UNIVERSITY OF APPLIED SCIENCES VAN HALL LARENSTEIN

Camera trapping in Southeast Norway

A method to estimate the number of Eurasian lynx (Lynx lynx) family groups

Janek Schmidt & Jordi Janssen

14 September 2011

Leeuwarden

University of Applied Sciences VAN HALL LARENSTEIN PART OF WAGENINGEN UR

NINA Norsk institutt for naturforskning

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BSc. Thesis

Version: 3

September, 2011

Photo front page: Lynx family group © Norsk Institutt for Naturforskning.

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Preface

We would like to express our sincere gratitude's to everyone who supported us with our study and give a special acknowledgment to the people below.

First of all we would like to thank John Odden for his unconditional support, an amicable collaboration and serving us a hot cup of coffee. We also would like to give our thanks to John Linnell, for giving us the chance to contribute to the research and making us part of the project; as well as serving us a delicate dinner and offering us a warm bed in his house. Thank both of you for your confidence you placed in us. To our brilliant docents Berend van Wijk and Ans Meiners we would like to express our deep gratitude for guiding us through the whole project and being so patient with us.

For his support we would like to thank Kjartan Sjulstad, for arranging equipment and supporting us in finding suitable locations. Thanks to Vegard Årnes for his suggestions and contact support with the landowners and locals around Spydeberg, as well as the Christmas surprises. Special thanks also to Odd Skjellerut and Øistein Høgseth for their support in finding suitable camera locations. We would also kindly thank all the landowners and locals of Oslo, Akershus and Østfold, who supported us and let us put up some cameras on their properties; particularly Erik Mollatt and his wife Lise, who always invited us into their home and offered us a warm beverage and snacks. Cordial thanks to our landlord Ragnhild Helle, her husband and family for letting us reside in their lodge, fixing the frozen water pipe and present us with the most delicious piece of Eurasian elk we found during the five months.

Last, but by no means least, we are deeply grateful to our families and friends. Who were there for us and who supported us at any time.

For us it was the first time we ever came to Norway. What we found is not that easy to put into words and difficult to explain to someone who has never been to the land of the Vikings before. What seemed to be a very harsh and rough place at the first glance turned out to be one of the most beautiful and impressive countries we have ever been to. Stunning fjords, ravishing landscapes, marvellous forests, incredible fresh air and of course the most fascinating cats were not the only reasons for us to hopelessly become attached to this country. Barely arrived in Oslo, we perceived a phenomenon which lasted for the whole five months of our visit and will stay in our minds. A warm welcome was extended to us, everywhere we came, which made even the coldest and darkest winter we've ever experienced much more pleasant.

Leeuwarden, September 2011,

Janek Schmidt & Jordi Janssen

Summary

Eurasian lynx in Norway are monitored with methods based on unreplicated counts of family groups (adult females with dependent kittens) since 1996. Two methods are used to monitor lynx population size. However, variable and often poor snow cover caused that an alternative method needed to be found. Camera traps proved to be a successful method for felids including lynx and is used all over the world. However camera trapping is never tried in the past with the goal to monitor lynx family groups and no such method is tried at all in Scandinavia to monitor lynx populations.

In order to analyze whether camera traps are suitable to estimate the number of family groups, a study site south of Oslo, encompassing ~2500 km2, was chosen and included the counties Oslo, Akershus and Østfold.

Photographic material of family groups was obtained by the use of 94 cameras of three different brands: 50x Cuddeback Capture; 24x Scoutguard SG550V and 20x Reconyx HC600 Hyperfire on 56 locations. In total 28 cameras on 18 locations were successful in capturing photographic material of lynx. Of those 18, four were successful in obtaining photographic material of Eurasian lynx family groups. To separate observations of family groups distance rules based on distance and days between observations according to prey density were used. Only one distance between two observations was large enough to estimate that both were separate family groups.

Results from camera trapping were compared with the results of conventional snow-based methods.

Snow-based methods resulted in 10 observations of family groups within the study area and according to distance rules found three different family groups.

A camera test was conducted to see if all three types of trapping cameras are capable to capture more than one simulated lynx. In the test two cameras of each brand were used at height of 45 and 100 cm and three different angles were tested. The largest percentage of set-ups was not successful (78.8%), in 5.2% one simulated lynx was captured and in 16% more than one simulated lynx was captured. Cuddeback cameras missed lynx in 90.6% of set-ups but were the most successful camera in photographing one simulated lynx. Reconyx camera had the lowest percentage of missed simulated lynx with 66.9%. It successfully captured only one lynx in 3.1% but was successful in capturing both simulated lynx in 30%. Results of the Scoutguard were consistent with mean percentages of all camera types.

To see whether it is possible to predict suitable locations distances to landscape features were used. Logistic regression resulted in one single variable and five interactions that showed significance. A small positive effect is noticeable for the predictor variable: roads and the interaction Cliff by Streams had also a minimal positive effect. All other interactions had neither a positive nor a negative effect.

Because camera trapping for monitoring is usually used on an individual recognition base, this study investigated if it is still possible to identify different animals with the photos from this new camera set-up. It is not impossible with this set-up to use capture mark recapture however it is very difficult to compare pictures from different angles and distinguish individuals. Flash photography is desirable because a clear view of the spots is necessary. Including date, location and likelihood an attempt was made to identify individuals.

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1 Introduction

Alterations of landscapes, habitats, resources and conditions, primarily induced by a growing and expanding human population, give rise to an increasing necessity of knowledge on the status and distribution of terrestrial carnivore populations throughout the world (Schaller, 1996 cited in Gese, 2001). As a result of on-going destruction of suitable habitat in combination with public interest, the protection and conservation of carnivores becomes a crucial issue. Having reliable and precise data on the size and trend of those carnivore populations is of major importance for the development of management plans and policies, especially where carnivores are being harvested (Linnell et al. 1998; Gese, 2001). When methods are available, capable of producing precise data, the large amount of fieldwork required, high costs, and invasive methods like radio collaring, can limit the suitability and practicability. Various objectives may demand different methods, which aim for a variety of parameters, as presence/absence, distribution, population trend indices, minimum counts, and statistical estimates of population size, reproductive parameters and health/condition. (Linnell et al., 1998)

Against the background of non-existing international standard methods, Linnell et al. (1998) reviewed the methods for monitoring European large carnivores and categorized monitoring methods according to levels of fieldwork. The first category includes the cheapest methods of monitoring large carnivores, which do not require any original fieldwork, but are less precise and accurate. Questionnaires and public observations, damage reports, analyses of harvest data and habitat evaluation are the underlying methods included in this first category. The second category includes methods, which are based on some fieldwork, but restricted to production of population abundance indices or estimates, without individual recognition. The methodology used within this category is based on three approaches, presence/absence, abundance indexes and estimates of population density. The third and most accurate category aims on individual recognition, for instance capture-mark-recapture, and requires most fieldwork. In return it can provide a much greater precision and accuracy.

In Norway lynx are monitored with a methods based on unreplicated counts of family groups (female with dependent kitten(s)) since 1996. The National Large Predator Monitoring Program based at the Norwegian Institute for Nature Research (NINA) coordinates the monitoring since 2002.

Currently two methods of monitoring lynx are used in Norway (Andrén et al., 2002; Brøseth et al., 2010). The first method is based on observations of family groups (e.g. tracks, observations and dead kittens) and estimates the minimum number of family groups with the help of a set distance rules derived from telemetry (Linnell et al., 2007; Brøseth et al., 2010). Tracks of two or more individuals are assumed to be a family group when found outside the mating season. Hunters, game wardens and the public collect these tracks within the period of October 1st until February 28th. The Statens NaturOppsyn (SNO) is responsible for verifying observations made in the field (Brøseth et al, 2010). The second method concerns snow track surveys along a network of fixed transects of three kilometers long (n=1900) before the annual lynx-hunting season (Brøseth et al., 2010; Odden, 2010). Track surveys for lynx are carried out once annually, but can only be done in winter with suitable snow conditions and sufficient snow cover.

Besides excrements, prey remains and sometimes hair, lynx leave very few signs of presence except for footprints in the snow (Breitenmoser et al., 2006). Snow transects are widely used as a method of monitoring lynx in Scandinavia, but due to variable and often poor snow cover, alternative methods need to be found for areas without suitable snow conditions (Odden, 2010).

Working with camera traps proved to be a successful method for monitoring large carnivores and is successfully used for many felids including lynx (Silveira et al., 2003; Karanth & Nichols, 1998; Heilbrun et al., 2003). Especially in spotted cats, cameras can provide useful information even on individual level due to the high variation in the natural markings (Weaver et al., 2005). In Europe the use of cameras for monitoring lynx is currently restricted to Switzerland and Germany (Arx et al., 2004). Previous studies in for instance Germany showed the suitability of several types of trapping cameras for individual recognition of lynx and thus monitoring lynx population size (Weingarth, 2009). However no such method is tried in the past with the goal to monitor lynx family groups and no such method is tried at all in Scandinavia to monitor lynx populations.

A study area of ~2500 km2 southeast of Oslo was chosen to investigate if camera traps are a suitable tool for estimating the number of family groups. Also this study aimed to compare these results with the results of snow-based methods and investigate the advantages and disadvantages of three different types of camera traps, their placement strategies and the possibility to predict suitable locations for camera traps.

Research questions

1) Are camera traps suitable to estimate the number of family groups of Eurasian lynx (*Lynx lynx*)?
   a) What is the estimated number of lynx family groups within the study area obtained with camera traps?
   b) To what extent are these numbers consistent with the results of snow-based methods?

2) Which camera type and trapping method is most suitable for estimating the number of lynx family groups?
   a) What are the disadvantages and advantages of three models of camera traps and various placement strategies in detecting lynx family groups?
   b) Which factors determine the possibility to predict good locations to maximize the chances of photographing lynx?
3) To what extend is this camera set up suitable to conduct capture-recapture analysis?
   a) To what extent can individuals be recognized using this camera set-up?

2 Lynx management in Norway

2.1 Lynx management 1846-2004

The management of lynx populating Norway throughout history can be divided in three different periods. The first period from is called the "The Bounty years" (1846-1980) in which the policy goal was to exterminate large carnivores due to their predation on livestock and wild ungulates. A state bounty was introduced for lynx in 1846 and besides state bounties also local bounties (ranging up to 2-4 times higher than the state bounty) could be received for dead lynx. Within this period lynx could be hunted by everyone, anywhere and all year round except for the week around Christmas (24-31 December). However there were some restrictions on different methods (e.g. poison, killing traps) during several periods in the mid-20th century. (Linnell et al., 2010)

The second period is called the "The transition years" (1980-1994) and meant a lot of changes in lynx management. After the state bounty was removed, lynx hunting became the right of the landowners and state hunting licenses were required. In this period the new hunting law of 1982 changed all species from being huntable unless protected towards all species being protected unless a specific hunting season was mentioned. Still no quota were set on the number of lynx that could be culled. Lynx were temporarily protected throughout southern Norway due to public pressure on the Norwegian government after a hunter shot an entire family group in 1992. Although the killing of an adult female and her kittens was not illegal, the government responded to the public opinion (Riding, 1999 in Linnell et al. 2010). During those years the first debates in the Norwegian government took place on large carnivore management and outlined a first political statement of ensuring the survival of viable lynx populations besides limiting damage to livestock as much as possible. These two management goals are still the base of the current lynx policy. Also a state compensation for livestock was introduced in 1994. Although still no nationally coordinated or standardized attempt was made to investigate the populations or coordinate lynx hunting, the responsibility for population censuses and hunting quota was handed over to 18 Norwegian counties.

The third and last period mentioned by Linnell et al. (2010) is the so-called "Early Quota Hunting Years" (1994-2004). Within this period the number of counties with quota for lynx hunting increased till 12 out of 18 in 1997. In 1997 the Ministry of Environment introduced more precise goals for lynx management. Lynx populations were supposed to be kept roughly at the level of 1996-1997, when 65 family groups (female with dependent kittens) were counted in Norway. In the Western part of Norway and some coastal areas of Northern Norway the conflict with livestock was too high, so the lynx was excluded from these regions. Female sub quotas were introduced to stop hunting as soon as a specific number of females are killed although not the whole quota was filled. Besides female sub quota, quotas were assigned to areas with the highest level of conflicts with livestock. (Linnell et al., 2010)

2.2 Lynx management 2005 – to date

The current management of the lynx is still based on the two management goals set in the early 90's. In 2005 changes were made in the management of lynx. Management was handed over from 18 counties to 8 regional units. Within these units a committee consisting of elected representatives from the county has responsibility for setting quota. Each unit consists out of one large county, or two or more smaller counties. National population goals were set for each region by the central government to supply regional committees with a framework in which they can operate.

Figure 1 Map of the eight hunting regions (taken from Linnell et al., 2010)

Harvesting of large carnivores requires careful and detailed monitoring to ensure that quotas are sustainable (Linnell et al., 1998). Over- or underestimation of lynx population size could result in overharvesting the population or increase of conflicts with livestock. The current national population goal for lynx in Norway is 65 family groups, which consist of a female lynx with a respective number of kittens.

Quota can only be set when regions reached their population goals and a regional Large Carnivore Management Plan is required from each committee. Annual hunting quotas are based on monitoring results from the previous year because monitoring results are not available when quotas are set. Quotas can include a female sub-quota and residual quota. Female sub-quotas are used to stop the whole hunt when a certain number of females are killed before the whole quota is filled. Residual quotas are designed to provide flexibility in allocation between regions or when mainly males are killed during the hunting season and thus female sub quota is not filled.

Because of the fixed policy goal of 65 family groups it is very important to know in detail how many lynx are living currently in Norway. See Figure 2 for the number of family groups in Norway related to the management target of 65 family groups in the period of 1996 – 2011.

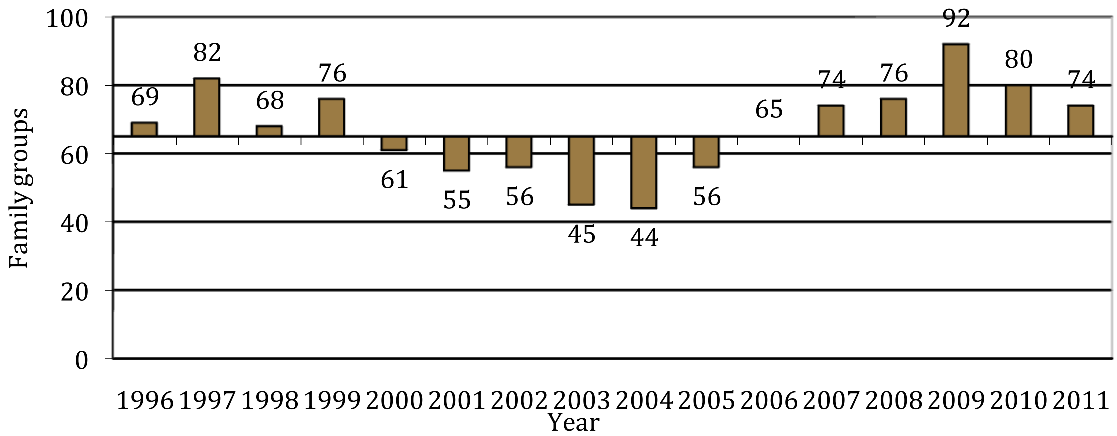

Figure 2 Estimated numbers of family groups living in Norway, related to the management target of 65, in the period 1996-2011

2.3 Hunting season 2011

The lynx population in Norway was estimated to be 70-74 lynx family groups or a total of 413-436 lynx prior to the hunting[1]- and reproductive[2] season of 2011 (Brøseth & Tovmo, 2011). Hunting quota for the 2011-hunting season were based on the monitoring results of 2010 and set at a total of 175 individuals or 58 females, respectively. This is a ~17% increase compared with 2010 when quota were set at 149 individuals with a female sub quota of 69 animals.

During the 2011 hunting season 137 individuals of which 46 adult females were killed. (Brøseth & Tovmo, 2011) Table 1 shows detailed hunting quota for 2011 for the eight regions and more details on the lynx shot during the hunting season. Within the study area, which is part of hunting region 4, a total of 4 lynx were killed during the hunting season, of which 2 adult females. One 3-year old female was shot on 05.02.2011, two 1-year old males were shot on 10.03.2011 and one 2-year old female was shot on 11.03.2011. For more detail on were lynx were killed in the study area see Figure 31

Table 1 Hunting quota for the 2011 hunting season specified per management region, type of quota (quota, female sub quota) and number of lynx killed during the hunting season. (RovviltPortalen, 2011)

Region	Quota	Female quota	Total killed	Females killed
Region 1: Vest-Norge	Quota-free		1	
Region 2: Sør-Norge	32	12	26	10
Region 3: Oppland	10	4	11	3
Region 4: Oslo/ Akershus/ Østfold	10	4	11	4
Region 5: Hedmark	9	4	9	3
Region 6: Midt-Norge	61	21	52	16
Region 7: Nordland	12	5	12	4
Region 8: Troms/ Finnmark	37	8	15	6
Total	175	58	137	46

[1] Hunting season starts on February 1st and will last until March 31st. (Linnell et al., 2010)
[2] Reproductive seasons starts between January and April.

3 Materials and Methods

3.1 Study area

The study area is located in southeast Norway (59°37’ N, 10°55’ W, Fig. 3), south of the Norwegian capital Oslo. The total study area encompasses ~2500 km2 and includes the counties Oslo, Akershus and Østfold. The study area is bordered by the city of Oslo in the north, by Lake Øyeren and river Glomma in the east, the city of Moss in the south and the Oslo fjord is bordering the west of the study area. Included in this study were the municipalities of Enebakk, Fet, Frogn, Vestby, Rælingen, Lørenskog and Oppegård (Akershus county), Moss, Spydeberg, Trøgstad, Våler, Sarpsborg, Skiptvet, Hobøl (Østfold county), and the municipality of Oslo. A 5x5 km grid was placed on the study area to obtain 81 grids in which cameras were placed (Figure 3). A grid size of 5x5 km is used instead of a $15km^2$ grid used in Southern Europe (Breitenmoser et al, 2006) because home ranges of Eurasian lynx in Scandinavia have found to be between two and four times the size as home ranges of Eurasian lynx in for instance the Swiss Jura mountains and Poland’s Bialowieza Forest (Linnell et al, 2001) (Appendix II shows a more detailed map of the study area)

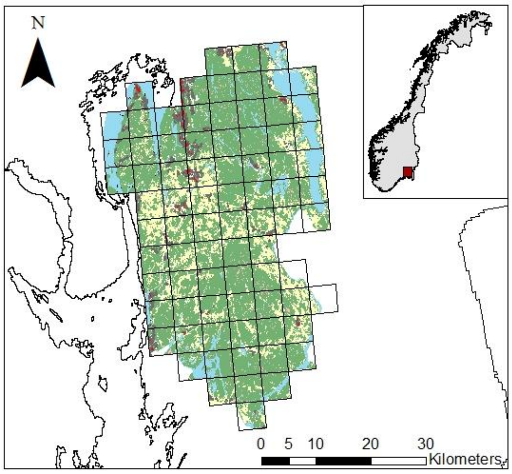

Figure 3 Map of the study area, showing the location within Norway and the study area in more detail with 5x5km grids.

The study area is characterized by a humid continental climate with hot summers and cold winters and an annual temperature range from 5.4 to 6.0 °C. The mean annual precipitation for the study area lies between 770 – 800 mm/year (Sauer et al., 2009). The area is part of the boreo-nemoral zone found in southern Norway (Moen et al., 1999). This zone is a transitional zone between the nemoral zone dominated by deciduous trees and the boreal zone, which is dominated by coniferous trees. The study area is characterized by forest, which encompasses about 60% of the whole study area. Common species in the study area are Norwegian spruce (*Pinus sylvestris*), Scots pine (*Picea abies*) and Birch (*Betula spp.*). Agriculture and water make up for respectively 16.3% and 15.5% of the whole study area. Urban areas make up 2.2% of the study area.

3.2 Methods

3.2.1 Family groups

To estimate the number of lynx reproductive units, camera traps were placed in the study area during the period of October 28th until March 5th. Observations collected during this period are least likely to contain bias (Linnell et al., 2007), as on one side at the end of February adult male lynx partner up with females and thus could be mistaken for family groups, or at the other hand juveniles may have already dispersed from the family group at the end of February.

Photographic material of family groups was obtained by the use of 94 cameras of three different brands: 50x Cuddeback Capture; 24x Scoutguard SG550V and 20x Reconyx HC600 Hyperfire (for all technical specifications see Appendix III).

Cuddeback cameras were selected because of their photo quality concerning individual pictures with an interval of 30 seconds between pictures when triggered. Scoutguard cameras were used on video mode recording 30-second videos with a 640x480 resolutions and set at high sensitivity and no delay between videos. The Reconyx were used as a control measure of the first two cameras due to their capability of taking photos in a near video mode speed. Reconyx cameras were set at high sensitivity, 5 pictures per trigger, 1 second delay between pictures, resolution of 1080 pixels and no delay between series.

To prevent theft or damage by people or animals, the cameras were attached to a tree with two or three 7 cm screws and locked with a protective case. Cameras were secured with CBS Cuddeback Bear Safe, SGSC Scoutguard Security and HFSE Hyperfire Security Enclosure Case and locks (Lince ®). All cameras were supplied with 2 GB SanDisk SD cards, 4 GB Mustang Flash SD cards or Kingston Technology 2 GB Micro SD Cards using an adapter. Photos were collected in the format .JPG and videos in the format .AVI.

The average height of a camera from the trail was set at 87.58±57 cm (min 35 – max 320 cm). This maximum height was caused by a slope in the trail and the only available tree was standing on a rock. Average angle from the camera in respect to the trail was 84°±10° (min 45° - max 94°). The average degree of the camera towards the trail was 33°± 25° (min 0°, max 90°). The average distance from camera to the trail where the lynx was expected to walk was 1.27 meters (range 0 - 8.2 meter) (see Figure 4).

Locations were chosen in cooperation with local residents and based on known trails of lynx derived from previous studies within the Scandlynx project and trails found during this study. When suitable locations are found a request for permission to place cameras was send to the landowner.

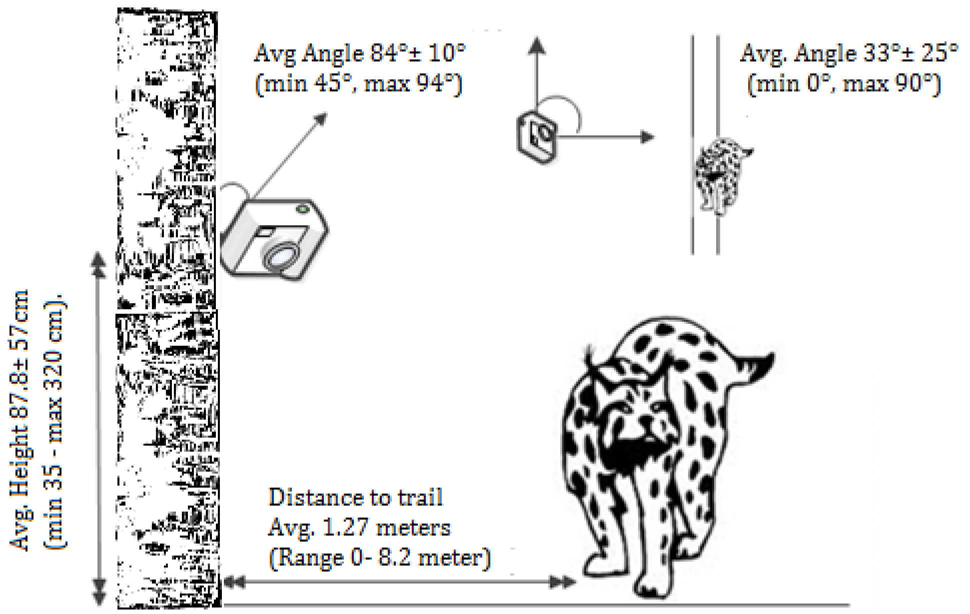

Figure 4 Camera trap placement during the field period. This figure displays the variation in angle of camera, distance to the trail, and height of the camera compared to the trail and degree of the trail. Image lynx ©Colormegood.com Image Tree bark ©Pearson Scott Foresman.

Synthetic Lynx urine (Fangstmann.no™) and Cat Nip Oil (Snareshop.com™) were used to attract lynx towards the area covered by the camera sensor to increase chances of capturing lynx in a rather open terrain. Moreover on locations with open terrain, artificial corridors towards the area covered by the camera sensor were created using branches. When snow cover was sufficient trampling created a trail of 50 m up and down the paths do direct the lynx towards the camera, with the location of the camera serving as center point. When a lynx track was found near the camera or when walking towards the camera, this track was followed several 100 meters until more than one set of tracks were visible showing two or more individuals or not. A Garmin GPSmap 60Cx with UTM UPS WGS84 coordinate system was used to document the coordinates of the tracks found.

Cameras were checked every 2 to 3 weeks. Photos obtained from the cameras received a unique ID consisting of the grid number, then the unique number of the camera, date of the photo and number of photo. Photos without any sign of animals were removed to conserve as much disk space as possible and photos containing persons were deleted immediately due to Norwegian privacy protection legislation. Photos were stored in a classifier sorted by camera number and date. A backup of all photos was made on two Western Digital My Passport Essential 500GB hard disks to prevent loss of data by human cause or technical failure.

All material containing pictures of videos of animals were uploaded onto an online Microsoft Access database resulting in a website http://viltkamera.nina.no for public viewing.

Distance rules for minimum counts of family groups developed by Linnell et al. (2007) were used to estimate the number of family groups in the study area. These distance rules were used to separate observations of family groups according to distance and time between observations. Linnell et al. (2007)

provided distance rules for three different eco-regions in Scandinavia, separated according to prey density. According to Linnell, the study area is classified as a medium-roe area with a density of 1-10 Roe deer per km^2. The maximum range of adult females was described at 24.9 km in a "Medium-Roe" area at 7 days. Assumed is that the same maximum range can be applied when the number of days between observations exceeds the 7 days.

3.2.2 Snow-based counts

Results from snow-based methods were obtained from the Statens NaturOppsyn (SNO), part of the Norwegian Directorate for Nature Management and responsible for conventional snow based monitoring methods of lynx in Norway.

3.2.3 Camera traps

To investigate the advantages and disadvantages of three different types of camera traps, their placement strategies and the possibility to predict suitable locations for camera traps several test were done.

Camera type and placement

To investigate if all three types of trapping cameras are capable to capture two of more lynx a test was conducted in which a mother lynx and kitten were simulated. Two cameras of all three brands were used at height 45 and 100cm. To simulate that two lynx walk by the camera at different distances from the camera and with different distance in between both animals, two spotted synthetic furs were used. Both furs were dragged along a line at different distances from the camera but also with different distances between both furs. The distances of 1m, 2m, 4m, and 6m were used as distances from the camera. The distances of 1m, 2m, 5m and 10m were used as distances between both simulated lynx. Cameras were placed in an angle of 90°, 67.5° and 45° of the simulated trail. Both simulated lynx were dragged in front of the camera at a speed of 4 km per hour. (See Appendix III) To see whether there is difference in success when the camera is pointed in an angle of the two runs were done when the camera was pointed in a 67,5° and 45° angle (See figure 4).

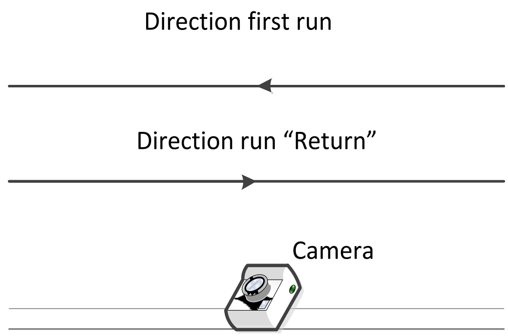

Figure 5 Direction of simulated lynx in first run and in "return" run.

In order to avoid bias from mixing up pictures the test was divided into "runs" according to the distance to camera, distance between simulated lynx and angle. A symbol (square, triangle, cross and blank) was placed on the simulated lynx were used to separate "runs" and time of each run was recorded. To separate the first and second lynx the symbol was tilted on the second simulated lynx.

In order to test the cameras the following settings were used:

Table 2 Settings used for three different types of trapping camera in a camera test with simulated lynx.

Reconyx H600 Hyperfire	Cuddeback Capture	Scoutguard SG550V
5 photos per series/trigger 1 second delay between photos No delay between series 1080 pixel resolution High sensitivity	30 second delay between photos	Video mode 640 x 480 pixel resolution 30 second video No delay between videos High sensitivity

Data on detect ability of several lynx for every camera were divided into three categories; both simulated lynx were missed by the camera (code: 0), the first simulated lynx or the last simulated lynx was missed by the camera (code: 0.5) and both simulated lynx captured by the camera (code: 1). This was documented for all distances to the camera, distances between simulated lynx, height differences for every camera and different angles.

Data obtained by the camera test was supplemented by data collected in the field. Data was collected on battery capacity, number of photos/videos, placement strategies and how often the batteries had to be changed. To measure relative camera performance and help improve maintenance protocols for future surveys (a detailed form can be found in Appendix IV (Adjusted from Weingarth, 2009)).

Remaining battery level was tested with a universal pocket Battery checker displaying battery level in three categories (e.g. Change batteries, low and good). For the camera settings the following data was documented: sensitivity, interval between pictures, duration of video and resolution. Regarding placement strategies four different variables were measured (distance towards a trail, angle towards the trail, degree towards the trail and height of a camera compared to the trail).

Microsoft Excel 2003 sheets were created to insert data obtained from the preliminary camera test. Sheets were created for each camera, respectively, with the following variables: different heights and distances from the cameras and between simulated lynx, as well as the different angles to the trail.

In order to investigate which camera type was most suitable in detecting one or two lynx the data obtained from the camera test was analysed using the crosstabs function under SPSS 19. A total of 160 different setups were tested under the same circumstances per camera type. Success was divided into capturing no lynx, capturing one lynx and capturing two lynx. Further analysis was done to determine which settings delivered the best results per camera type. Variables were "distance from the cameras", "distance between artificial lynx models", "degree pointing at the trail", "height" and "direction". Direction was only analysed for cases other than 90° those were thought to deliver the same results for the way there and the way back. Crosstabs were made for each camera type and setting for both, capturing one or two lynx. Analysis focused only on those events that were successful after the first test.

3.2.4 Prediction of suitable locations

In order to evaluate if it is possible to predict suitable locations, data on landscape features of all cameras were analyzed to see whether there is a difference between camera locations successful and unsuccessful in capturing lynx family groups.

Exact locations of the cameras were documented with a Garmin GPSmap 60Cx using the UTM UPS WGS84 coordinate system, together with camera types and dates.
ArcGIS Shape files containing data on the following features were used: Location of urban areas, roads, railroads, streams, open water and contour lines will be used. Roads include private roads, municipal roads and highways. Open water meant any surface water except for streams/rivers.
Data on camera GPS locations and landscape features was analyzed using ArcGIS Desktop10 (ESRI) using ET Geowizard Point distance tool from ET Spatial Techniques in order to evaluate whether it is possible to predict good locations to maximize the chance of capturing lynx on camera. The shortest straight-line distances, from camera locations to buildings, roads, railroads, streams, open water and contour lines were calculated. See Appendix XIII for detailed information on the used shape files.

Logistic regression analysis and SPSS 19 were used to calculate the effect of above standing variables on the chance of lynx evidence on the camera. The dichotomous variable lynx (presence or absence of lynx evidence on camera) was used as dependent variable and the variables: buildings, roads, rail road's, Open_Water and Contour were used as covariates. When multiple cameras were present on one location only one would be included in the dataset to prevent a bias in the results. Both cameras stationed on one "location" were only included both when there was a difference in coordinate or distances measured. If both cameras display the same distances but there is a difference in lynx detection only the camera with successful lynx detection is included. This because lynx were there but possible flaws in positioning the camera or technical failure caused the missed lynx. Distances above 10 km were rounded at 10 km. Method used for analysis was "Enter" instead of stepwise. All predictor variables were added including all possible interactions. Variables not significant were removed until the value of Nagelkerke Pseudo R^2 and Hosmer and Lemeshow displayed the best fit of the model and the highest classification prediction result was obtained.

3.2.5 Individual recognition

As described earlier, camera trapping is successfully used as a method for monitoring lynx (Silveira et al., 2003; Karanth & Nichols, 1998; Heilbrun et al., 2003). Especially in spotted cats, cameras can provide useful information even on individual level due to the high variation in the natural markings (Weaver et al., 2005), therefore obtaining high quality pictures of the fur patterns is crucial for individual recognition as well as conducting capture-recapture analysis. In contrast to simple presence/ absence studies, where it is sufficient to obtain pictures for species recognition, for individual recognition it is necessary to place the camera in such an angle, that the distinctive fur patterns are clearly visible and comparable (Silveira et al., 2003; Karanth & Nichols, 1998).

Due to the fact that capturing family groups and not individual recognition was the aim of the study, a set-up was chosen which was thought to be more successful in photographing several individuals at a time. Consequential, in contrast to ordinary camera trapping for individual recognition where cameras are placed at angles of more or less 90° to the trail, in this study cameras were placed pointing on the trail in angles between 90° and 22,5°, depending on the surroundings. Besides also pictures of one additional camera, placed at a lynx kill site and pictures taken of lynx shot within the border of the study area during the hunting season 2011 were taken into account.

In order to investigate if the footage obtained using this method is still suitable for recognizing individuals, all pictures and videos were examined. Subsequently distinctive patterns were marked and a short description of each subject on each photo or video was made. Thereupon clusters were made with footage that possibly contained the same individuals, based on individual recognition. As the footage often was not as good as required, also date of and distance between sightings and number of lynx captured was taken into account.

4 Results

General

A total of 94 cameras were placed in the field spread over 56 different locations with the first one placed on 28.10.2010 and the last one on 18.02.2011. Cameras were removed between 28.02.2011 and 05.03.2011. The total number of trapping days (24 hours) was 7199 with a mean of 79.11± 35.05 (range 3 -125) per camera, in addition, 9 cameras were used at two lynx kill sites for a total of 63 trapping days. At the first site 6 cameras were placed at two locations 25m apart around three killed roe deer with a total of 4 trapping days per camera. At the second kill site, 2 cameras were placed around one killed roe deer with a total of 3 trapping days per camera. Besides lynx, 9 other species were photographed or filmed. See Appendix X for more detail on the other species.

4.1 Family groups

Lynx were photographed or filmed 50 times at 18 different locations by 28 cameras including 1 temporary location at a lynx kill site. On 4 locations lynx family groups were photographed or filmed.
(See Figures 6/7)

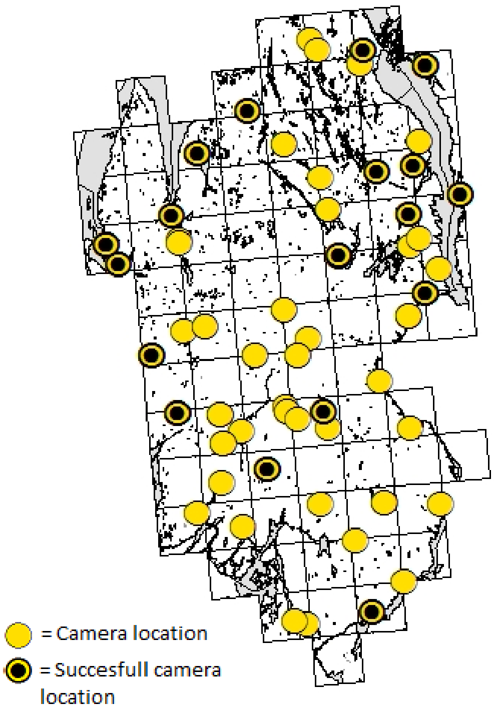

Figure 7 Map of all 54 camera locations of which 18 locations were successful in capturing lynx on camera

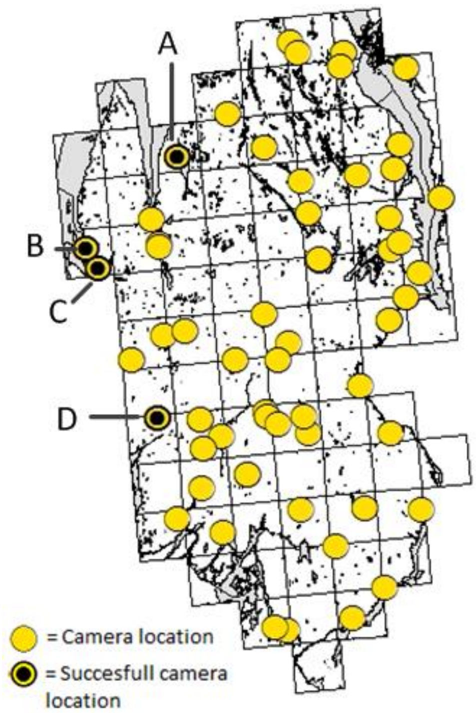

Figure 6 Map of all 54 camera locations of which 18 locations were successful in capturing lynx on camera

Table 3 Four different camera locations (See figure 5) with date of observation, number of lynx family groups

Location	Date of photo /video	Number of lynx observed
A	17-12-2010	2
B	26-11-2010	3
C	07-02-2011	2
D	15-01-2011	3

Table 4 Four different locations with number of days between observations above the diagonal and distance in km between observations under the diagonal

Locations	A	B	C	D
A		20	52	29
B	13.44		72	49
C	14.15	02.39		22
D	***27.11***	19.06	16.71	

Distances between almost all observations are shorter than the maximum range mentioned by Linnell et al. (2007). All observations exceed the maximum number of 7 days between observations also mentioned by Linnell et al. However the distance between A and D exceeds the 24.9 km. The distance between observation A and D is 27.11 km and therefore can be assumed that A and D are observations of two different family groups.

4.2 Snow-based counts

Snow-based Observations of family groups that were reported to Statens NaturOppsyn (SNO) resulted in 10 observations within the study area.

When Linnell's distance rules are applied, the distance between three locations is larger than the 24.9 km mentioned by Linnell et al. (2007) (A-B: 26.13 km, A-C: 36.21 km and B-C: 37.99 km). This suggests that there are 3 different family groups in the study area. The same result was published by Brøseth & Tovmo (2011). This means that the conventional snow-based counts resulted in 3 family groups (See figure 8)

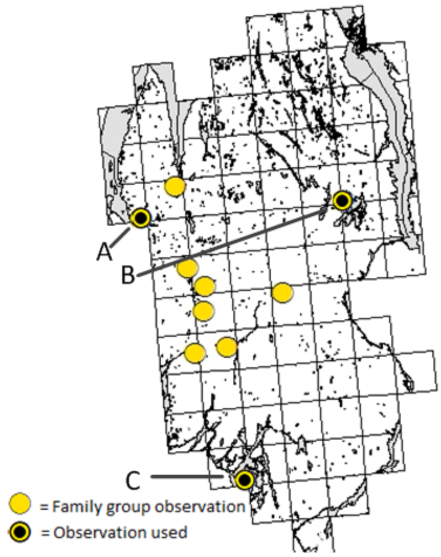

Figure 8 Map displaying 10 snow-based observations of family groups by SNO and 3 locations used for calculation of the number of family groups.

4.3 Camera trap suitability

4.3.1 Camera test

Cameras were tested in their ability to successfully capture lynx family groups.

The results from the camera test showed that only a small percentage of set-ups (n=160 per camera type, n=480) proved to be successful in capturing either one or both lynx. For all camera types, the largest percentage of 78.8% (n=378) of set-ups was not successful. However in 5.2% (n=25) of the cases one lynx was captured and in 16% (n=77) both could be photographed or filmed. Differences were found among the camera types as displayed in table 5. The Cuddeback missed the lynx in 90.6% (n=145), had the largest success rate for successfully capturing one lynx with 7.5% (n=12), but the smallest for both lynx with 1.9% (n=3). For the Reconyx the percentage of missed lynx was the smallest with 66.9% (n=107); it successfully captured one lynx in 3.1% (n=5) and showed the best performance for capturing both lynx with a success rate of 30.0% (n=48). The results of the Scoutguard however were almost consistent with the mean percentage of all camera types. It missed the lynx in 78.8%

(n=126), took videos in 5.0% (n=8) of one and in 16.3% (n=26) of both lynx. Figure 9 and 10 visualize the results for each camera type for capturing one or both lynx.

Table 5 Number and percentage of cases in which each camera type captured no lynx, one lynx or both lynx.

Camera type * Success

			camera_type			
			Cuddeback	Reconyx	Scoutguard	Total
Succes	caught_no_lynx	Count	145	107	126	378
		% within camera_type	90.6%	66.9%	78.8%	78.8%
	caught_one_lynx	Count	12	5	8	25
		% within camera_type	7.5%	3.1%	5.0%	5.2%
	caught_both_lynx	Count	3	48	26	77
		% within camera_type	1.9%	30.0%	16.3%	16.0%
Total		Count	160	160	160	480
		% within camera_type	100.0%	100.0%	100.0%	100.0%

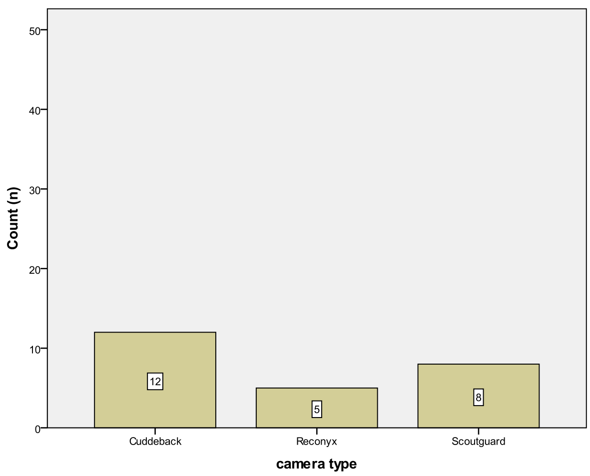

Figure 9 Number of cases in which the different camera types Cuddeback, Reconyx or Scoutguard successfully captured one lynx with a total of n=160 per camera type.

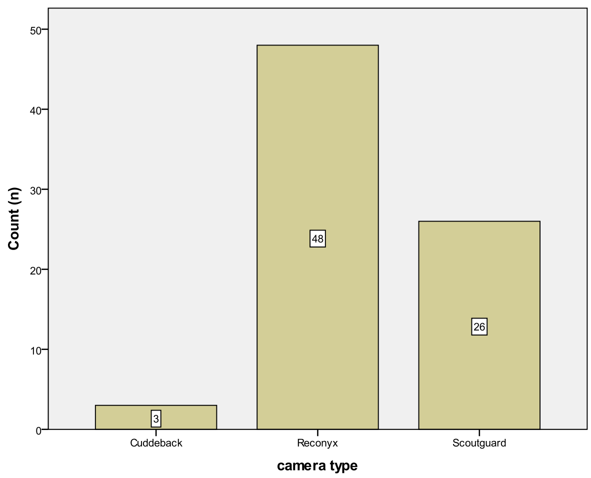

Figure 10 Number of cases in which the different camera types Cuddeback, Reconyx or Scoutguard successfully captured both lynx with a total of n=160 per camera type.

For all cases in which one lynx was captured, the findings for each camera type and settings are displayed in table 5. Especially concerning height all camera types showed consistent results and performed best at 0.45 meters. The Cuddeback took all pictures at an angle of 90°, whereas the Reconyx and Scoutguard delivered the best results at 67.5°. Results for distance from the cameras and distance between lynx were more homogeneously distributed and do not seem to be that important. As mentioned earlier for direction only those cases were taken into account where a lynx was captured at an angle others than 90°. The Cuddeback was only able to take pictures at 90° and therefore is not from interest here. The Reconyx however took most pictures on the way there, whereas the Scoutguard performed better on the way back.

The findings for each camera type and settings for cases in which both lynx were captured are displayed in Appendix VII. Again all camera types showed the best performance at a height of 0.45 meters. As for a single lynx the Cuddback requires an angle of 90°. Also the Scoutguard showed delivered better results at 90°, whereas in this case for the Reconyx the angle does not seem to be important. Almost no differences in performance could be found for distance between the individuals for the Reconyx and the Scoutguard. The Cuddeback however was only able to capture both lynx at the largest distance between both animals. The results for distance from the cameras were predominantly homogeneously distributed and do not seem to be that important. For direction the Cuddeback again was only able to take pictures at 90° and therefore is not from interest here. Also for both other camera types the direction does not seem to be from great significance for the Reconyx and Scoutguard.

4.4 Battery level

One camera (Scoutguard) was found with empty batteries during the field period. However this camera was removed from the field due to technical failure when found with empty batteries. When only taking into account cameras that were not subject to technical failure, cameras were checked in total 329 times (N=87) on average 3,75 ± 1,90 times ranging from 1 time to 9 times during the field period depending on when they were placed. Cameras were checked on average every 21.90 ± 9.96 days (range 6-66).

4.5 Drawbacks

4.5.1 Missed trapping nights

Cameras missed trapping nights due to various causes. Table 6 displays the different causes and the number of cameras specified per brand that were affected by each problem.

Three cameras had no trapping nights at all due with various causes. Trapping nights (n=130) were missed due to a full SD card as result of technical problems by 9 cameras. Three cameras of the Scoutguard SG550 model took non-stop videos and stopped when the SD card was full. Fourteen trapping nights were missed due to empty batteries. However this was only 1 camera that had this problem. Snow coverage resulted in 14 missed trapping nights. Extensive amounts of snow covered the camera and made it impossible to take pictures. This was the case for in total 7 cameras of all three brands.

A total 953 photos and 100 videos were obtained.

Table 6 Total numbers of cameras (C) that missed trapping nights (N) specified per brand displayed for 3 causes.

Cause	N	C (Reconyx)	C (Scoutguard)	C (Cuddeback)	C
Snow covered	14	2	2	3	7
Empty batteries	14	0	1	0	1
Technical failure	130	1	5	3	9
Total missed nights	158	3	8	6	17

4.5.2 Avoidance behavior

On three locations lynx avoided the location where the camera was placed after being photographed. On all three locations lynx were photographed with Cuddeback cameras from the front. The effect of the flash was photographed by a Reconyx and photos show a scare reaction in the lynx a second after the flash.

Figure 11 The moment at which a single lynx was photographed by Cuddeback with a visible flash. Photographed by Reconyx with IR light.

Figure 12 Reaction of the lynx on the visible flash photographed a second after figure 9.

4.5.3 Condensation

Condensation on the glass in front of the lens was found at 14 of 30 Cuddeback cameras. This did not occur with Reconyx or Scoutguard. Condensation resulted in 22 photos with decreased visibility or no visibility at all. Figure 13 and 14 show the effect of a completely covered lens by condense and a partially covered lens when a lynx is photographed.

Figure 14 Single lynx photographed with the lens partially covered by condense.

Figure 13 Single lynx photographed with the lens completely covered by condense.

4.5.4 Overexposure

In the field both the Cuddeback capture and Scoutguard showed problems with overexposure. Overexposure was generated when animals walked too close to the camera, resulting in completely or partially white pictures from the Cuddeback (Figure 16) Also the strong reflection of the flash in snow resulted in overexposed photos(See figure 15).

Figure 15 Overexposure of a lynx due to reflection of the flash in snow by Cuddeback Capture

The infrared beam from the Scoutguard was too strong when animals came too close, resulting in loss of detail. As can be seen in figure 16 the animal turns white when it walks through the beam and no detail is visible.

Figure 17 Overexposure of the lynx by Cuddeback camera caused by not enough distance between camera and animal.

Figure 16 Over exposure of lynx by infrared beam from Scoutguard caused by not enough distance between animal and camera.

4.5.5 Branches

Branches hanging in front of the camera after heavy snowfall resulted in branches that blocked the sensor of the camera (Figure 18) and that the branches absorbed all the light of the flash produced by the Cuddeback Capture (Figure 19).

Figure 18 Branches blocking the trail and causing deprive of sight on the trail.

Figure 19 Branches absorbing all the light of the visible flash from Cuddeback cameras.

4.5.6 Missed or almost missed lynx

The slow trigger time of Scoutguard (1.2 seconds) resulted in several videos with only half of the lynx on the video as can be seen in fig. 20. This figure shows the first frame when the Scoutguard is triggered containing the date, time and duration of the video. However the frame is only displaying a very small part of the lynx due to a slow trigger time. Reconyx (<0.33 sec) and Cuddeback (0.24 sec) did not show this problem.

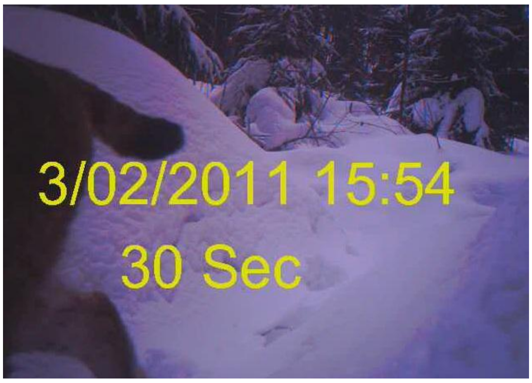

Figure 20 Scoutguard that almost missed lynx due to a slow trigger time (1,2s).

Eight cameras missed lynx ten times, of which one camera missed a family group and two cameras missed lynx two times. Reconyx missed lynx one time, Cuddeback three times and Scoutguard missed lynx five times. Only taking into account locations where tracks of lynx were found in front of the camera or when a second camera confirmed lynx walking by the camera.

Another problem encountered was the narrow sensor of both Scoutguard and Cuddeback. At both the Cuddeback and Scoutguard, the sensor is placed in the middle. This resulted in at least two known occasions where lynx tracks were present in front of the camera but just out of reach of the sensor. Reconyx on the other hand didn't have this problem due to a different sensor system.

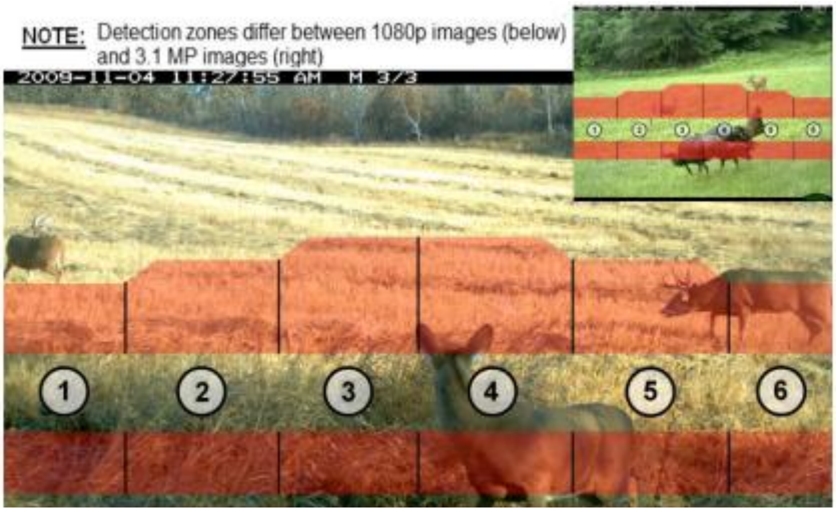

Figure 21 Sensor system of Reconyx. With two detection bands and 6 detection zones. Triggered when something warmer or colder than surrounding temperature transfers at least in and out of one of the detection band in or out of at least one detection zone. (Reconxy, 2010)

4.6 Prediction of suitable locations

Logistic regression analysis was used to predict the probability of a camera trap capturing a lynx. Six initial predictor variables were distances between camera and the nearest building, roads, railroad, streams, open water and presence of a steep cliff. The final model included 5 of the initial variables and 14 interactions. Out of 61 observations 70.5 % (n=43) were negative for lynx evidence and 29.5% (n=18) were positive for lynx evidence. A test of the full model versus the model with the constant only was statistically significant $\chi 2$ (14, N=61 = 34.70, p .002) The model was able to correctly classify 95.3% of the cameras without lynx evidence and 72.2% of cameras with lynx evidence, with an overall success rate of 88.6%.

Table 7 Multicollinearity test for variables used in Logistic regression analysis with lynx as a dependent variable.

Multicollinearity test

		Collinearity Statistics	
Model		Tolerance	VIF
1	Streams	,941	1,063
	Open_water	,867	1,154
	Railroad	,967	1,034
	Roads	,871	1,148
	Cliff	,973	1,028
	Buildings	,874	1,144

Multicollinearity test showed no serious collinearity problems between the six original predictor variables as can be seen in table 5.

Table 6 shows the logistic regression coefficient, Wald Test and significance value for each of the predictor variables. At a 0.05 criterion for statistical significance the initial predictor variable roads was found significant (p 0.045) and five interactions. (See Appendix IX for the full output)

Table 8 Logistic regression coefficient, Wald Test and significance value for one predictor value and five interactions.

Variables in the Equation

							95% C.I.for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Roads	,036	,018	4,009	1	,045	1,037	1,001	1,074
Buildings by Roads	,000	,000	8,212	1	,004	1,000	1,000	1,000
Buildings by Streams	,000	,000	5,893	1	,015	1,000	1,000	1,000
Railroad by Streams	,000	,000	8,323	1	,004	1,000	1,000	1,000
Open_water by Streams	,000	,000	4,702	1	,030	1,000	1,000	1,000
Cliff(1) by Streams	,025	,009	8,624	1	,003	1,026	1,009	1,043
Constant	-1,123	2,303	,238	1	,626	,325		

Note R^2 =.617 (Nagelkerke), .434 (Cox & Snell), Model $\chi 2$ (14, N=61 = 34.70, p .002)

4.7 Individual recognition

After closely examining the footage two lynx family groups consisting of the same individuals were found, as well as five solitary lynx. A few pictures of lynx could not be recognized or clustered with other pictures. A detailed table with coordinates and dates can be found in appendix XII. Figure 22 shows coloured clusters indicating which lynx sightings might be from the same individuals. Figure 23 – 30 show each one picture of the individuals in question. Photographs and screenshots of the videos of each sighting can be found in appendix XII or online at http://viltkamera.nina.no.

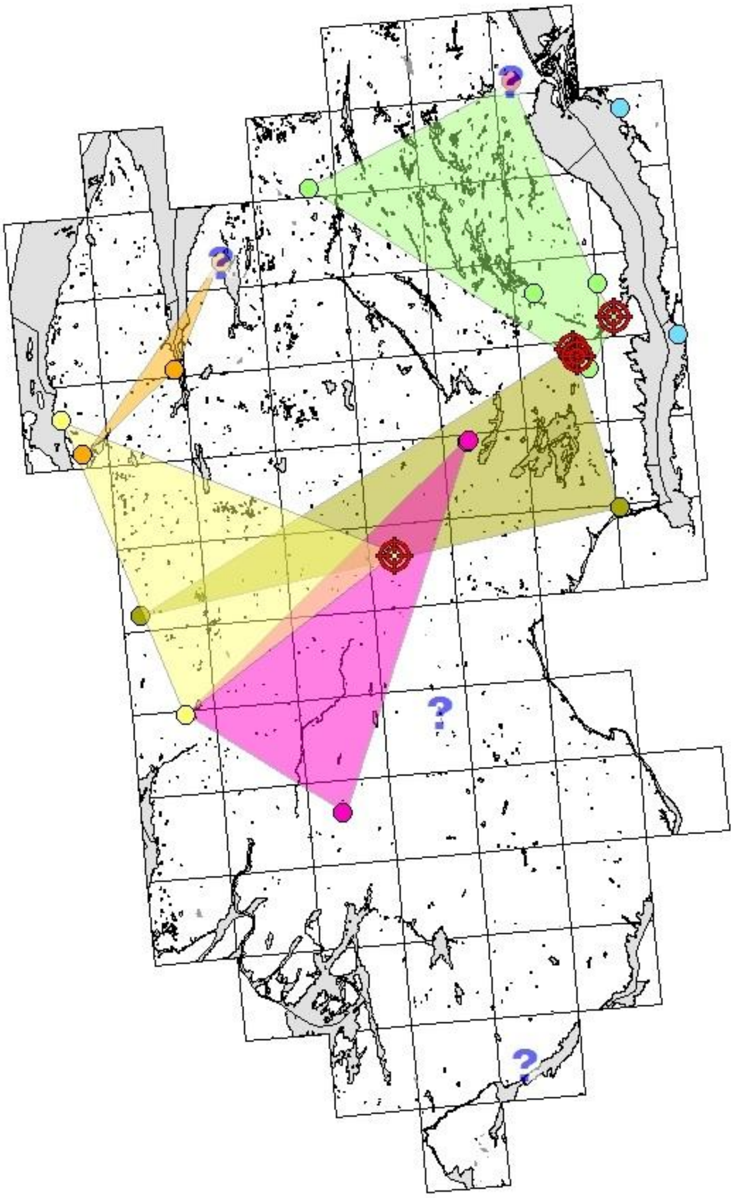

Figure 22 Map of the study area with a 5x5 km grid showing the different family groups (orange and yellow) and individuals, as well as locations of sightings of unknown (?) and shot lynx (⊕). For each cluster with at least three sightings from different locations a cluster area was marked to increase readability of the figure.

Figure 23 The first family group consisting of mother with two associated kittens was captured twice; once in grid 27 and once in grid 54. More pictures of this family group can be found in appendix XII under “yellow”. The female shot on 5th of February in grid 44 could be the mother of this family group

Figure 24 The second family group consisting of mother with one kitten was captured in grid 12 and another time in grid 27. A female was captured in grid 28 by a Cuddeback. It is possible that this is the mother of this family group and that the kittens were missed. See appendix XII under “orange” for more pictures of this group.

Figure 25 This solitary individual was captured several times in grid 9, twice in grid 34 and once in grid 39. For more footage of this individual see appendix XII under “blue”.

Figure 26 The second solitary individual was captured in grid 3, 5, 25, two times in grid 33 and on three different times in grid 24. It could be the same individuals as the one of the two lynx shot in Enebakk on 10th of March. For footage of the other sightings see appendix XII under "green".

Figure 27 Photos and videos of this third solitary lynx were made in grid 42 on two dates and in grid 48 three different times. This lynx looks similar to the one shot in Enebakk on 11th of March. See appendix XII, "olive", for more footage.

Figure 28 The fourth solitary lynx was captured twice in grid 39, three times in grid 54 and three times in See appendix XII, "pink", for more footage.

Figure 29 This last individual classified as "red" was photographed only once in grid 3. It was presumable shot on 10th of March in Enebakk. The other photos of this lynx can be found in appendix XII under "red".

Figure 30 It wasn't possible to cluster all individuals. Those photos were taken in grid 3, 12, 56 and 80. For the other unknown individuals see appendix XII under unknown.

5 Discussion

Hunting season

During this study the annual lynx hunting season took place. Within the timeframe of this study one adult female lynx was shot within the research area on 05-02-2011. The lynx was shot in an area where two cameras were placed just 13 days before the hunting season. Cameras were placed in that area because snow tracks of several individuals were found in the local quarry. Presence of a family group in the quarry was confirmed by SNO the day after, based on photo documentation. It is possible that the adult female shot in Haslerud-Elvestad was the female of that family group. This might have caused that no pictures or videos have been made of the family group on this location (See Figure 31). However photo documentation of the shot female did not provide conclusive evidence that this was the female of one of the two found family groups. Although the female looks similar as the one photographed in grid 27 and grid 54 with two kittens. But other photo documentation was not suitable to give certainty on the identity of the shot animal.

Family groups

Although snow-based methods found one family group more, camera traps proved to be suitable to capture lynx family groups and thus estimate the number of family groups. The group that was missed by the camera traps is based on an observation found at the southern border of the study area and might only partially live in the study area.

Cameras

Due to privacy legislation in Norway it was not possible to place cameras on locations where the chance was high to photograph people. Therefore locations had to be found were lynx are present but also suitable for camera trapping and with a small chance of photographing people. However lynx are known to use often human roads and trails to save energy and travel faster (Breitenmoser & Breitenmoser-Würsten, 2008). The heavy snowfall during the winter of 2010-2011 made it more likely for the lynx to use human roads/trails instead of their normal routes. At least on one occasion the lynx followed the inevitable trail made by the authors while checking the camera instead of walk towards the camera. To avoid this, a trail was made by them by trampling the snow for 50 meters on both sides of the camera, but not all locations were suitable for this measure. Heavy snowfall also resulted in several cameras being covered with snow and thus in missed trapping nights. However without the considerable amount of snow it would have been a lot harder to place cameras at the right location. After snowfall cameras could be adjusted according to the tracks found. However regular snowfall, and a time of 2-3 weeks between checking the cameras it was often hard to see if a lynx was missed.

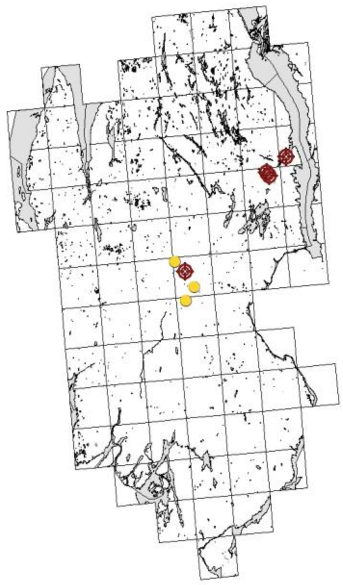

Figure 31 Locations of shot lynx (⊕)within the study area (grid size 5x5 km) and three camera locations close to the adult female shot during the hunting

The sometimes long process of the search for a location and obtain permission to put up the camera could last for several weeks. In the case of the missed family group, which is mentioned in paragraph "Hunting season", was the family group found on 17.12.2010 and confirmed the day after. However permission to place cameras was not obtained until 23.01.2011 with the adult female shot on 05-02-2011. This might have also resulted in missed lynx on other locations during this period.

Technical problems resulted in missed trapping nights as can be read in the results. This was mainly due to the problems with Scoutguard cameras. Often no response was received of the camera or non-stop videos were recorded without any trigger until the SD card was full. Also three Cuddeback cameras showed technical problems and didn't respond any more. This resulted in 4 locations were lynx were missed. On all location were lynx were missed due to technical problems, lynx were photographed in a later stadium of the field study. But in case a lynx only visits a location once this might result in a bias in the data.

Camera test

Each of the 160 runs with different settings was only performed once, resulting in a small sample size of only 1 per setting. This was due to limited time and restricted access to the test room. For conducting a statistical analysis the sample size per settings is too small. Furthermore due to the limited amount of cameras available for conducting this test, each setting was tested with one camera per type only. It might be the case that there are differences in performance among cameras of the same type. Therefore performance results might be only valid for the one camera used in the test and not universally for all cameras of this type.

Prediction of suitable locations

Wald Chi-Square is used to test the unique contribution of each predictor, in the context of the other predictors. However Wald Chi-Square is criticized for a lack of power (Wuensch, 2009).

Hosmer and Lemeshow is normally used as a Good of Fit statistic to measure how well the model fits the data. However Hosmer and Lemeshow recommend not using this Good of Fit statistic with a sample size smaller than 400 (Hosmer and Lemeshow, 2000) Instead usage of a Pseudo R2 like Cox & Snell or Nagelkerke is recommended. Nagelkerke modified Cox & Snel Pseudo R2 so 1.0 became a possible value for R^2.

A large sample size is recommended of at least 10 per variable. Excluding the interactions this sample size is met. However including the interactions the sample size is not large enough.

Individual recognition

When comparing this camera set-up to a conventional one for capture-recapture analysis like used by Weingarth (2009) the disadvantages are obvious. In contrast to such a set-up it was hard to get clear pictures from the same angle of all both sides of all individuals. Consequently, because of this heterogeneity it becomes very hard to compare all the pictures. Moreover for individual recognition monochrome photos are not that suitable; it becomes harder to recognize distinctive fur patters and distinguish between the individuals.

Another crucial problem which is also disadvantageous for individual recognition is, but cannot be solved by changing the camera set-up is that lynx in Norway are not that spotted as elsewhere, like lynx found in the Bavarian National Park in Germany. In this study only the one individual classified as "red" (Figure 29) was well marked with big dark spots. All the others lynx had few to almost no spots.

Consequently not only the pictures, but also date, time, proximity and likelihood were taken into account; all from a subjective point of view. Therefore it has to be mentioned that the findings should not be seen as proven facts, but more as an attempt.

6 Conclusions

Family groups

Based on the distance rules provided by Linnell et al. (2007) and four observation made by camera traps, it can be concluded that two family groups are present in the study area. The distance between two observations was large enough to exceed the maximum of 24.9 km mentioned by Linnell et al.. Conventional snow-based methods resulted in 10 lynx family group observations. Based on the same distance rules this would mean that three family groups are present within the study area. Although not the same number of family groups is observed by camera traps as was observed with conventional methods, it can be concluded that camera traps to be suitable to capture lynx family groups and thus estimate the number of family groups.

Camera traps

Camera test

The results showed that of the three camera types the Reconyx was the best choice for successfully capturing family groups. To obtain the best result, each camera should be placed at the preferable height of 45 centimetres. It was not surprising that performance in all cases was best at 0.45 meters, as this is consistent with Karanth and Nichols (1998) suggestion to place cameras at knee height when working with camera traps and felids. An interesting finding however was, that none of the cameras took any pictures when placed at an angle of 45°. However for capturing family groups with Reconyx cameras, there was almost no difference in success when placed at 67.5° or 90°. Both other camera types, Cuddeback and Scoutguard, performed best when placed at a right angle to the trail, as commonly used in ordinary individual recognition camera trapping set-ups (Karanth & Nichols, 1998).

Observed problems

Several problems were encountered during the field period. Out of 17 cameras that missed trapping days, 52% were Scoutguard cameras. The most common problem encountered with Scoutguard cameras was technical failure. Other problems that resulted in loss of trapping days were snow coverage and empty batteries. Reconyx (13%) and Cuddeback (35%) contributed less to cameras that missed trapping days. Out 94 cameras that had a total of 7199 trapping days only 1 camera (Scoutguard) ran out of batteries. With an average of 21.90 ± 9.96 days between checks, cameras should have no problem to stand in the field for at least 3-5 weeks. Although this will also depend on the location and frequency of other animals in front of the camera. In the winter this will be less of a problem due to hibernation activities of other species.

Cuddeback

Disadvantages found during the camera test were that Cuddeback cameras were too slow to photograph more than one lynx. However it performed well with only one lynx. Condensation on the lens was a big problem with Cuddeback cameras. Due to a different build, it is possible that condensation builds up on the lens resulting in partially or completely unrecognizable pictures. The visible flash of

Cuddeback cameras resulted in several problems, avoidance behavior was documented at three locations. On all three locations lynx were photographed with Cuddeback at which lynx tracks were found at a later date where the lynx walked around the camera. A scare reaction was photographed with IR light by Reconyx of a lynx that was photographed by Cuddeback. The second problem encountered with Cuddeback cameras due to visible flash was overexposure of photos. This resulted in poorly recognizable photos with little or no detail. Heavy snow resulted in branches that fell in front of the lens, resulting in reduced sight for the camera or overexposure of the branch resulting in reduced visibility of the animal.

Reconyx

Reconyx cameras showed the least problems during the study. The only disadvantage that could be found is poor quality of pictures for individual recognition. Photos made during the night are often not good enough to be used for individual recognition.

Scoutguard

Scoutguard cameras showed the most problems during the field period. The camera has the longest response time of all three brands. This resulted in partially or completely missed lynx. The strength of the infrared beam of the Scoutguard made it hard to see any detail. However, 5 out of 30 Scoutguard showed technical problems which resulted in occasions where lynx were missed.

Prediction of locations

When interpreting the results of the logistical regression analysis can be seen that the model fits the data reasonable. Both pseudo R^2 (Cox & Snell .434 and, Nagelkerke .617) give a slightly different result. According to the Nagelkerke pseudo R^2 the model fits a little bit better, while the Cox & Snell R^2 is not that good. Of all 6 single predictor variables and 14 interactions only 1 single variable and 5 interactions are statistically significant. A small positive effect is noticeable for the predictor variable roads (Exp(B) 1.037). The interaction Cliff (1) by Streams had also a minimal positive effect (Exp (B) 1.026. All other interactions had neither a positive nor a negative effect. However in this analysis only a few variables have been taken into account. Better view of the possibility to predict camera locations can be gained by adding more variables and a larger sample size.

Individual recognition

An ordinary camera set-up for capture-recapture analysis works way better when looking at individual recognition. It isn't impossible with this set-up either, but it is very difficult to compare pictures and distinguish between individuals, where the subjects are photographed from different angles. Moreover when it comes to individual recognition coloured photographs are clearly desirable. The flash photograph made by Cuddeback is a clear and high quality color picture. The good quality of the picture makes it possible to get a good look at the spots for individual recognition.

In many cases it was almost impossible to give a proven estimation of which individuals could be the same. This was only a subjective test if it is possible to recognize individuals with this set-up.

7 Recommendations

As can be read in the conclusion of this report, camera trapping certainly has the potential to be used for monitoring lynx family groups. However there are certain aspects to keep in mind. The choice of locations remains important. Because of the sessile character of the cameras vision, choice of location and placement will be an important factor for this method to succeed.

- Tests show that Reconyx is the best camera to photograph family groups. Therefore it is recommended to use Reconyx for monitoring family groups. However individual recognition is more difficult with Reconyx instead of Cuddeback cameras. A combination of Reconyx (for family groups) and Cuddeback (individual recognition) would obtain the best results.

- Preliminary testing showed that the success in photographing more than one lynx was the highest at a height of 45 cm and a 90° angle (perpendicular) towards the trail.

- The use of anti-fog spray is recommended with the use of Cuddeback cameras. With heavy rain/snowfall condensation might be visible in front of the lens resulting in poorly recognizable images.

- Use weather protection to prevent snow building up on top of the camera.

- If possible remove or tie up branches or vegetation to prevent them from blocking the sight of the camera.

- Use scents to attract lynx towards the camera. Personal experience showed that Catnip Oil worked better than synthetic lynx urine.

- Build natural barriers to guide lynx in front of the camera and to prevent them from walking behind the camera.

- With heavy snowfall try to get permission to use (private) roads or hiking trails whenever possible. This because lynx will more often use them with snow than their regular routes.

- All successful locations of last year resulted in at least one sighting of lynx. It is recommended to use these locations again in a follow up study. Besides it is recommended to use also the location near Hobøl Quarry where tracks of a family groups were found (location 52_1) (See Figure 32).

- To obtain a better dispersion of camera locations throughout the area it is recommended to find suitable locations in the areas displayed in Figure 32.

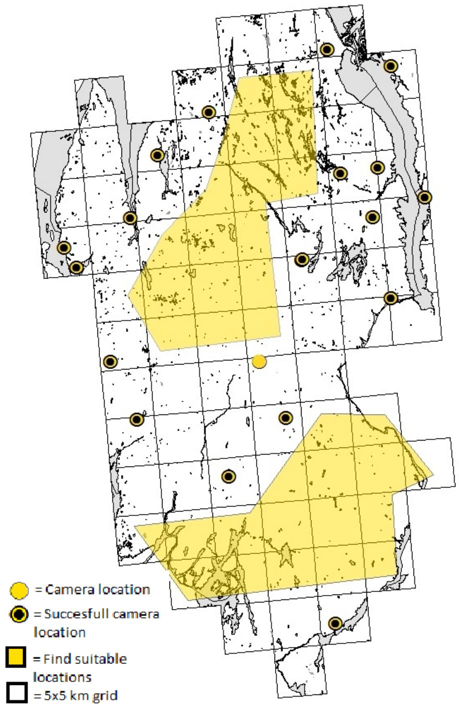

Figure 32 Map displaying recommended camera locations and two areas where suitable locations have to be found.

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8 Appendix I Eurasian Lynx

Study species

General biology

The Scandinavian Eurasian lynx (*Lynx lynx*)

Taxonomy

Order:	Carnivora
Superfamily:	Feloidea
Family:	Felidae
Subfamily:	Felinae
Genus:	Lynx
Species:	Eurasian lynx (*Lynx lynx*)
Subspecies:	Lynx lynx lynx
Population:	Scandinavia
IUCN status	Least Concern (Breitenmoser et al., 2008)

Figure 33 Eurasian Lynx (*Lynx lynx*)

Morphology

The Eurasian lynx is the biggest member of the family Felidae native to Europe. Of the four members of the genus Lynx that populate earth up today, it is the biggest in shape and size. The specimens populating Norway belong to the nominotypical subspecies Lynx lynx lynx and the Scandinavian population of the Eurasian lynx, which are of a rather intermediate size. Average values for acromion height of Eurasian lynxes are 55 centimeters for males and 53 centimeters for females, respectively; the average weight of a male Eurasian lynx is 24 kilos and 17 kilos for females. Concerning fur patterns, there are notable differences and similarities among and within populations; fur patterns of the Scandinavian populations however are rather unincisive, varying from small dark brownish spots in most specimens to either larger or no spots in about 20% of the population. (Breitenmoser & Breitenmoser-Würsten, 2008)

Geographic range, home range and population size

The Eurasian lynx is native to the temperate forest of the Northern hemisphere, stretching from the Atlantic to the Pacific coast. Members of the subspecies Lynx lynx lynx however inhabit most parts of Scandinavia, Finland, White Russia, Russia, Ural Mountains and parts of Siberia. (Breitenmoser & Breitenmoser-Würsten, 2008) The Scandinavian population is restricted to Norway, Sweden and Finland, with Norwegian specimens having the largest home ranges for the species, with averages of 600 to 1400 km^2 for resident males and 300 to 800km^2 for resident females (Linnell et al., 2001). More recent data showed that home ranges in the counties Troms and Finnmark in north Norway are even larger, in fact the largest ever found for lynx, with 415 to 2268 km^2 for females and 1467 to 3920 km^2 for males. However, the average winter home ranges for females within the study area are comparably small, encompassing an area of averagely 266 km^2 (Linnell et al., 2007). A strong preference of Norwegian lynxes for lowland forest types was recognized especially in central Norway, (May et al., 2008) and the avoidance of higher attitudes, due to less abundance of prey species (Basille, 2008; Basille et al., 2009; Melis et al, 2009).. A recent study by the Norwegian Institute for Nature Research measured the Norwegian lynx at a level of 75 – 80 family groups and a total of 441-470 specimens before the hunting season of 2010 (Brøseth et al, 2010).

Reproduction

The Eurasian lynxes are solitary living animals (Breitenmoser & Breitenmoser Würsten, 2008, p.17), which only pair up to mate. Indications were found, that lynxes, unlike most felids, are monoseasonal breeders (Jewgenow et al., 2006). Variations in the mating period of free ranging Eurasian lynxes caused by regional conditions, years and individuals were recognized (Henrisken et al., 2005). In general mating takes place between January and April, with the highest rate of ovulation in February and March for females and the highest serum testosterone concentration, as well as highest testis sizes for males, reported to be in March (Jewgenow et al., 2006). Male lynx reach sexual maturity after 15 month, making them capable of producing the first offspring in the mating period of their second year (Axner et al. 2009); females are reported to be fully sexual mature after two years (Kvam, 1991; Lindemann, 1955, Stehlik, 2000). After a gestation period of about 70 days females give birth. The an average litter size counts 2 cubs of equal sex ratio, with a reduced litter size for young females of 2 – 3 years (Henrisken et al., 2005). Kittens stay with their mothers for about one year until weaning takes place in early late winter or early spring and disperse as subadults (Zimmermann et al., 2007).

Diet and livestock predation

In contrast to other members of the genus, which prey predominantly on lagomorphs (Werdelin, 1981), the diet of the Eurasian lynx consists foremost of ungulate species (i.e. Krofl, 2006; Jedrzejewski et al., 1993), of which a lynx averagely kills one every 5-10 days (Breitenmoser & Haller, 1993; Okarma et al. 1997; Jobin et al. 2000). In scat samples of Norwegian lynxes remains of >30 species were found, ranging from hares to moose (Odden et al., 2006) and even occasional cases of scavenging were reported (i.e. Sunde et al., 2000). Independent of habitat or season, medium-sized ungulates, like roe deer (*Capreolus capreolus*), reindeer (*Rangifer tarandus*) and domestic sheep (*Ovis aries*) were found to contribute significantly (81% of ingested biomass) to the diet of Norwegian lynxes, with mountain hares (*Lepus timidus*) and galliform birds serving as alternatives (Sunde et al., 2000). A more recent study supporting these findings, showed that roe deer contribute up to 83% to the diet (% biomass ingested) of Norwegian lynx populations during winter months (Odden et al., 2006). Studies indicate that, in Norway lynx predation together with human hunting might reduce roe deer numbers in a way that populations might not sustain (Melis et al., 2010). Nevertheless roe deer are the main prey species of lynx within the study area, followed by hares and Tetraonids (Linnell et al., 2007).

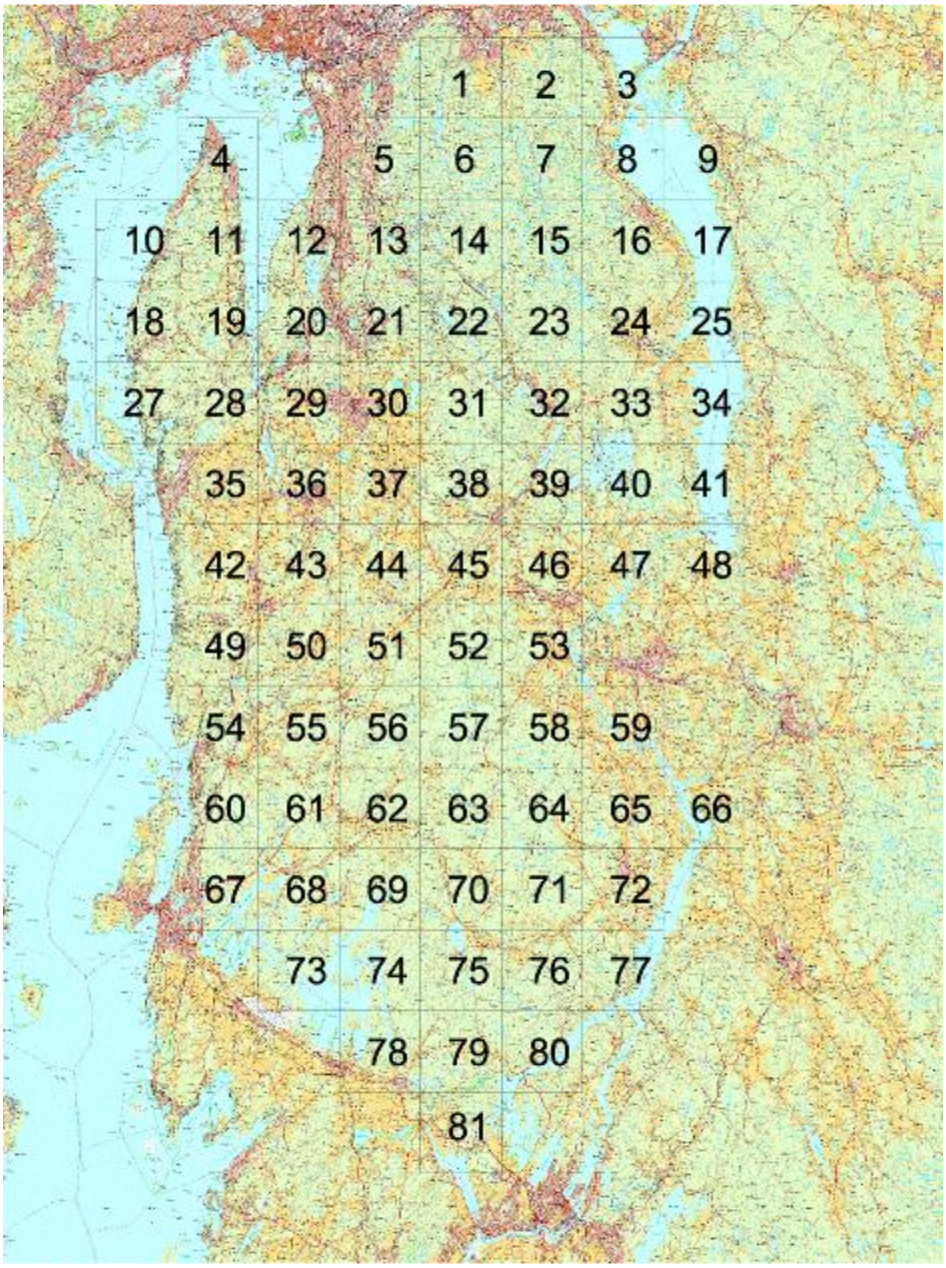
Regardless of indications pointing that lynx might be the least important predator on livestock, particularly in Norway depredation of sheep by lynx is notable higher than in other European countries (Kaczensky, 1999). According to the Norwegian Directorate for Nature Management, lynx were held responsible for depredation of 5.462 and 9.862 sheep annually between the years 1995 and 2005 (2005 cited in Odden, 2006). Studies suggest a strong preference for lambs (Aanes et al., 1996; Warren et al., 1995) and the ratio of lambs being killed even amounted to 93% of total sheep killed by lynx (Odden et al., 2002). Male lynx were responsible for both, most of the livestock depredation and most cases of surplus killings (Odden et al., 2002). Reasons for the notable high amount of sheep depredation could be that flocks often graze unattended and are killed incidentally (Odden et al., 2005).

Lynx and human disturbance

Norway isn't densely populated; however especially in the South lynx are confronted with human population and activities, which are in fact the major cause for lynx mortality in Scandinavia (Woodroffe & Ginsberg, 1998) and resulting in conflicts between humans and lynx (Linnell et al., 2007; Kaczensky, 1999). Recent studies found that lynx presence was relatively high in areas with intermediate disturbance by human activities, especially streets, which could be due to higher prey abundance in those areas (Basille, 2008; Basille et al., 2009; May et al., 2008). Lynx seem to be attracted to the higher number of prey clumping around agricultural areas, resulting in a trade-off between high prey densities and high mortality risks (Bunnefeld et al., 2006). Furthermore Bunnefeld et al. (2006) found, that the distance of females with kittens to human disturbed areas was greater than for males

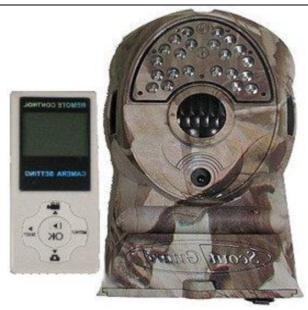
9 Appendix II Study area map

Map of study area



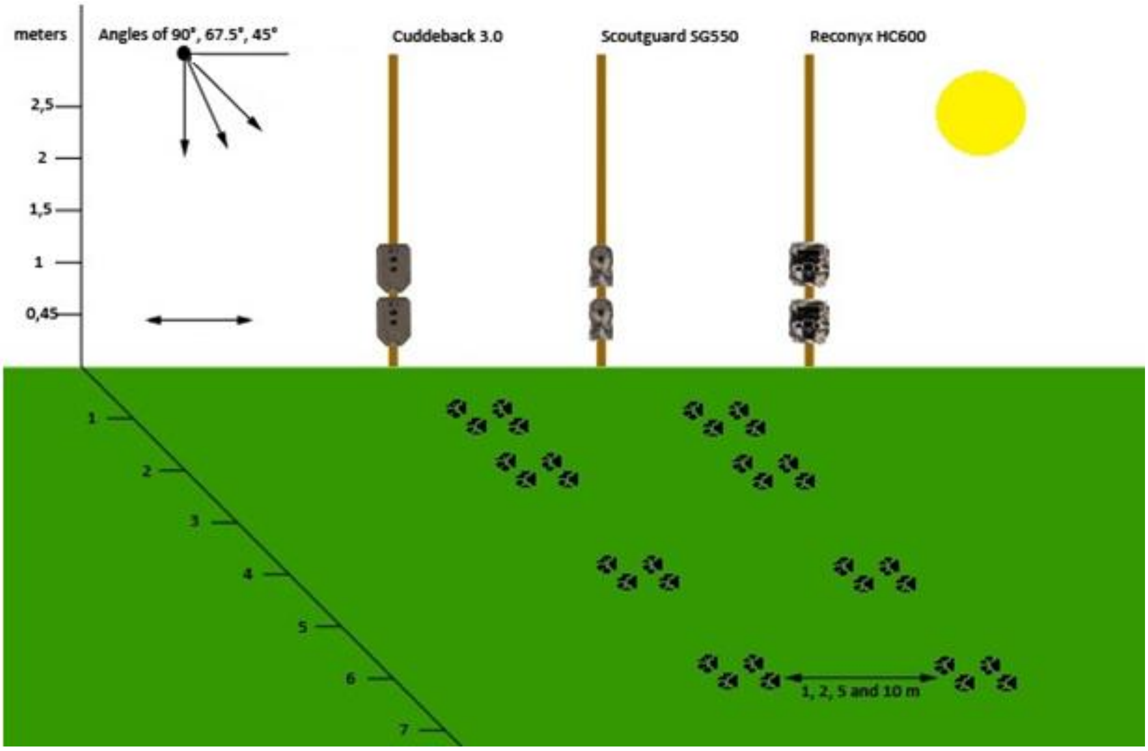
10 Appendix III Camera trap technical features

Specifications of 3 camera models used as stated on the manufacture's websites (accessed on 26th October, 2010)

	Cuddeback Capture	HCO Scoutguard SG550	Reconyx HC600
Price	189 $	205 $	535 $
Power supply	4 alkaline D-cells	4 or 8 1.5V AA or 6V DC	12 AA NiMH Rechargebles or 1.5V Lithium
Type of memory cards	SD-card (2 GB max.)	SD-card (8 GB max.)	SD- or SDHC-card (32 GB max.)
Trigger-speed	< 0.33 sec	1.2 sec	0.2 sec
File-format	JPEG	JPEG, AVI	JPEG
Resolution	3 MP	3 or 5 MP 640x480 (16fps) or 320x240 (20fps)	1080 pixels 3.1 MP
Video length	-	1 – 60 sec	-
Monochrom/Polychrom	polychrom	polychrom (day)/ monochrom (night)	polychrom (day)/ monochrom (night)
Flash-type	Visible light	Infra red	Infra red
Flash-range	50 ft	40 ft	50 ft
Delay	30 sec, 1, 5, 15 or 30 min	1 sec – 60 min	0, 1, 3, 5 or 10 sec
Time stamp	Yes	Yes	Yes
Time of operation	24 hrs	Selectable	Selectable
Operation	Rotatory switch	Remote control	Touchpad
Operation temperature	?	- 20 to 140° Fahrenheit	- 4 to 140° Fahrenheit
Photo			

11 Appendix IV Camera test set-up

Set-up of the preliminary camera test



Appendix V Camera trap field collection form

Field collection form

Camera traps Lynx Project

Sampler				Date	
Grid number		Camera Number		Camera Model	

Batteries					Weather conditions			
Number	1	2	3	4	Temperature: °C		Time:	
Percentage					Sun	Yes / No	Rain	Yes/ No
Replaced	Yes / No				Snow	Yes / No	Depth	cm

SD Card Number				Damage	Yes	No	Animal	Human
Replaced	Yes/ no	By number:		Details				
Number images								
Days since last snowfall		Lead time		Snow shoe	Skis	Other	

Sp→ Photo ID ↓	Roe deer	Hare	Lynx	Marten	Elk	Sheep	Other	Specify

12 Appendix VI Snow tracking field collection form

Field form for snow tracking

Sampler				Date	
Grid number		Camera Number		Camera Model	

Weather conditions			
Temperature: (°C)		Time	
Snow	Yes / No	Lead Time	
Days since last snowfall		Depth (cm)	

Enter the photo id of the track in the box concerned with ID. Enter GPS coordinates for every species separately.

Sp→ Photo ID ↓	Roe deer	Hare	Lynx	Marten	Other	Specify	GPS

Draw in the box the following details; transect, distances, tracks found, camera position and which way it is pointing. Also other details concerning the landscape features of the tracks have to be drawn in the box below.

13 Appendix VII Camera test results

Table 9 Capture success of two simulated lynx by three different camera types at different distances from the camera and different distances between the simulated lynx at an angle of 90° and 45cm height

90°		Reconyx HC600 Hyperfire				Scoutguard SG550				Cuddeback Capture			
Distance between lynx		1m	2m	5m	10m	1m	2m	5m	10m	1m	2m	5m	10m
Distance to camera	1m												
	2m												
	4m												
	6m												

Legenda
= Both lynx captured
= One lynx captured
= No lynx captured

Table 10 Capture succes of two simulated lynx by three different camera types at different distances from the camera and different distances between the simulated lynx at an angle of 67,5° and 45cm height

67,5°		Reconyx HC600 Hyperfire				Scoutguard SG550				Cuddeback Capture			
Distance between lynx		1m	2m	5m	10m	1m	2m	5m	10m	1m	2m	5m	10m
Distance to camera	1m												
	2m												
	4m												
	6m												

Table 11 Capture success of two simulated lynx by three different camera types at different distances from the camera and different distances between the simulated lynx at an angle of 67,5° Return and 45 cm height.

67,5° Return		Reconyx HC600 Hyperfire				Scoutguard SG550				Cuddeback Capture			
Distance between lynx		1m	2m	5m	10m	1m	2m	5m	10m	1m	2m	5m	10m
Distance to camera	1m												
	2m												
	4m												
	6m												

Table 12 Capture success of two simulated lynx by three different camera types at different distances from the camera and different distances between the simulated lynx at an angle of 90° and 100 cm height.

90°/ 100 cm		Reconyx HC600 Hyperfire				Scoutguard SG550				Cuddeback Capture			
Distance between lynx		01m	02m	05m	10m	01m	02m	05m	10m	01m	02m	05m	10m
Distance to camera	1m												
	2m												
	4m												
	6m												

14 Appendix VIII Avoidance behaviour

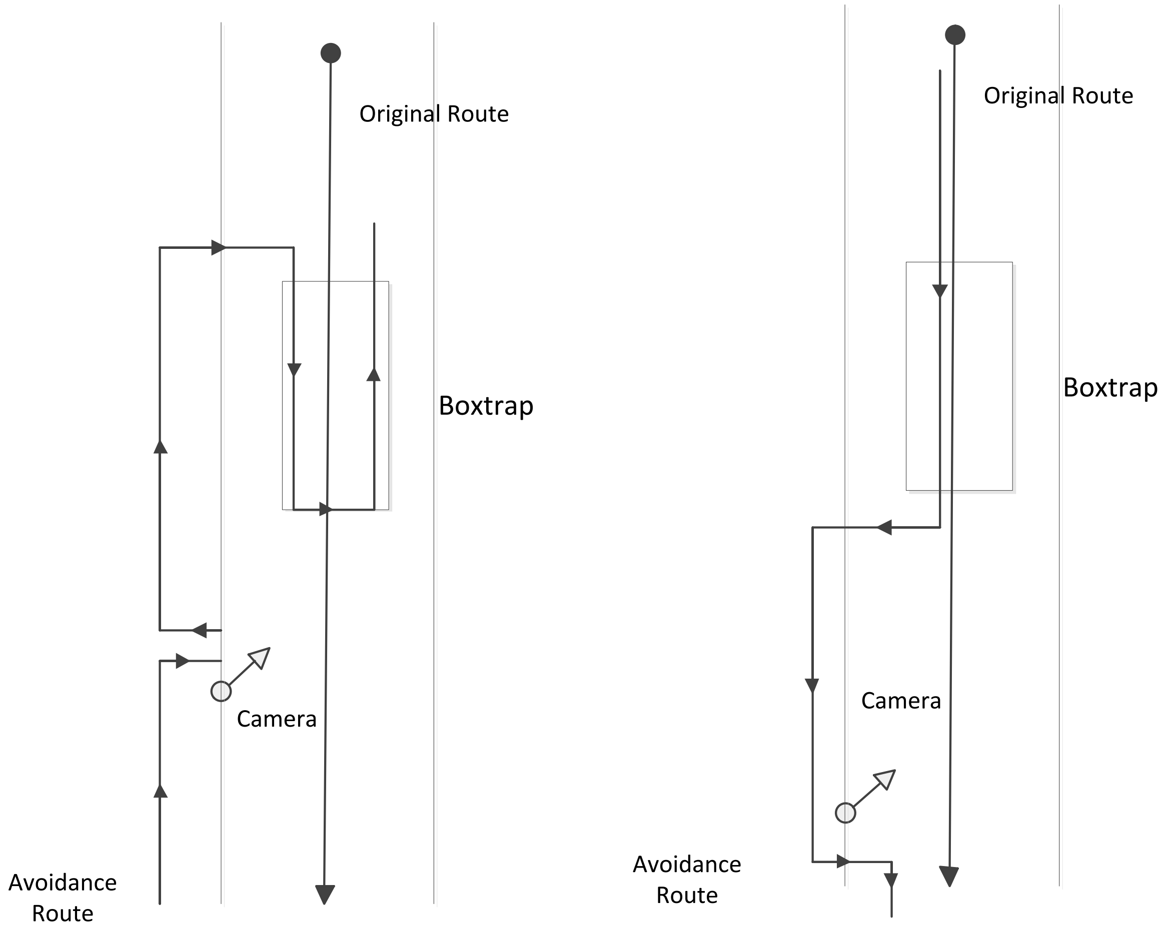


Figure 34 Two examples of avoidance behaviour noticed in Eurasian lynx after being photographed with Cuddeback Capture. Showing the original route of the lynx, the camera and its angle and the new route avoiding the camera location.

15 Appendix IX Location prediction output

Original output Logistic regression analysis

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	34,700	14	,002
	Block	34,700	14	,002
	Model	34,700	14	,002

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	39,310[a]	,434	,617

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than ,001.

Classification Table[a]

			Predicted		
			Lynx		
	Observed		No	Yes	Percentage Correct
Step 1	Lynx	No	41	2	95,3
		Yes	5	13	72,2
	Overall Percentage				88,5

a. The cut value is ,500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	Cliff(1)	-6,152	3,842	2,564	1	,109	,002	,000	3,966
	Buildings	-,016	,013	1,557	1	,212	,984	,960	1,009
	Roads	,036	,018	4,009	1	,045	1,037	1,001	1,074
	Railroad	,000	,000	,774	1	,379	1,000	,999	1,000
	Buildings by Roads	,000	,000	8,212	1	,004	1,000	1,000	1,000
	Buildings by Railroad	,000	,000	2,890	1	,089	1,000	1,000	1,000
	Buildings by Streams	,000	,000	5,893	1	,015	1,000	1,000	1,000
	Buildings by Cliff(1)	-,020	,012	2,931	1	,087	,980	,957	1,003
	Railroad by Roads	,000	,000	1,071	1	,301	1,000	1,000	1,000
	Railroad by Streams	,000	,000	8,323	1	,004	1,000	1,000	1,000
	Cliff(1) by Railroad	,001	,000	3,829	1	,050	1,001	1,000	1,002
	Open_water by Streams	,000	,000	4,702	1	,030	1,000	1,000	1,000
	Cliff(1) by Open_water	-,007	,004	2,928	1	,087	,993	,986	1,001
	Cliff(1) by Streams	,025	,009	8,624	1	,003	1,026	1,009	1,043
	Constant	-1,123	2,303	,238	1	,626	,325		

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18 Appendix X Sightings of other species

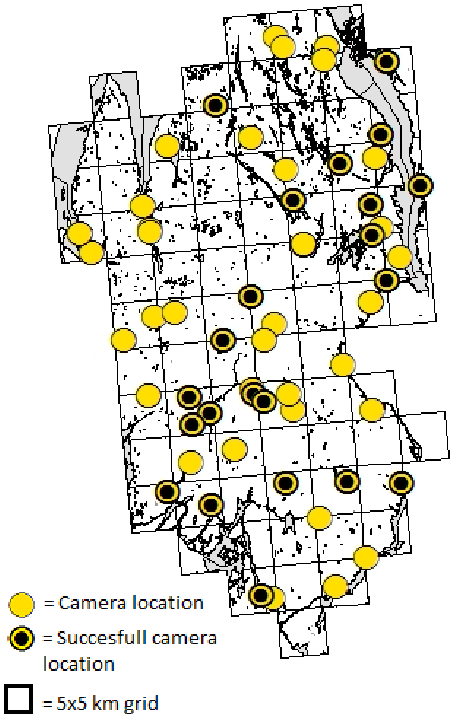


Figure 37 Map of all camera locations that displays locations with successful capture of elk on camera (n=22)

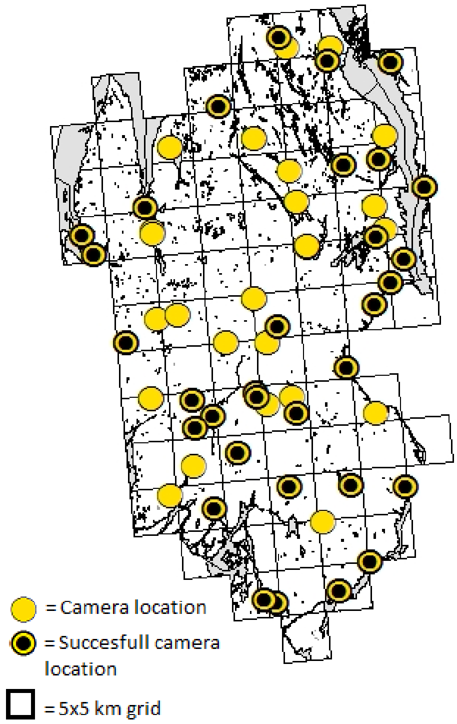


Figure 38 Map of all camera locations that displays locations with successful capture of fox on camera (n=30)

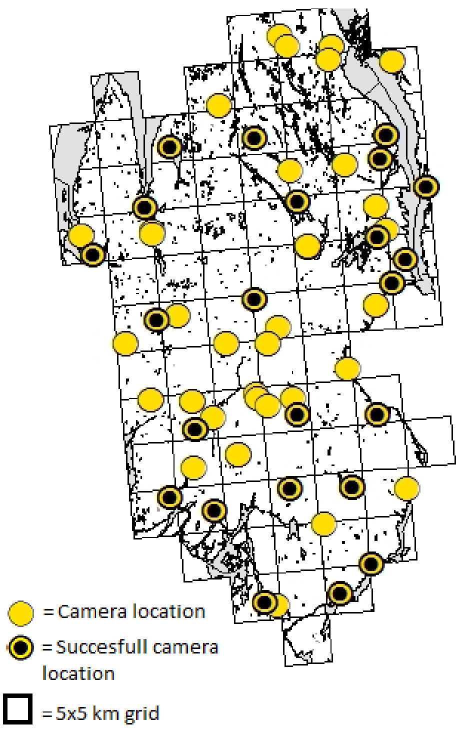


Figure 36 Map of all camera locations that displays locations with successful capture of Roe deer on camera (n=23)

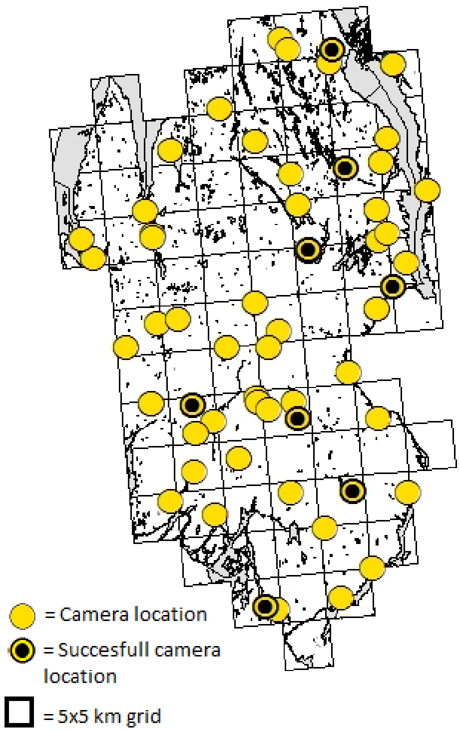


Figure 35 Map of all camera locations that displays locations with successful capture of Snowshoe hare on camera (n=8)

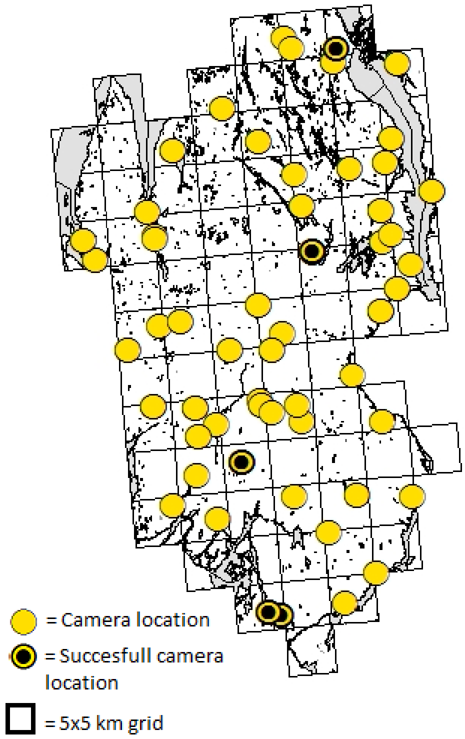


Figure 39 Map of all camera locations that displays locations with successful capture of Pine Marten on camera (n=5)

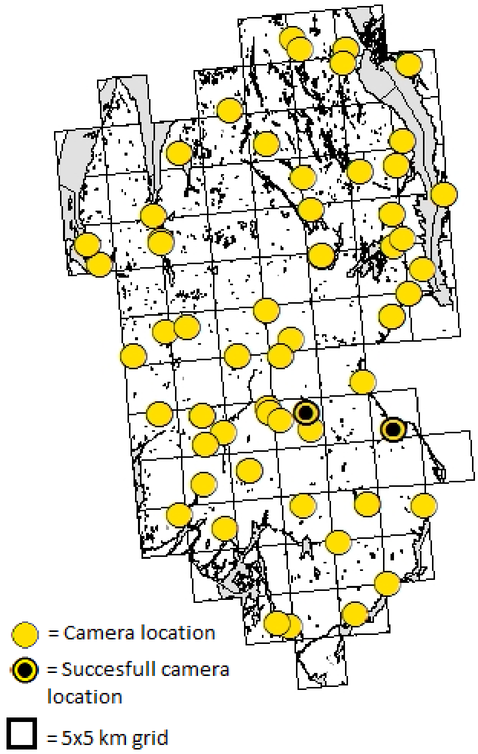


Figure 42 Map of all camera locations that displays locations with successful capture of Raven on camera (n=2)

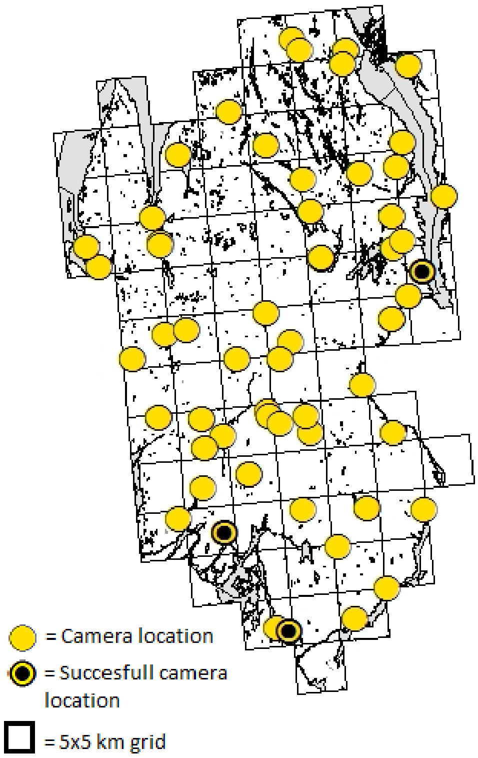


Figure 40 Map of all camera locations that displays locations with successful capture of Great Tit on camera (n=3)

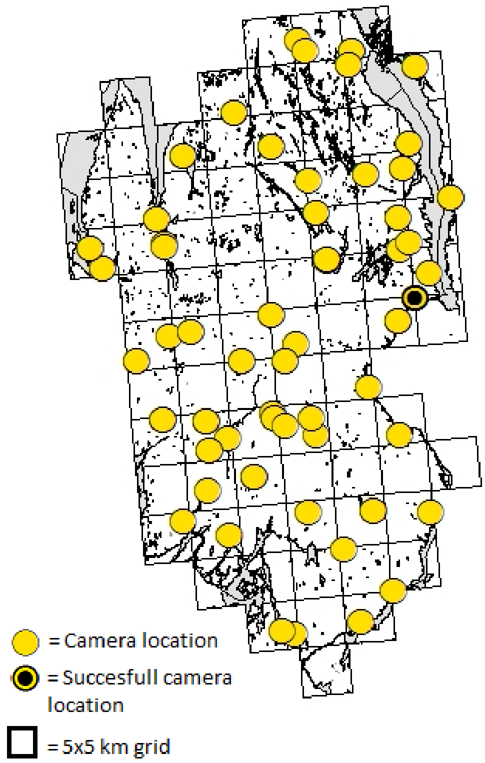


Figure 41 Map of all camera locations that displays locations with successful capture of Red Squirrel on camera (n=1)

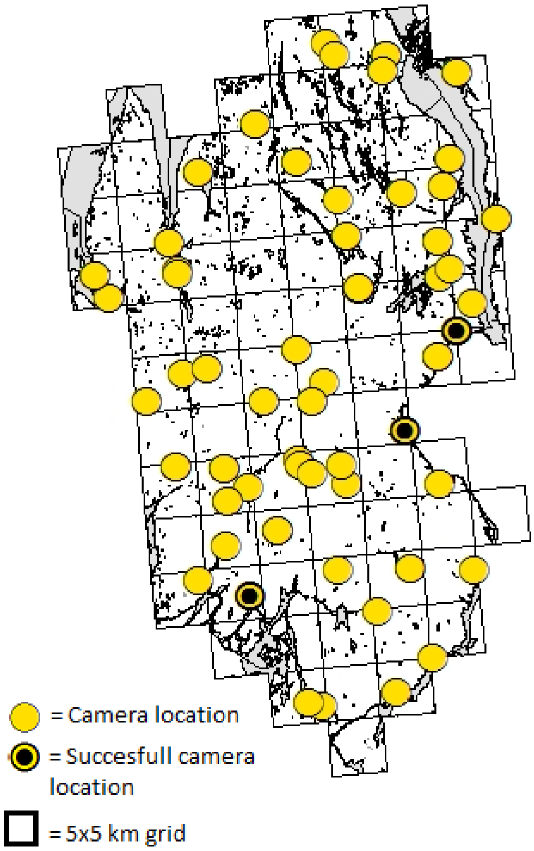


Figure 45 Map of all camera locations that displays locations with successful capture of Domestic cat on camera (n=3)

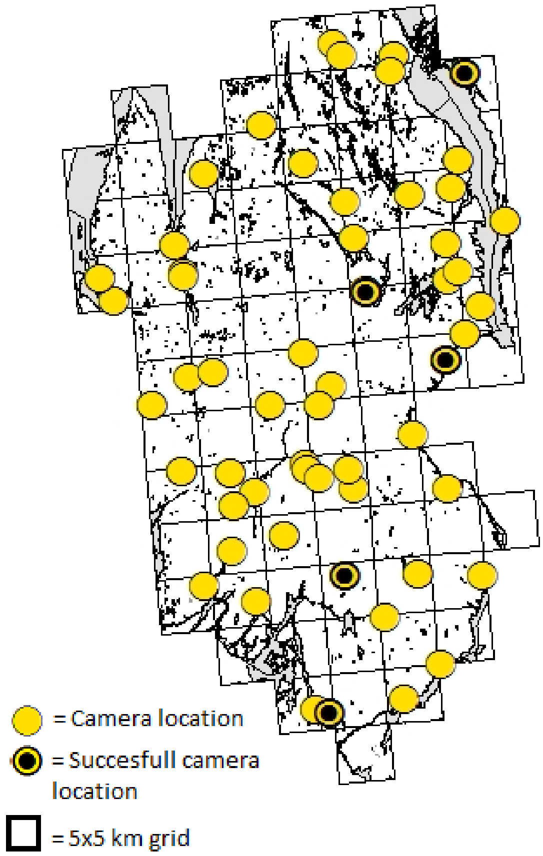


Figure 44 Map of all camera locations that displays locations with successful capture of Domestic dog on camera (n=5)

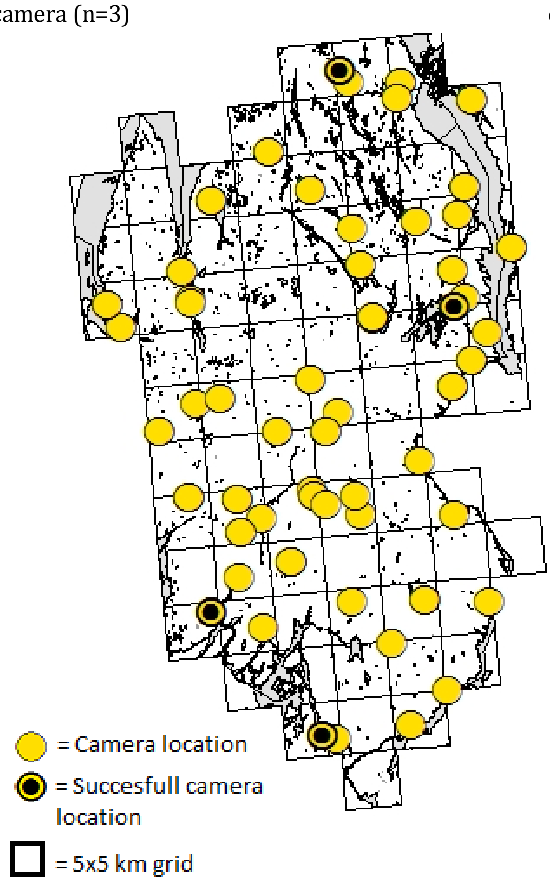


Figure 43 Map of all camera locations that displays locations with successful capture of unknown species on camera (n=4)

Camera nr.	Cam type	Placed	Grid	X	Y	Lynx	Fam group	Elk	Roe deer	Fox	Marten	Squirrel	tit	Snow Hare	Cat	Unknown	Dog	Raven
Lynx29C	Cuddeback	14-11-10	02_1	611049	6642273	-	-	-	-	X	-	-	-	-	-	X	-	-
Lynx52C	Cuddeback	30-11-10	02_2	611938	6641123	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx30C	Cuddeback	14-11-10	03_1	616710	6641122	X	-	-	-	-	X	-	-	X	-	-	-	-
Lynx63S	Scoutguard	12-12-10	03_1	616706	6641111	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx86R	Reconyx	03-02-11	03_1	616706	6641111	X	-	-	-	-	X	-	-	-	-	-	-	-
Lynx18C	Cuddeback	07-11-10	05_1	604587	6634732	X	-	X	-	X	-	-	-	-	-	-	-	-
Lynx84R	Reconyx	30-01-11	05_1	604587	6634732	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx61C	Cuddeback	12-12-10	08_1	616343	6639625	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx62S	Scoutguard	12-12-10	08_1	616343	6639625	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx07S	Scoutguard	31-10-10	09_1	623222	6639488	X	-	X	-	-	-	-	-	-	-	-	-	X
Lynx31R	Reconyx	14-11-10	09_1	623222	6639488	X	-	X	-	X	-	-	-	-	-	-	-	-
Lynx64S	Scoutguard	14-12-10	12_1	599356	6630271	-	X	-	X	-	-	-	-	-	-	-	-	-
Lynx65C	Cuddeback	14-12-10	12_1	599356	6630271	-	-	-	X	-	-	-	-	-	-	-	-	-
Lynx85R	Reconyx	31-01-11	12_1	599356	6630271	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx17S	Scoutguard	07-11-10	14_1	608396	6631311	-	-	-	X	-	-	-	-	-	-	-	-	-
Lynx40C	Cuddeback	28-11-10	14_1	608396	6631311	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx10S	Scoutguard	01-11-10	17_1	622509	6631612	-	-	X	X	-	-	-	-	-	-	-	-	-
Lynx39C	Cuddeback	28-11-10	17_1	622509	6631612	-	-	X	X	-	-	-	-	-	-	-	-	-
Lyxn16C	Cuddeback	07-11-10	23_1	612140	6627792	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx01R	Reconyx	27-10-10	24_1	618061	6628439	X	-	X	-	X	-	-	-	X	-	-	-	-
Lynx04C	Cuddeback	27-10-10	24_1	618063	6628437	X	-	X	-	X	-	-	-	X	-	-	-	-
Lynx59C	Cuddeback	08-12-10	25_1	621866	6629002	X	-	-	X	-	-	-	-	-	-	-	-	-
Lynx60S	Scoutguard	08-12-10	25_1	621866	6629002	X	-	-	X	X	-	-	-	-	-	-	-	-
Lynx23S	Scoutguard	10-11-10	27_1	591122	6618787	-	X	-	X	X	-	-	-	-	-	-	-	-
Lynx37C	Cuddeback	25-11-10	27_1	591122	6618787	-	-	-	X	-	-	-	-	-	-	-	-	-
Lynx24C	Cuddeback	10-11-10	27_3	589827	6620801	-	X	-	-	-	-	-	-	-	-	-	-	-
Lynx87R	Reconyx	03-02-11	27_3	589827	6620801	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx51C	Cuddeback	30-11-10	28_1	596584	6623866	X	-	-	X	X	-	-	-	-	-	-	-	-
Lynx88R	Reconyx	03-02-11	28_1	596584	6623866	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx49C	Cuddeback	30-11-10	29_1	597401	6621216	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx50C	Cuddeback	30-11-10	29_2	597416	6620958	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx53S	Scoutguard	05-12-10	32_1	613031	6624371	-	-	X	X	-	-	-	-	-	-	-	-	-

Camera nr.	Cam type	Placed	Grid	X	Y	Lynx	Fam group	Elk	Roe deer	Fox	Marten	Squirrel	tit	Snow Hare	Cat	Unknown	Dog	Raven
Lynx54C	Cuddeback	05-12-10	32_1	613031	6624371	-	-	X	X	-	-	-	-	-	-	-	-	-
Lynx25S	Scoutguard	10-11-10	33_2	621360	6623981	X	-	X	-	-	-	-	-	-	-	-	-	-
Lynx36C	Cuddeback	24-11-10	33_2	621360	6623981	X	-	X	-	-	-	-	-	-	-	-	-	-
Lynx08S	Scoutguard	31-10-10	34_1	626751	6625971	X	-	X	X	X	-	-	-	-	-	-	-	-
Lynx91R	Reconyx	08-02-11	34_1	626751	6625971	X	-	X	-	X	-	-	-	-	-	-	-	-
Lynx56C	Cuddeback	05-12-10	34_1	626751	6625971	-	-	X	X	X	-	-	-	-	-	-	-	-
Lynx02S	Scoutguard	27-10-10	39_1	614164	6619655	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx03C	Cuddeback	27-10-10	39_1	614115	6619556	X	-	-	-	-	-	-	-	X	-	-	-	X
Lynx32S	Scoutguard	17-11-10	39_1	614167	6619633	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx58R	Reconyx	08-12-10	39_1	614167	6619633	X	-	-	-	-	X	-	-	X	-	-	-	-
Lynx12C	Cuddeback	01-11-10	40_1	621644	6620654	-	-	X	X	X	-	-	-	-	-	-	X	-
Lynx92R	Reconyx	08-02-11	40_2	622513	6621505	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx26C	Cuddeback	10-11-10	41_1	624623	6618282	-	-	-	X	X	-	-	X	-	-	-	-	-
Lynx11S	Scoutguard	01-11-10	42_2	597989	6611724	-	-	-	X	-	-	-	-	-	-	-	-	-
Lynx79C	Cuddeback	06-01-11	42_3	594563	6609160	X	-	-	-	-	-	-	-	-	-	-	-	-
Lynx80S	Scoutguard	06-01-11	42_3	594563	6609160	X	-	-	-	X	-	-	-	-	-	-	-	-
Lynx68C	Cuddeback	06-01-11	43_1	600095	6612142	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx69S	Scoutguard	06-01-11	43_1	600095	6612142	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx74S	Scoutguard	06-01-11	44_1	605442	6609270	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx75C	Cuddeback	06-01-11	44_1	605442	6609270	-	-	X	-	-	-	-	-	-	-	-	-	-
Lynx09C	Cuddeback	01-11-10	45_1	610937	6610905	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx19S	Scoutguard	08-11-10	45_2	608406	6613995	-	-	X	X	-	-	-	-	-	-	-	-	-
Lynx41C	Cuddeback	29-11-10	45_2	608406	6613995	-	-	X	X	-	-	-	-	-	-	-	-	-
Lynx77C	Cuddeback	24-01-11	47_1	621429	6613392	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx66C	Cuddeback	15-12-10	47_1	621429	6613392	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx90R	Reconyx	07-02-11	47_1	621429	6613392	-	-	-	-	X	-	-	-	-	-	-	-	X
Lynx78S	Scoutguard	06-01-11	47_1	621429	6613392	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx55S	Scoutguard	05-12-10	48_1	623215	6615669	X	-	X	-	X	-	-	-	X	-	-	-	-
Lynx57C	Cuddeback	05-12-10	48_1	623215	6615669	X	-	X	X	X	-	X	-	-	X	-	-	-
Lynx94R	Reconyx	17-02-11	48_1	623215	6615669	X	-	X	-	-	-	-	-	-	X	-	-	-
Lynx76S	Scoutguard	21-01-11	52_1	609826	6609163	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx81R	Reconyx	21-01-11	52_1	609823	6609169	-	-	-	-	-	-	-	-	-	-	-	-	-

Camera nr.	Cam type	Placed	Grid	X	Y	Lynx	Fam group	Elk	Roe deer	Fox	Marten	Squirrel	tit	Snow Hare	Cat	Unknown	Dog	Raven
Lynx48C	Cuddeback	01-12-10	53_1	618450	6606488	-	-	-	-	X	-	-	-	-	X	-	-	-
Lynx70C	Cuddeback	06-01-11	54_1	597248	6603239	X	X	-	-	-	-	-	-	-	-	-	-	-
Lynx71S	Scoutguard	06-01-11	54_1	597248	6603239	X	X	-	-	-	-	-	-	-	-	-	-	-
Lynx89R	Reconyx	04-02-11	54_1	597248	6603239	X	-	-	-	-	-	-	-	-	-	-	-	-
Lynx35C	Cuddeback	22-11-10	55_1	603928	6601299	-	-	X	-	X	-	-	-	-	-	-	-	-
Lynx67S	Scoutguard	15-12-10	55_2	601668	6603003	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx72S	Scoutguard	06-01-11	55_2	601668	6603003	-	-	X	-	-	-	-	-	X	-	-	-	-
Lynx73R	Reconyx	06-01-11	55_2	601668	6603003	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx82S	Scoutguard	21-01-11	55_3	602049	6600010	-	-	X	X	-	-	-	-	-	-	-	-	-
Lynx83R	Reconyx	21-01-11	55_3	602052	6600010	-	-	X	X	X	-	-	-	-	-	-	-	-
Lynx45C	Cuddeback	30-11-10	56_1	608601	6603827	-	-	-	-	X	-	-	-	-	-	-	-	-
Lynx47C	Cuddeback	30-11-10	56_2	608740	6603325	-	-	X	-	X	-	-	-	-	-	-	-	-
Lynx93R	Reconyx	16-02-11	56_2	608740	6603325	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx34C	Cuddeback	22-11-10	57_1	613019	6601646	-	-	-	X	X	-	-	-	X	-	-	-	-
Lynx46C	Cuddeback	30-11-10	57_2	609884	6602545	-	-	X	-	-	-	-	-	-	-	-	-	-
Lynx22S	Scoutguard	08-11-10	61_1	601845	6595855	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx05C	Cuddeback	28-10-10	62_1	606686	6597348	X	-	-	-	-	-	-	-	-	-	-	-	-
Lynx06S	Scoutguard	28-10-10	62_1	606686	6597348	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx38R	Reconyx	26-11-10	62_1	606686	6597348	X	-	-	-	X	X	-	-	-	-	-	-	-
Lynx20C	Cuddeback	08-11-10	67_1	599385	6592738	-	-	X	X	-	-	-	-	-	-	-	X	-
Lynx21C	Cuddeback	08-11-10	68_1	604044	6591246	-	-	X	X	X	-	-	X	-	X	-	-	-
Lynx27C	Cuddeback	11-11-10	70_1	612177	6593619	-	-	X	X	X	-	-	-	-	-	-	-	X
Lynx15R	Reconyx	05-11-10	71_1	618879	6593837	-	-	X	X	X	-	-	-	X	-	-	-	-
Lynx33C	Cuddeback	19-11-10	71_1	618879	6593837	-	-	-	-	X	-	-	-	X	-	-	-	-
Lynx14C	Cuddeback	05-11-10	72_2	624807	6593609	-	-	X	-	X	-	-	-	-	-	-	-	-
Lynx13C	Cuddeback	05-11-10	76_1	615929	6589911	-	-	-	-	-	-	-	-	-	-	-	-	-
Lynx28C	Cuddeback	11-11-10	77_1	621006	6585526	-	-	-	X	X	-	-	-	-	-	-	-	-
Lynx43C	Cuddeback	29-11-10	78_1	610790	6581059	-	-	-	-	X	X	-	X	-	-	-	-	X
Lynx44C	Cuddeback	29-11-10	78_2	609506	6581348	-	-	X	X	X	X	-	-	X	-	-	X	-
Lynx42C	Cuddeback	29-11-10	80_1	617583	6582331	X	-	-	X	X	-	-	-	-	-	-	-	-
LynxT1	RS	13-01-11		621647	6601512	-	-	-	X	-	-	-	-	-	-	-	-	-
LynxT2	RS	06-02-11		612482	6603365	X	-	-	-	-	-	-	-	-	-	-	-	X

19 Appendix XI Camera placement strategies output

Number and percentage of cases in which a camera type successfully captured for different settings

			1 lynx						2 lynx					
			Cuddeback		Reconyx		Scoutguard		Cuddeback		Reconyx		Scoutguard	
			n = 12	%	n = 5	%	n = 8	%	n = 3	%	n = 48	%	n = 26	%
Settings	Distance from camera	1	3	25.0	1	20.0	2	25.0	1	33.3	11	22.9	10	38.5
	in meters	2	3	25.0	2	40.0	3	37.5	1	33.3	12	25.0	5	19.2
		5	3	25.0	-	-	2	25.0	1	33.3	14	29.2	7	26.9
		6	3	25.0	2	40.0	1	12.5	-	-	11	22.9	4	15.4
	Distance between lynx	1	3	25.0	3	60.0	2	25.0	-	-	11	22.9	8	30.8
	in meters	2	4	33.3	1	20.0	2	25.0	-	-	11	22.9	6	23.1
		5	4	33.3	1	20.0	3	37.5	-	-	13	27.1	5	19.2
		10	1	8.3	-	-	1	12.5	3	100.0	13	27.1	7	26.9
	Angle	90	12	100.0	1	20.0	1	12.5	3	100.0	23	47.9	19	73.1
	in degree	67.5	-	-	4	80.0	7	87.5	-	-	25	52.1	7	26.9
		45	-	-	-	-	-	-	-	-	-	-	-	-
	Height	0.45	12	100.0	5	100.0	6	75.0	3	100.0	40	83.3	20	76.9
	in meters	1	-	-	-	-	2	25.0	-	-	8	16.7	6	23.1
	Direction*	f	-	-	3	75.0	1	14.3	-	-	11	44.0	4	57.1
	forwards and backwards	b	-	-	1	25.0	6	85.7	-	-	14	56	3	42.9

* in case angle others than 90°

20 Appendix XII individual recognition

Table 13 Results of the attempt to recognize individuals. Individuals that were thought to be the same or groups that thought to consist of the same individuals was given the same colour.

Grid	Camera	Date	N°	Same as in	Why?	Nord (WGS84 sone 32)	Øst (WGS84 sone 32)
3	Lynx30C	01.01.2011	1		Fur and distance (for the one with almost no spots)	616710	6641122
		01.01.2011	1		Fur and distance	616710	6641122
		13.01.2011	1	?		616710	6641122
	Lynx86R	22.02.2011	1		Fur and distance	616706	6641111
5	Lynx18C	21.01.2011	1		Fur and distance	604587	6634732
9	Lynx07S	14.02.2011	1		Date and distance	623222	6639488
		01.03.2011	1		location	623222	6639488
	Lynx31R	21.11.2011	1		Fur and distance	623222	6639488
		25.02.2011	1		location	623222	6639488
		14.02.2011	1		Date and distance	623222	6639488
		01.03.2011	1		location	623222	6639488
12	Lynx64S	17.12.2010	2		Number of lynx, size of the kitten and distance,STRIPE	599356	6630271
		31.01.2011	1	?		599356	6630271
24	Lynx01R	22.01.2011	1		Fur and distance	618061	6628439
		25.01.2011	1		location	618061	6628439
	Lynx04C	18.12.2010	1		Fur and distance	618063	6628437
		22.01.2011	1		Fur and distance	618063	6628437
25	Lynx59C	22.02.2011	1		Fur and distance	621866	6629002
	Lynx60S	22.02.2011	1		Fur and distance	621866	6629002
27a	Lynx24C	26.11.2010	3		Number of lynx, size of the kittens and distance	591122	6618787
27b	Lynx23S	07.02.2011	2		Number of lynx, size of the kitten and distance,STRIPE	589827	6620801
28	Lynx51C	02.01.2011	1		location	596584	6623866
33	Lynx25S	06.02.2011	1		location	621360	6623981
	Lynx36C	06.02.2011	1		location	621360	6623981
34	Lynx08S	04.12.2010	1		location	626751	6625971
	Lynx91R	15.02.2010	1		Date and distance	626751	6625971
39	Lynx03C	19.11.2010	1			614115	6619556
	Lynx58R	19.12.2010	1		location	614167	6619633

42	Lynx79C	15.02.2011	1		Fur and distance	594563	6609160
		02.03.2011	1		Fur and distance	594563	6609160
	Lynx80S	15.02.2011	1		location	594563	6609160
48	Lynx55S	19.01.2011	1			623215	6615669
		04.02.2011	1			623215	6615669
	Lynx57C	21.02.2011	1			623215	6615669
	Lynx94R	21.02.2011	1			623215	6615669
54	Lynx70C	15.01.2011	3		Number of lynx, size of the kittens and distance	597248	6603239
		29.01.2011	1		Fur and distance	597248	6603239
		30.01.2011	1		Fur and distance	597248	6603239
		03.02.2011	1		Fur and distance	597248	6603239
	Lynx71S	15.01.2011	3		Number of lynx size of the kittens and distance	597248	6603239
		29.01.2011	1		Fur and distance	597248	6603239
		30.01.2011	1		Fur and distance	597248	6603239
		03.02.2011	1		Fur and distance	597248	6603239
	Lynx89R	03.02.2011	1		Fur and distance	597248	6603239
62	Lynx05C	15.11.2010	1		Fur and distance	606686	6597348
		29.11.2010	1		Fur and distance	606686	6597348
		09.01.2011	1		Fur and distance	606686	6597348
	Lynx38R	29.11.2010	1		Fur and distance	606686	6597348
		09.01.2011	1		Fur and distance	606686	6597348
		22.02.2011	1		Fur and distance	606686	6597348
80	Lynx42C	03.02.2011	1			617583	6582331
		20.02.2011	1			617583	6582331

Other sightings							
56	Vegard	06.02.2011	1	?		612482	6603365
44	F1	05.02.2011	1		Fur and distance	609676	6612809
25	F2	11.03.2011	1		Fur and distance	620349	6625104
32	M1	10.03.2011	1		Fur and distance	620665	6624674
32	M2	10.03.2011	1		Fur and distance	622873	6627080

*These results should NOT be seen as proven. It is based on a subjective impression and not supported by facts other than above mentioned.

Yellow

2724C261110001

5470C150111001

5470C150111002

5471S150111001_screenshot

Shot in grid 44 on 5th February

Orange

1264S171210001

2723S070211001

2851C020111001

Blue

0907S010311001

0907S140211001

0931R01031100

0931R14021100

0931R211110003

0931R211110012

3408S041210001

3491R15021100

Green

0330C010111003

0518C20110121001

2401R220111001

2401R250111004

2404C181210001

2404C220111001

2559C220211001

2560S220211001

3325S060211001

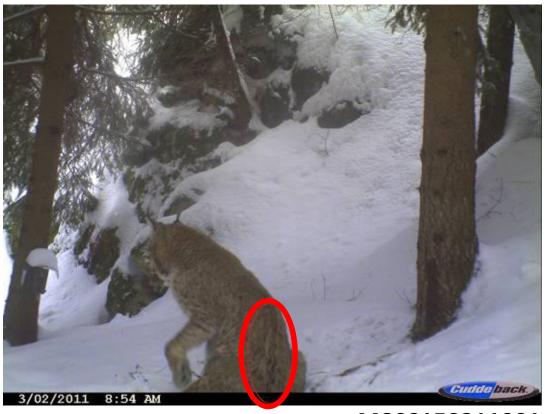
3336C060211001


Shot in grid 32 on 10th February

Olive

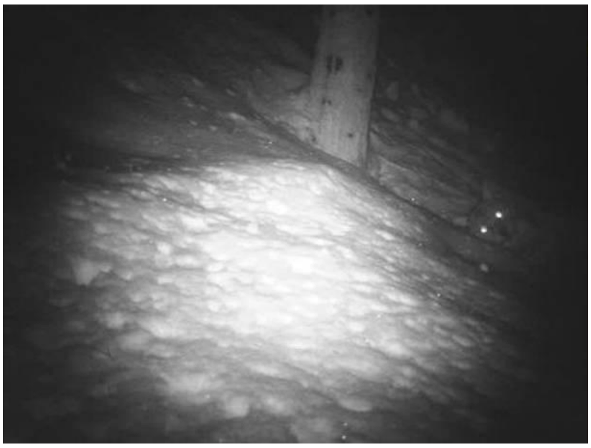
4279C020311001

4279C020311006



4279C150211002

4480S150211001



4855S040211001

4855S190111001

4857C210211001

4894R21011100

Shot in grid 25 on 11th February

Pink

3903S191110001

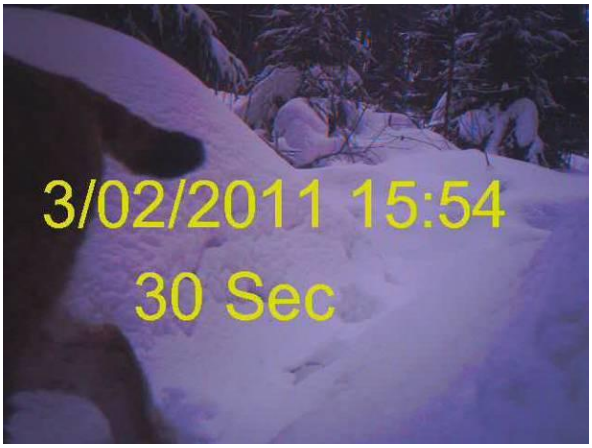
3958R191210001

5470C030211001

5470C290111003

5470C300111002

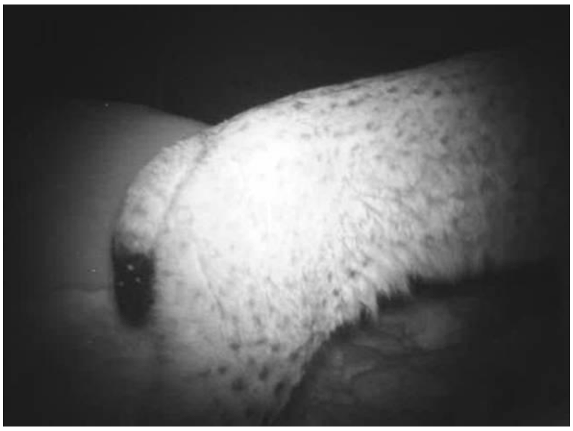
5471S020311001



5471S290111001

5471S290111002

5471S300111001



5489R020311007

6205C090111002

6205C151110001

6205C291110001

6238R22021100

6238R090111013

6238R291110038

Red

0330C010111002 **0386R220211007**

Shot in grid 32 on 10th February

Unknown

0330C130111001

1264S310111001

8042C030211001

8042C200211001

8042C200211002

Temporary camera in grid 56

21 Appendix XIII GIS shapefiles

Area	Number	Name	Name	Name	Name	Name	Name	Name	Scale	Owner	Description	Year
Oslo	0301	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Lørenskog	0230	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Rælingen	0228	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Frogn	0215	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Nesodden	0216	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Vestby	0211	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Oppegård	0217	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Ås	0214	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Ski	0213	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Enebakk	0229	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Hobøl	0138	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Spydeberg	0123	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Moss	0104	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Våler	0137	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Sarpsborg	0105	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Råde	0135	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
fet	0227	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001

Trøgstad	0122	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
Skiptvet	0127	Anlegg (Facilities)	Vann (Water)	Veg (Streets)	Bane (Railroad)	Bekk (River)	Bygg (Buildings)	Grunnrissbygg (Urbanization)		NINA		2001
		Cam GRID								NINA	Grid file	2010
		Nord_adm								GADM	Administrative boundaries	2009