male is detected in direction to feeding station 1.

with three cubs from the same year (2015) (Fig. 5); a female with two cubs from last year; the above-mentioned huge dominant male; another (young?) bear with white spot on the buttock; and the other (mentioned above) male, about eight years old (2015). All these bears were recorded at the game supplementary feeding station 1 (Fig.4), while the giant with the scar on the muzzle was absent from the area. Its presence was documented on the ridge, moving towards this feeding station, as well as along the mountain ridge of the border between Bulgaria and Greece (see Figs.3-4). All females with cubs are likely to visit the game feeding station during the same night with time distance of 2-3 hours. The female with three cubs was recorded also at feeding station 2 (near Yagodina). The second big bear (with golden head) was seen near the hunters cabin (to the south-west of Kojari Village) and probably also the same male was detected at feeding station 2. In November, all these ten bears (cubs incl.) were found practically simultaneously in the mentioned territory (Fig.4). Here the density at this time of the year was about one bear (cubs incl.) per 700 ha., or about one (adult) bear per 1000 ha (having in mind that the biomass of the noted cubs corresponds roughly to two free-living adult/subadult bears). This high density, which



Fig 5. Mother with three cubs born in 2015 at feeding station 1 (see Fig. 4) and their tracks on the pathway. (Photo by Assen Ignatov, 2015).

represents in fact a concentration of individuals on the above-mentioned territory, might be related to the existence of game feeding stations, permanently visited by bears, especially in spring and in autumn. For comparison we could present the following data on bear density:

Mazalat Hunting Husbandry in the Central Balkan Mountains: approximately seven bears were recorded based on our observations on footprints, in the optimal habitats of the regions of the basins of the Leshnitsa and Gabrovnitsa Rivers from an area of approx. 50 km², for the period August – September 2012. The average density of the bears in the area of Eleshnitsa – Gabrovnitsa Rivers was also very high: one bear per less than 1,000 ha, most probably resulting from the presence of the game-feeding stations for ungulate that were visited by the bears as well. This density is close to the data for a very high density presented by GUNCHEV RAYCHEV (1989) for the same region 23 years earlier with 0.5 bears per 1,000 ha. It is necessary to note, however, that these bears also inhabit the adjacent territories to the east of the area, to the north – in the Natural Park of Bulgarka, and to the west in the Protected Zone of Central Balkan. Therefore, the real density of whole territory inhabited by these bears (including the region of the entire hunting husbandry and its adjacent territories) should be lower: probably one bear per 1,500 or max. 2,000 ha, which is also a high density for the species. In October, it is possible

that also other individuals visit the area due to the abundance of additional food there.

Vitosha Mountain Hunting Husbandry: our footprint and camera-trap data collected in spring 2012 – 2013 demonstrate that bears concentrate on a territory of ca. 20,000 ha in Vitoshko hunting husbandry (density of about 2,000 ha per individual, cubs incl.), likely owing to the supplementary feeding of the game.

In the southern part of the Dinaric Mountains (Slovenia) 95% of all bears live in an area of 3,855 km², i.e., in areas with bear population densities over two bears/100 km² (on average, 13 bears/100 km²). The highest bear population densities amount to over 40 bears/100 km². However, such areas are relatively small and fragmented. This is one of the highest population densities reported so far for this species worldwide (JERINA, 2013). According to us, such density (concentration) would be impossible without supplementary feeding, related to activities in the hunting husbandry.

In order to assess these values, the estimated data on the average bear density in the Central Balkan Mountains from previous studies are given below: according the comprehensive work of GUNCHEV RAYCHEV (1989) the average bear density there was one bear per about 3000 ha, while the maximum density could reach three – five ind. per 1000 ha in small territories with high availability of food re-

sources, during some periods of the year (temporary concentration). The average density in the optimal territories of this suitable bear habitat is one bear per 1000-1200 ha (SPASSOV et al., 2000) and the optimal/maximal natural density in virgin taiga was estimated to one bear per 1000 ha (PAJENTOV, 1990).

Conclusions

The proposed hereby amended and enhanced table (Table 1) for metric identification and individualisation of the bear footprints increases the efficacy in identification of individual bears and in determining the age and sex of the registered animals. It could be considered a reliable instrument for field studies on the structure of the local populations of the species. This method could be applied in:

(i) Establishing the current absolute number of species from relatively small territories (up to 20-30,000 ha), where animals tend to concentrate, i.e. game feeding stations in hunting husbandries, bear feeding places in the autumn. To guarantee the maximum reliability in determining the number of bears

an additional use of photo traps is recommended. According our estimates, the reliability of such census may reach 90%.

(ii) Establishing the approximate number and relative density of species from large territories, using transect method and statistics within the frames of the method applied in the national monitoring of the bear in country.

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Следите на мечката (*Ursus arctos* L.) и използването им за мониторинга и определяне на числеността на вида в България

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(Резюме)

В това изследване е представена, осъвременена таблица на размерите на следите на мечката (*Ursus arctos* L.) от България и Източна Европа. Тя показва както съответствието между дължината на задната следа и ширината на предната, така и между размерите на следите и размера/теглото, възрастта и пола на индивидите. Следите са класифицирани според размера в шест категории, съответстващи на определено тегло/размер на индивида, възраст и пол. Таблицата би била полезна за идентификация на индивидите според следите им и може да се използва в националния мониторинг на мечката. Представени са примери, показващи ефикасността на използваните размерни параметри на следите за определяне числеността и структурата на локалните популации.