Change in Occupancy among Ungulates during two Camera Trap Surveys in the Northern Swiss Jura Mountains

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Abstract

Regular estimation of lynx abundance and density is carried out in different reference areas of Switzerland by means of photographic capture-recapture. Beside lynx, a lot of photographs of other species are available. Given that important means were invested to collect this large data set, I would like to assess if it is possible to infer valuable information about population status for other species. By applying multiple-season dynamic site occupancy models, I aimed to infer population trends of three ungulate species, namely roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*) and wild boar (*Sus scrofa*), based on data of two lynx surveys (2010 and 2012/13) conducted in the northern Swiss Jura Mountains. To counterbalance possible heterogeneity in detection probability, we introduced site specific covariates into the model describing the detection probability (camera type and daily coverage). The quality of the results strongly depended on the species considered. Nevertheless, valuable conclusions could be drawn for future studies, providing useful insights for both the analysis of older datasets and the improvement of the current sampling scheme.

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1 Introduction

KORA[1] estimates lynx abundance and density every two to three years in different reference areas in Switzerland by means of photographic capture-recapture (see http://www.kora.ch/index.php?id=240). This kind of monitoring methodology allows collecting reliable data on the evolution of abundance of the species and, if necessary, to implement targeted and appropriate conservation and management measures. The monitoring is carried out using fixed analogue and digital camera-traps triggered by heat and motion to take photos of passing animals. In the reference area to be examined, camera traps are systematically placed during the winter over 60 nights at sites regularly used by lynx, principally along forest roads, and on rare occasions along animal trails. Beside lynx, which makes up only a small proportion of the species photographed over the course of the surveys, a lot of photographs of carnivore and ungulate species are available. Given that important means were invested in terms of field work and material to collect this large data set, I would like to assess if it is possible to infer valuable additional information (e.g. distribution and relative abundance) for species without individually-distinct fur pattern.

For these species, absolute estimations of population size are not possible; hence metrics based on occupancy probability may become very interesting. Occupancy is sometimes viewed as a surrogate for abundance, since changes in the population size can be reflected by changes in its proportion of area occupied (MacKenzie & Nichols, 2004). One aspect that needs to be considered is the issue of imperfect detection of the target species, which negatively impacts the occupancy estimates. New approaches are currently developed, which estimate detection probability directly from the data set and adjust occupancy (MacKenzie *et al.* 2002; MacKenzie & Nichols 2004).

1.1 Research objectives

The aim of this study is to analyse by-catch of two surveys conducted in winter 2010 (6th February 2010 – 6th April 2010) and winter 2012/13 (1st December 2012 - 29th January 2103) in the northern Swiss Jura Mountains to infer population trends of three wild ungulate species, namely roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*) and wild boar (*Sus scrofa*). By applying multiple-season dynamic site occupancy models on these species, the main questions that will be addressed are:

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[1] Coordinated Research Projects for the Conservation and Management of Carnivores in Switzerland, www.kora.ch

1) are there sufficient data to apply robust multiple-season dynamic site occupancy models on these species?
2) can heterogeneity in the detection process (due to the use of different cameras) be corrected by including relevant covariates into the detection model?
3) are the camera-trapping sites used during the lynx monitoring representative for the three ungulate species?

2 Methods

2.1 Study area

The KORA Jura north 882 km^2 camera trap reference area lies in the northern part of the Swiss Jura Mountains. It is limited by the Central Plateau to the south-east, the Vallée de Delémont in the north-west, Biel in south-west and Olten in the north-east (see Fig. 1, area outlined in blue). The area was chosen for an optimal lynx monitoring, so that: 1. the area is sufficiently large and thus representative of the lynx population in the northern Swiss Jura Mts., 2. the reference area is comparable to the lynx surveys conducted in the Alps, and 3. it extends over several cantons.

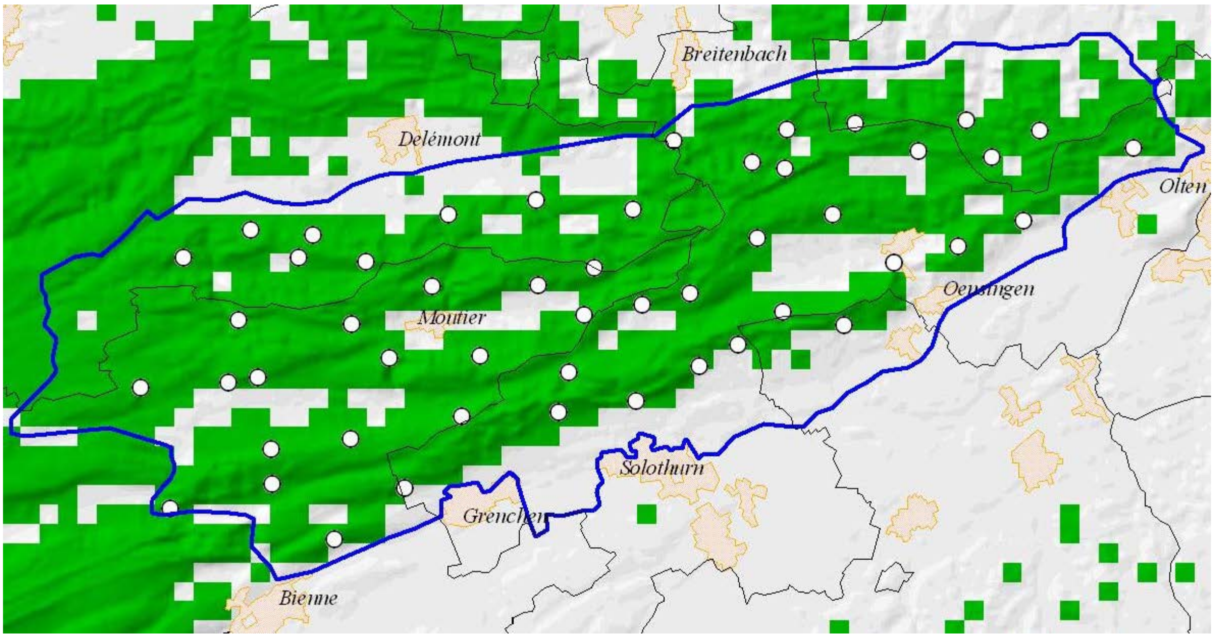

Figure 1: Study area in the northern Swiss Jura Mountains. Locations marked with white circles indicate camera trap sites. The green areas indicate the suitable lynx habitat based on a habitat suitability model. The black lines mark the borders of the cantons (Zimmermann *et al.* 2010).

2.2 Camera Site Sampling Design

The sampling design was optimized to maximize the detection of lynx. For the survey in 2010, the 882 km² study area was overlaid with a random generated 2.7 km x 2.7 km sampling grid. In every second grid cell (sampling unit) containing large proportions of suitable habitat based on a habitat suitability model (Zimmermann 2004), a site considered to have a high likelihood of lynx detection was selected, usually on a forest road or hiking trail. A total of 50 camera trap sites were deployed, each with two opposing cameras. The use of two cameras allowed to photograph both flanks of a lynx and thus facilitates the identification of individuals (Zimmermann *et al.* 2010).

In contrast with the previous survey, in 2012/13 the study area was overlaid with a finer grid of 2.5 km x 2.5 km (Zimmermann *et al.* 2013). The increase of trap density introduced eleven additional sites that were not considered in the present analysis, since they have been sampled only during the second winter and therefore do not carry any useful information about changes in occupancy across time periods.

A preliminary analysis on the sites that have been strictly conserved from the first survey to the second one (n=34) suggested that the sample size would be too small to provide reliable estimations on the basis of a small selection of sites. I therefore decided to only dismiss the sites that encountered repeated and systematic malfunctioning, resulting in 47 sites for the analyses of the population trends of roe deer, wild boar and chamois.

2.3 Model framework

The software PRESENCE version 6.1 (USGS Wildlife Research Center/Proteus Wildlife Research Consultants, New Zealand) was used to model multiple-season dynamic site occupancy. Multiple-season dynamic models assume that sites are closed to changes in occupancy within primary sampling periods (e.g. a survey season), but open to changes between primary periods (e.g. between the surveys 2010 and 2012/2013). Changes in occupancy between the primary periods occur according to the colonization and extinction parameters, defining a temporal relationship for a given sites across surveys. This dynamic aspect is biologically more relevant than applying twice a single-season model. Occupancy models additionally take into account imperfect detection of species by estimating the detectability of the target species and correcting the values of occupancy, colonization and extinction.

As mentioned above, the sites were selected for optimizing the detection of lynx by choosing mainly forest roads and hiking trails. Although it would be possible to account for occupancy heterogeneity by considering relevant environmental covariates (e.g. distance to railway tracks, altitude etc.), no such covariates were used for modelling in the present essay, because sites were assumed to have similar ecological conditions for the target species. One assumption of occupancy modelling is that detection of one species at a given site is independent from the detection on the neighbouring sites (according to Mackenzie et al 2002). I assume that this assumption is fulfilled as home ranges of roe deer (0.82 km², Lamberti *et al.* 2004), chamois (0.32 km², Nesti *et al.* 2010) and wild boar (4 km², Keuling *et al.* 2008) are smaller than the trap density of one site per 12.5 km² used for the lynx survey.

During the survey in 2010, around 75% of all cameras were analogue. They had limited storage capacity (36 exposure films); therefore 70% of them were programmed to function only at night, in order not to waste photographs on passing people during daytime. The resting 25% of the cameras were digital, working 24 hours a day. During the survey in 2012/13, all the sites were monitored by digital cameras. To counterbalance heterogeneity in detection probability that may arise from the use of cameras with different characteristics (see also Mackenzie et al 2002), site specific covariates were prepared and introduced into the model describing the detection probability: the covariates included camera type (1. only analogue; 2. minimum one camera digital; 3. only digital) and variation in daily coverage (1. night only; 2. minimum one camera 24 hours; 3. only 24 hours).

2.4 Model design and data

The sampling window for each survey was 60 nights. For the purpose of this study, a sampling occasion was defined as 5 consecutive trap nights – a pentad – resulting in a total of 12 sampling occasions. A detection event is therefore defined as the photographic capture of at least one individual of the target species at a given camera trap station within a predefined period of five consecutive nights. Encounter histories were constructed according to a matrix format, where ‘1’ indicated the detection of a species and ‘0’ indicated non-detection. In situations where there were incomplete survey histories (for example where cameras had stopped working) a missing value entry (-) was incorporated into the matrix.

For every species, a baseline model was created where occupancy (psi/ψ), colonization (gamma/γ), extinction (epsilon/ε) and detection probability (p) remained constant over the surveys (psi[.], gamma[.], eps[.], p[.]). The next model considered detection probability to be year specific over the surveys. In a final step, more refined models were created where detection probability was considered to be year specific and included all possible combinations of covariates describing camera type and daily coverage.

3 Results

During the survey of 2010, a total of 3,396 wildlife photographs were collected (50 sites). Photos that were captured outside the 60 day sampling window or were taken at a dismissed site (with bad camera coverage) were eliminated, leaving a total sample size of 3,103 photos (47 sites). 87 were roe deer, 100 chamois and 31 wild boars. The 47 sites x 60 days gave a potential sampling effort of 2,820 trap nights, but due to technical failure and camera theft, the effective effort for the sampling period was reduced to 2,707 trap nights, which equates to 96% of the potential. During the survey of 2012/13, a total of 3,146 wildlife photographs were collected (50 sites). A total sample size of 2,457 photos remained after photos irrelevant for the analysis were removed. 205 were roe deer photographs, 180 chamois and 64 wild boars. Due to technical failures with cameras, problems with heavy snowfall and camera theft, the potential sampling effort of 2,820 trap nights was reduced to 2,721, corresponding to 96.5% of the potential.

3.1 Dynamic site occupancy modelling

Chapters 3.1.1 to 3.1.3 describe the modelling results of each species, considering 47 sites for the analyses of population trends. For each species, the top three ranking models are listed in the respective tables (see tables 1-3). For each top ranking model, the estimated occupancy, colonization and extinction are described. An overview of the naïve and estimated occupancy of each species is provided in Figure 2.

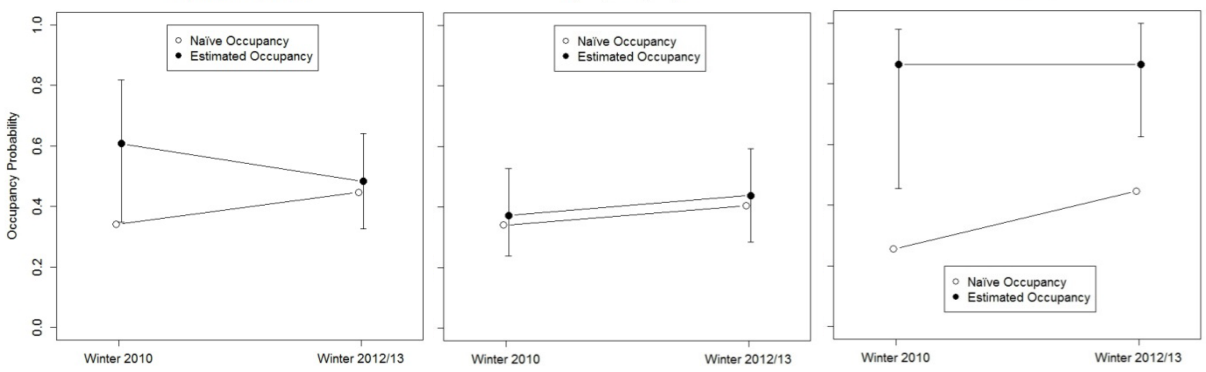

Figure 2: Naïve (black dots) and estimated (white dots) occupancy estimations according to the best model for roe deer (left), chamois (centre) and wild boar (right). The bars represent the 95% Confidence Interval of the estimated occupancy.

3.1.1 Occupancy modelling of roe deer (47 sites)

Table 1: Top three ranking dynamic models (best on top) describing the occupancy of roe deer in the Jura North in years 2010-2012/13.

Roe deer	AIC weight	Model likelihood	Parameters
psi(.),gamma(.),eps(.),p(year specific+analogue+digital+ night only+24hrs)	0.9020	1.000	9
psi(.),gamma(.),eps(.),p(year specific+analogue+digital)	0.0504	0.0559	7
psi(.),gamma(.),eps(.),p(year specific+analogue+digital+ night only+minimum 1 camera 24hrs)	0.0383	0.0424	9

With an AIC model weight of over 90%, the top ranking model considered detection probability to be year specific. Covariates included camera type (only analogue vs. only digital) and variation in daily coverage (24 hours vs. night).

According to this model, site occupancy of roe deer was 60.8% in 2010 and 48.3% in 2012/13. Estimates colonization and extinction probabilities in between the surveys were 49.4% and 52.4%, respectively.

The growth rate (lambda/λ) was 0.7948 (SE ± 0.2156), but the decrease was not significant.

3.1.2 Occupancy modelling of chamois (47 sites)

Table 2: Top three ranking dynamic models (best on top) describing the occupancy of chamois in the Jura North in years 2010-2012/13.

Chamois	AIC weight	Model likelihood	Parameters
psi(.),gamma(.),eps(.),p(.)	0.3221	1.000	4
psi(.),gamma(.),eps(.),p(year specific+analogue+digital)	0.2148	0.6670	7
psi(.),gamma(.),eps(.),p(year specific)	0.2013	0.6250	5

With a weight of 32.2% the baseline model (constant psi, gamma, eps and p) fitted best the data. However there is no clear outstanding model based on the AIC weights.

According to this model site occupancy of chamois was 37.2% in 2010 and 43.9% in 2012/13. Estimates colonization and extinction probabilities in between the surveys were 29.7%, and 32.1%, respectively.

The growth rate (lambda/λ) was 1.1808 (SE ± 0.2619), but the increase was not significant.

3.1.3 Occupancy modelling of wild boar (47 sites)

Table 3: Top three ranking dynamic models (best on top) describing the occupancy of wild boar in the Jura North in years 2010-2012/13.

Wild boar	AIC weight	Model likelihood	Parameters
psi(.),gamma(.),eps(.),p(year specific+analogue+digital+ night only+24hrs)	0.4089	1.000	9
psi(.),gamma(.),eps(.),p(year specific+night only+24hrs)	0.3700	0.9048	7
psi(.),gamma(.),eps(.),p(year specific+analogue+minimum 1 camera digital+night only+24hrs)	0.1527	0.3734	9

There is no real evidence for a top ranking model, results were unclear. AIC model weight of the top listed model (detection probability year specific; covariates including camera type [only analogue vs. only digital] and variation in temporal coverage [24 hours vs. night]) is only slightly better than the second listed model.

According to this model the site occupancy of wild boar was 86.4% in 2010 and 86.4% in 2012/13. The model encountered problems in estimating colonization and extinction probability, the occupancy estimations for the survey 2012/13 therefore needs to be carefully interpreted.

4 Discussion

Seasonal occupancy of roe deer

According to the results the inclusion of information on camera-trap type and daily coverage increases the performances of the model. Models that did not combine information about camera-trap type and daily coverage did not perform as well as the full model. A naïve occupancy analysis would suggest that the roe deer occupancy increased from 2010 to 2012/13 (see figure 2). However when taking into account imperfect detection the occupancy remained unchanged between winters.

A long term study of roe deer activity patterns in the Bavarian Forest National Park (Krop-Benesch *et al.* 2013) showed that activity patterns of roe deer have a significant 24-hour periodicity in all seasons, but the time of its emphasis changes. Roe deer are mostly diurnal during winter – even though daily activity levels and the number of activity peaks per day are lower in winter than the rest of the year. This is confirmed by the roe deer photographs taken during the survey 2012/13, where camera-trap worked around the clock as 79.5% of all photos were taken between 06:00-18:00. The use of appropriate covariates (i.e. daily coverage, camera-trap type) can to some extent correct for heterogeneity in detection probability. However for future roe deer studies, especially during winter time, it would be recommended to reduce as much as possible the heterogeneity by setting all camera-traps on 24-hours. Species such as roe deer that do not move predominantly along forest roads and that have relative small home ranges radius compared to the mesh size of the trap array are more difficult to be detected by camera-traps. For such species it is important to improve the location of the camera-trap sites in relation to animal movement paths and to increase camera-trap site density within their home range.

Seasonal occupancy of chamois

There was no clear outstanding model describing seasonal variation in chamois occupancy. The true occupancy is running parallel to the naïve occupancy but is slightly higher. Even though chamois show a similar activity pattern compared to roe deer (66.7% of all photos were taken between 06:00-18:00 in winter 2012/13), the camera-trap covariates did not significantly improve the performance of the models.

Chamois have a different spatial behaviour compared to roe deer as they move over longer distances from the resting areas (rock patches) to reach the feeding areas. Since they make large movements and need to save energy because of the snow cover, it could be expected that they use preferentially forest roads and hiking trails. As camera-trap sites are set along trails and forced passages in rocky areas, assumption is that chamois are easily detected when they move back and forth during both day and night time (however, this would need to be validated by a study on the activity patterns of both species, e.g. with telemetry datasets). Results therefore suggest that for chamois it is sufficient to set the camera-traps on night mode to get adequate occupancy estimates. This has important implications for the analysis of past datasets when inferring population trends using multiple season occupancy analyses, allowing including data that were collected only at night with analogue cameras.

Seasonal occupancy of wild boar

Modelling occupancy for wild boar did not show evidence for a top ranking model. The model with the best fit failed in calculating colonization and extinction rates. All the lower ranking models showed the same problem for at least one of the two parameters, suggesting that the data set of wild boars is too sparse for such analyses. In fact, few wild boar photographs were taken resulting in very low detection probabilities (i.e. $p = 0.059 \pm 0.013$ for the simpler model). It is known that the software encounter problems in estimating population parameters when the detection probability is too low (MacKenzie *et al.*, 2002). Knowing that the wild boar hunting bags (BAFU[2]) are steadily increasing over years such a low detection probability is surprising. A first explanation could be that wild boars have a lower activity at night during winter (see Keuling *et al.* 2008) but this is not supported by the photographs taken during winter 2012/13, where 85.7 % of them were taken at night. A more plausible explanation would be that wild boars are only partially exposed to camera-traps as they spend part of the time in agricultural areas outside of the habitat sampled by means of camera-traps. Additionally, wild boars may not use trails as much as lynx. For future studies I therefore suggest that the sampling design and the camera-trap site selection - which were optimized to maximise lynx detections - should be adjusted if we wish to further analyse this species as by-catch.

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[2] Bundesamt für Umwelt BAFU, Eidgenössische Jagdstatistik: http://www.wild.uzh.ch/jagdst/index.php?la=1

Conclusion and future perspectives

Occupancy modelling for the three species shows some interesting results, but they strongly depend on the species considered. Caution is required in the interpretation of the results, especially when the biology and spatial behaviour of the by-catch species differ substantially from the focal species.

In the present case we have only two measures separated by a time period of three years. Even though a significant difference would have been detected, one would have not been allowed to reliably describe the population as being increasing or decreasing since several measures are required.

For future studies we can make following recommendations:

- Since some of the target species might not move during cold weather or when there is lots of snow, it would be helpful to record relevant weather parameters that could be included as covariates for detection probability into the model.
- As the camera-trap type and programming (night vs. 24h modus) influence detection probability for some species, heterogeneity among sites should be reduced as much as possible. For example, when digital and analogue camera-traps are employed during the same survey, a combination of the two types at each site would be preferred over setting the same type twice.
- In order to avoid possible bias due to the daily activity pattern of the species, I recommend using systematically digital camera-traps set on 24 hours. This will additionally provide useful insights in the activity pattern of all mammalian species living in the area. This important information enables to validate hypotheses as the ones formulated in the present work and to decide if camera-trapping data collected in the past can be reliably integrated in the analyses of population trends.
- Small modifications of the lynx sampling design such as installing additional camera-trapping sites for by-catch species could significantly improve the quality of the data collected, without disrupting the lynx survey, and with minimal additional costs. This last recommendation would however need additional studies to test what could be an optimal strategy for measuring population trends of several mammalian species within a single sampling design.
- In order to validate occupancy trends of by-catch species, reliable abundance estimates based on a different approach would be needed, like for example capture-recapture methods of male roe deer.

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