An assessment of the applicability of photo trapping to estimate wild boar population density in a forest environment

Authors: Plhal, Radim, Kamler, Jiří, Homolka, Miloslav, and Adamec, Zdeněk

Source: Folia Zoologica, 60(3) : 237-246

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: https://doi.org/10.25225/fozo.v60.i3.a8.2011

Folia Zool. – 60 (3): 237–246 (2011)

An assessment of the applicability of photo trapping to estimate wild boar population density in a forest environment

Radim PLHAL[1], Jiří KAMLER[1,2], Miloslav HOMOLKA[2] and Zdeněk ADAMEC[1]

[1] *Mendel University in Brno, Faculty of Forestry and Wood Technology, Zemědělská 3, 613 00 Brno, Czech Republic; e-mail: r.plhal@seznam.cz*

[2] *Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic*

Received 4 November 2010; Accepted 1 April 2011

Abstract. Wild boar is an autochthonous animal species of the Czech Republic that has significantly increased its population density in recent years. There are concerns that there is an associated negative impact upon agricultural crop production however, objective methods for sustainable management of wild boar, especially for estimation of its population density and intensity of regulation are still lacking. Wild boar differs markedly from the other free-living ungulates in its spatial activity and food selection, which limits applicability of the experiences and methods used for other species. Two methods of wild boar population censusing in a forest environment were tested in this study.

The density of wild boar was evaluated in an area of 2256 ha, circumscribed by both natural and man-made barriers that restrict wild boar migration. Wild boar abundance was estimated using traditional snow-track counting and photo trapping data analysis. Both field methods were used in the winter season 2009-2010. Wild boar abundance as assessed by snow-track counting was 6.3 ind./km^2 and by phototrapping 6.8 ind./km^2. The results have revealed that if correctly performed, both of the tested methods are applicable to estimate wild boar abundance. Photo trapping seems to be more accurate; it requires special equipment and is time-consuming, however, it provides additional information on the structure of the population and requires less experience to undertake. Combination of several methods is advisable.

Key words: *Sus scrofa*, snow-track counting, photo-traps, feeding site

Introduction

Wild boar is a native species of the Czech Republic fauna, whose distribution and abundance is thought to have varied significantly throughout the last centuries. These fluctuations are believed to be linked to climatic conditions (Geisser & Reyer 2005), and hunting; where this has been undertaken with the principal aim of agricultural crop protection (Hladíková et al. 2008, Braga et al. 2010). The only reliable source of data for either national or regional wild boar populations is from hunting records, and it is evident that despite the efforts to reduce numbers, the wild boar is increasing (Hladíková et al. 2008). Anecdotal evidence suggests that the first real signs of wild boar overpopulation such as extensive damage to agricultural crops and an outbreak of classical swine fever appeared in the 1980's.

Today, the growing populations of wild boar present a serious economic, ecological and social threat not only in the Czech Republic but across central Europe (Frank 2008, Kirschning et al. 2008). The most serious consequences of the increase is the associated damage to agricultural crops, road accidents, transmission of infectious diseases and the destruction of managed green space in populated areas (Geisser 1998, Brauer et al. 2006, Herrero et al. 2006, Acevedo et al. 2007).

Various methods of wild boar population control have been tested, including poisons, sterilization of females and trapping (Killian et al. 2006, West et al. 2009, Braga et al. 2010, Gentle 2010). In spite of their partial successes, the most widespread and best proven technique to reduce the population would appear to be intensive hunting (Fruzinski & Labudzki 2002). However, the required level of cull significantly varies in relation to the abundance of wild boar and their annual productivity. A relatively new approach to determining the control of wild boar population growth, based on observed reproductive rate, has been described in Frantz et al. (2009) and Servanty et al. (2010). However, one crucial question in determining whether pest control is effective, is the need to ascertain whether the cause-specific mortalities are additive, dispensatory, or compensatory and it is our opinion that further work is required. Furthermore, such hunting has to be supported not only by legislation, but by detailed knowledge of wild boar biology, feeding behaviour and spatial activity. Hunting success in turn depends on several factors in relation to: 1) population (e.g. total abundance of wild boar, sex ratio and age structure of population); 2) the local environment (e.g. natural food supply affecting the willingness of boar to visit the baiting area, density and size of resting places, maize on fields within reach); 3) the skills of hunters and hunting pressure where high hunting pressure can significantly lower the efficiency of hunting due to the adaptation of wild boar groups to the hunting methods used (e.g. avoiding places preferred by hunters, escaping during drive hunts and aggressiveness to hunting dogs).

One of the considerable obstacles in the effort to stop the population growth of wild boar is the inaccuracy of current abundance estimations used to inform the decisions on the numbers of individuals that need to be removed (Merli & Meriggi 2006). For this reason, improved methods to determine wild boar abundance is a key pillar in the management of this species.

As with other wild animals it is virtually impossible to determine the abundance of wild boar accurately. The reliability of population estimation depends on a number of factors (species, method used, experience of surveyors, season of the year and many others) (Mayle et al. 1999). The actual game stock is generally being underestimated and often the reality is several-fold higher than the "qualified" estimates (Andersen 1953). Determination of wild boar abundance is, compared to other free-living ungulates, very problematic due to their secretive habits, movements and their highly variable reproductive rate. Different modifications of direct observation have been used in studies to determine various wild boar populations in Europe (Focardi et al. 2002); they are simple, but often inaccurate (Mayle et al. 1999). Additionally, wild boar numbers have been assessed by repeated counting of marked individuals (Waithman et al. 1999), counting of tracks on snow cover (Fonseca et al. 2007), dung counting (Heinken et al. 2002) or by photo-traps combined with marked individuals (Sweitzer et al. 2000, Hebeisen et al. 2008).

A general feature of most of the studies concerned with monitoring of wild boar populations is that the methods used are very time consuming and technically demanding, which limits their applicability in more widespread management of this species. One of the options to obtain accurate data and lower the demands on observers in the field is photo trapping. Analyses of photographs can greatly contribute to the study of population density (Huckschlag 2008, Morimando et al. 2008), distribution and spatial activity (Jánoska & Varju 2008, Molina-Vacas et al. 2008) or feeding behaviour (Kuijper et al. 2009) of wild boars. The objective of this study was to assess the applicability of winter photo trapping data analysis for estimation of wild boar populations.

Material and Methods

Study area

The study area of 2256 ha is situated in the Drahanská vrchovina highlands in the south-eastern part of the Czech Republic at the average altitude of 450 m a.s.l. (Fig. 1). The selected area is enclosed within natural borders and man-made barriers that limit the migration of wild boar. From the south and the west it is surrounded with vast agricultural land and a water basin, and from the north and the east with a busy public road. Although the fields and the road do not prevent migration of wild boar, movement of wild boar during winter is believed to be extremely limited. Animals were encouraged to remain in the study area by placing supplementary feeding on permanent sites whilst the surrounding areas remained covered with deep snow and were devoid of any attractive food item or cover. The study area is completely afforested and consists of mixed stands (50 %), spruce (30 %) and beech (20 %) monocultures. It is believed that the natural food supply in the forest had no significant effect on wild boar distribution in our sampling period. Mast tree stands are evenly distributed over the study area and at the time of survey, most of the acorns and beechnuts had been consumed whilst the remainder was inaccessible to wild boar under a thick layer of snow and ice-cover. Therefore, the only appreciable source of food were the supplementary feeding sites, keeping wild boar in the forest, increasing the efficiency of hunting and ensuring greater survival of the population than the natural conditions would allow. Game management is predominantly performed by professional foresters in the study area. As well as wild boar, roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) are wide spread in the study area, whilst fallow deer (*Dama dama*) and sika deer (*Cervus nippon*) are found sporadically. Top predators are absent and disturbance of game in winter due to public recreation is believed to be negligible.

Snow track counts

During the study period there were very good conditions to use line transects to identify the movement patterns of the wild boar. Two types of transects were used.

Firstly, circular transects were set out enclosing the individual feeding sites with the feeding sites located in the centre. The diameter of these circular transects was variable (30-100 m) and was determined by the intensity of visiting animals. Transect diameter had to allow trouble-free counting of the tracks and avoid areas of intense trampling around the feeders. At the intensively visited feeding sites with a high number of tracks, the circles had to be larger and vice versa. Only the tracks leading out of the circular transects were counted. Counts were undertaken on five different days, always on fresh snow cover not older than one night, during periods when wild boars were visiting the feeding sites.

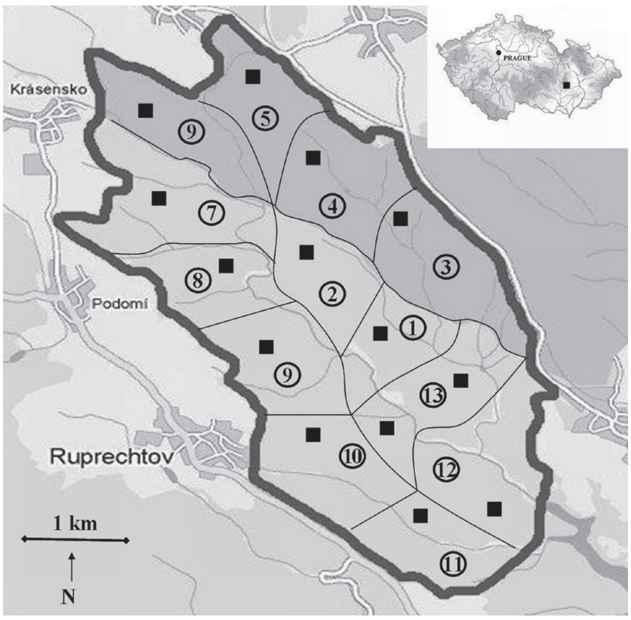

Fig. 1. *A map of the study area. Study area border is marked by the thick black line. Agricultural land is shown in white, forested area in light grey and forested area without public access in dark grey colour. The feeding sites with phototraps are marked with numbers from 1 to 13 in the circle and localities where dung samples were collected are marked by black squares.*

Secondly, linear transects were established between feeding sites (total length of 22 km), dividing the study area into 13 sectors (Fig. 1). The linear transects allowed detection of wild boar movements between the feeding sites. The direction and number of tracks crossing individual transects were mapped and were subsequently evaluated together with the phototrapping data. Tracks on these linear transects were checked concurrent with the inspections of the cameras at two to three-day intervals.

The total number of wild boar in the study area was determined from the number of boars (tracks) that had visited the individual feeding sites (Priklonskij & Kuzjakin 1980, Lomanov 2000). Errors due to duplicate entries of the same individual at the same feeding site during one night were eliminated by analyses of the phototrapping records. Individuals which were found to move between two or more feeding sites during one night were counted only on the first site.

Census with the use of phototraps on feeding sites

In the winter season 2009-2010, 13 feeding sites were established to attract wild boar to specific areas within the study area. These feeding sites were regularly frequented by other additional ungulate species. The phototraps were installed at each of the feeding sites from the 16^{th} to the 29^{th} of January 2010 inclusive. Of the 13 phototraps installed, four were Scoutguard SG550, four were Cuddeback Capture and five were Wildview Extreme 5. Apart from Infra-Red (IR) flash and flashlight there was no significant difference between the parameters of the cameras used (Table 1). The phototraps were attached to tree trunks approximately 40 cm above the ground or snow cover, at a distance of between three and ten meters from the feeding site centre, according to the individual manufacturer's recommendations. The phototraps were active for 24 h/day and were checked at two to three-day intervals. Their software was programmed to shoot with a time delay of one minute. During each inspection, the correct functioning of the camera was checked and the feed on the feeding site was replenished. Hunting was prohibited over the entire study area during the period of study and for two weeks prior, in order to minimize disturbance.

For each night, the number of males, females and piglets of wild boar that had visited a site was established by direct counting of animals on the pictures. Where individuals were repeatedly photographed on a feeding site in an evening these were only counted once. When large groups were recorded the pictures often did not capture all the individuals, but by using a combination of photographs it was possible to determine their number with sufficient accuracy. The final overall size of the wild boar population within the study area was established by assessing the total number of individuals recorded on each of the 13 sites. Duplicate records caused by the repeated presence of the same animal/s on a feeding site during one night were removed, as were visits to more than one site by the same individual/s if these occurred on the same night. The individual sounders (groups of wild boar) were identified on the basis of the number of members within the group, estimated social (age, sex) structure within the group and physical characteristics of members (estimation of body size, colour or visible abnormalities).

Analysis of wild boar faeces

Estimation of the total wild boar abundance within the area was further improved by determining the number of animals that did not visit the feeding sites at all. This was determined by dietary analyses of their faeces. Of the places used by boars as daytime shelters, 14 localities were chosen, evenly distributed over the area at the distances of 100-1000 m from the feeding sites. From these, samples of 2-14 days old faeces were collected at the end of the study period after phototrapping had ceased. Before and during the study period, all feeding sites had been replenished with barley. Microscopic analysis of the food remains was performed to assess the percentage of food from the feeding sites; based on this information, the number of individuals that did not visit the sites at all was estimated.

Data analysis

The estimated numbers of wild boar were analyzed through STATISTICA 9 software. The average number of wild boar detected by phototrapping together with the confidence interval was calculated for all 13 feeding sites and for each of 14 individual days. These 14 mean values are detailed in Fig. 2. The size of wild boar population was estimated as the mean of the observed numbers of wild boar on feeding sites during the monitoring period. This number indicates the average daily wild boar attendance to the feeding sites in the study area.

Furthermore, a single-factor analysis of variance (ANOVA) was performed, comparing the values from the 14 days of the monitoring with each other. The objective of the analysis was to verify if the mean values of wild boar numbers estimated by phototrapping from all feeding sites (attendance of feeding sites) are the same in individual days. The hypothesis holds true if the “p” value as calculated by ANOVA is higher than the significance level alpha, which we have set to 0.05 or if the confidence intervals of the mean values overlap.

To compare the estimation of wild boar abundance by track counts and by phototrapping, ANOVA with repeated measurement was used. The aim was to verify if the counting method (factor 1) and the day of the count (factor 2) have a significant influence on the accuracy of the population size estimation. The effect of interaction of the above mentioned factors was also investigated. Statistically significant influence of the individual factors as well as their interaction is confirmed if the “p” value is smaller than the significance level alpha, which we have set to 0.05. This analysis was performed with the data obtained through phototrapping and through snow track counts at 13 places during five days with fresh snow cover.

***Table 1.** Technical characteristics of the applied phototraps.*

	Scoutguard SG550	Cuddeback Capture	Wildview Extreme 5
Trigger Time:	0.97 s	0.24 s	0.19 s
Recovery Time:	6-10 seconds	30 seconds	20 seconds
Detection Range:	15 m	15 m	15 m
Detection Width:	Wide	Narrow	Wide
Flash Range:	12 m	18 m	9 m
Battery Life:	3-5 months	4-6 weeks	1 month
Battery Type:	8 AA	4 D cell	4 C cell
Flash:	IR	Light	Light

Results

Snow track counts

Counting of tracks around all feeding sites was performed on five days: 17th, 21st, 23rd, 26th and 28th January 2010. After these five counts, the average number of wild boar in the study area was estimated as 130 ± 10 individuals (5.8 ind./km^2), confidence level 95 %. This number was obtained as a mean of the totals of wild boars at all localities on the individual days.

Only two sounders of boars frequented more than one feeding site during one night. In the first case it was a group of five animals that moved irregularly between the feeding sites seven and eight. Within the 14 days of monitoring, this group visited both feeding sites on the same night four times. In the second case, a couple of two-year old wild boars moved between the feeding sites 1 and 13 and in five cases they had visited both sites in one night.

Wild boar counting with phototraps

During a fortnights monitoring on the 13 feeding sites, using 13 phototraps, 10092 photographs were exposed; 4864 (48 %) of them capturing wild boar. Between 32 and 1024 pictures of wild boar were taken on individual feeding sites (Table 2). Each feeding site attracted from 0 to 23 wild boar individuals (average values show Table 2). The total number of wild boar in the area of interest was estimated on the basis of the obtained photographs to be 139 ± 2 ind., confidence level 95 %. This number was determined as the mean of the 14 values; each of these values was calculated as the total of wild boar captured by phototraps at all 13 feeding sites for individual days of investigation. Wild boars frequented the feeding sites on a regular basis during the monitored period and there is no significant difference between the mean values of the wild boar numbers observed during the 14 days (ANOVA: $F = 0.0165$, $df = 13$, $p = 1.0$) (Fig. 2). Analysis of the photographs allowed us to estimate the social structure of the population: tusker/wild sow/yearling/piglet = 1/1.4/2.8/3.9.

Correction of density estimation

Further correction of the total number of wild boar was established by estimating the percentage of animals that did not visit the feeding sites at all. Out of the 174 samples of faeces collected from 14 localities within the study area, 16 samples (9.2 %) did not contain any remains of the feed from the feeding sites. The percentage of feed from the feeding sites in the faeces samples ranged from 10 to 100 % of their volume. 106 samples (61 %) contained purely the feed from the feeding sites and this group of animals consumed practically no other food. The 9 % of the present wild boars that did not frequent the feeding sites were added to the final estimation. The final wild boar population size estimated by the photo trapping and snow track count in the study area was 153 ± 3 individuals (6.8 ind./km^2) and 142 ± 11 individuals (6.3 ind./km^2) respectively.

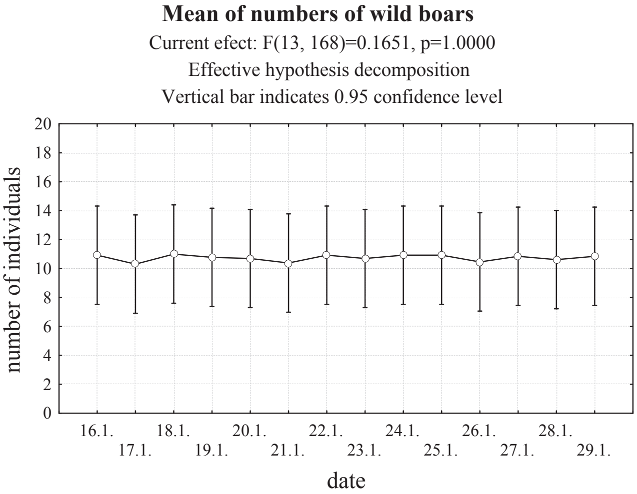

Fig. 2. *Mean numbers of wild boars. The average numbers of wild boar per feeding site and per day with 95 % confidence levels on 14 days of observation are recorded. The graph clearly shows that all confidence levels overlap; it indicates that the 14 observations are with 95 % probability of no difference.*

Table 2. *Number of photos of wild boar acquired by phototrapping; the mean of the number of wild boar individuals in each locality during 14 days, confidence level of the mean (CL) and coefficient of variance (CV).*

Locality	N photos	N wild boars	CL (significance 95 %)	CV (%)
1	387	6.4	1.6	44.29
2	414	4.8	1.2	43.51
3	509	3.3	0.8	43.75
4	275	17.1	0.8	8.2
5	721	10.9	3.3	52.83
6	156	10.3	1.7	27.87
7	193	15.4	0.5	6.08
8	684	21.9	1.7	13.29
9	196	8.1	1.4	29.24
10	1024	11.6	0.5	7.36
11	32	2.6	0.6	42.36
12	129	13.9	1.2	15.28
13	144	13.3	0.8	10.82

Table 3. *Numbers of counted and hunted wild boars by local hunters within the study area (2256 ha) during the period 1997-2009.*

Year	Counted	Hunted
1997	61	48
1998	71	45
1999	61	81
2000	66	49
2001	83	125
2002	65	93
2003	86	111
2004	60	67
2005	65	77
2006	38	96
2007	52	57
2008	62	95
2009	57	113

even in a free-living wild boar population it is possible to obtain sufficiently accurate data on their abundance to facilitate informed population management decisions using two relatively simple methods. The first method – snow track counting, has the character of an indirect method, while the second one – phototrapping at feeding sites, is a direct method.

A significant prerequisite for obtaining high quality results is the selection of a suitable environment and time. The area chosen for this study was sufficiently large and well bordered to restrict the migration of wild boar both to and from the study population. We believe the size of wild boar population was stable during the study period and this allowed repeated collection of data. The census was undertaken in mid winter during extreme climatic conditions that markedly affected the spatial activity of boars as well as their feeding behaviour. Very low temperatures (average daily minimum temperature –18 °C) and high snow cover (45 cm on average) lasted throughout the whole data collection period. Wild boar reacted to these conditions with reduced activity which was limited to regular short-distance movements between the feeding sites and the resting places. Plentiful supply of attractive food at the feeding sites, severe climatic conditions and hunting prohibition together supported the regular attendance of wild boar at the feeding sites concurrent with other studies (Massei et al. 1997). In our opinion, if such conditions can be replicated, it would be possible to shorten the period of phototrapping.

The method of snow track counting was undertaken during ideal natural conditions. Fresh snow fell on five occasions during the two-week study period. In this period, the boars preferred to use shared passages where the tracks often overlapped, making accurate

Table 4. *Numbers of counted wild boars during wild boar drive hunts. Calculation of the density in the total study area is based on the area of wild boar resting places (483 ha).*

Drive hunt number	Year	Hunted area (ha)	Estimated numbers of wild boar per hunted area	Estimated numbers of wild boar per study area
1	2005	191	64	162
2	2006	230	79	166
3	2007	230	74	155
4	2007	230	84	176
5	2008	230	75	158
6	2009	230	82	171
7	2009	230	77	161

Discussion

One of the principle causes of failing to undertake appropriate wild boar population management is the difficulty in determining their abundance in any given area. It is possible to use similar methods for wild boar census as for other large ungulate species; however, it is necessary to consider the characteristics that are markedly different in this species. Assessment of wild boar population size and structure is complicated by their secretive lifestyle (Fernandez-Llario 2004), nocturnal activity (Lemel et al. 2003), no marked sexual dimorphism and the difficulty in estimating the age of living animals. As well as these factors, appropriate wild boar management is hampered by inappropriate interventions: the social structure is often disturbed due to hunting and the animals are given high rations of supplementary feeding. Therefore the hunters' information on population structure and abundance often differs from reality. This study has confirmed that assessment of the number of animals in the group complicated (Bobek et al. 1984). This problem was solved by prolonged monitoring of a passage up to the point where the group had split up whereupon it was possible to differentiate between the tracks of individual animals. With this method, the estimated population density was marginally lower than with the application of phototraps. This result may be due to the fact that some boars had chosen their resting places in such a close proximity to a feeding site that the tracks of their footprints did not cross any line, or perhaps in some cases, tracks of some individuals were overlooked, because the tracks of different animals were overlapping in one line. The accuracy of snow track counts was checked by comparison with photo trapping data. With ANOVA, the following p values were calculated for the individual factors (method, day): for factor "method" $p = 0.846$, for factor "day" $p = 0.788$ and for interaction $p = 0.888$. As all of the calculated p values are higher than 0.05, the hypothesis that neither of the factors or their interaction have a statistically significant influence on the accuracy of the population size estimation has been confirmed. Therefore, the results of ANOVA clearly proved that the track count on fresh snow provided statistically equal results as photo trapping in all five days with 95 % probability and so the population sizes as assessed by the two methods can be regarded as equal. This implies that duplicate data in snow tracking were correctly removed.

Conditions were ideal for both methods of assessment as the feed available at the feeding sites was the most easily accessible source of food for wild boar in this period. In case of lower snow cover, movements would be higher and attendance to the feeding sites lower, which would require prolonging the monitoring period to obtain an accurate result. Use of phototraps is very convenient as it allows obtaining a great amount of information over a short period of time (Swann et al. 2004). Use of this new technology saves a lot of time compared to direct observation requiring presence of a researcher in the field (Roberts et al. 2006). This equipment provides records of high quality that can be archived and repeatedly studied from many aspects, which enables us to acquire valuable data on population of the studied species (Ridout & Linkie 2009). Within this research, quality of the pictures from the phototraps was mostly influenced by shortened life of batteries in the phototraps due to low air temperatures and high air moisture. Sometimes the objective lens or the flash was covered with freshly fallen snow or with frost deposit, which led to poor quality photographs. Occasionally, analysis of the photographs was compromised when there were by too many animals in one shot -as the bodies were overlapping each other- and also, by heavy snowfall reducing the visibility. However, the number of shots from individual days and from each feeding site was sufficient to allow an accurate estimation of the number of animals. All three types of cameras used served well for the purpose of this study. Night pictures shot by phototraps with flashlight were of better quality; nevertheless, quality of the pictures from IR phototraps was also sufficient. Disturbance of wild boar by the flashlights was not observed. Due to the fact that the boars spent longer time on the feeding sites, differences in the trigger speed (0.19-0.97 s) of different photo-trap types were insignificant.

The percentage of those wild boars that did not visit the feeding sites and used natural food sources despite the unfavourable climatic conditions, was assessed with the help of microscopic analysis of food remains in faeces. Due to the limited spatial activity of wild boar it was not difficult to find enough fresh faeces samples. Faecal collection points were chosen to give an even distribution across the study area at distances that would minimise the probability of duplicate collection from the same individual and the number of fresh faecal samples was not limiting. The same food was offered at all feeding sites and the boars could not have obtained it from any other source within the area of interest. Regular periods of snowfall throughout the study period assisted in assessing the age of the faeces. Remains of feed from the feeding sites were absent in approx. 10 % of the faeces samples, which confirms the initial hypothesis that most of the boars had visited the feeding sites on a regular basis. This fact is also supported by steady numbers of boars that had been monitored on the feeding sites every day. The individuals who did not come to the feeding sites at all could have been affected by some earlier negative experiences from the feeding sites, suffered prior to the beginning of the monitoring and hunting prohibition. These individuals could have reacted to an injury (a shot) or other traumatic experience and change their spatial activity as well as foraging behaviour (Keuling et al. 2008).

Other available sources of information on the abundance of wild boar are the estimates based on direct observations at feeding sites undertaken by the local hunters or game managers. In recent years, the population of wild boar in the area in question had been estimated to be around 60 individuals (spring population) and about 80 individuals were hunted here annually (Table 3). If the average number of wild boar hunted per year equalled the average number of individuals born every year, there would have to be at least 124 boars (5.5 ind./km^2) living in the study area at present (sex ratio 0.8 : 1; reproduction rate 3.4 piglets per mature female; average annual harvest 81 ind.). The estimated numbers indicate a slight decrease in the population size, but due to inaccuracy of the method we do not consider them to be significant. Correlation between the estimated and the hunted numbers is not significant ($r^2 = 0.251$). Due to the variability of the data, the applicability of the hunted numbers returned annually is limited; however, they still show a moderate increase in the population. However, the presented population size was calculated using a mathematical relationship that presumes an ideal case (uncommon in nature) when the increment equals the decrement (Boer 1988). Therefore, we can assume that the population density of wild boar in the area of interest is presently slightly higher that the aforesaid 124 individuals (5.5 ind./km^2).

The hunting tenant in the study area undertakes annual joint drive hunts for wild boar. As a part of these hunts, organizers also conduct a census of the game. They recorded all game that was chased out of each hunted area and extrapolate the numbers to the whole area of interest. In this way, the abundance of wild boar in the years 2005-2009, for example, had been estimated as 155-176 individuals (6.9-7.8 ind./km^2) (Table 4). These numbers are somewhat higher than those officially reported by the game managers and also higher than the abundances found in our monitoring.

The methods applied in our study have provided higher and mutually similar estimates using two different techniques (snow tracks – 142 ± 11 ind., phototraps – 153 ± 3 ind., hunting statistics – 124 ind.). Our results are similar to those obtained using drive hunt data (2009 – 166 ind. in average) and significantly greater than the estimates obtained by hunters practicing direct observation (2009 – 57 ind.).

Conclusion

The estimates of wild boar abundance assessed by the two methods used in our study, notably photo trapping and snow track counting, gave comparable results. These differed significantly (by approximately two individuals per km^2) from the population estimates previously obtained using direct observations associated with traditional game management techniques. It is evident that a combination of several complimentary methods will improve the accuracy of annual population assessment and that actual abundance is often underestimated by hunters using traditional techniques. We can recommend the application of photo trapping or snow track counting during periods of heavy snow cover to accurately establish wild boar populations. Whilst photo trapping involves a significant initial capital investment, the technology provides a significant amount of information and is less labour intensive than other methods. In the presented case, we believe the most accurate population estimate is that obtained using phototrapping when complemented by faecal analysis; that is, 153 ± 3 wild boar individuals (6.8 ind./km^2).

Acknowledgements

This study was supported by the Grant Agency of the Faculty of Forestry and Wood Technology, Mendel University Brno, Grant No. 25/2009.

Literature

Acevedo P., Vicente J., Höfle U., Cassinello J., Ruiz-Fons F. & Gortazar C. 2007: Estimation of European wild boar relative abundance and aggregation: a novel method in epidemiological risk assessment. *Epidemiol. Infect. 135: 519–527.*

Andersen J. 1953: Analysis of a Danish roe-deer population. *Danish Rev. Game Biol. 2: 127–155.*

Bobek B., Boyce M.S. & Kosobucka M. 1984: Factors affecting red deer (*Cervus elaphus*) population-density in southeastern Poland. *J. Appl. Ecol. 21: 881–890.*

Boer A.H. 1988: Mortality-rates of moose in New-Brunswick – a life table analysis. *J. Wildl. Manage. 52: 21–25.*

Braga C., Alexandre N., Fernandez-Llario P. & Santos P. 2010: Wild boar (*Sus scrofa*) harvesting using the *espera* hunting method: side effects and management implications. *Eur. J. Wildl. Res. 56: 465–469.*

Brauer A., Lange E. & Kaden V. 2006: Oral immunisation of wild boar against classical swine fever: uptake studies of new baits and investigations on the stability of lyophilised C-strain vaccine. *Eur. J. Wildl. Res. 52: 271–276.*

Fernandez-Llario P. 2004: Environmental correlates of nest site selection by wild boar *Sus scrofa*. *Acta Theriol. 49: 383–392.*

Focardi S., Isotti R., Pelliccioni E.R. & Iannuzzo D. 2002: The use of distance sampling and mark-resight to estimate the local density of wildlife populations. *Environmetrics 13: 177–186.*
Fonseca C., Kolecki M., Merta D. & Bobek B. 2007: Use of line intercept track index and plot sampling for estimating wild boar, *Sus scrofa* (Suidae), densities in Poland. *Folia Zool. 56: 389–398.*
Frank B. 2008: Understanding the nature of human dimensions: intergrating people in wild boar management. In: 7th international symposium on wild boar (*Sus scrofa*) and on sub-order Suiformes. *Sopron: 22.*
Frantz A.C., Cellina S., Krier A., Schley L. & Burke T. 2009: Using spatial Bayesian methods to determine the genetic structure of a continuously distributed population: clusters or isolation by distance? *J. Appl. Ecol. 46: 493–505.*
Fruzinski B. & Labudzki L. 2002: Management of wild boar in Poland. *Z. Jagdwiss. 48: 201–207.*
Geisser H. 1998: The wild boar (*Sus scrofa*) in the Thurgau (Northeastern Switzerland): population status, damages and the influence of supplementary feeding on damage frequency. *Gibier Faune Sauvage 15: 547–554.*
Geisser H. & Reyer H.U. 2005: The influence of food and temperature on population density of wild boar *Sus scrofa* in the Thurgau (Switzerland). *J. Zool. 267: 89–96.*
Gentle M. 2010: Alternative toxins for feral pig (*Sus scrofa*) management in Australia? In: 8th international symposium on wild boar and other suids. *York, UK: 23.*
Hebeisen C., Fattebert J., Baubet E. & Fischer C. 2008: Estimating wild boar (*Sus scrofa*) abundance and density using capture-resights in Canton of Geneva, Switzerland. *Eur. J. Wildl. Res. 54: 391–401.*
Heinken T., Hanspach H., Raudnitschka D. & Schaumann F. 2002: Dispersal of vascular plants by four species of wild mammals in a deciduous forest in NE Germany. *Phytocoenologia 32: 627–643.*
Herrero J., García-Serrano A., Couto S., Ortuno V.M. & García-González R. 2006: Diet of wild boar *Sus scrofa* L. and crop damage in an intensive agroecosystem. *Eur. J. Wildl. Res. 52: 245–250.*
Hladíková B., Zbořil J. & Tkadlec E. 2008: Population dynamics of the wild boar (*Sus scrofa*) in central Moravia, Czech Republic (Artiodactyla: Suidae). *Lynx 39: 55–62.*
Huckschlag D. 2008: A digital infrared video camera system for recording and remote capturing. In: 7th international symposium on wild boar (*Sus scrofa*) and on sub-order Suiformes. *Sopron: 26.*
Jánoska F. & Varju J. 2008: Application of digital camera at man-made game feeders. In: 7th international symposium on wild boar (*Sus scrofa*) and on sub-order Suiformes. *Sopron: 86.*
Keuling O., Stier N. & Roth M. 2008: How does hunting influence activity and spatial usage in wild boar *Sus scrofa* L.? *Eur. J. Wildl. Res. 54:729–737.*
Killian G., Miller L., Rhyan J. & Doten H. 2006: Immunocontraception of Florida feral swine with a single-dose GnRH vaccine. *Am. J. Reprod. Immunol. 55: 378–384.*
Kirschning J., Unici R. & Hartl G.B. 2008: Population genetics of the wild boar in Europe. In: 7th international symposium on wild boar (*Sus scrofa*) and on sub-order Suiformes. *Sopron: 32.*
Kuijper D.P.J., Cromsigt J.P.G.M., Churski M., Adam B., Jedrzejewska B. & Jedrzejewski W. 2009: Do ungulates preferentially feed in forest gaps in European temperate forest? *For. Ecol. Manage. 258: 1528–1535.*
Lemel J., Truve J. & Soderberg B. 2003: Variation in ranging and activity behaviour of European wild boar *Sus scrofa* in Sweden. *Wildl. Biol. 9: 29–36.*
Lomanov I.K. 2000: Winter transect count of game animals for large territories: results and prospects. *Zool. Zh. 79: 430–436.*
Massei G., Genov P.V., Staines B.W. & Gorman M.L. 1997: Factors influencing home range and activity of wild boar (*Sus scrofa*) in a Mediterranean coastal area. *J. Zool. 242: 411–423.*
Mayle B.A., Peace A.J. & Gill R.M.A. 1999: How many deer? *Edinburgh, Forestry Commission: 96.*
Merli E. & Meriggi A. 2006: Using harvest data to predict habitat-population relationship of the wild boar *Sus scrofa* in Northern Italy. *Acta Theriol. 5: 383–394.*
Molina-Vacas G., Bonet-Arboli V. & Rodrigez-Teijeiro J.D. 2008: Use of camera traps to study wild boar distribution and group composition in Mediterranean habitats. In: 7th international symposium on wild boar (*Sus scrofa*) and on sub-order Suiformes. *Sopron: 94.*
Morimando F., Plantamura G., Galardi L. & Pianigiani F. 2008: Wild boar census by extensive camera trapping: a population management approach in Tuscany (Central Italy). In: 7th international symposium on wild boar (*Sus scrofa*) and on sub-order Suiformes. *Sopron: 42.*

Priklonskij S.G. & Kuzjakin V.A. 1980: Metodičeskije ukazanija po organizacii zimnego maršrutnogo učeta ochotničich životnych v RSFSR [Metodology of winter game census on traces in snow in Russia]. *Moskva. (in Russian)*

Ridout M.S. & Linkie M. 2009: Estimating overlap of daily activity patterns from camera trap data. *J. Agr. Biol. Envir. St. 14: 322–337.*

Roberts C.W., Pierce B.L., Braden A.W., Lopez R.R., Silvy N.J., Frank P.A. & Ransom D. 2006: Comparison of camera and road survey estimates for white-tailed deer. *J. Wildl. Manage. 70: 263–267.*

Servanty S., Choquet R., Baubet E., Brandt S., Gaillard J.M., Schaub M., Toigo C., Lebreton J.D., Buoro M. & Gimenez O. 2010: Assessing whether mortality is additive using marked animals: a Bayesian state-space modeling approach. *Ecology 91: 1916–1923.*

Swann D.E., Hass C.C., Dalton D.C. & Wolf S.A. 2004: Infrared-triggered cameras for detecting wildlife: an evaluation and review. *Wildl. Soc. Bull. 32: 357–365.*

Sweitzer R.A., Van Vuren D., Gardner I.A., Boyce W.M. & Waithman J.D. 2000: Estimating sizes of wild pig populations in the North and Central Coast regions of California. *J. Wildl. Manage. 64: 531–543.*

Waithman J.D., Sweitzer R.A., van Vuren D., Drew J.D., Brinkhaus A.J. & Gardner I.A. 1999: Range expansion, population sizes, and management of wild pigs in California. *J. Wildl. Manage. 63: 298–308.*

West B.C., Cooper A.L. & Armstrong J.B. 2009: Managing wild pigs: a technical guide. *Human-Wildlife Interactions Monograph 1: 1–55.*