Factors affecting the ability and accuracy of dogs (*Canis familiaris*) to track brown bears (*Ursus arctos*).

Faktorer som påvirker evne og nøyaktighet hos hund (Canis familiaris) til å spore brunbjørn (Ursus arctos).

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ABSTRACT

Trained dogs (*Canis familiaris*) are known for their use in finding and identifying individual humans and wildlife. In Scandinavia, hunters are required by law to have access to approved dogs to be able to track potentially wounded brown bears (*Ursus arctos*). Bear hunting is increasing with the increasing bear population in Scandinavia, and corresponds with an increase in wounded bears. The need for tracking teams that are able to correctly follow individual wounded bears is thus increasing as well. To investigate whether dogs can be used for tracking individual bears, I tested ability and accuracy of tracking teams (i.e. a dog and its handler), used by public authorities to track potentially wounded bears. The ability of a tracking team to track bears is defined as meter successful tracking until first loss (MSFL), denoting the length of a bears' trail from the first successful tracking start to first loss of trail. Tracking accuracy is measured in percent successful tracking (PST), denoting the percent of successful tracking of a bear in relation to the total track length of the bear. Two different tracking methods were used for tracking teams sent by the authorities. In addition also trials with specially trained odor detection dogs but with no prior experience with bears were carried out. The results of this study show that, when using dogs in tracking brown bears, the accuracy is relatively high, but the length of the trail the dog can follow before losing it is short. Accuracy decreased with increasing age of the dog, and the dog group retrieving dogs had higher success than the groups barking hounds and dachs, baying and tracking hounds.

The start of a tracking seems to be the most challenging part when tracking bears, because in 48 % of the trials the tracking team had to start over again. Dogs easily switch to following other species while tracking bears, in as much as 81.7 % of the trials. For each time a tracking team switched to another game species and lost the track and had subsequently be brought back onto the bear track, the distance of successful bear tracking became shorter. Special trained odor detection dogs were more accurate, had longer successful tracking distances, and switched less often to other game species. In conclusion, the results from this study show the high potential of dogs as a tool for tracking bears, but presently tracking teams in Norway and Sweden lack the training and expertise that is needed for successfully tracking bears. The success of in tracking bears in tracking brown bears is more a function of training level than the level of experience that the tracking team has with bears or the influence of environmental factors. To improve the success of tracking teams relevant training programs should be developed, and potentially the use of dog breeds other than the traditional Scandinavian hunting dogs should be evaluated.

SAMMENDRAG

Trente hunder (*Canis familiaris*) er kjent for deres egenskaper i å finne og identifisere individer og dyreliv. I Skandinavia er det påkrevd ved lov, for jegere å ha tilgang på godkjent ettersøkshund for å spore potensielt skadet brun bjørn (*Ursus arctos*) under jakten. Bjørnejakten øker med den økende bjørnepopulasjonen i Skandinavia, og skadeskytingsfrekvensen øker i samme takt. Behovet for ekvipasjer som kan følge sporet av riktig bjørneindivid vil derfor øke. For å undersøke om hunder kan brukes til å spore individer av bjørn, har jeg testet evne og nøyaktighet på sporing av bjørn, utført av ekvipasjer som brukes av myndighetene for å spore potensielt skadet bjørn. Evnen til å spore bjørn måles i suksessfull sporing inntil første tap (MSFL), som er antall meter bjørnespor fra sporstart til sporet mistes første gang. Nøyaktigheten måles i andel suksessfull sporing (PST), som er prosent bjørnespor i forhold til den totale sporlengden. Det ble benyttet to forskjellige sporings metoder for ekvipasjene utsendt av myndighetene. Til sammenlikning ble sporinger utført av hunder som var spesialtrent på spor, men uten erfaring med bjørn. Resultatene av denne studien viser at når hunder benyttes til å spore brun bjørn, er nøyaktigheten relativt høy, men lengen på sporet inntil første tap er kort. Nøyaktigheten sank med økende alder på hund, og hundegruppen apporterende hunder (Retrieving dogs (RD)) hadde høyere suksess enn gruppene spisshunder (Barking hounds (BH)) og dachs- driv- og sporhunder (Dachs baying and tracking hounds (DBTH)). Studien viser at sporstarten er en utfordring ved bjørnesporing, fordi ekvipasjene måtte starte på nytt ved opp til 48 % av sporingene. Hunder bytter lett til annet vilt når de sporer bjørn, og ved hele 82 % av sporingene inntraff bytte til annet vilt. For hver gang ekvipasjen byttet til annet vilt og mistet sporet, minket meter suksessfull sporing inntil neste tap. Spesialtrente luktpåvisnings hunder hadde både bedre nøyaktighet, lenger suksessfull sporing og færre bytter til annet vilt. Jeg konkluderte med at suksessen av sporingene heller var en funksjon av treningsnivå, enn erfaring med bjørn eller påvirkning av miljøfaktorer. Ettersøksekvipasjer i Norge og Sverige har per dags dato ikke den treningen og kompetansen som er nødvendig for å kunne spore bjørn. Man bør se på hvilke muligheter man har for å gi relevant utdanning, og eventuelt bringe inn nye raser og videreutvikle treningsmetoder i ettersøksarbeidet.

1. INTRODUCTION

The ability to use odor for tracking and finding food, prey, mates, or to avoid predators is of vital importance for many animals. The domestic dog (*Canis familiaris*) is a species known for its olfactory acuity. The dogs olfaction has been estimated to be as much as an estimated 100 million times more sensitive than human olfaction (Syrotuck 2000, cited in Cablk & Heaton 2006). because their area of olfactory epithelium (18 to 150 cm^2) is much greater than that of humans (~3 cm^2) (Browne et al. 2006). Because of the superior olfactory acuity of dogs, they are often used by humans to find a wide variety of substances. Dogs are more reliable and cost efficient than electronic scent-detection devises for detecting explosives (Furton & Myers 2001; Lorenzo et al. 2003), and can search thousands of items at airports, seaports, and post offices to find illegal drugs, such as cocaine, heroin, and marijuana (Lorenzo et al. 2003). Dogs have also contributed to biological studies and conservation, being used successfully to find scat of kit foxes (Vulpes macrotis; Smith et al. 2003), fishers (*Martes pennanti*), and bobcats (Lynx rufus; Long et al. 2007a; Long et al. 2007b), and individual desert tortoises (Gopherus agasszii; Cablk & Heaton 2006), and brown tree snakes (Boiga irregularis; Engeman et al. 1998; Engeman et al. 2002). Dogs are also useful in biological studies of large carnivores. Usually large carnivores are difficult to monitor, because they are elusive, occur at low densities, move over large areas, and are rarely observed. By including dogs in the methodology, studies have successfully detected scats and identified individuals of Amur tigers (Panthera tigris altaica; Kerley & Salkina 2007), grizzly bears (*Ursus arctos horribilis*), and black bears (U. americanus; Wasser et al. 2004). Wasser at al. (2004) studied the impacts of human disturbance on black and grizzly bear populations in Canada by using trained dogs to locate bear scats along transects within a 5,200 km^2 area. They found that this methodology was a promising tool in bear studies to answer both research and management questions.

In Scandinavia, hunters are required by law to have access to approved dogs when hunting bears; if a hunter wounds a bear, such a dog must be on site within two hours in order to search for the wounded bear (Jaktförordningen 1987:259). The bear must be followed until it is found dead or is killed, unless other signs show that the wound was not fatal (Naturvårdsverket 2008).

The Scandinavian brown bear (*Ursus arctos*) population experienced a drastic decline to near extinction by the early 1900s as a result of persecution (Swenson et al. 1995). The population began to increase in Sweden after receiving protection that took place in the late 1800s (Bjärvall 1990;

Swenson et al. 1995). Since protection, the annual increase of the population in Sweden has been approximately 5.5% (Sahlèn et al. 2006), until today, when the population is about 3,200 (J. Kindberg, unpublished data). Simultaneously with the growing bear population, the annual hunting quotas have more than tripled in the last ten years (Naturvårdsverket 2008), resulting in a national quota of 233 bears for the hunting year 2007/2008 (Statens veterinärmedicinska anstalt 2008).

The wounding rate of bears has increased with the increased quotas (Stokke et al. 2008). Stokke et al. (2008) found a wounding rate of 32 % during bear hunting in Sweden, based on a survey of 218 hunters who had shot at bears in Sweden during 2006 and 2007. Wounding of bears can expose the hunters and others to risk of injury. During 1750-1962, hunting and wounding of bears were the dominant risk factors for people attacked and injured by bears in Norway and Sweden (Swenson et al. 1999b). In addition to the increased wounding of bears, the growing bear population also leads to conflicts between bears and people, such as livestock depredation and traffic collisions.

With a growing bear population the need for handler-dog teams that can track wounded or nuisance bears is increasing. A handler-dog team consists of one dog handler and one dog, and will hereafter be referred to as a *tracking team*. It is necessary that tracking teams are capable of following the trail of the correct individual bear as required by law but also for ethical reasons to such as animal welfare. When following the trail of a wounded bear, it is of importance that the dog is able to discern between its target individual and all other extraneous background odors, including other individual bears or other species. During searching for wounded bears in Sweden in 2007, the bear was found in only half of the cases (Jaxgård 2007). In those cases where the bear was not found, the tracking team followed the bear for an average of 4.6 km (Jaxgård 2007). This localization success for wounded bears is low, considering that dogs are capable of following a trail of human scent trough busy urban centers 48 hours after they were laid with an average success rate of 77.5 % (Harvey & Harvey 2003). Although dogs potentially can be remarkably effective at detecting and following a variety of targets, little is known about their success in tracking brown bears or the effectiveness with which they do so. Similarly, little is known about how to optimize a dog's performance in finding the correct individual bear. Information about the success of tracking bears and the factors contributing to successful tracking of bears is therefore important for management purposes, human and animal safety, and ethical reasons.

In this study I examined, with the help of Global Positioning System (GPS) technology, the accuracy and ability of tracking teams to locate and follow individual bear trails. By using different tracking methods, My goal was to document 1) the accuracy with which tracking teams follow a bear trail; 2) the length of successful tracking before the tracking team loses the track; 3) factors affecting the quality of the tracking; 4) whether switching to other game species occurs during a tracking, and what factors affect such a switch; and 5) whether tracking success improves within a season of specialized training.

2. METHODS

2.1 Study area

The study was conducted in the southern study area of the Scandinavian Brown Bear Research Project (SBBRP), which is situated in Dalarna and Gävleborg counties in south-central Sweden (61°N, 15°E). The topography is characterized by gently rolling hills with coniferous forests, with the main tree species being Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*), mixed with deciduous tree species, such as silver and mountain birch (*Betula pendula, B. pubescens*), gray alder (*Alnus incana*), aspen (*Populus tremula*), and European mountain ash (*Sorbus aucuparia*). The shrub layer consists of common juniper (*Juniperus communis*) and willows (*Salix* spp.). The ground vegetation is a mixture of dwarf shrubs, including bilberry (*Vaccinium myrtillus*), cowberry (*V. vitis-idaea*), crowberry (*Empetrum hermaphroditum*), and heather (*Calluna vulgaris*). The soil surface is mostly covered with mosses and lichens. The study area is generally (> 90%) below the timberline (~750m a.s.l.) (Dahle & Swenson 2003) and interspersed with numerous lakes, creeks, and bogs. This is an area of intensive forestry, resulting in a patchwork of tree monocultures and large clearcuts. About 8 % of the forested area is covered by clearcuts, and 40 % of the forest is younger than 35 years (Swenson et al. 1999a). The area is sparsely populated by humans, who are mostly confined to a few villages and cabins, many of which are only seasonally inhabited. However, due to forestry management, there is an extensive network of roads. The brown bear density in the area is approximately 30 individuals per 1000 km^2 (Solberg et al. 2006).

2.2 Tracking teams

2.2.1 Dog handlers

The dog handlers were selected by the public wildlife management authorities in Norway and Sweden. Dog handlers attending from Sweden were selected by the County Administrative Board (Länsstyrelsen (LST)) in the seven counties with bears, and the Swedish Hunting Association (SHA). Dog handlers attending from Norway were selected from among dog handlers employed by the Norwegian Nature Inspectorate (Statens naturoppsyn (SNO)) and whose job includes removal of carnivores for management purposes. From each country one dog instructor attended to participate in the trackings and develop tracking methods for the participants from the public authorities. In addition, teams from the Fallow Deer (*Dama dama*) Research Project (FDRP) were invited to participate.

2.2.2 Dogs

To analyze if tracking success differed with the type of dog used, the dogs were separated into groups based on breeding group standards by the Norwegian Kennel Club (Norwegian Kennel Club 2009). The following three dog groups are mainly used by public authorities for tracking bears:

1) **Barking hounds (BH)**: Hunting dogs mainly used for big game hunting, where the hunter releases the dog to seek out game independently and make the game stop and stand still. The dog signals to the hunter that the game has been stopped by barking loudly and repetitively.
2) **Dachs baying and tracking hounds (DBTH)**: Hunting dogs that are particularly well suited to tracking game. They have relatively little contact with the hunter during the hunt and leave for long drifts while tracking.
3) **Retrieving dogs (RD)**: Hunting dogs that are used for short-distance hunts, consisting of bird hunting dogs that flush the game. Some dog breeds in this group are classified as "retrievers", others as both "finders" and "retrievers".

Dog breeds that were not included in any of the three above-mentioned, groups were excluded from the analysis regarding dogs used by the public authorities to track wounded animals. However, they were included in the other analyses to improve the sample size. If a dog group was represented by one individual only, the group was not evaluated.

2.3 Questionnaire

A questionnaire was prepared to obtain information on the tracking teams' experience with bears, i.e. tracking and/or hunting bears, including the dog's experience in hunting other game (Appendix 1). The questionnaire was distributed to all dog handlers from SNO, LST, and SHA who participated in tracking bears in 2008. In addition, the questionnaire was distributed to the dog instructors and the dog handler from FDRP, who followed more than one track who followed more than one track.

2.4 Documenting the movements of GPS-collared bears prior to tracking

Due to research activities of the SBBRP several GPS collared brown bears were available for this study. The process of capturing and marking bears has been described in Arnemo et al. (2006). All bears were equipped with GPS Plus-3 or GPS Pro-4 collars with activity sensors and Global System for Mobile communications (GSM) modems (Vectronic Aerospace, Berlin, Germany). Locations and activity data from the bear were stored in the GPS collar. Data packages of seven stored GPS locations were automatically transmitted by the GSM modem as a text message, and stored in a database. The bears GPS collar registered a GPS location every half hour during the spring, summer and autumn, but prior to a tracking exercise, the GPS collars of a randomly selected individual was programmed to record locations every minute. This detailed movement pattern of the bear was then used for the tracking exercise. The minute locations were recorded during 02:00-05:00 GMT (04:00-07:00 local time) in 2007, and 18:00-20:00 GMT (20:00-22:00 local time) in 2008. The time periods for minute locations were chosen to obtain positions from active bears (Moe et al. 2007).

All GPS minute locations of the bear was selected in ESRI ® ArcMap ™ 9.2 (ESRI Inc. 1999-2006) and downloaded to a hand-held GPS (Garmin GPSMAP 60csx (Olathe, Kansas, USA)). The locations from the bears' GPS collar are hereafter referred to as GPS *locations*. During the tracking exercise the hand-held GPS unit was used to follow the bear's GPS locations, as well as to record the trail of the tracking team. The hand-held GPS was programmed to register a position from the tracking every ten meters, hereafter referred to as GPS *points*. When measuring distances of the trails the distance between GPS points may vary due to error of GPS accuracy (Cain et al. 2005; D'Eon 2003; DeCesare et al. 2005), but it is assumed that this distance error is equalized through the progress of a tracking exercise.

2.5 Tracking exercises

Tracking of GPS-collared bears was carried out between 11 June and 13 September in 2007 and 27 May to 9 August in 2008. Each tracking was carried out on 10 - 24-hour-old tracks. In this way disturbance of the bear was avoided while detection of relatively fresh signs after the bear was possible. GPS-technology is known to include certain error margins of localizations (e.g. Cargnelutti et al. 2007; D'Eon & Delparte 2005). Therefore I had to account for the localization errors of the GPS units of the bear and the tracking team during the tracking exercises. The GPS location of the bear was defined to have a buffer zone with a radius of 8 m, because error in GPS localizations on wild animals is suggested to be within a radius of ≤ 7.98 m 99% of the time (DeCesare et al. 2005). The margin of error of the hand-held GPS was presumed to be lower, because it can be controlled to a far greater degree (Garmin 2007). The error in the hand-held GPS was therefore defined to be a buffer zone with a radius of 6.5 m, as a average of maximum 10 m and a minimum of 3 m (Garmin 2007). During tracking exercises the tracking team was defined to successfully reach a GPS location when < 15 m from the GPS location. The distance of < 15 m was chosen because it summarizes the localization errors of the bears' GPS collar and the hand-held GPS unit.
During the tracking on GPS collared bears, two different methods were used in 2008, in order to compare the tracking methods:

2.5.1 Tracking Method 1 (TM1)

TM1 was used by all tracking teams in 2007 and by the SNO tracking teams in 2008. One to three dog handlers attended training for five days, with two trackings carried out per day.

Tracking Start using TM1
GPS location number two was chosen as starting location of the selected bear trail. The tracking teams were guided to the starting location by the tracking leader(s) (Silje Vang and/or Lena Brorsdotter). Starting locations were found by using the "GO TO" function of the hand-held GPS receiver, so that the tracking leader knew the direction and distance to this location. The tracking leader approached the starting location at a 90° angle using locations 1 and 3 to determine the angle) (Figure 1). Within 20 m from the starting location, the tracking team received information about the direction and distance to the starting location and the next location (Figure 1). The distance of 20 m was selected for the tracking team in order to be close to the starting location when they started tracking. Dog handlers performed the startup procedure for the dog, by attaching a harness and

tracking line, and commanded the dog to start the search. When the dog marked tracks within the radius of the summarized localization errors of the GPS (< 15 m) the actual tracking started. If the tracking team had a bad tracking start, i.e. the trail of the bear was not found by the dog or it started following a wrong track, the tracking team was guided to the third GPS location, and had the opportunity to start over again. This procedure was repeated until the tracking team had a successful start.

Following the bear's trail and end of tracking in TM1

The tracking team followed the bear's trail from the tracking start to the subsequent GPS location, which was verified as successful when < 15 m from the GPS location (Figure 1). When the tracking team reached a GPS location, they were informed about the next GPS location. At the start of the trackings the tracking teams were informed about both direction and distance between each GPS location. The amount of information was then reduced throughout the week, until only the distance to the next GPS location was known. The tracking team was assumed to have committed a tracking error when it had tracked 1.5 times the distance between two subsequent GPS-locations without arriving within the buffer zone of the second location. In such cases the tracking team was reset by the tracking leader, i.e. was guided to the next GPS-location to commence tracking from there (Figure 1). Tracking was terminated when the tracking team reached the final GPS location of the trail, or the GPS location where it had been agreed to switch tracking teams.

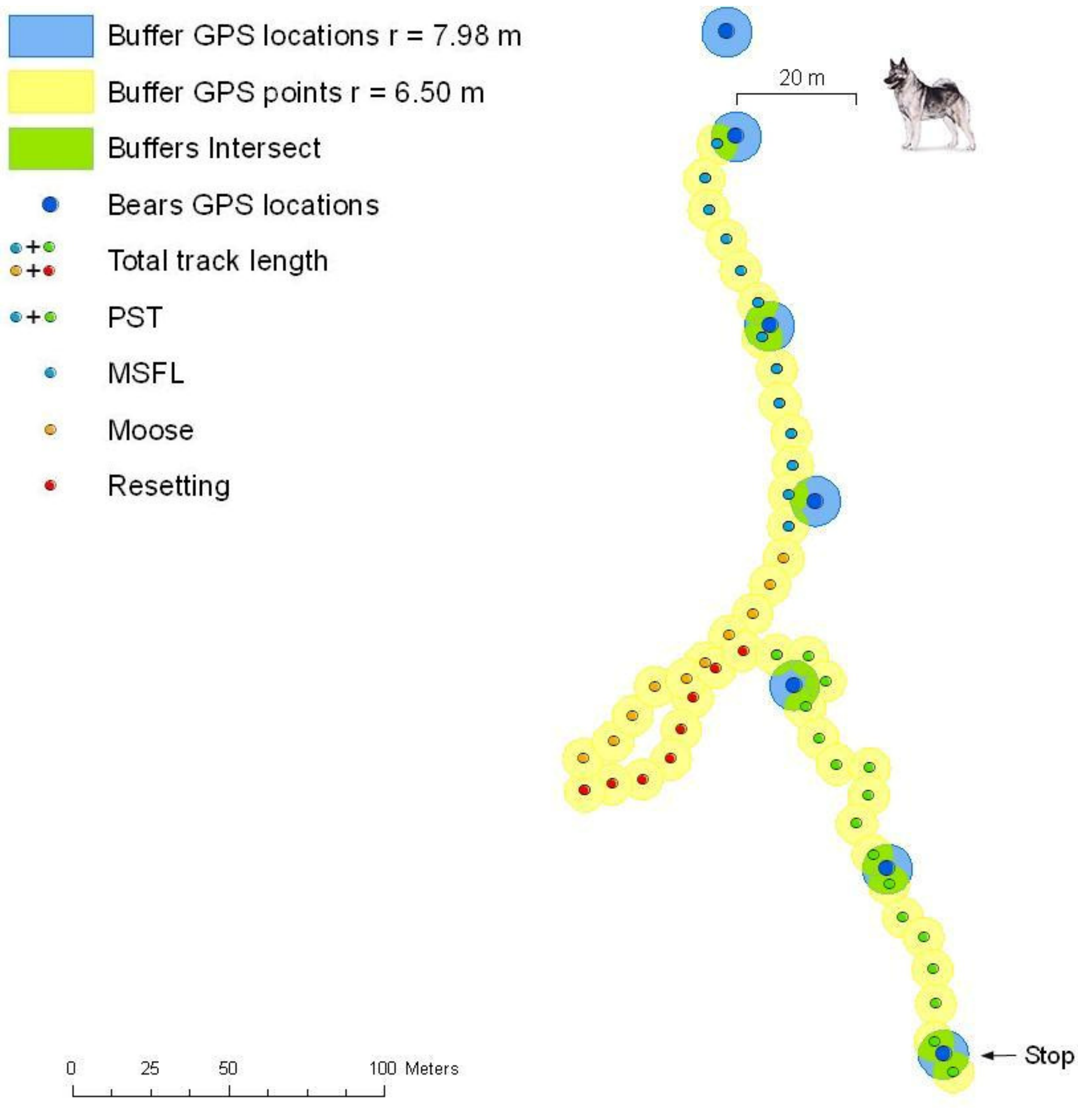

Figure 1 Example of a trail of a dog tracking a GPS collared brown bear in central Sweden in summer 2007 and 2008. The bears GPS locations are illustrated by blue circles with a buffer zone of 7.98 m, and the tracking teams GPS points are illustrated by small circles with 10 m apart with a buffer zone of 6.5 m. The tracking teams GPS points consist of the following: (**i**) All GPS points = Total track length; (**ii**) Blue + Green = Percentage successful track (PST); (**iii**) Blue = Meter successful tracking until first loss (MSFL); (**iv**) Orange = Disturbance of moose; (**v**) Red = Resetting the tracking team.

2.5.2 Tracking Method 2 (TM2)

TM2 was used by the Swedish tracking teams; Dog handlers received two intensive weeks of training prior to the trials. After the training the dog handlers received an offer to return to train for one to three days, with one tracking per day. The intensive training weeks started with a tracking test to examine the level of the tracking team and to identify strengths and weaknesses with regards to further training needs. Day 2 consisted of using human tracks to train on the difficulties of tracking, adjusted to the individual tracking team. The remaining days consisted of tracking human during mornings and GPS-collared bears during evenings.

Tracking Start using TM2

The tracking team was guided to within 20 m from the starting location from a 90 ° angle (see TM1) (Figure 1). The tracking start was then located by the dog handler in cooperation with the tracking leader, by searching for signs from the bear, while the dog observed. This procedure was performed to build up the dog's interest, and thereby provide a good tracking start. The dog handler then performed the starting procedure as described for TM1 and walked orthogonally to the bear's trail. When the dog found and marked the bears' tracks, it was rewarded and the tracking started. If the tracking team had a bad tracking start (see TM1) it was guided to the next GPS location to start over again.

Following the bear's trail and end of tracking in TM2

When following a bears' trail TM2 used competition tracking, i.e. one tracking team was tracking, and the remaining tracking teams walked behind to build up their dogs' motivation. The tracking team that was tracking was stopped when the dog was considered to be performing at its best, and the next tracking team resumed tracking. The tracking teams started with short tracks (3-4 GPS locations) with a successive increase of track length with the numbers of tracking. If the tracking teams lost the trail they were reset (see TM1).

2.6 Analyses (Both methods)

2.6.1 Switching to other game species

The tracking leader recorded a switch to another bear or other game species (e.g. moose (*Alces alces*), birds) when the tracking team had walked > 1.5 times the distance between the previous and the following GPS location but was still following an obvious trail (Figure 1). A switch to another bear individual was obvious when the trail of the GPS-collared bear diverged from the trail the tracking team followed, but still bear sings were visible (i.e. a second bear had been in the area). A switch to another game species was documented in the form of fresh tracks or visual observation of the animals. Switching was registered as caused by moose (*Alces alces*), birds, other game species or other bear individuals. Without documentation of other animals, switches were recorded as "uncertain". In these cases it was assumed that the tracking team followed other animals because the tracking teams exceeded the limit distance from previous GPS location (> 1.5 times the length between previous and subsequent GPS location).

2.6.2 Tracking success

A GIS project file was made for each tracking using ESRI ® ArcMap ™ 9.2. To indicate the localization error of the GPS, a buffer zone of 8 m was made for each GPS location (bear), and one of 6.5 m for each GPS point (tracking team) (Figure 1), and each GPS point was recorded as successfully reached or not. The success was determined by using the following criteria: 1) *Successful tracking* between two GPS locations was defined when the tracking team had followed the bear's track from the previous to the subsequent GPS location (within < 15 m of both GPS locations) without resetting. If the tracking team lost the trail but discovered it by itself (and thus was not reset by the track leader), the trail was still considered to be successful. In such cases the dog lost the trail but actively searched and found the trail again, or a change in the dogs' behavior alerted the dog handler who then directed the dog back on the trail. In such cases a cluster of GPS points was formed and for analytical purposes the directest way through the cluster was assumed to be the bear's real route. 2) *Tracking start* was defined from the first GPS point of the first successful tracking between a minimum of two GPS locations (Figure 1). Trackings that only consisted of bad tracking starts, i.e. the tracking team had to be reset throughout the entire length of the trail and the track therefore included no successful tracking were excluded from the analyses. 3) *Loss of track* was defined as where resetting of the tracking team was necessary, because the tracking team walked too far from the subsequent GPS location, defined as > 1.5 times the length between the previous and the subsequent GPS location. The loss of track was recorded at the last successful GPS point of the last successful track (Figure 1). 4) *Tracking end* was when the tracking team reached the final GPS location, or the GPS location where it had been agreed to switch tracking team for TM1 and when the dog was considered to be performing at its best for TM2. 5) *Total trail* length was the distance form tracking start to tracking end, including all portions of non-successful tracking (Figure 1). The quality of the tracking was evaluated by *percentage successful tracking* (PST), which was defined as the percent of successful bear tracking in relation to the total track length (Figure 1), and *meter successful tracking until first loss* (MSFL), which was the length of the track from the first successful tracking start to first loss of the bears' trail (Figure 1).

2.6.3 Statistical analyses

I used general linear models (GLM) to evaluate differences in tracking success for the different tracking methods and to analyze differences in dog groups. To obtain parametric predictor variables, MSFL was log transformed and PST was arcsine square-root transformed. Both predictors were tested for equality of variance with the Levene's test. The statistical software Minitab 15 (Minitab Inc. 2007) was used for these analyses. When analyzing the success of the different tracking methods and dog groups, only participants from the public authorities (SNO, LST, and SHA) and the dog instructors were included. In the rest of the analyses the participants from FDRP were included to increase the sample size.

To examine the relationships between tracking success (PST and MSFL) and several potentially explanatory variables, I used generalized linear mixed models (GLMM) and included random effects of individual dogs. The response variable PST was divided by 100 to obtain a proportion between 0 and 1 of the total track, and MSFL was log transformed to obtain a parametric variable. The explanatory variables used in the analyses were temperature, age of the dog, age of the trail, and walking speed along the trail. GLMM models were also used to analyze the tracking success in relation to the questionnaire for both the dogs and the dog handlers. The model regarding the dogs' questionnaire included random effects of the individual dog, and the model regarding the dog handlers' questionnaire included random effects of the individual person. The explanatory variables used were differences in tracking success in relation to the dog handlers' experience with bears, and the dogs' experience with tracking bears and other game spices. Difference in tracking success for dogs whose behavior when encountering a bear in a bear park had been tested and approved by SHA or the Norwegian Hunting and Fishing Association (NHFA), was analyzed using a two-sample t-test, because the sample size was too small to use a global model. A GLMM model was used to analyze the change of success within one season. The dependent variables were PST and MSFL and the response variables were tracking number and tracking method (TM1, TM2). The model included the random effect of the dog within the different tracking methods. To analyze the number of times a tracking team switched to other game species during the course of a trial a quasi-poisson model was fitted for the number of switches using a GLMM, which included the random effects of individual dog. The explanatory variables were tracking method (TM1, TM2), age of the dog and trail length, in addition to replies from the questionnaire such as whether the dog was used for hunting or searching for wounded bears and whether the dog had won tracking prizes.

Predictor variables were chosen according to their P-values for all the models; an α level of ≤ 0 .05 was considered to be statistically significant, and an α level ≤ 0.1 was considered to be statistically suggestive. The best model was selected using a backward elimination procedure. For the GLMM the statistical software R 2.8.1 (R Development Core Team 2009) and the glmmPQL (MASS library) module were used.

3. RESULTS

I used the trails of a total of 26 different GPS-collared bears (9 males and 17 females) in 2007 and 2008. Of the 11 bears tracked in 2007, five were also tracked in 2008. The age of the bears varied from 3 to 19 years. A total of 43 tracking teams participated in tracking bears in 2007 and 2008. These teams consisted of 29 dog handlers who administered 1-3 dogs. From the public authorities, eight dog handlers participated from SNO, with six and eight persons in 2007 and 2008 respectively (six individuals came both years). Nine dog handlers came from LST in both 2007 and 2008 (six individuals came both years), and three dog handlers participated from SHA. Two dog instructors and five dog handlers from FDRP also participated. A total of 42 dogs, with the ages between half a year and nine years participated in 2007 and 2008 (Table 1). Of the participating dogs, 38 were dispatched from SNO, LST or SHA. These were mainly represented in the groups barking hounds (N = 27), dachs, baying, and tracking hounds (N = 8), and retrieving dogs (N = 4). Dog instructors used a retrieving dog and an Australian kelpie. Three more breeds (one individual each) were used for bear tracking by FDRP.

Table 1 Overview of the number of dogs, of different breeds within different dog groups, conducting tracking trails on GPS-collared brown bears in central Sweden in 2007 and 2008 and dogs conducting trails both years.

			Numbers		
Group	**Breed**	**N**	2007	2008	2007+2008
Barking hounds	Swedish elkhound	13	9	9	5
	Karelian bear dog	1	1	1	1
	Norwegian elkhound	7	2	5	
	East Siberian laika	6	4	5	3
Dachs, baying, and tracking hounds	Plot hound	4		4	
	Bavarian mountain hound	2		2	
	Russian hound	2		2	
Retrieving dogs	Labrador	3	2	1	
	Wachtel hound	1		1	
Gun dogs	German shorthaired pointer*	1		1	
Pastoral and herding dogs	Australian kelpie*	1		1	
	Belgian malinois*	1		1	
Mix	Mix*	1		1	

* Dog breeds were excluded from the analysis regarding dogs used by the public authorities to track wounded animals. The results from these dog breeds were included in the remaining analyses.

3.1 The trackings

A total of 131 trails were conducted in 2007 and 2008, 42 and 69 with TM1 and TM2, respectively, and 14 conducted by dog instructors. The remaining 6 trails were conducted by FDRP. The total lengths of the trails were 1049 ± 128 m ($\bar{x}$ ± SE) for TM1, 641 ± 63 m for TM2, and 639 ± 100 m for dog instructors. One trail conducted by TM1 and one by TM2 only consisted of bad tracking starts, and did not have any successful tracking.

A binary model analyzing difference in PST between the different tracking methods showed significant differences in PST between the tracking methods (GLM: $F_{2,122} = 9.33$, $P \leq 0.001$). The dog instructors had significantly higher PST than TM1 (Tukey Post-hoc test: $P \leq 0.001$) and TM2 (Tukey Post-hoc test: $P = 0.025$). In addition, TM1 had significantly higher PST than TM2 (Tukey Post-hoc test: $P = 0.026$) (Figure 2a).

The parametric model analyzing difference in MSFL between the different tracking methods showed significant differences in MSFL between the tracking methods (GLM: $F_{2,102} = 9.59$, $P \leq 0.001$). The dog instructors had significantly higher MSFL compared to TM1 (Tukey Post-hoc test: $P = 0.001$) and TM2 (Tukey Post-hoc test: $P \leq 0.001$). MSFL did not differ between TM1 and TM2 (Tukey Post-hoc test: $P = 0.703$) (Figure 2b).

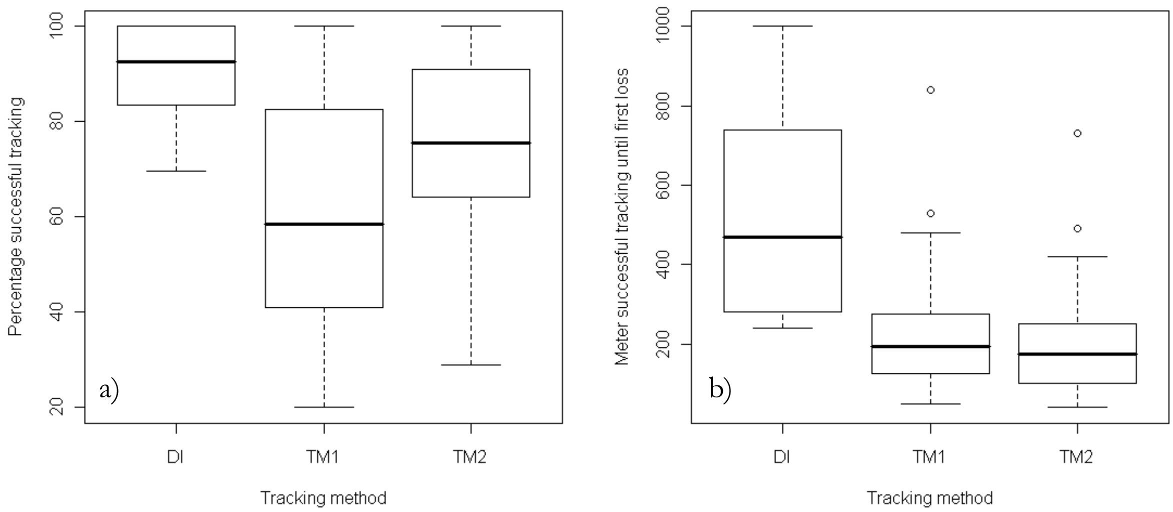

Figure 2 (a) Difference in percentage successful tracking (PST) conducted by tracking method 1 (TM1), tracking method 2 (TM2) and dog instructors (DI), while tracking GPS-collared brown bears in central Sweden in summer 2007 and 2008. DI had significantly higher PST compared to TM1 and TM2 (P = <0.001). **(b)** Differences in meters of successful tracking until first loss (MSFL) conducted by tracking method 1 (TM1), tracking method 2 (TM2) and dog instructors (DI). DI had significantly higher MSFL than TM1 and TM2, and TM2 had significantly higher MSFL than TM1 (P ≤ 0.001).

3.2 Tracking start

Tracking teams had an unsuccessful start, and were restarted in 48 % (N = 42) of the trails using TM1. Using TM2, competition tracking, the first tracking team had an unsuccessful start in 43 % (N = 30) of the trails. The second tracking team, despite starting tracking directly at the point where tracking team one was taken of the trail, had an unsuccessful start in 26 % (N = 39) of the trails. The dog instructors had a bad tracking start in 31 % (N = 13) of the trails, and 0 % (N = 1) when resuming a trail when using competition tracking. The tracking start did not differ between the different tracking methods (GLM: $F_{3,124} = 1.71$, P = 0.169)

3.3 Environmental and other factors affecting tracking success

A negative relationship between PST and age of the dog was found using a binary model (GLMM: $\beta = -0.141$, $t_{84} = -3.060$, P = 0.003) (Figure 3). The other variables tested were not significant (Age of track: $\beta = 0.312$, $t_{83} = 1.594$, P = 0.115; Walking speed: $\beta = 0.001$, $t_{81} = 1.071$, P = 0.287; Temperature: $\beta = -0.003$, $t_{80} = -0.132$, P = 0.895). The temperature averaged 17 ± 0.3 °C (min = 7 °C, max = 27 °C) during the trackings.

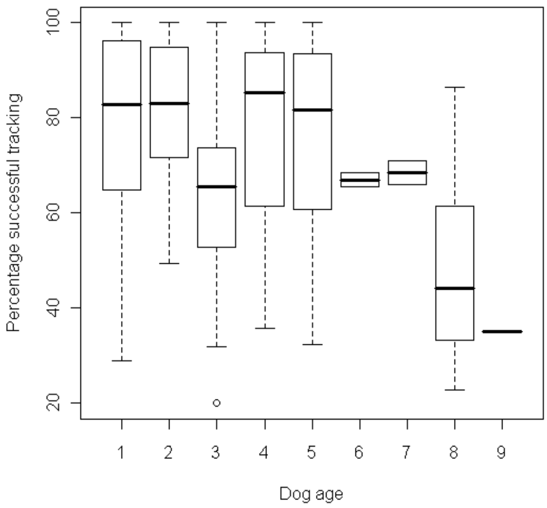

Figure 3 Percentage successful tracking (PST) in relation to age of the dogs that tracked GPS-collared brown bears in central Sweden in summer 2007 and 2008.

A parametric model analyzing MSFL in relation to different environmental and other factors indicated that none of the variables considered had a significant effect on MSFL (GLMM: Age of track: $\beta = 0.165$, $t_{66}=1.26$, P=0.213; Temperature: $\beta = -0.01$, $t_{65} = -0.801$, P = 0.426; Age of the dog: $\beta = 0.026$, $t_{64} = 0.761$, P = 0.449; Walking speed: $\beta = -0.000$, $t_{62} = -0.398$, P = 0.692).

3.4 Dog groups

The three groups of dogs used by public authorities for tracking bears showed significant differences in PST ($F_{117,2} = 8.87$, $P \leq 0.001$) (Figure 4a). Retrieving dogs had significantly higher PST compared to barking hounds (Tukey Post-hoc test: $P \leq 0.001$) and dachs, baying and tracking hounds (Tukey Post-hoc test: P = 0.016). Barking hounds and dachs, baying and tracking hounds showed no difference in PST (Tukey Post-hoc test: P = 0.332).

The three groups of dogs used by public authorities for tracking bears also showed significant difference in MSFL ($F_{100,2} = 4.57$, P = 0.013). Retrieving dogs had significantly higher MSFL than barking hounds (Tukey Post-hoc test: P = 0.019) and dachs baying and tracking hounds (Tukey Post-hoc test: P = 0.011) (Figure 4b). There was no difference between barking hounds and dachs baying and tracking hounds (Tukey Post-hoc test: P = 0.997).

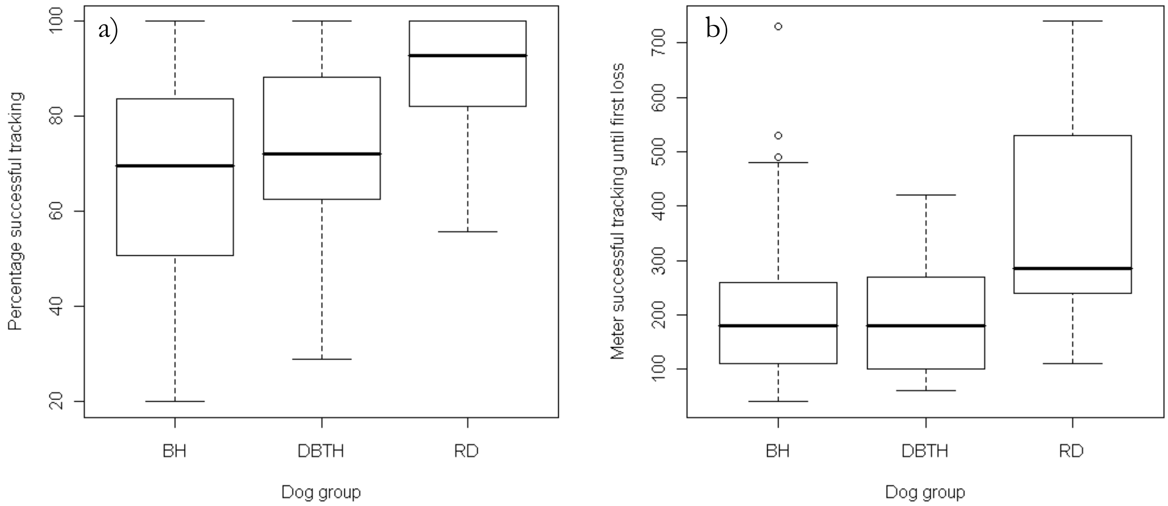

Figure 4 (a) Percentage successful tracking (PST) conducted by the dog groups, retrieving dogs (RD), dachs, baying and tracking hounds (DBTH) and barking hounds (BH), used by the public authorities for tracking GPS-collared brown bears in central Sweden in summer 2007 and 2008. RT had significantly higher PST than BTH and BH ($P \leq 0.001$). **(b)** Meter successful tracking until first loss (MSFL) conducted by retrieving dogs (RD), dachs, baying and tracking hounds (DBTH) and barking dogs (BH). RD had significantly higher MSFL than BTH and BH ($P = 0.013$).

3.5 Questionnaire

3.5.1 Questionnaire regarding dogs

Each dog handler who replied to the questionnaire also answered a questionnaire for all their dogs ($N = 28$). Twenty of these dogs had been used for hunting bears, 18 for hunting moose, and 15 for hunting both bear and moose. Thirteen of the dogs were known to have encountered bear(s), either by successful hunting or testing in a bear park under the auspices of the NHFA or SHA. During hunting, nine dogs had engaged a mean of 3.4 ± 0.8 (min = 1, max = 10) bears that subsequently had been shot. For ten of the dogs the behavior when encountering a bear had been tested in a bear park, and six of the tested dogs had been approved. Twelve of the dogs had performed a mean of 2.2 $\pm$ 0.3 searches for wounded bears. The bears were successfully found in 55 % of the searches. Nine dogs had won prizes in competitive tracking of game, moose, or blood trails, and two dogs were specially trained for tracking carnivores. The one specially trained dog was experienced in detection of wolf odor, and the other was in a training program for specializing in detection of bear odor.

The dogs whose behavior when encountering a bear in a bear park had been tested and had been approved, did not differ in either PST (Approved: 72.3 ± 5.0 %; Not approved: 78.6 ± 5.0 %; two-sample t-test; t_{28} = 1.00, P = 0.328) or MSFL (Approved: 168.2 ± 27.2 m; Not approved: 146.9 ± 24.1 m; two-sample t-test; t_{23} = -0.84, P = 0.411) compared to dogs that had not been approved.

A binary model examining the PST (proportion successful tracking between 0-1 of the total track length) showed that using dogs that had hunted bears and/or moose and searched for wounded bears negatively affected the PST (Table 2), but using dogs that had been involved in engaging a bear that had subsequently been shot positively affected PST (Table 2). Whether or not a dog had won tracking rewards did not significantly influence PST (Tracking prizes: β = 0.385, t_{75} = 0.246, P = 0.121).

A parametric model showed that using dogs which that had searched for wounded bears previously positively affected MSFL (Table 3). The model also showed that dogs used for hunting bears and/or moose and those that had been involved in engaging a bear that had subsequently been shot negatively affected MSFL (Table 3). The last variable tested was not significant (Tracking prizes: β = 0.057, t_{21} = 0.328, P = 0.746).

Table 2 Generalized linear mixed model explaining the effect on percentage successful trail (PST) while tracking GPS collared bears in central Sweden in summer 2008 when using dogs that had hunted brown bears, searching for wounded bears, or been involved in a hunt where a bear had been shot (yes = 1 and no = 0). The variables were based on a questionnaire about the dogs. The model excluded the least significant terms and included random effects of individual. β is the slope, SE is the standard error, df is degrees of freedom, t denotes the t-value and P denotes the significance level.

Explanatory variables	β	SE	df	t	P
Dogs used for hunting	-0.914	0.318	79	-2.868	0.005
Shot bear using dog	0.906	0.347	26	2.610	0.015
Searched for wounded bears	-0.765	0.316	26	-2.423	0.023

Table 3 Generalized linear mixed model on the effects of meters of successful tracking (MSFL) by dogs used for tracking GPS collared bears in central Sweden in summer 2008 in relation to whether the dogs had been used for for hunting brown bears and/or moose, had been involved in a hunt where a bear had been shot, or had searched for wounded bears (yes = 1 and no = 0). The variables were based on a questionnaire The model excluded the least significant terms and included random effects of individual. β is the slope, SE is the standard error, df is degrees of freedom, t denotes the t-value and P denotes the significance level.

Explanatory variables	β	SE	df	t	P
Dogs used for hunting	-0.690	0.197	23	-3.497	0.002
Shot bear using dog	-0.444	0.228	23	-1.950	0.064
Searched for wounded bears	0.581	0.210	23	2.774	0.011

3.5.2 Questionnaire regarding dog handlers

All dog handlers, except one, answered the questionnaire (N = 20). Of these, 17 were bear hunters, 16 had shot bear(s), 14 were working with bears as a part of their job, 15 had completed a course in searching for wounded bears through NHFA or SHA, and 12 had conducted a mean of 6.9 ± 1.2 (min = 1, max = 13) searches for wounded bears. The bear was successfully found in 45% of the searches.

A binary model examining the PST (proportion successful tracking between 0-1 of the total trail length) showed that dog handlers that had completed a course in searching for wounded bears had a tendency towards lower PST compared to dog handlers without the course (GLMM: β = -1.032, t_{17} = -1.963, P = 0.066). The other variables tested were not significant (Hunting bears: β = 0.017, T_{13} = 0.023, P = 0.982; Shot bear(s): β = 1.044, t_{14} = 1.349, P = 0.199; Conducted searches for wounded bears: β = -0.362, t_{15} = -0.910, P = 0.377; Working with bears: β = -0.380, t_{16} = -1.054, P = 0.3074).

A parametric model showed that MSFL was significantly lower for dog handlers that had a course in searching for wounded bears compared to dog handlers without the course (GLMM: β = -0.796, t_{16} = -3.166, P = 0.006). The other variables tested were not significant (Hunting bears: β = -0.404, t_{15} = -1.544, P = 0.144; Shot bear(s): β = -0.079, t_{12} = -0.184, P = 0.857; Conducted searching for wounded bears: β = 0.044, t_{13} = 0.144, P = 0.888; Worked with bears: β = 0.211, t_{14} = 1.257, P = 0.229).

3.6 Change in tracking success within a season

PST increased significantly with the number of trackings within a season (GLMM: Trail number: β = -0.118, t_{67} = -2.200, P = 0.031), and the increase depended on tracking method, with TM2 having a significantly higher PST than TM1 (factor (Method) 1: β = -0.921, t_{24} = -3.258, P = 0.003) (Figure 5). However, no difference were found in MSFL within a season for either TM1 or TM2 (GLMM: Trail number: β = -0.009, t_{55} = -0.252, P = 0.802; Factor (Method) 1: β = 0.156, t_{23} = 0.824, P = 0.419).

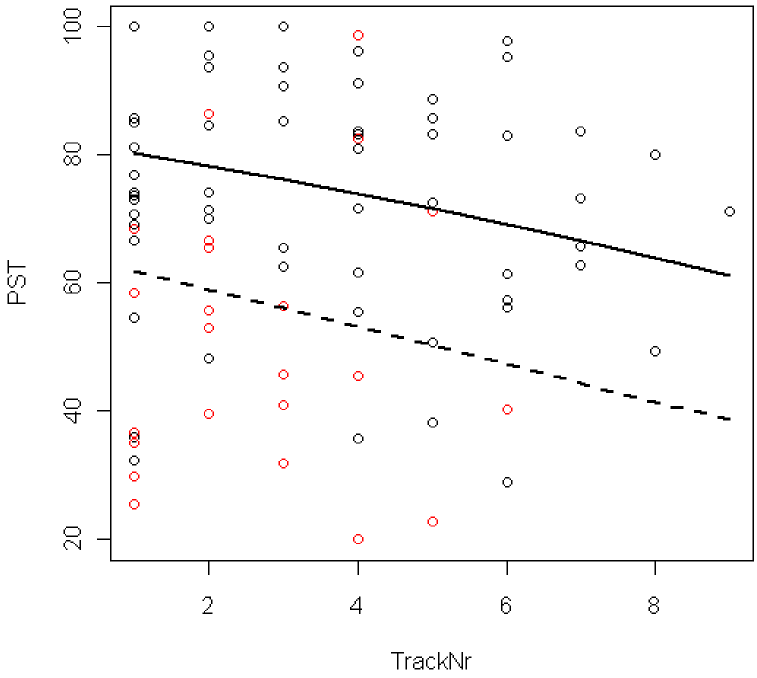

Figure 5 Predicted model of percentage successful tracking (PST) based on the number of trackings (TrackNr) of two different tracking methods (TM1 and TM2) when tracking GPS collared bears in central Sweden in summer 2008. The model included random effects of individual for the tracking methods. The solid line represents tracking method 2 and the dashed line represents tracking method 1.

3.7 Loss of trail/Switch to other species

Switching to other species when the tracking team did not discover the switch and lost the trail occurred in 82 % of the trackings. A mean of 1.5 ± 0.1 (min = 0, max = 9) switches to other bears or other species occurred in each trial. Most of the disturbance (52 %) was due to "undetermined" species, followed by moose (25 %), birds (10 %), other bear individuals (9 %), and other species (3 %) such as hare (*Lepus timidus*) and wolf (*Canis lupus*). MSFL decreased as the number of trail losses increased (GLM: β = -0.069, t_{249} = -5.55, P = <0.001), i.e. the distance of successful tracking became shorter for each time a tracking team lost the trail, and had to be reset (Figure 6).

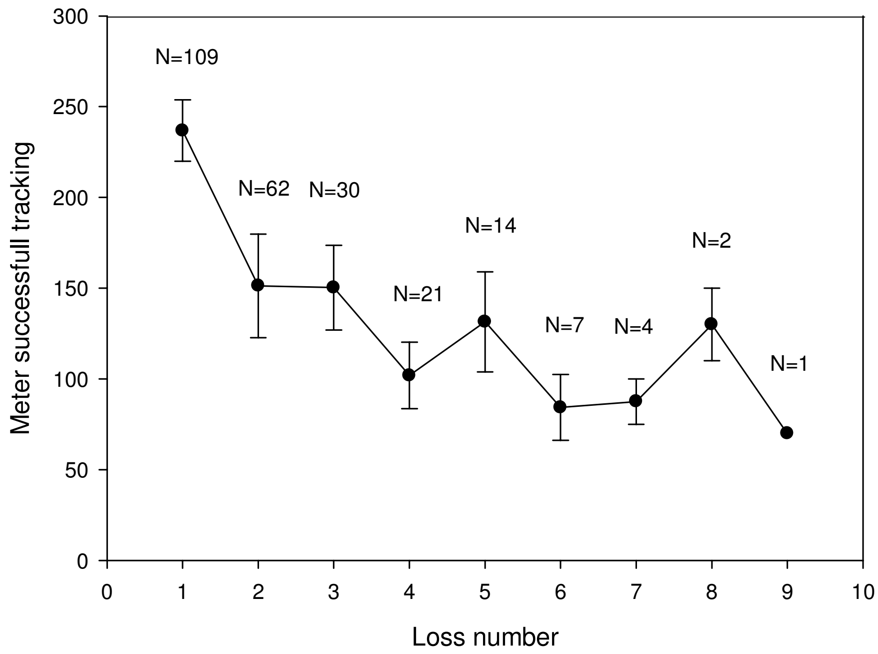

Figure 6 Meters of successful tracking ($\bar{x}$ ± SE) in relation to the number of times a tracking team lost the trail (Loss number) when tracking GPS collared brown bears in central Sweden in summer 2007 and 2008.

The number of switches to other species in each trail was affected by trail length and tracking method (Table 4). The number of switches in each trail was significantly higher for longer tracks. There were significantly fewer switches in each trail conducted by DI compared to TM2 and a tendency for fewer switches for DI compared to TM1 (Table 4). The other variables tested were not significant (Tracking prizes: β = 0.081, t_{20} = 0.251, P = 0.750; Searching for wounded bears: β = -0.029, t_{22} = -0.118, P = 0.907; Dog age: β = -0.043, t_{77} = -1.066, P = 0.290; Shot bear using the dog: β = -0.235, t_{23} = -1.216, P = 0.237; Used dog for hunting bear and/or moose: β = 0.421, t_{24} = 1.500, P = 0.147)

Table 2 Generalized linear mixed model of the factors effecting number of switches to other species when tracking GPS collared brown bears in central Sweden in summer 2007 and 2008. The variables effecting the number of switches were the length of the trail and method. Dog instructors (DI) had significant lower number of switches compared to tracking method 2 (TM2) and a tendency toward a lower number compared to tracking method 1 (TM1) . The model excluded the least significant terms and included random effects of individual. β is the slope, SE is the standard error, df is degrees of freedom, t denotes the t-value and P denotes the significance level.

Explanatory variables	β	SE	df	t	P
Track length	0.001	0.000	81	8.417	<0.001
DI vs. TM1	0.757	0.340	81	1.894	0.061
DI vs. TM2	1.041	0.393	81	2.652	0.010

4. DISCUSSION

The results of this study show that, the accuracy of dogs used in tracking brown bears is relatively high, but the length of the trail the dog can follow before losing it is relatively short, and that dogs easily switch to following other species while tracking bears. This study also demonstrates that the success of tracking brown bears is more a function of training level than the level of experience that the tracking team has with bears or the influence of environmental factors.

I did not find that tracking success was influenced by environmental factors, such as temperature, age of the trail, or the speed of tracking. Other studies have and have not found that environmental factors affect a dog's success rate (Cablk & Heaton 2006; Shivik 2002). Extreme temperatures can limit the time a dog can work, because it may become overheated (Harrison 2006; Smith et al. 2003). Smith et al. (2003) suggested that dogs are capable of working in hot climates and seasons, but that they must be habituated and used with care. The temperatures were relatively low during the trials, with an average of ~17 °C, because we avoided conducting trials during the warmest times of the day. However, the trials were conducted during conditions typical for a Swedish summer.

We found no significant difference in tracking success due to the age of the trail, but we only investigated 10 – 24-hour-old trails. Kristoffersson et al. (2000) examined a category of < 2 hour-old tracks when testing tracking teams following bear trails and also found no differences in performance in relation to age of tracks. Dogs are capable of detecting scent molecules at concentrations as low as 10 parts per quadrillion (10^{15}) (Garner et al. 2001, cited in Cablk & Heaton 2006), and Schoon & Debruin (1994) found that dogs are able to identify human scent on fragments of glass that have been kept indoors for a month, or outdoors for two weeks. A maximum trail age of 24 hours should therefore not be a problem for a dog to identify and follow. Kristoffersson et al. (2000) interviewed the dog handlers who participated in the tracking, and found that the perceived difficulty increased with age of the trail. We believe that a trail age of 10 – 24 hours was a greater psychological barrier for the dog handlers than a factor explaining tracking success. When searching for wounded bears, dog handlers are called within minutes to many days after an event and it is therefore necessary to have experience in various age categories of trails.

Our results showed that the accuracy of the tracking is related to the age of the dog, with young dogs having greater accuracy than older dogs, which agrees with Wells & Hepper (2003), who found that younger dogs (<2 years) were more successful in tracking people than older dogs. Young dogs may be more successful because they are more receptive to training (Adams et al. 2000; Head et al. 1995). Head et al. (1995) examined dogs' spatial learning and memory and found that both acquisition and performance decreased with age. This is supported by Adams et al. (2000), who found that younger dogs had a better spatial learning and a higher maximum work capacity than older dogs. Alternatively, the low success in older dogs may be a consequence of earlier "wrong" training. Older dogs may have been exposed to more changes in training regimes than younger dogs. Such changes can influence the understanding of the task, and thereby influence the success of the tracking. One cannot ignore the possibility that a dog's work is related to external factors. A dog and his handler work as a "team". The dogs are largely influenced by the dog handlers' behavioral/facial cues in detection of human attention (Fukuzawa et al. 2005; Gacsi et al. 2004), therefore the dog handler can influence the dog while tracking without knowing it. The dog handler also has greater confidence in the older more "experienced" dog compared to a younger dog (Boström & Lännbjer 2008). Because the dog handler has less confidence in a young dog, the dog handler increases his awareness of working with a younger dog. As a result the dog handler may detect small changes in the dog's behavior more readily, which increases the accuracy of the tracking.

I found that the group retrieving dogs had a higher success than barking hounds and dachs, baying, and tracking hounds. This result is based on different group sizes (and must therefore be interpreted cautiously), with most representatives of barking hounds (N = 27), some in dachs, baying, and tracking hounds (N = 8) and only a few retrieving dogs (N = 4). One of the retrieving dogs was in addition a specially trained odor-detection dog. Other studies have shown that different dog breeds have tendencies toward different behavioral characteristics (Bradshaw et al. 1996; Bradshaw & Goodwin 1999; Notari & Goodwin 2007), including differences in the characteristics that are important for odor detection (Rooney & Bradshaw 2004). For example, Rooney & Bradshaw (2004) found that the breeds English springer spaniel and border collie scored highest in qualities like motivation, perseverance, and were least often disturbed during the search. In professional organizations where dogs are used, i.e. police and military, certain dog groups and breeds are more commonly used for odor detection and tracking. The qualities of these breeds can be useful also in bear tracking. However, one cannot predict the success of an individual from its breed alone. In a situation involving a wounded bear, it may be preferable to use two dogs with different types of characteristics and training, with one track specialist tracking the bear, while the other dog is released when close to the bear to stop and distract the bear such that a hunter can approach.

The specialist odor-detection dogs that were specially trained for the of tracking large carnivores exhibited a higher tracking success, in both length and accuracy, than dogs that had much experience in hunting bears. In addition, tracking method 2 produced dogs with a higher accuracy than tracking method 1. None of the tracking specialists had any experience with real bears, but were specially trained for tracking individual humans and motivated with bear scent from a laboratory. These results indicate that training is necessary to track a particular individual, rather than motivating the dogs with bear hunting. Hunting as a training method to provide motivation to follow a bear track did not improve tracking success. We found that both tracking length and accuracy was lower for dogs that had been used for hunting bears. During a typical hunt such dogs work independently of the hunter, and have to learn tracking by themselves. Pongracz et al. (2003) found that the performance of dogs was poorer if they had to learn to solve a task on their own. The dog handler determines the content of a task or tracking assignment, and how the dog shall perform it. If the dog learns to track bears by itself, the dog will have little understanding of a tracking assignment. When searching for wounded bears, the tracking consists of several sub-themes, where the dog will have do the following: 1) search for the odor of the target individual, 2) indicate that it has found the target species/individual when it makes a find, 3) accurately follow the trail from that particular individual bear, 4) be able to solve problems along the track, and 5) work with that specific trail as long as the dog handler requires. For a dog to learn all these sub-themes appropriately, the dog must have basic tracking training. Each of the sub-themes must be trained on trails that are known to the dog handler, to be able to determine the performance of the dog (and the handler!) and to reward and motivate it appropriately. It is unlikely that a dog learns to perform the various sub-themes on its own during hunting situations. On the other hand, my results show that dogs that had been involved in engaging bears that subsequently had been shot were more accurate when tracking bears, but these dogs also tracked a shorter distance until the first loss. The reason for this may be nervousness, because a bear is not a natural prey for the dog, compared to moose or birds. The dog is not genetically predisposed to follow a bear trail, rather the opposite. A dog that has been confronted with a bear, knows that there is a bear at the end of the trail. That they follow the trail more accurately could be due to being more careful, precisely because they know what it is all about. According to Apfelbach et al. (2005) the smell of a predator affects the endocrine system in a prey species, which increases the level of stress hormones. This can lead to characteristic behavioral changes, such as reduced activity (Apfelbach et al. 2005). Whether dogs that have been confronted with bears are more nervous should be investigated.

NHFA and SHA offer courses in searching for wounded bears, the goal of which is to qualify and improve the participants ability to search for wounded bears (NHFA 2009; SHA 2009). My results show that dog handlers who have completed this course have lower tracking success than dog handlers who have not participated in the course. The course offers a test of dogs in a bear park, where the trainers determine whether the dog's behavior was appropriate or not when encountering a bear. Our results show no difference in dogs that were judged to be appropriate or not appropriate in a bear park in tracking the success. The reason for this may be that neither course offers training or testing of dogs in tracking. As tracking itself is crucial for finding the correct individual, these courses must focus more on tracking to fully educate tracking teams.

Dogs that had been used for searching of wounded bears followed tracks further until first loss than dogs that had not searched for wounded bears. However, the dogs that had not searched for wounded bears were more accurate when tracking. That the dogs that had searched for wounded bears have longer MSFL may be because they have acquired expectations for the tracking. Dogs obtain a higher motivation to perform a specific task, when they have expectations for it. This can cause the dog to track longer, because motivation helps to increase a dog's concentration and arousal during the execution (T. Gustavsson pers.com.). On the other hand, dogs used for searching for wounded bears had lower accuracy when tracking bears. Boström & Lännbjer (2008) have recommended that tracking teams should use the older more "experienced" dogs, whose behavior has been judged to be appropriate when encountering bears, when searching for wounded bears. However my results suggest that there are certain disadvantages when using older dogs, as they are less accurate when tracking than younger dogs.

I found no difference in tracking success between dogs that had or had not received prizes in competitive tracking, i.e. first or second place in game, moose, or blood-track competitions. This suggests that such competitions do not set high enough or the correct requirements in order to follow a bear's trail. Movement patterns and vegetation density used by bears and moose are not comparable (Kristofferson et al. 2000), and higher requirements for ability and accuracy are required to succeed when tracking bears. Brown bears are plantigrades, which makes bear tracks hard for the dog handler to notice. In addition, the bear's irregular route when walking and their preference for dense vegetation create additional challenges when tracking bears compared to moose. The dog handler must therefore rely to a higher degree on the dogs' olfactorail capabilities to find bear sign. When searching for wounded bears, this sign is important to determine whether the bear has been wounded or not, i.e. by finding blood or by interpreting the bear's behavior. However, when searching for wounded bears, it is important to be aware of the fact that blood may not be found along the trail, even if the bear is wounded. Many wounded bears are incorrectly determined to be in good health during these searches, because of lack of blood in the trail (Stokke et al. 2008). Stokke et al. (2008) showed that hunters did not find blood in the trail in 42 percent of the cases when wounded bears were shot later. Stokke et al. (2008) believe that the reason for the lack of blood is the bears' thick subcutaneous fat layer in autumn, which prevents the blood from leaving the wound.

There was an increase in accuracy of tracking bears throughout a season, and it depended on tracking method, with TM2 having a higher accuracy than TM1. It seems that a week of intensive training, as used in TM1, is too much for a dog. We experienced that dogs became tired by the end of the week for TM1. Greater accuracy for TM2 can be related to the fact that the tracking is divided over several trials. This is supported by Meyer & Ladewig (2008), who examined the effect of two different training programs, where one group of dogs was trained once a week and one group of dogs was trained five times a week. The survey studied the number of training sets that were needed to reach a certain training level. They concluded that when the dogs learn a given assignment, weekly training provides better results in relation to performance than training five times a week.
The tracking start can be decisive for a tracking being successful or not. Tracking start went wrong in up to 48 % of the trials, and this despite much information about the tracking start. The tracking teams knew both the distance and direction to GPS location of the tracking start and subsequent GPS location. The results show that both tracking methods and even the dog instructors did not perform very well during tracking start. This suggests that a main focus of future training should be directed to obtain good tracking starts.

The accuracy of trackings decreased during the course of a season, with TM1 generally performing poorer than TM2. This suggests that a week of intensive training is too much for a dog, because we experienced that dogs got tired by the end of the week for TM1. The greater accuracy of TM2 may be related to the layout of the training, where tracking is divided into several trackings periods during a season. This is supported by Meyer & Ladewig (2008), who examined the effect of two different training programs on dog performance. One of the test groups was trained once a week and the other group of dogs were trained five times a week. The authors concluded that weekly training provided better results in relation to performance than training five times a week. That accuracy decreases with the number of trackings and that successful track length decreases with increasing number of trail losses may be related to a lack of proper training and proper rewarding of the dog during a tracking trial. Few of the dog handlers rewarded the dogs, which makes the dogs looking for alternatives, e.g. following the trail of other game species. This can also explain the high number of switches to other game species, as found in this study. As most of the dogs (82 %) were used for hunting, they probably have positive experience with other game, and have been rewarded for following and finding other game species while hunting. During the tracking of a bear it is likely that a tracking team will encounter several disturbances, such as tracks and trails of other species. If the encounter and handling of such disturbances has not been properly trained and habituated to disturbances in a controlled environment, the dog can become sensitized to the disturbance, which may cause it to increase in response by repeated presentation of a stimulus (Chance 1999), i.e. the dog will start tracking the disturbance.

5. MANAGENENT APPLICATIONS

There are several stages when searching for wounded bears: 1) bear sign must be identified at the place of the shot, the collision, or a carcass taken by a bear, 2) the track of the correct individual bear should be followed, with such an accuracy that the bears' behavior can be documented. This is required by public authorities, and it can give information about whether the bear is wounded or not. Finally when the bear is tracked down, 3) the bear is stopped, and possibly killed. Today, there is much knowledge and training for th3 third stage when searching for wounded bears, but little is known about the first and second stages. My study has analyzed the last-mentioned stages of tracking bears. The results show that the accuracy is relatively high when tracking bears, which indicates that dogs are useful for obtaining information about sign from the bear to interpret the bears' behavior, and whether the bear is wounded or not. During searches, wounded bears have been found in only half of the cases (Jaxgård 2007). In those cases where the bear was not found, the tracking team followed the bear for an average of 4.6 km (Jaxgård 2007). This length strongly contrasts with the results in my study, where the tracking teams that are used by public authorities tracked an average of 232 ± 28 m (TM1) and 202 ± 17 m (TM2). In addition, the tracking start often was wrong and the dogs easily switch to following other species while tracking bears. This may explain the low success rate during searching for wounded bears, and it indicates that bears often are incorrectly assumed to not be wounded. My results indicate that tracking training is necessary if the tracking teams are to reach an acceptable level of accuracy when tracking bears. My study also shows that previous traditional trainings methods have little or even negative effect on tracking performance. Additionally, courses in searching for wounded bears probably focus too little on the first and second stages when searching for wounded bears, because those who have completed the course have significantly lower tracking success. We know that dogs have incredibly sensitive olfaction capabilities; our challenge lies in training them to find what we want them to find and to communicate that to us, as well as in selecting appropriate dogs and dog handlers that are physically and mentally up to the task. Further studies to expand the data set for more age categories of trails (both fresher and older) would be of great interest. Old trails would be of interest to study how old a bear trail can be that dogs are able to follow, because this is a mental challenge especially for the dog handler. In addition, fresh bear trails would be of interest, to test for any nervousness and behavior of the dog when encountering the bear. It may be necessary to use different dog groups with different behavior characteristics in the different stages when searching for wounded bears. For the first and second stages, it might be advantageous to use dog groups with characteristics such as high motivation, persistence, and low tendency to be disturbed during the tracking, whereas it may be necessary to use a traditional hunting dog in the third stage. We need more research and monitoring, evaluation, and quality control of the training to achieve a better expertise in the tracking of brown bears.

Appendix 1

Spørreskjema angående hund

Dette spørreskjemaet gjelder for hundene som er benyttet i sportrening i regi av det skandinaviske bjørneprosjektet. Det fylles ut ett eget skjema for hver hund som har deltatt. Spørreskjemaet er konfidensielt!

Generelle opplysninger om hunden:

Hundens navn:…………………………. Rase:……………………………………….

Alder:………………………………………. Kjønn: Tispe☐ Hannhund☐

Hundens erfaringer med bjørn og annet vilt:

	Ja	*Nei*
Er hunden testet i bjørnepark? (*Inkl. Junsele for svenskene*)……………………………………	☐	☐
Er hunden godkjent i bjørnepark?……………………………………………………………………………	☐	☐
Har hunden gått sporprøver? (*Elgsporprøver, viltsporprøver o.l.*)…………………………..	☐	☐
- Dersom ja: Hvilke sporprøver?………………………		
Har hunden meritter i sporing?………………………………………………………………………………	☐	☐
- Dersom ja: Hvilke meritter?…………………………….		
Benyttes hunden på bjørnejakt?………………………………………………………………………………	☐	☐
Har det blitt skutt bjørn for hunden?……………………………………………………………………	☐	☐
- Dersom ja: Antall bjørn skutt for hunden:…………		
Har hunden blitt benyttet i ettersøk på bjørn?…………………………………………………………	☐	☐
- Dersom ja: Antall ettersøk:………………………………. Antall funnet:…………………………………..		
Benyttes hunden på elgjakt?………………………………………………………………………………………	☐	☐
- Dersom ja: Hvor ofte?……………………………………..		
	☐	☐

Benyttes hunden på annet vilt?..

Spørreskjema angående hundeførere

For å utrede utdannelsen i bjørnesporing ønsker vi å få dine erfaringer som hundefører etter treningsopplegget. Vi ber deg derfor fylle ut spørreskjema, hvorav ett er til deg som hundefører og ett er for hver av hundene dine som har deltatt.
Spørreskjemaet er konfidensielt!

Personopplysninger:

Navn:…………………………………………………………… Alder:…………………………………………………………

Litt om dine personlige erfaringer omkring bjørnejakt og ettersøk:

	Ja	*Nei*
Jeg jakter bjørn?...	☐	☐
Jeg har skutt bjørn?..	☐	☐
- Dersom ja: Antall bjørner skutt:…………………		
Er bjørnen(e) skutt for hund:………………………………………………………	☐	☐
Jeg har utført ettersøk på bjørn?..	☐	☐
- Dersom ja: Antall ettersøk:………………………..		
Antall funnet (Kun bjørner som har vært mer enn 100 m fra vei eller skuddplass):………………………………		
Jeg har gått ettersøkskurs gjennom jegerforbundet?..	☐	☐
Jeg jobber med bjørn i yrket mitt?..	☐	☐

Litt om dine personlige erfaringer omkring treningsopplegget i bjørnesporing:

	Helt uenig				*Helt enig*
Sporingsarbeidet generelt har blitt forbedret etter utdannelsen…………	☐	☐	☐	☐	☐
Hunden har blitt bedre til å spore bjørn……………………………………………	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

Jeg som fører har generelt blitt bedre når det gjelder sporarbeid...........

	Helt uenig				*Helt enig*
Jeg som fører har blitt bedre til å finne spor og sportegn etter bjørn......	☐	☐	☐	☐	☐
Jeg som fører har blitt bedre til å veilede hunden tilbake til sporet........	☐	☐	☐	☐	☐
Jeg som fører har blitt bedre på å lese hundens reaksjoner.....................	☐	☐	☐	☐	☐
Jeg som fører kjenner meg tryggere med hundens sporarbeid................	☐	☐	☐	☐	☐
Kunnskapen om sporingsproblem (veier, virvar o.l.) er forbedret...........	☐	☐	☐	☐	☐
Jeg som fører har blitt bedre til å avgjøre om hunden benytter luft eller mark..	☐	☐	☐	☐	☐
Jeg har blitt bedre til å individanpasse treningen....................................	☐	☐	☐	☐	☐
Jeg har fått nye idéer om treningsopplegg...	☐	☐	☐	☐	☐
Jeg kommer til å trene mer på sporstart og sporopptak..........................	☐	☐	☐	☐	☐
Jeg forstår koblingen mellom teorien og praktisk sporing........................	☐	☐	☐	☐	☐
Jeg kan definere hvorfor en del sporinger tidligere har misslyktes..........	☐	☐	☐	☐	☐
Utdanningen er nødvendig for å gjennomføre ett effektivt ettersøk......	☐	☐	☐	☐	☐
Kursets innhold var relevant i forhold til kursets mål..............................	☐	☐	☐	☐	☐
Jeg ønsker å gå et fordypningskurs for å utvikles....................................	☐	☐	☐	☐	☐
Fordelingen mellom de ulike arbeidssettene (teori, praksis) var vel avveid..	☐	☐	☐	☐	☐
Jeg hadde tilstrekkelig med forkunnskaper for å kunne få utbytte av kursets innehold..	☐	☐	☐	☐	☐

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REFERENCES

Adams, B., Chan, A., Callahan, H., Siwak, C., Tapp, D., Ikeda-Douglas, C., Atkinson, P., Head, E., Cotman, C. W. & Milgram, N. W. (2000). Use of a delayed non-matching to position task to model age-dependent cognitive decline in the dog. *Behavioural Brain Research*, 108 (1): 47-56.

Apfelbach, R., Blanchard, C. D., Blanchard, R. J., Hayes, R. A. & McGregor, I. S. (2005). *The effects of predator odors in mammalian prey species: A review of field and laboratory studies*: Pergamon-Elsevier Science Ltd. 1123-1144 p.

Arnemo, J. M., Ahlqvist, P., Andersen, R., Berntsen, F., Ericsson, G., Odden, J., Brunberg, S., Segerstrom, P. & Swenson, J. E. (2006). Risk of capture-related mortality in large free-ranging mammals: experiences from Scandinavia. *Wildlife Biology*, 12 (1): 109-113.

Bjärvall, A. (1990). The brown bear in Sweden. *Aquilo, Serie Zoologica*, 27: 17-19.

Boström, R. & Lännbjer, J. (2008). *Svensk björnjakt*. [In Swedish]. 137 p.

Bradshaw, J. W. S., Goodwin, D., Lea, A. M. & Whitehead, S. L. (1996). A survey of the behavioural characteristics of pure-bred dogs in the United Kingdom. *Veterinary Record*, 138 (19): 465-468.

Bradshaw, J. W. S. & Goodwin, D. (1999). Determination of behavioural traits of pure-bred dogs using factor analysis and cluster analysis; a comparison of studies in the USA and UK. *Research in Veterinary Science*, 66 (1): 73-76.

Browne, C., Stafford, K. & Fordham, R. (2006). The use of scent-detection dogs. *Irish Veterinary Journal*, 59 (2): 97-104.

Cablk, M. E. & Heaton, J. S. (2006). Accuracy and reliability of dogs in surveying for desert tortoise (*Gopherus agassizii*). *Ecological Applications*, 16 (5): 1926-1935.

Cain, J. W., Krausman, P. R., Jansen, B. D. & Morgart, J. R. (2005). Influence of topography and GPS fix interval on GPS collar performance. *Wildlife Society Bulletin*, 33 (3): 926-934.

Cargnelutti, B., Coulon, A., Hewison, A. J. M., Goulard, M., Angibault, J. M. & Morellet, N. (2007). Testing Global Positioning System performance for wildlife monitoring using mobile collars and known reference points. *Journal of Wildlife Management*, 71 (4): 1380-1387.

Chance, P. (1999). *Learning and behavior*. 4. ed. Pacific Grove: Brooks and Cole Publishing Company. 505 p.

D'Eon, R. G. (2003). Effects of a stationary GPS fix-rate bias on habitat selection analyses. *Journal of Wildlife Management*, 67 (4): 858-863.

D'Eon, R. G. & Delparte, D. (2005). Effects of radio-collar position and orientation on GPS radio-collar performance, and the implications of PDOP in data screening. *Journal of Applied Ecology*, 42 (2): 383-388.

Dahle, B. & Swenson, J. E. (2003). Home ranges in adult Scandinavian brown bears (*Ursus arctos*): effect of mass, sex, reproductive category, population density and habitat type. *Journal of Zoology*, 260: 329-335.

DeCesare, N. J., Squires, J. R. & Kolbe, J. A. (2005). Effect of forest canopy on GPS-based movement data. *Wildlife Society Bulletin*, 33 (3): 935-941.

Engeman, R. M., Rodriquez, D. V., Linnell, M. A. & Pitzler, M. E. (1998). A review of the case histories of the brown tree snakes (*Boiga irregularis*) located by detector dogs on Guam. *International Biodeterioration & Biodegradation*, 42 (2-3): 161-165.

Engeman, R. M., Vice, D. S., York, D. & Gruver, K. S. (2002). Sustained evaluation of the effectiveness of detector dogs for locating brown tree snakes in cargo outbound from Guam. *International Biodeterioration & Biodegradation*, 49 (2-3): 101-106.

Fukuzawa, M., Mills, D. S. & Cooper, J. J. (2005). More than just a word: non-semantic command variables affect obedience in the domestic dog (Canis familiaris). *Applied Animal Behaviour Science*, 91 (1-2): 129-141.

Furton, K. G. & Myers, L. J. (2001). The scientific foundation and efficacy of the use of canines as chemical detectors for explosives. *Talanta*, 54 (3): 487-500.

Gacsi, M., Miklosi, A., Varga, O., Topal, J. & Csanyi, V. (2004). Are readers of our face readers of our minds? Dogs (Canis familiaris) show situation-dependent recognition of human's attention. *Animal Cognition*, 7 (3): 144-153.

Garmin. (2007). GPSMAP 60CSX, Owner's manual. 116 p.

Garner, K. J., Busbee, L., Cornwell, P., Edmonds, J., Mullins, K., Rader, J., Johnston, M. & Williams, J. M. (2001). Duty cycle of the detector dog: A case study. Alabama, USA: Final report to the FFA (Federal Aviation Administration). Institute for Biological Detection Systems, Auburn University.

Harrison, R. L. (2006). A comparison of survey methods for detecting bobcats. *Wildlife Society Bulletin*, 34 (2): 548-552.

Harvey, L. M. & Harvey, J. W. (2003). Reliability of bloodhounds in criminal investigations. *Journal of Forensic Sciences*, 48 (4): 811-816.

Head, E., Mehta, R., Hartley, J., Kameka, M., Cummings, B. J., Cotman, C. W., Ruehl, W. W. & Milgram, N. W. (1995). Spatial-learning and memory as a function of age in the dog. *Behavioral Neuroscience*, 109 (5): 851-858.

Jaxgård, P. (2007). Björneftersök 2007. Grimsö, Sweden [in Swedish]: Wildlife Damage Center. 34 p.

Kerley, L. L. & Salkina, G. P. (2007). Using scent-matching dogs to identify individual Amur tigers from scats. *Journal of Wildlife Management*, 71 (4): 1349-1356.

Kristofferson, M., Brunberg, S. & Swenson, J. E. (2000). *Försök att spåra björn med tillgängliga björneftersöksekipage under sommaren år 2000.* Orsa, Sweden [in Swedish]: Wildlife Damage Center, Scandinavian Brown Bear Project. 17 p.

Long, R. A., Donovan, T. M., Mackay, P., Zielinski, W. J. & Buzas, J. S. (2007a). Comparing scat detection dogs, cameras, and hair snares for surveying carnivores. *Journal of Wildlife Management*, 71 (6): 2018-2025.

Long, R. A., Donovan, T. M., Mackay, P., Zielinski, W. J. & Buzas, J. S. (2007b). Effectiveness of scat detection dogs for detecting forest carnivores. *Journal of Wildlife Management*, 71 (6): 2007-2017.

Lorenzo, N., Wan, T. L., Harper, R. J., Hsu, Y. L., Chow, M., Rose, S. & Furton, K. G. (2003). Laboratory and field experiments used to identify *Canis lupus var. familiaris* active odor signature chemicals from drugs, explosives, and humans. *Analytical and Bioanalytical Chemistry*, 376 (8): 1212-1224.

Meyer, I. & Ladewig, J. (2008). The relationship between number of training sessions per week and learning in dogs. *Applied Animal Behaviour Science*, 111 (3-4): 311-320.

Minitab Inc. (2007). *Minitab* ®. U.K.

Moe, T. F., Kindberg, J., Jansson, I. & Swenson, J. E. (2007). Importance of diel behaviour when studying habitat selection: examples from female Scandinavian brown bears (*Ursus arctos*). *Canadian Journal of Zoology-Revue Canadienne De Zoologie*, 85 (4): 518-525.

Naturvårdsverket. (2008). Beslut om skyddsjakt på björn 2008. Stockholm, Sweden [In Swedish]: Swedish Environmental Protection Agency. 25 p.

NHFA. (2009). *Course in searching for wounded bears.* Nord-Trøndelag [In Norwegain]: Norwegian Fishing and Hunting Accosiation (NFHA). Available at: http://www.njff.no/portal/page/portal/nord_trondelag/nyhet?element_id=5007270&displaypage=TRUE (accessed: 14.04.09).

Norwegian Kennel Club. (2009). *Breeding group standards*. Oslo [In Norwegaian]: Norwegian Kennel Club (NKK). Available at: http://www.nkk.no/nkk/public/openIndex?ARTICLE_ID=1086195989321 (accessed: 01.05.09).

Notari, L. & Goodwin, D. (2007). A survey of behavioural characteristics of pure-bred dogs in Italy. *Applied Animal Behaviour Science*, 103 (1-2): 118-130.

Pongracz, P., Miklosi, A., Kubinyi, E., Topal, J. & Csanyi, V. (2003). Interaction between individual experience and social learning in dogs. *Animal Behaviour*, 65: 595-603.

R Development Core Team. (2009). *R*. Vienna, Austria: R Funtation for Statistical Computing.

Rooney, N. J. & Bradshaw, J. W. S. (2004). Breed and sex differences in the behavioural attributes of specialist search dogs - a questionnaire survey of trainers and handlers. *Applied Animal Behaviour Science*, 86 (1-2): 123-135.

Sahlèn, V., Swenson, J. E., Brunberg, S. & Kindberg, J. (2006). Björnen i Sverige. En rapport från Skandinaviska Björnprojektet till den svenska rovdjursutredningen. Rapport 2006-4 [In Swedish]: Scandinavian Brown Bear Research Project. 45 p.

Schoon, G. A. A. & Debruin, J. C. (1994). The ability of dogs to recognize and cross-match human odors. *Forensic Science International*, 69 (2): 111-118.

SHA. (2009). *Course in searching for wounded bears*. Umeå [In Swedish]: Swedish Hunting Accosiation (SHA). Available at: http://www.jagareforbundet.se/utbildning/eftersokbjorn/default.asp (accessed: 14.04.09).

Shivik, J. A. (2002). Odor-adsorptive clothing, environmental factors, and search-dog ability. *Wildlife Society Bulletin*, 30 (3): 721-727.

Smith, D. A., Ralls, K., Hurt, A., Adams, B., Parker, M., Davenport, B., Smith, M. C. & Maldonado, J. E. (2003). Detection and accuracy rates of dogs trained to find scats of San Joaquin kit foxes (*Vulpes macrotis mutica*). *Animal Conservation*, 6: 339-346.

Solberg, K. H., Bellemain, E., Drageset, O. M., Taberlet, P. & Swenson, J. E. (2006). An evaluation of field and non-invasive genetic methods to estimate brown bear (*Ursus arctos*) population size. *Biological Conservation*, 128 (2): 158-168.

Statens veterinärmedicinska anstalt. (2008). *Björnjakten 2008, Vilda djur, Djurhälsa*: Statens veterinärmedicinska anstalt (SVA) [In Swedish]. Available at: http://www.sva.se/sv/navigera/Djurhalsa/Vilda-djur/Stora-rovdjur/Bjornjakt/ (accessed: 10.05.09).

Stokke, S., Arnemo, J. M., Kristofferson, M. & Söderberg, A. (2008). Märkbart många björnar skadeskjuts. *Våra rovdjur*, [in Swedish], 2: 18-20.

Swenson, J. E., Wabakken, P., Sandgren, F., Bjärvall, A., Franzèn, R. & Söderberg, A. (1995). The near extinction and recovery of brown bears in Scandinavia in relation to the bear management polices of Norway and Sweden. *Wildlife Biology*, 1: 11-25.

Swenson, J. E., Jansson, A., Riig, R. & Sandegren, F. (1999a). Bears and ants: myrmecophagy by brown bears in central Scandinavia. *Canadian Journal of Zoology-Revue Canadienne De Zoologie*, 77 (4): 551-561.

Swenson, J. E., Sandegren, F., Söderberg, A., Heim, M., Sørensen, O. J., Bjärvall, A., Franzén, R., Wikan, S. & Wabakken, P. (1999b). Interactions between brown bears and humans in Scandinavia. *Biosphere Conservation*, 2: 1-9.

Syrotuck, W. G. (2000). *Scent and the scenting dog*. Second ed. New York, USA: Arner Publishing, Rome.

Wasser, S. K., Davenport, B., Ramage, E. R., Hunt, K. E., Parker, M., Clarke, C. & Stenhouse, G. (2004). Scat detection dogs in wildlife research and management: application to grizzly and black bears in the Yellowhead Ecosystem, Alberta, Canada. *Canadian Journal of Zoology-Revue Canadienne De Zoologie*, 82 (3): 475-492.