Estimating population size of wolves in Sweden using spatial capture-recapture based on noninvasive genetic sampling: suggestions for sampling design

Compilation of discussions and e-mail correspondence, regarding a design to conduct noninvasive sampling suitable for capture-recapture modelling of wolf population size, between Richard Bischof, Cyril Milleret (Norwegian University of Life Sciences), Linn Svensson (Wildlife Damage Centre, SLU), Håkan Sand, Camilla Wikenros, and Mikael Åkesson (SKANDULV, SLU).

Background

The Scandinavian wolf population has been monitored since 1978 (Wabakken et al. 2001; Liberg et al. 2012) with the aim to identify the annual number of all solitary resident wolves (until 2013), wolf pairs that scent-mark a territory, family groups (i.e., a group with at least 3 wolves) and annual reproductions. Since total population size (N) is often of greater interest for conservation and management than e.g. number of reproductions, number of reproducing pairs are currently used as informative segments of the population to estimate N. Since 2011, this is done by multiplying the number of reproductions with a conversion factor, estimated from total counts of the population (given as minimum-maximum estimates) during three years (survey seasons 2000/2001–2002/2003) and assuming that all individuals in the population had been observed these years. From the 2014/2015 season onward, the monitoring of the Scandinavian wolf population was revised and today it is based on joint instructions and fact sheets for Norway and Sweden (http://www.naturvardsverket.se/Stod-i-miljoarbetet/Vagledningar/Vilt/Inventeringsmetodik-for-stora-rovdjur/). The revised instructions include a change in the monitoring goal where the number of reproductions no longer had to be counted, but rather it would be sufficient to estimate the number of family groups. A family group is defined as a pack of at least three wolves, with at least one of these marking the territory. With the change to family groups, the conversion factor needed to be revised. The population size of the Scandinavian wolf population can be estimated using two partly independent estimations, 1) the use of a wolf-specific individual based model using Approximate Bayesian Computation informed by data from collared individuals (Chapron et al. 2016), or 2) the use of spatial capture-recapture (SCR) models based on noninvasive genetic sampling (NGS) data (see Bischof et al. 2016). During the monitoring season 2016/2017 the sampling for SCR was initiated, involving extra efforts in NGS and the DNA-analysis of principally all samples that was collected. The sampling was conducted by the County Administrative Boards within the regular annual winter monitoring, but without extra search and snow tracking effort. Moreover, about 300 samples were collected by the Swedish Association for Hunting and Wildlife Management. To increase the sample size, the decision to collect a second year was taken and a design giving all social classes in the population a chance to be detected was requested by the Swedish Environmental Protection Agency in June 2017. During the regular winter monitoring, no national effort was dedicated to detecting vagrant wolves or additional pack members beyond the minimum 3 wolves required based on the definition of family groups. Wolves in Scandinavia are tracked on snow every winter, starting October 1 and ending February 28 (2005-2013) and March 31 (2014-2016) by trained

personnel. Each tracking event is aimed to be at least 3 km long (regarding family groups and territorial pairs).

Spatial Capture-Recapture (SCR) using noninvasive sampling (NGS)

As a part of the larger project RovQuant - “Integrated analysis using Rovbase 3.0”, which aims to generate abundance estimates and population dynamic prediction for wolverine, bear, and wolf in Norway and Sweden, the size of the Scandinavian wolf population can be estimated. The objective is to generate annual spatially-explicit wolf population estimates that take into account social structure and changes therein, and derive a corresponding factor for converting number of packs into the total number of individuals in the population, while accounting for imperfect detection during monitoring.

SCR estimates will be aided by an intensified NGS collection in 2016/2017 and 2017/2018.

Here we revise the sampling design used during the 2016/2017 monitoring season to:

1) Increase probability of detection for all individuals in the population:
    a. within territories
    b. between territories
    c. outside the currently known wolf distribution
2) Ensure that each sampling event is associated with data on search effort
3) Ensure that search effort is also recorded when no samples have been found/collected
4) Increase the size of the area searched

Study area

The goal of the intensified sampling during two monitoring seasons is to estimate the total population size in Sweden during the monitoring period October-March. The estimates from a SCR-model only applies to the areas that have been searched and a limited buffer around these. It is therefore vital that the study area is properly defined. Within the study area, search effort needs to be spatially (and temporally) exhaustive, so that all wolves have a chance of being sampled. SCR models require multiple detections of individuals at different spatial locations). This means that searches should occur at different locations within a wolf home range in order to obtain multiple spatial detections of individuals. Given the goal of estimating the total population size in Sweden, the study area should ideally include the entire country. Still, given the known distribution of breeding wolves, the average and distribution of natal dispersal distance among collared wolves, and the limited number of visual observations of wolves outside the known distribution range we suggest that the required search effort is highest in the wolf breeding range.

Overall recommendation

The overall recommendation for the sampling is that all wolves should have the probability of being sampled. Given that the regular annual wolf monitoring also has to take place this winter (2017/2018) the recommendation is to continue using as much as possible the regular

monitoring but with the aim to search the entire study area and keeping and registering search logs (i.e. the searches made from roads on snow or bare ground for tracks and/or DNA samples, such as scats and urine) and track logs (i.e. the following of wolf tracks), regardless of whether samples were found or not. The recommendations listed in more detailed below can be implemented with some flexibility to address logistic constraints and resource limitations.

Increase the probability of detecting 1a) individuals within territories, 1b) individuals between territories, and 1c) individuals outside the current known wolf distribution

- It is suggested to divide the study area (Sweden) into a regular grid system, where each grid cell is defined as the unit for defining minimum search efforts and number of tracking events to find and collect DNA-samples. Searches conducted by the county administrative boards are primarily based on driving routes to find wolf tracks in snow, followed by tracking to gather information about territorial markings, group size and for sampling DNA etc. Since the search logs from the driving routes informs the SCR-model about the probability of finding a track and the track logs about the probability to find a DNA-sample, it is vital that the search and track logs are recorded and registered in Rovbase 3.0 (the Scandinavian database used by the management of large carnivores).

- A 5*5 km grid system is suggested. The goal with this approach is to detect more wolves (different ages, social classes, locations) and detect the same wolves in multiple locations (different grid cells).

- Ideally, each cell should be searched 2-3 times during the monitoring season (October to March), with at least 1 week between searches. This will facilitate detection of the same wolf in different grid cells, as wolves move over time (either within the territory or, in the case of vagrants, beyond territory boundaries). However, having a good spread of search effort in space (and good tracking conditions) is more important, and should be prioritized over repeated sampling. In other words, it is fine to search a grid cell only once as long as that and other grid cells in the area are searched thoroughly.

- It is important that tracks from both single individuals and groups are followed, since an important goal with this season’s monitoring is to detect both vagrant and solitary wolves. However, at least some tracks from solitary wolves found should be followed in each grid cell. If a wolf track is detected, but not followed, the coordinates and date of the track observation should be noted. This will allow us to evaluate driving distances needed for track detection.

- Make an effort to find DNA-samples in any new grid cell that an individual/individuals enters during tracking.

- All family groups and territorial pairs should be tracked according to the regular monitoring system.

- Single wolf tracks should be followed for at least 500 meters or until a DNA-sample is found no matter if vagrant or resident.

- All search logs and track logs should be recorded and registered in Rovbase.

- Collect all scats while tracking, or aim to collect enough samples so that there is a chance of detecting all individuals that are tracked and to compensate for unsuccessful attempts at DNA extraction/amplification.

- Aim for search logs covering 25 km distance per grid cell with a minimum of 10 km search distance.

- We recommend using an existing grid system (Lantmäteriet etc.) instead of setting up a new one.

Ensure that 2) each sampling event is associated with data on search effort and 3) that search effort is recorded regardless of whether a sample is found or not

- It is vital that all search and track logs are registered, including those when no DNA-samples are found.

- Double registration of driving routes ("slingor"), i.e. when driving blind end roads, is not a problem for the model estimation.

- Even though we stress the importance of registering search and track logs, we acknowledge that this could not always be required from the public participants, such as representatives from the Swedish Association for Hunting and Wildlife Management. We encourage that the public participants register the grid cell and the date of the searches made. Nevertheless, the samples collected by the public are valuable irrespective of these registrations.

- If public search effort is not possible to record for different reasons, just make sure to indicate that the DNA-samples originated from for example opportunistic searches by the public.

- It is vital that all DNA-samples and searches conducted by the County Administrative Boards, independent of tracking conditions (bare ground or snow) or whether DNA-samples were found or not, are registered in Rovbase.

4) Increase the area searched for samples

- The study area will be Sweden, meaning the grid system will cover the entire country. Still, it is recommended that all grid cells within the current wolf breeding zone are searched. Outside this area, search log and track log should be recorded irrespective of the amount of effort.

- As many grid cells as possible should be searched during the monitoring season. A single search per grid cell is acceptable and valuable, if multiple searches in the same cell are not feasible.

- If feasible, no more than 4 adjacent cells (5*5 km grid cells = 100 km^2 (corresponding to 1/3 of the area of the smallest territory) should remain unsearched.

- Searches can be made both on snow and on bare ground and search conditions should be noted (e.g. days since snowfall, bare ground).

- Use of camera traps: If wolves are photographed, an effort to collect DNA-samples should be made. Record the location and recording time period of all active camera traps, including the ones that did not detect any wolves.

References

Bischof, R., Brøseth, H., & Gimenez, O. (2016). Wildlife in a politically divided world: insularism inflates estimates of brown bear abundance. *Conservation Letters*, *9*, 122–130.

Chapron, G., Wikenros, C., Liberg, O., Wabakken, P., Flagstad, Øystein, Milleret, C., Månsson, J., Svensson, L., Zimmermann, B., Åkesson, M., & Sand, H. (2016). Estimating wolf (*Canis lupus*) population size from number of packs and an individual based model. *Ecological Modelling*, *339*, 33–44.

Liberg, O., Aronsson, Å., Sand, H., Wabakken, P., Maartmann, E., Svensson, L., & Åkesson, M. (2012). Monitoring of wolves in Scandinavia Olof. *Hystrix*, *23*(1), 2934.

Wabakken, P., Sand, H., Liberg, O., & Bjärvall, A. (2001). The recovery, distribution, and population dynamics of wolves on the Scandinavian peninsula, 1978-1998. *Canadian Journal of Zoology*, *79*(4), 710–725.