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Note

Can wild boar be surveyed using GPS?

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Abstract: The Global Positioning System (GPS) is an important new technology for spatial behaviour studies of terrestrial vertebrates. Although VHF telemetry has been substantially used, our study is the first report, to our knowledge, on GPS technology used to track free-ranging wild boars. Although the need for collars larger than those used for VHF tracking, the crowded vegetation of habitat and the particular features of social group behaviour of wild boars led to some technical difficulties, three adult sows were successfully fitted with two GPS collars and one dummy GPS. The collars remained on the wild boars for over 283 days without causing any injury to the animals. Forty-one daily cycles (24 hours), as well as daily locations over 142 days, could be recorded for a single animal. Detection efficiency and fixes were better during the night than during the day. In the light of these results, the GPS technique appears to be an efficient tool to study wild boar movements. Progress in the survey of animal movements at a fine scale is of prime interest for animal management programs in order to obtain and maintain a sustainable level of animal population regarding damage problems.

key words: wild boar, *Sus scrofa*, GPS collar, satellite telemetry, fix success rate

Introduction

The bio-logging method most frequently used for a wide range of terrestrial animals is VHF telemetry (see Cochran and Lord, 1963). Subsequently, various sensors, *e.g.* activity sensors, head position sensors, temperature sensors, jaw movement sensors, etc. were used simultaneously with VHF systems (see Kimmich, 1980 for an historical review of biotelemetry). Recently, methods using satellite survey (Argos system and GPS based system) have been deployed, on many vertebrates such as marine mammals (*e.g.* southern elephant seals *Mirounga leonina*, Bornemann *et al*., 2000), fish (*e.g.* Atlantic bluefin tuna *Thynnus thunnus*, Block *et al*., 1998), birds (*e.g.* wandering albatross *Diomedea exulans*, Jouventin and Weimerskirch, 1990) and terrestrial mammals (*e.g.* elephant *Loxodonta africana*, Tchamba *et al*., 1995). However, satellite telemetry using GPS system is often restricted to large or medium size terrestrial mammals such as moose (*Alces alces*, Rodgers and Anson, 1994; Moen *et al*., 1996; Rodgers *et al*., 1996) polar bear (*Ursus maritimus*), caribou (*Rangifer* *tarandus*, Fancy *et al*., 1988); white tailed deer (*Odocoileus virginianus*), wolves (*Canis lupus*, Merrill *et al*., 1998) and cougar (*Puma concolor*, Anderson and Lindzey, 2003). Concerning the wild boar (*Sus scrofa* L.), numerous studies have been carried out on this species, since Mauget (1979, 1980) and Singer *et al*. (1981) using VHF telemetry collars to investigate home ranges, habitat use, activity pattern and social behaviour. Nevertheless, despite the important progress in the understanding of wild boar ecology, such techniques showed some limits regarding location accuracy (White and Garrot, 1990). Nowadays, "Global Positioning System" (GPS) technology used in differential mode (DGPS) offers an alternative to other solutions (such as VHF telemetry) to study wildlife ecology with an accuracy never obtained until now (Moen *et al*., 1997; Rempel and Rodgers, 1997; Steiner *et al*., 2000; Dussault *et al*., 2001; Adrados *et al*., 2002; Weimerskirch *et al*., 2002). However, to our knowledge no studies have yet been performed, using GPS technology on wild boar and numerous questions were raised by the use of such a technique on this species. The challenge consisted of fixing a collar heavier than the classical one on a stocky animal with short neck. One constraint was that wild boar would try to actively remove the collar, which would increase the risk that the collar broke off. In addition, the considerable weight of the collar restricted its use to large adult boar. Moreover, wild boars use preferentially treed areas (Douaud, 1983; Welander, 2000; Virgos, 2002) often with heavy vegetation. The collar could therefore easily catch on vegetation or other obstacles, such as fences used around the forested plot in regeneration, which would lead to loosen it rapidly. Adding to these problems, other environmental parameters can directly affect the success rate of recording data. Location accuracy depends on the number of satellite signals received by the GPS receiver at one time. To obtain a 3D fixed location the receiver must acquire signals from at least 4 satellites (Moen *et al*., 1996; Rodgers *et al*., 1996). Thus, the efficiency and/or accuracy of GPS location can be affected by physical obstructions (Wells, 1986; Rodgers *et al*., 1996; Rodgers, 2001; Adrados *et al*., 2002). For instance, the general topography can decrease the area of the sky available above the collar and thus reduce the probability for the collar to connect with a sufficient number of satellites (Wells, 1986). At a finer scale, the presence of large tree trunks, or dense canopy may also affect the signal reception (Moen *et al*., 1996; Edenius, 1997; Dussault *et al*., 1999; Janeau *et al*., 2001). Adding to topographic obstructions, the social group behaviour of wild boars may also lead to disturbances in the efficiency of location. Wild boars display a social organisation based on a matrilinear structure allowing them to live in groups of various sizes (Mauget, 1980). During the daytime, they sometimes gather at a resting place and this concentration of individuals around the receiver may increase the risk of poor GPS signal reception. Finally, a wild boar lying down on its side may be difficult to locate because of the variation in the position of the antenna, factor which is known to affect reception performance (Moen *et al*., 1996; Adrados *et al*., 2002).

In the light of these potential difficulties, we decided to investigate the possibility of using GPS systems on wild boars. To that end we tried to address the following questions: i) How long would a wild boar retains the collar?; ii) How much data could be gathered using this technique?; iii) Are there any significant differences in the efficiency of data collection due to wild boar activities (*i.e.* day *versus* night activity) since most of the foraging movements occurs at night (Janeau and Spitz, 1984)?; iv) Are there any seasonal differences related to the change of vegetation coverage? For this test we assumed that the leaf cover was weaker in the months of fall than during summer months (D'Eon *et al*., 2002); v) Could the protocol set in the collar influence the fix success rate?

Material and methods

Field experiments have been carried out in the north-eastern part of France, in the Haute-Marne department. Wild boars were tracked in the widest national forest of France, Chateauvillain-Arc-en-Barrois, (48°02′N, 4°56′E) covering 11000 ha of mixed deciduous wood formation (Fig. 1). In this forest, the dominant tree species are durmast oak (*Quercus petreae*), beechnut (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*). The forest administration fenced in some plots to prevent access to red deer, and to allow tree regeneration. This resulted in the development of dense woody thickets, which are favourable habitats for wild boars that used them as resting places. Two female wild boars weighing 75 kg and 71 kg, respectively, were fitted with two DGPS_1000 collars (Lotek Engineering, Canada, software 2.15, Fig. 2). The main electronic housing was linked with the battery pack and utilised three separate antennas for GPS, UHF modem and VHF tracking beacons. The upper housing, which contained the GPS receiver and modem antennas, needed to be oriented to the zenith for optimal success of location fixation. Location accuracy was *ca*. 10 m (Adrados *et al*., 2002). Data were downloaded via a radio modem command unit to a personal computer using GPShost_1000 software (Lotek inc, Canada, software version 2.15). The fully equipped DGPS_1000 collar complete, *i.e.* with a radio-activated "break-away" fastening system or "drop-off" (Rodgers *et al*., 1996), weighed 2.25 kg thereby representing *ca*. 3.1% of the wild boars weights. Similar materials have previously been used in studies on moose (Moen *et al*., 1996, 1997; Rodgers *et al*., 1996). In addition, a third female wild boar, weighing 74 kg, was fitted with a dummy GPS collar. The dummy GPS was a home-made collar, which was similar in size, shape and weight to the genuine DGPS_1000 collar. The dummy collar, contained a classical VHF transmitter to perform a survey of the behaviour of the animal following its release, as well as to ensure that the animal did not damage the collar after being released (Rutter *et al*., 1997). The schedule set in the DGPS collar was changed twice

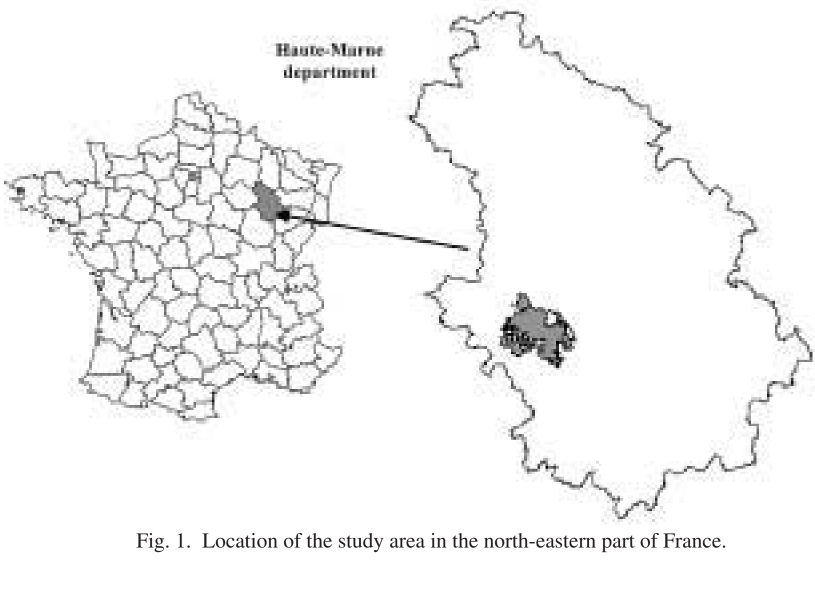

Fig. 1. Location of the study area in the north-eastern part of France.

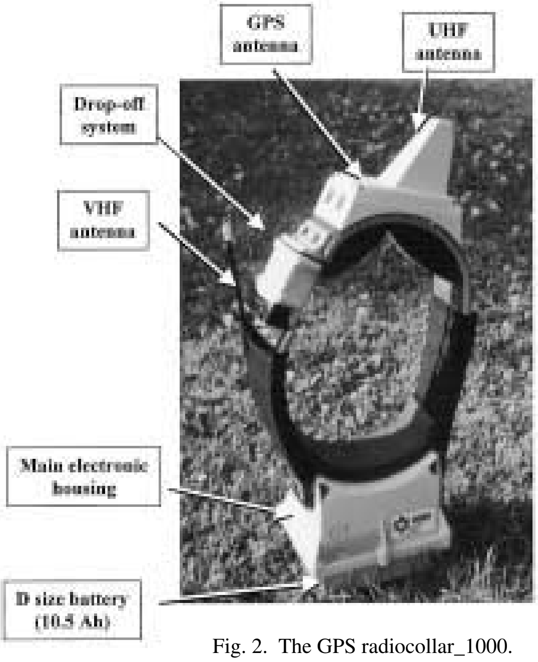

Fig. 2. The GPS radiocollar_1000.

during the whole survey. It started with 4 fixes every day from June 8th to June 19th: two fixes during the daytime at 0900 and 0930 AM and two fixes during the night at 1000 and 1030 PM. Then, from June 21st to September 24th, we performed 24 h tracking from 1000 AM until 1000 AM. Fixes were recorded every hour from 1000 AM to 0800 PM, then every 15 min during the night (0800 PM to 0600 AM the following day) and finished with fixes every hour from 0600 AM to 0900 AM. The 24 h tracks were separated by one day and two days alternately during which two daily fixes were recorded during the daytime (at 0900 and 0930 AM). Finally, from September 25th to November 11th, the 24 h tracks were separated by two days and three days, respectively, during which two fixes were performed during the daytime, in addition to a night survey. The night survey consisted of fixes recorded every hour from 0800 PM to 0600 AM.

The DOP (dilution of precision) is a measure of the quality of the satellite geometry. Satellites that are far apart in the sky provide the smallest triangulation error and the lowest DOP, while that are close together result in a large triangulation error and larger DOP (Moen *et al*., 1997). Thus, tests in our study were done after withdrawing the DOP values >10 from our data (Adrados *et al*., 2002), which accounted for 4,6% of the fixes (98/2127).

All tests were done using one way and two way analyses of variance with Bonferroni post-hoc comparisons. The level of significance for all tests was 0.05. Statistical tests were conducted using Statistica 5.0 software (Statsoft Inc., USA).

Results

i) and ii) The three collars were retained on average for more than 9 months by the wild boars: 350 days for the dummy and 156 and 343 days for the two DGPS collars. The dummy dropped off after 350 days because of a leader belt failure. The quality of the leader as well as the belt construction were different from the belt system provide by the Lotek firm. Although no GPS data have been obtained yet (probably because of batteries or electronic malfunctions), visual observation and VHF survey revealed that the GPS showing a 343 days survey is still on the wild boar. We could not retrieved the collar from the animal because of a failure in the drop-off system. The last collar has allowed us to get more than 2800 fixes over 5 months, with a global fix success rate of 76% (Table 1).

iii) The comparison between the percentage success rate of fixes during daily sensus versus night sensus during the 24 h tracks showed a significant effect of the interaction ($F_{5,70}$=3.44; p=0.0078). Thus, for a given month the percentage success rate of fixes varies differently depending on the time and at a given time the percentage success rate of fixes varies differently according to the month (Table 2).

iv) During the 24 h tracks no significant differences of the percentage of fix success rate between months were found during the night sensus ($F_{5,35}$=1.69; p=0.16). However, a significant effect of the month was found during the daily sensus of the 24 h tracks with higher percentage of fix success rate during autumn months than summer months ($F_{5,35}$=2.96; p=0.025). Moreover, with data obtained during the day time (double points) the month effect was again the only factor that had a significant influence on the percentage of fix success rate and again with a higher percentage of fix success rate during autumn months ($F_{5,82}$=2.56; p=0.03).

v) The comparison between the night survey and the night trip during 24 h tracks emphasizes a significant effect of the recording protocol ($F_{1,49}$=4.42; p=0.02). The percentage fix success rate dropped from 72.65% during the night part of the 24 h sessions to 60.46%

Table 1. Description of the raw data collected on a free-ranging sow during the five months of the study with different monitoring schedules.

Monitoring schedules	Number of data collected	Number of session	Number of data failure (no fix)	Fix success (%)
24 h track	2214	41	464	79%
Night survey	385	35	160	58%
Night fixes (double points)	20	10	10	50%
Daily survey	11	1	1	91%
Daily fixes (double points)	176	88	46	74%
Diverse	6	1	4	33%
Total	2812	-	685	76%

Table 2. Comparison of fix success percentage between daily and night recordings during the 24 h sessions.

Months	Fix success during day time (%)	Fix success during night time (%)
June	61.11	91.27
July	65.74	82.54
August	60.19	80.42
September	54.16	75.89
October	79.62	72.22
November	69.44	69.89
Total	65.24	78.22

during the night surveys, which indicates that the shorter the sampling interval, the higher the success rate of data collection. In contrast, the comparison between the daytime 24 h tracks and the daily fix (double points) showed no significant effect on the percentage fix success rate that could be due to differences in the recording protocol ($F_{1,117}$=3.28; p=0.73). However, these data emphasise the seasonal effect seen beforehand ($F_{1,117}$=2.66; p=0.026).

Discussion

Our study showed that it is possible to fix DGPS collars on wild boars and to subsequently track this animal over a year, allowing researchers to collect large amounts of accurate data location, although the percentage fix success rate seems to be weaker than previous results obtained from studies on moose that used the same material (Rodgers *et al.*, 1996; Moen *et al.*, 1997; Rempel and Rodgers, 1997). However, technical difficulties remain. For instance, one of the two GPS collar did not work at all. In this particular case, it was unfortunately impossible to assess if the problem was due to electronic or battery malfunctions. Such malfunctions are unavoidable and independent from the progresses in technology. The selective availability removal since 2000, which led to an increase in the accuracy of location (Adrados *et al.*, 2002) may help in reducing the proportion of non valid data with a DOP >10 and thereby increase the global success percentage of fixes collected.

In fact, several factors probably interact together to decrease the success rate of fixes. For instance, the increased percentage success rate of fixes during the day time during the months of fall could be explained by a change in the extent of canopy cover. Previous studies have already stressed the negative effect of canopy coverage on the percentage fix success rate (Moen *et al.*, 1996, 1997; Rempel and Rodgers, 1997). In open habitats, the percentage of fix success rate can reach >98% (Rutter *et al.*, 1997; D'Eon *et al.*, 2002). However, this increase in the success rate of fixes may also be the result of a change in the behaviour of wild boars. Wild boars tend to avoid the use of heavy vegetation plots during autumn because of hunter harassment at that time. Hunting period in France starts from October until February and during this period, hunters track more frequently in dense woody thicket, such as those generally used by wild boars as a resting place.

None-the-less, this study stressed out the importance of a preliminary, thorough clarification of the goal of the research that is to be conducted. Indeed, the challenge is to find a trade-off between the reduction of data recording to extend the lifetime of battery (Rutter *et al.*, 1997), and to increase the efficiency of data collection by shortening the sampling interval. In addition, the performance of GPS collars should be tested beforehand to identify much more precisely the main field problems that need to be overcome (Rempel and Rodgers, 1997; D'Eon *et al.*, 2002). The results from the present study where a large, heavy collar was used, should prove useful for the development of the next generation of collars. Based on our results, we suggest the use of a greater memory capacity to store data so that surveys can be conducted over several months, which is often crucial in order to report informative behavioural ecology data. If such a survey were to be conducted over an entire year, a number of behavioural parameters could be quantified, such as daily movements, the preferred foraging place of wild boar, as well as their foraging paths, the influence of protected areas and many other factors that could serve to improve and enrich wild boar management. Such a long term survey could not be undertaken using VHF telemetry techniques because of their lacks of accuracy, errors being often >100 m (Baubet, 1998; Haller *et al*., 2001), and their need for a heavy logistic (Merrill *et al*., 2002). Moreover, some GPS receivers are now equipped with optional sensors, *e.g*. temperature transducers, motion sensors or mortality sensors (Rodgers *et al*., 1996; Lotek Engineering, Inc, 1999), allowing for multiple data collection. Recently, devices that record jaw movements were incorporated into GPS systems (Rutter *et al*., 1997). Similarly, IMASEN loggers that measure the duration and angle of mouth opening in a variety of animals (Ropert-Coudert *et al*., unpublished data) have been successfully tested on piglets. These types of bio-logging tools may be added to the GPS system without being a supplementary discomfort for the animal and will surely open new areas in wildlife research, such as the study of animal-habitat relationships at a very fine spatial scale combined with information on the foraging behaviour of animals.

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