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Estimating abundance of wolverines in Sámi reindeer herding villages and herding areas in Sweden

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COVER PICTURE

Wolverine. Source: shutterstock

NYCKELORD

Gulo gulo, rovdjur förvaltning, populationstäthet, detektionssannolikhet, icke-invasiv insamling av genetiskt material, öppen population rumslig fångst-återfångst, järv

NØKKELORD

Gulo gulo, rovdyrforvaltning, bestandstetthet, deteksjonssannsynlighet, ikke-invasiv innsamling av genetisk materiale, åpen populasjon romlig fangst-gjenfangst, jerv

KEY WORDS

Gulo gulo, carnivore management, population density, detection probability, non-invasive genetic sampling, open-population spatial capture-recapture, wolverine

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Summary

Background Project RovQuant has produced density maps and abundance estimates for large carnivores (brown bear *Ursus arctos*, grey wolf *Canis lupus*, and wolverine *Gulo gulo*) throughout Scandinavia since 2019. These estimates are based on non-invasive genetic sampling and dead recovery data collected annually by Swedish and Norwegian authorities. The analysis method (open-population spatial capture-recapture model, OPSCR) produces population-level estimates, as well as regional estimates of abundance. Naturvårdsverket (Swedish Environmental Protection Agency), in coordination with the Sámi parliament, has expressed interest in obtaining sex-specific wolverine abundance estimates for different regions and administrative entities associated with the Swedish reindeer herding areas.

Approach Using spatially explicit estimates from the latest OPSCR models produced by RovQuant, we calculated sex-specific wolverine abundances and their associated uncertainties in Sámi villages, reindeer calving areas, and other related jurisdictions in Swedish reindeer herding areas. We used and compared two approaches to derive those estimates; one that estimated jurisdiction-specific abundances based on the model-predicted distribution of individual activity centers and one based on the model-predicted individual space use. Estimates were generated and are reported for the three years with the most comprehensive wolverine monitoring in Sweden: 2017, 2018, 2019.

Results The OPSCR model estimated that the total number of wolverines in 2019 was likely (95% credible interval) between 291 and 328 individuals within the 45 Sámi villages ("Åretrunt by") included in this analysis. Between 0 [95% credible interval: 0-0] and 22.3 [18-27] wolverines were estimated in any given Sámi village based on the utilization distribution approach. Comparable estimates were produced using the model-predicted activity center locations (between 0 [0-0] and 22.4 [17-29] wolverines). We further provide a three-year time series (2017, 2018, 2019) of wolverine abundance estimates and associated uncertainty for the different jurisdictions.

Contents

1 Introduction

1.1 Large carnivores and Sámi villages

Predation by wolverines (*Gulo gulo*) and brown bears (*Ursus arctos*) is a source of conflict with semi-domestic reindeer husbandry practices in Scandinavia (Persson et al., 2015). The Sámi parliament is seeking information about the distribution of wolverines and bears across the various jurisdictions within the reindeer herding areas, in order to consider alternative ways of defining the compensation schemes. In this context, Naturvårdsverket (Swedish Environmental Protection Agency), in coordination with Sametinget (Sámi parliament), tasked RovQuant at the Norwegian University of Life Sciences with obtaining abundance estimates of wolverines for different regions and administrative entities associated with the Swedish reindeer herding areas.

1.2 Large carnivore monitoring, Rovbase, and RovQuant

Non-invasive genetic sample collection, in combination with dead recoveries, have become a centerpiece of national and regional large carnivore monitoring in Norway and Sweden. Over almost two decades, both countries have accumulated extensive individual-based data sets for brown bear (*Ursus arctos*), wolverine (*Gulo gulo*) and wolf (*Canis lupus*), and plan to continue periodic monitoring in the future. The resulting data collected by the different monitoring programs are recorded in the multi-national large carnivore database Rovbase 3.0 (www.rovbase.se). This database is used jointly by Norway and Sweden to record information associated with large carnivore monitoring including non-invasive genetic sampling (NGS) data, dead recoveries, GPS search tracks, and carnivore observations. Detailed descriptions of the different data types can be found in Bischof et al. (2019b) and Bischof et al. (2020).

In 2019, after two years of development, project RovQuant published the results from the first large scale open-population spatial capture-recapture (OPSCR) analysis based on the data available in Rovbase (Bischof et al., 2019b, 2020). The analysis yielded density and abundance estimates for brown bear (*Ursus arctos*), gray wolf (*Canis lupus*), and wolverine (*Gulo gulo*) for a seven year period (2012/13 - 2018/19). Since then, RovQuant published annual reports with updated density and abundance estimates for the wolf (Bischof et al., 2019a; Milleret et al., 2021, 2022c) and wolverine (Milleret et al., 2022a,b) populations in Scandinavia.

The present project (NV-02444-23) focuses on the extraction and comparison of wolverine abundance estimates for multiple administrative units in Sweden in 2017, 2018 and 2019. It is a follow-up of projects NV-06567-20 (Bischof et al., 2021, "Brown bear and wolverine abundance in the reindeer herding areas in Sweden") and NV-06882-21 (Dupont et al., 2021, "Estimation of bear population size in Sámi villages based on data from Rovbase"). The current report is based the latest population estimation for the Scandinavian wolverine population which included wolverine non-invasive genetic data collected until 2022 (Milleret et al., 2022b). The analysis method (open-population spatial capture-recapture models, OPSCR) produces spatially explicit estimates that can be used to extract abundance estimates and associated uncertainty for any desired spatial extent within the Scandinavian range of the species. Using the spatially explicit estimates from the last RovQuant OPSCR model, we calculated wolverine abundances and associated uncertainties for the different regions and administrative entities. We used and compared two approaches to derive those estimates; one that estimated region-specific abundances based on the model-predicted distribution of individual activity centers ("AC-based") and one based on the model-predicted individual space use distributions ("UD-based").

This document is intended for orientation and planning by Naturvårdsverket and Sametinget. It serves as explanation for the main deliverables associated with the project:

- tables (in .xlsx format) of sex-specific UD- and AC-based abundance estimates of wolverines for all spatial layers provided by Sametinget in 2017, 2019 and 2019.
- wolverine UD-based density maps throughout Sweden in 2017, 2019 and 2019 (in .pdf format).

All of the aforementioned information is made available at https://github.com/richbi/RovQuantPublic.

Box 1: Definitions and acronyms

AC: Activity center. Equivalent to the center of an individual's home range during the monitoring period. "AC location" refers to the spatial coordinates of an individual AC in a given year, and "AC movement" to the movement of an individual AC between consecutive years.
CrI: 95% credible interval associated with a parameter estimate.
MCMC: Markov Chain Monte Carlo.
NGS: Non-invasive genetic sampling.
OPSCR: Open-population spatial capture-recapture.
p0: Baseline detection probability; probability of detecting an individual at a given detector, if the individual's AC is located exactly at the detector location.
$\boldsymbol{\sigma}$: Scale parameter of the detection function; related to the size of the circular home-range.
RovQuant: Research project (2017-2019) funded by the Swedish Environmental Protection Agency (Naturvårdsverket) and the Norwegian Environment Agency (Miljødirektoratet).
Sámi parliament (Sametinget): The Sámi Parliament is a democratically elected indigenous parliament and deals with all matters concerning the Sámi people. The tasks of the Parliament are regulated by the Swedish Sámi Parliament Act.
SCR: Spatial capture-recapture.
Swedish Environmental Protection Agency (Naturvårdsverket): Naturvårdsverket is the Swedish Environmental Protection Agency. It carries out assignments on behalf of the Swedish Government relating to the environment in Sweden, the EU and internationally.
UD: Utilization distribution or individual space-use distribution, describing the proportion of time an individual spends in a given location.

2 Methods

2.1 Spatial extent and configuration

The objective of the analysis was to use estimates of wolverine density previously generated by RovQuant to extract jurisdiction-specific abundance estimates throughout the Swedish reindeer herding areas. The results described in the remainder of this document were derived for multiple shapefiles (**Figure 1**) provided by P. Benson (Sametinget) to R. Bischof (RovQuant; NMBU) on September 28, 2021:

1. Sámi reindeer calving areas (**"A.Kalv praxis by"**): 52 polygons associated with 51 Sámi village names and 1 unidentified polygon (name: "NA").
2. Year-round Sámi villages (**"B.Åretrunt by"**): 45 polygons associated with 45 Sámi village names.
3. Sámi year-round counties (**"C.Åretrunt Lan"**): 4 polygons associated with 4 unique county names.
4. Sámi winter counties (**"D.Vinter Lan"**): 5 polygons associated with 5 unique county names.

5. Swedish counties (**"E.Lan nfo"**): 21 polygons associated with 21 Swedish county names.
6. Sámi concessions (**"G.Koncession by"**): 9 polygons associated with 9 Sámi concession names.

2.2 Source of spatially-explicit density for wolverine

Spatially-explicit density of wolverines that form the starting point of the present study were obtained during the most recent annual analysis by RovQuant (Milleret et al., 2022b). That analysis involved all wolverine data available in Rovbase 3.0 collected 2014 - 2022 and an updated version of the Bayesian open-population spatial capture-recapture (OPSCR) model developed by RovQuant (Bischof et al., 2019b, 2020). The OPSCR model specifically adresses three major challenges associated with population-level wildlife inventories:

1. Detection is imperfect and sampling effort heterogeneous in space and time: not all individuals present in the study area are detected (Williams et al., 2002).
2. Individuals that reside primarily outside the surveyed area may be detected within it. Without an explicit link between the population size parameter and geographic space or area, density cannot be estimated and population size is ill-defined (Efford, 2004).
3. Non-spatial population dynamic models usually estimate "apparent" survival and recruitment, as these parameters include the probability of permanent emigration and immigration, respectively. By explicitly modelling movement of individuals between years, the OPSCR model can return unbiased estimates of demographic parameters (Ergon and Gardner, 2014; Schaub and Royle, 2014).

The OPSCR model is described in Bischof et al. (2019b) and Bischof et al. (2020). For details about the latest wolverine OPSCR analysis and its results, see Milleret et al. (2022b) and the RovQuant github page.

2.3 MCMC concept and uncertainty

The OPSCR model in (Milleret et al., 2022b) was implemented in a Bayesian framework using Markov chain Monte Carlo (MCMC) algorithms. Here we briefly describe the MCMC process and output as this has a bearing on the extraction of jurisdiction specific abundance estimates. For further details see de Valpine et al. (2017); Bischof et al. (2020); Milleret et al. (2022b). The MCMC procedure consists in repeatedly drawing random values for all parameters in the model before evaluating the resulting model fit to the data and accepting or rejecting the proposed parameter values. Over many thousand iterations, the retained parameter values, called the posterior samples, constitute distributions of likely values for all model parameters to be estimated; *i.e.* the posterior distributions. Eventually, as the MCMC algorithm runs long enough and model-sampled parameters approach values that are most likely, the acceptance of proposed parameter values does not influence the posterior distributions further and the model is considered as converged. Using the retained posterior samples, we can then summarize each parameter of interest by calculating its mean, median, and associated uncertainty (*i.e.*, 95% credible interval; the range of posterior values between the 2.5% and 97.5% quantiles of its posterior distribution).

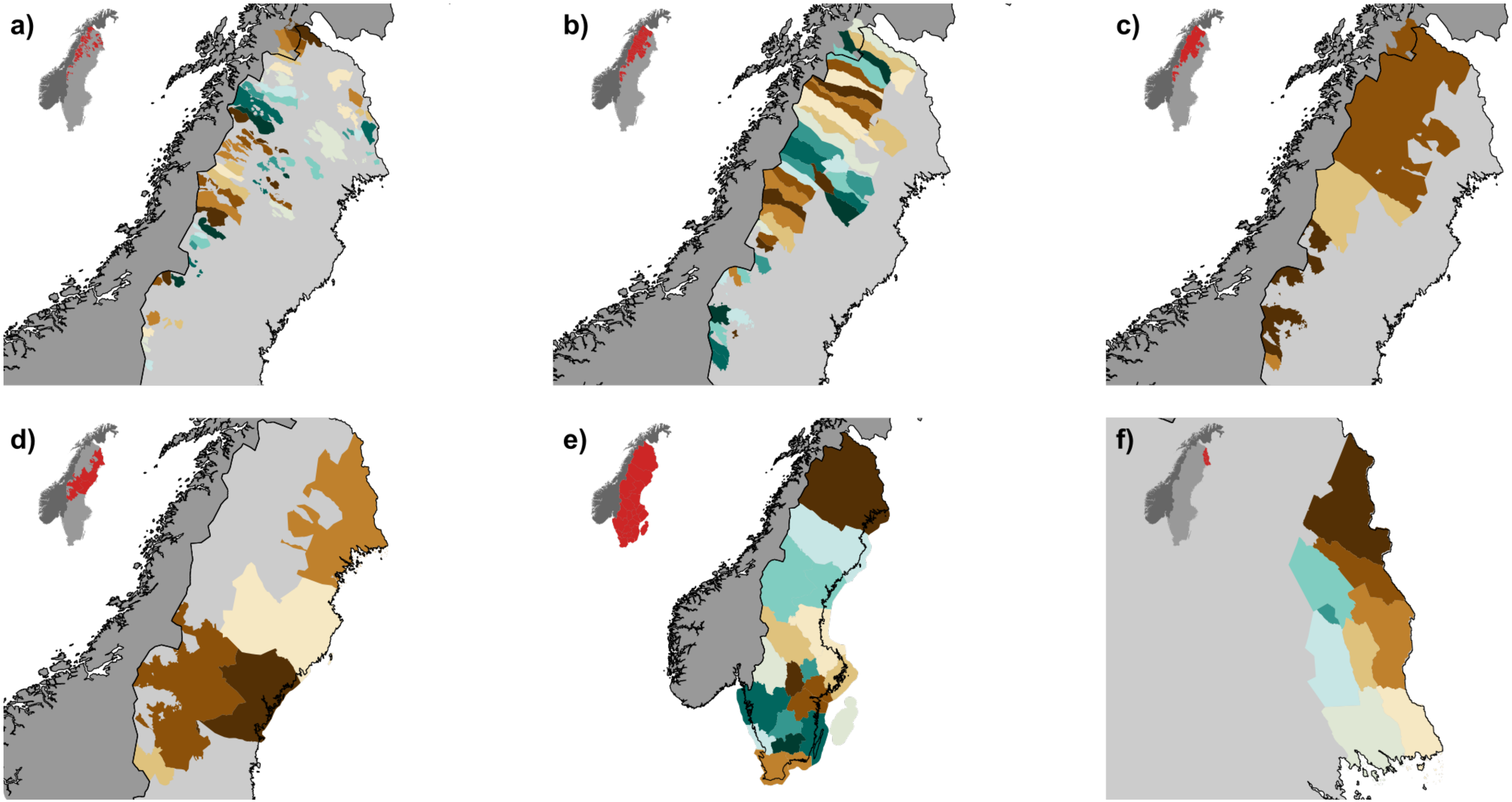

Figure 1: Shapefiles for which the region-specific wolverine abundances were estimated: a) Sámi reindeer calving areas ("A.Kalv praxis by"), b) Year-round Sámi villages ("B.Åretrunt by"), c) Sámi year-round counties ("C.Åretrunt Lan"), d) Sámi winter counties ("D.Vinter Lan"), e) Swedish counties ("E.Lan nfo"), and f) Sámi concessions ("G.Koncession by").

2.4 Abundance estimation

In OPSCR models, individuals are characterized by their activity center (AC, **Figure 2**), which represents the center of their circular home range. Using the posterior estimates for individual AC locations produced by the OPSCR model, region-specific abundances and associated uncertainty can be calculated in two ways:

1. **Abundance based on activity center locations** In SCR studies, density is usually defined as the number of ACs of individuals considered alive per unit area. Thus, to estimate abundance for any arbitrary region, we can sum the number of OPSCR-predicted ACs that fall within this region. Because of the MCMC process, each individual AC location is estimated with some uncertainty and is therefore not a single point but rather a cloud of points which can potentially overlap several regions (the posterior samples; **Figure 2a**). We can then calculate abundance as described above for each iteration of the MCMC algorithm, thus generating a posterior distribution of abundance for the region of interest which we can summarize by its mean, median and 95% credible interval limits. Due to the MCMC process, the region-specific abundance estimates may be non-integer, as the AC of a given individual may end up inside a region during one iteration and outside during another.
2. **Abundance based on individual space-use** The expansive home ranges of large carnivores and their capacity for long-distance movement are in stark contrast with the comparatively small areas (individual Sámi villages and reindeer calving areas) for which abundance estimates were to be generated in this project. The impact (e.g., predation on livestock) of a single large carnivore may readily spread over multiple jurisdictions/villages and management may want to take this into account. Therefore, as an alternative to purely AC-based estimates, we also calculated abundance based on individual space-use or utilization distributions (UD-based estimates). SCR models assume a bivariate normal model of individual space use whereby individuals spend most time near the center of their home range (AC), and space use intensity decreases as distance to the AC increases. The width of this individual space-use distribution, or home range, is determined by the standard deviation of the bivariate normal σ. Based on the AC locations and σ estimates, we can calculate individual space-use and the proportion of time an individual spends in a given region as the integral of its space-use distribution within this region. Abundance within a given region is then simply the sum of the individual proportions of time spent within that region (**Figure 2b**). Similar to the AC-based approach, this calculation can be done for each iteration of the MCMC algorithm, leading to a posterior distribution for the UD-based abundance in each region. As a result, in addition to the uncertainty in the location of the individual AC locations, the UD-based approach also takes into account individual space-use and therefore uncertainty in home range size.

We obtained combined (female/male) abundance estimates by merging the posterior samples for the AC locations and scale parameters (σ from the sex-specific models. In order to process the thousands of posterior samples for all individuals and years, we developed custom C++ functions using the Rcpp package (Eddelbuettel and Balamuta, 2018) in R (R Core Team, 2021) for efficient calculation of AC-based and UD-based abundance estimates and associated uncertainty for any region defined by the user.

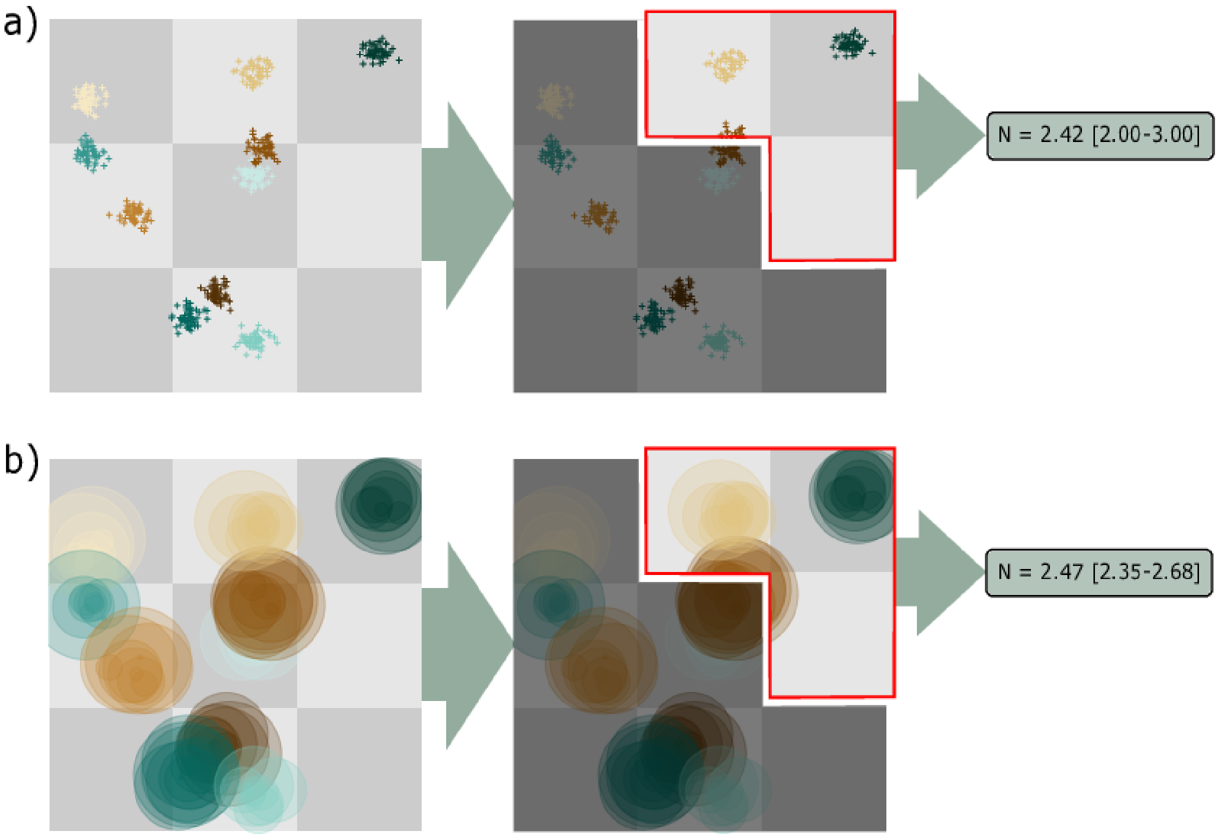

Figure 2: Illustration of the two methods used to derive region-specific abundance estimates; a) the AC-based method sums the number of OPSCR-predicted activity centers (AC) that fall within the region of interest, while b) the UD-based method sums the individual proportions of time spent within a region of interest for each iteration of the MCMC algorithm. Each color represents an individual. The different points in a) and the different circles in b) represent the different AC locations and home range sizes for different MCMC iterations, respectively. Corresponding abundance estimates and 95% credible intervals for the highlighted region are shown on the right.

3 Results

3.1 Wolverine density in Sweden

Based on the utilization distribution posterior estimates, the wolverine population size for Sweden was likely (95% credible interval) between 524 and 577 individuals in 2017, between 573 and 615 in 2018, and between 624 and 681 in 2019 (Table 5). Note that the country-wide estimates provided here differ slightly (±2 individuals) from the numbers provided in Milleret et al. (2022b). The reason for this difference is that the current analysis used a finer resolution ($1km^2$ vs. $25km^2$) to be able to extract abundance estimates for small areas of interest, *e.g.* Sámi concessions (**Figure 1**). Spatial variation in wolverine population density, as well as changes therein over time, are displayed for both the UD-based and AC-based methods in **Figure 3**.

Annual UD-based abundance estimates for all regions of interest are provided below (Table 1, Table 2, Table 3, Table 4, Table 5, and Table 6). A further breakdown into sex- and method-specific annual estimates for each geographical region is provided in the attached excel tables (*table_A_Kalv_Praxis_by.xlsx*, *table_B_Aretrunt_by.xlsx*, *table_C_Åretrunt_Lan.xlsx*, *table_D_Vinter_Lan.xlsx*, *table_E_Lan_nfo.xlsx*, and *table_G_Koncession_by.xlsx*)

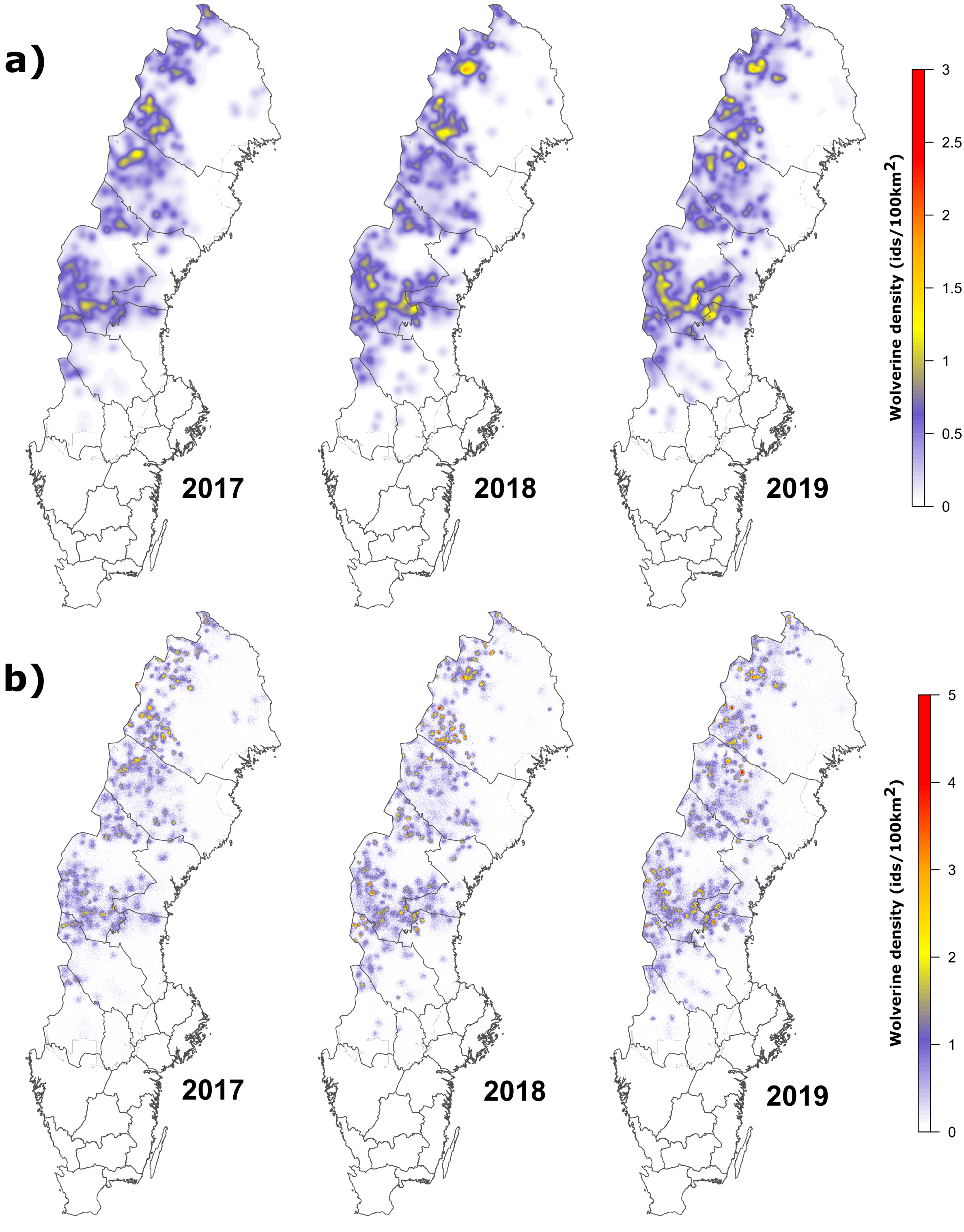

Figure 3: Wolverine densities throughout Sweden in 2017, 2018 and 2019 based on a) OPSCR-estimated utilization distributions (UD-based abundance) and b) OPSCR-estimated AC locations (AC-based abundance).

3.2 Abundance in the reindeer herding areas

Table 1: Wolverine abundance estimates for the different Sámi reindeer calving areas each winter, during the years 2017 to 2019 based on estimated individual space use (UD-based abundance). These total estimates were obtained by joining the sex-specific posterior estimates. Credible intervals (95%) are shown in parentheses. Small deviations between the total estimate and the sum of abundance estimates from the constituent subregions may arise due to rounding. Sex-specific UD- and AC-based estimates are provided in the attached excel file (**"table_A_Kalv_Praxis_by.xlsx"**).

	2017	2018	2019
Ängeså	0.1 (0-0)	0 (0-0)	0.1 (0-0)
Baste cearru	6 (4-8)	9.7 (8-12)	8.1 (6-11)
Gabna	3.6 (2-5)	2.8 (2-4)	2.5 (1-4)
Gällivare	2.2 (1-4)	1.1 (0-3)	1.3 (0-3)
Girjas	6.1 (4-8)	10.3 (9-12)	8.2 (6-11)
Gran	3.1 (2-5)	2.6 (1-4)	3.9 (3-6)
Handölsdalen	5.4 (4-7)	4.9 (3-7)	5.3 (4-8)
Idre	1.7 (1-2)	1.6 (1-3)	1.5 (1-2)
Jåhkågaska tjiellde	2.8 (2-4)	1.5 (1-3)	2.5 (1-4)
Jijnjevaerie	1.5 (1-2)	1.2 (1-2)	1.7 (1-3)
Jovnevaerie	1.8 (1-3)	1.2 (1-2)	0.9 (0-2)
Kalix	0 (0-0)	0 (0-0)	0 (0-0)
Kall	0.3 (0-1)	0.6 (0-1)	0.8 (0-2)
Könkämä	9.8 (8-11)	7.8 (6-10)	7.2 (6-9)
Korju	0.7 (0-2)	0.5 (0-2)	0.5 (0-2)
Laevas	3.6 (2-5)	4 (3-6)	3.5 (2-5)
Lainiovuoma	6 (5-7)	4.4 (3-6)	5.4 (4-7)
Liehittäjä	0 (0-0)	0 (0-0)	0 (0-0)
Luokta-Mávas	7.7 (7-9)	6.3 (5-8)	6.1 (5-8)
Malå	0.6 (0-1)	0.8 (0-2)	0.6 (0-2)
Maskaure	0.4 (0-1)	0.5 (0-1)	0.2 (0-1)
Mausjaur	0.6 (0-1)	0.6 (0-1)	0.5 (0-1)
Mittådalen	2.2 (1-4)	2.7 (2-4)	2.4 (1-4)
Muonio	0.1 (0-1)	0.1 (0-1)	0.2 (0-1)
Njaarke	1.5 (1-3)	1.5 (1-2)	2 (1-3)
Ohredahke	2.3 (1-4)	2.6 (2-4)	2.8 (2-4)
Östra Kikkejaure	0 (0-0)	0 (0-0)	0 (0-0)
Pirttijärvi	0.3 (0-1)	0.5 (0-1)	0.3 (0-1)
Raedtievaerie	0.4 (0-1)	1.2 (1-2)	1 (0-2)
Ran	10 (8-13)	9.3 (7-12)	9 (7-11)
Ruvhten sijte	1.9 (1-3)	1.1 (0-2)	1.3 (1-3)
Saarivuoma	5.4 (4-7)	5.9 (4-8)	6.2 (5-8)
Sattajärvi	0.3 (0-1)	0.2 (0-1)	0.2 (0-1)
Semisjaur-Njarg	7.3 (6-9)	7 (6-9)	7.8 (6-10)
Sirges	7.4 (6-9)	8 (6-10)	7.8 (6-10)
Slakka	0 (0-0)	0 (0-0)	0 (0-0)
Ståkke	2.4 (2-3)	2.3 (2-3)	2 (1-3)
Svaipa	4.1 (3-6)	6.5 (5-9)	5.8 (4-8)
Talma	4.5 (4-6)	3.7 (3-5)	3.5 (2-5)
Tärendö	0.3 (0-1)	0.5 (0-1)	0.3 (0-1)
Tåssåsen	2 (1-3)	2.8 (2-4)	2.5 (2-4)
Tuorpon	3 (2-4)	2 (1-3)	1.9 (1-3)
Ubmeje tjeälddie	10.1 (8-12)	6.5 (5-9)	7.4 (5-10)
Udtja	0.2 (0-1)	0.3 (0-1)	0.3 (0-1)
Unna Tjerusj	3.8 (3-5)	4.6 (4-6)	5.6 (4-7)
Vapsten	12.3 (10-15)	11.2 (9-14)	14.1 (11-17)
Västra Kikkejaure	1.3 (1-2)	1.2 (1-2)	0.9 (0-2)
Vilhelmina Norra	7.3 (5-10)	7.5 (6-10)	7.2 (5-9)
Vilhelmina Södra	2.5 (1-4)	2.7 (1-4)	3.2 (2-5)
Vittangi	0.2 (0-1)	0.2 (0-1)	0.5 (0-2)
Voernese	1.6 (1-2)	1.9 (1-3)	1 (0-2)
Unknown	0.1 (0-0)	0 (0-0)	0.1 (0-0)
Total	158.8 (150-169)	156.9 (149-166)	158.1 (147-170)

Table 2: Wolverine abundance estimates for the different "year-round" Sámi villages each autumn, during the years 2017 to 2019 based on estimated individual space use (UD-based abundance). Total estimates are obtained by joining the sex-specific posterior estimates. Credible intervals (95%) are shown in parentheses. Small deviations between the total estimate and the sum of abundance estimates from the constituent subregions may arise due to rounding. Total AC-based estimates and sex-specific estimates for AC and UD-based abundance are provided in the attached excel file (**"table__B__Aretrunt__by.xlsx"**).

	2017	2018	2019
Baste cearru	7.7 (6-10)	11.9 (10-14)	10.9 (9-14)
Gabna	8.7 (7-11)	7.7 (6-10)	7.4 (5-11)
Gällivare	2.2 (1-4)	1.4 (0-3)	1.7 (0-4)
Girjas	8.3 (6-11)	12.9 (11-15)	11.1 (8-14)
Gran	5.5 (4-8)	4.6 (3-7)	6.4 (5-8)
Handölsdalen	10.5 (8-13)	10.7 (8-13)	11.4 (9-14)
Handölsdalen, Tåssåsen, Mittådalen	1.2 (1-2)	1.1 (1-2)	1.2 (1-2)
Idre	6.4 (5-8)	6.6 (5-8)	5.8 (4-8)
Jåhkågaska tjiellde	3 (2-4)	1.6 (1-3)	2.6 (1-5)
Jijnjevaerie	5.6 (4-8)	4.9 (3-7)	5.9 (4-8)
Jovnevaerie	2.2 (1-3)	1.6 (1-3)	1.3 (0-3)
Kall	0.6 (0-2)	1 (0-2)	1.4 (1-3)
Könkämä	13.2 (11-15)	11.3 (9-14)	10.9 (8-14)
Laevas	8.5 (7-11)	8.4 (7-11)	8.3 (5-12)
Lainiovuoma	7.6 (6-9)	5.2 (4-7)	7.7 (6-10)
Luokta-Mávas	23.1 (21-26)	21.1 (19-24)	20.1 (17-23)
Malå	2.7 (1-4)	3.3 (2-5)	2.6 (1-5)
Maskaure	4.5 (3-6)	4.7 (3-6)	3.9 (3-6)
Mausjaur	1.6 (1-3)	1.8 (1-3)	1.5 (1-3)
Mittådalen	5.9 (4-8)	6 (4-8)	6.9 (5-10)
Njaarke	2.1 (1-3)	2 (1-3)	3.1 (2-5)
Ohredahke	2.7 (2-4)	2.9 (2-4)	3.5 (2-5)
Östra Kikkejaure	0.6 (0-2)	0.3 (0-1)	0.7 (0-2)
Raedtievaerie	2.1 (1-3)	4 (3-5)	3.5 (2-5)
Ran	11.1 (9-14)	10.5 (8-13)	10.1 (8-13)
Ruvhten sijte	4.8 (3-7)	4.1 (2-6)	4.9 (3-7)
Saarivuoma	6.4 (5-8)	7.1 (5-9)	8.5 (6-11)
Semisjaur-Njarg	23.4 (20-27)	24.2 (21-28)	22.3 (18-27)
Sirges	9.4 (7-12)	10.3 (8-13)	10.1 (8-13)
Slakka	0.1 (0-1)	0.2 (0-1)	0.1 (0-1)
Ståkke	5.2 (4-7)	4.7 (4-6)	4.7 (3-7)
Svaipa	8.4 (6-11)	11.6 (10-14)	10.3 (8-13)
Talma	12.3 (10-14)	10.7 (9-13)	11.6 (8-15)
Tåssåsen	7.1 (5-9)	8.5 (7-11)	8.3 (6-11)
Tuorpon	7.4 (6-9)	5.9 (4-8)	5.7 (4-8)
Ubmeje tjeälddie	16 (13-19)	11.3 (8-15)	12.7 (10-16)
Udtja	0.3 (0-1)	0.9 (0-2)	0.4 (0-2)
Unna Tjerusj	12 (10-15)	14.1 (12-17)	16.1 (13-19)
Vapsten	12.3 (10-15)	11.2 (9-14)	14.1 (11-17)
Västra Kikkejaure	4.1 (3-5)	3.5 (3-4)	3 (2-5)
Vilhelmina Norra	13.1 (10-16)	13.3 (11-16)	13.7 (11-17)
Vilhelmina Södra	5.6 (3-8)	6.9 (4-10)	10.7 (8-14)
Vilhelmina Södra, Voernese	0 (0-0)	0 (0-0)	0 (0-0)
Vittangi	0.3 (0-1)	0.3 (0-1)	0.6 (0-2)
Voernese	2.6 (2-4)	3 (2-4)	1.8 (1-3)
Total	298 (284-313)	299.1 (286-314)	309.3 (291-328)

Table 3: Wolverine abundance estimates for the different Sámi "year-round counties" each autumn, during the years 2017 to 2019 based on estimated individual space use (UD-based abundance). Total estimates are obtained by joining the sex-specific posterior estimates. Credible intervals (95%) are shown in parentheses. Small deviations between the total estimate and the sum of abundance estimates from the constituent subregions may arise due to rounding. Total AC-based estimates and sex-specific estimates for AC and UD-based abundance are provided in the attached excel file (**"table_C_Aretrunt_Lan.xlsx"**).

	2017	2018	2019
Dalarnas län	6.1 (5-8)	6.2 (5-8)	5.4 (4-8)
Jämtlands län	47.6 (42-54)	50.1 (45-56)	53.5 (47-60)
Norrbottens län	178 (168-189)	181.6 (173-191)	180.1 (166-194)
Västerbottens län	66.3 (60-73)	61.2 (55-69)	70.3 (63-78)
Total	298 (284-313)	299.1 (286-314)	309.3 (291-328)

Table 4: Wolverine abundance estimates for the different Sámi "winter counties" each autumn, during the years 2017 to 2019 based on estimated individual space use (UD-based abundance). Total estimates are obtained by joining the sex-specific posterior estimates. Credible intervals (95%) are shown in parentheses. Small deviations between the total estimate and the sum of abundance estimates from the constituent subregions may arise due to rounding. Total AC-based estimates and sex-specific estimates for AC and UD-based abundance are provided in the attached excel file (**"table_D_Vinter_Lan.xlsx"**).

	2017	2018	2019
Dalarnas län	15.7 (13-19)	16.7 (14-20)	16.6 (14-21)
Jämtlands län	123 (113-136)	141.7 (133-151)	157.6 (146-170)
Norrbottens län	9.1 (5-14)	8.2 (5-13)	9.9 (4-17)
Västerbottens län	49.8 (43-57)	50.8 (44-58)	61.2 (54-69)
Västernorrlands län	22.5 (18-27)	31.2 (27-36)	37.2 (32-44)
Total	220 (206-237)	248.5 (235-262)	282.6 (265-302)

Table 5: Wolverine abundance estimates for the different counties in Sweden each autumn, during the years 2017 to 2019 based on estimated individual space use (UD-based abundance). Total estimates are obtained by joining the sex-specific posterior estimates. Credible intervals (95%) are shown in parentheses. Small deviations between the total estimate and the sum of abundance estimates from the constituent subregions may arise due to rounding. Total AC-based estimates and sex-specific estimates for AC and UD-based abundance are provided in the attached excel file (**"table_E_Lan_nfo.xlsx"**) .

	2017	2018	2019
Dalarnas län	35.5 (31-41)	46.3 (42-51)	48.4 (43-54)
Gävleborgs län	18 (13-24)	22.3 (18-27)	35.6 (32-40)
Jämtlands län	170.5 (159-185)	191.8 (182-203)	211.1 (198-225)
Norrbottens län	169.7 (159-182)	172.7 (163-183)	171.8 (157-186)
Örebro län	1.5 (0-4)	1.8 (0-4)	1.5 (0-4)
Östergötlands län	0 (0-0)	0 (0-0)	0 (0-0)
Södermanlands län	0.1 (0-0)	0.1 (0-0)	0.1 (0-0)
Uppsala län	0.1 (0-0)	0 (0-0)	0.1 (0-1)
Värmlands län	12 (9-15)	11.6 (9-14)	12.2 (10-16)
Västerbottens län	114.8 (107-124)	110.7 (102-121)	130 (121-141)
Västernorrlands län	25.6 (21-31)	35 (31-40)	40.2 (34-47)
Västmanlands län	0.6 (0-2)	0.4 (0-2)	0.5 (0-2)
Västra Götalands län	0.4 (0-2)	0.3 (0-1)	0.4 (0-1)
Total	548.7 (524-577)	593.1 (573-615)	651.9 (624-681)

Table 6: Wolverine abundance estimates for the different Sámi concessions each autumn, during the years 2017 to 2019 based on estimated individual space use (UD-based abundance). Total estimates are obtained by joining the sex-specific posterior estimates. Credible intervals (95%) are shown in parentheses. Small deviations between the total estimate and the sum of abundance estimates from the constituent subregions may arise due to rounding. Total AC-based estimates and sex-specific estimates for AC and UD-based abundance are provided in the attached excel file (**"table_G_Koncession_by.xlsx"**).

	2017	2018	2019
Ängeså	1 (0-2)	0.2 (0-1)	0.4 (0-2)
Kalix	0.2 (0-1)	0.2 (0-1)	0.4 (0-2)
Korju	1.5 (1-3)	0.9 (0-2)	1 (0-3)
Liehittäjä	0.2 (0-1)	0.2 (0-1)	0.3 (0-2)
Muonio	0.5 (0-2)	0.4 (0-2)	0.8 (0-3)
Pirttijärvi	0.7 (0-2)	0.7 (0-2)	0.5 (0-2)
Sattajärvi	0.7 (0-2)	0.6 (0-2)	0.4 (0-2)
Tärendö	0.4 (0-2)	0.8 (0-2)	0.5 (0-2)
Tärendö, Ängeså	0 (0-0)	0 (0-0)	0 (0-0)
Total	5.3 (3-8)	4.1 (2-7)	4.4 (1-8)

3.3 Comparison between AC and UD-based abundance estimates

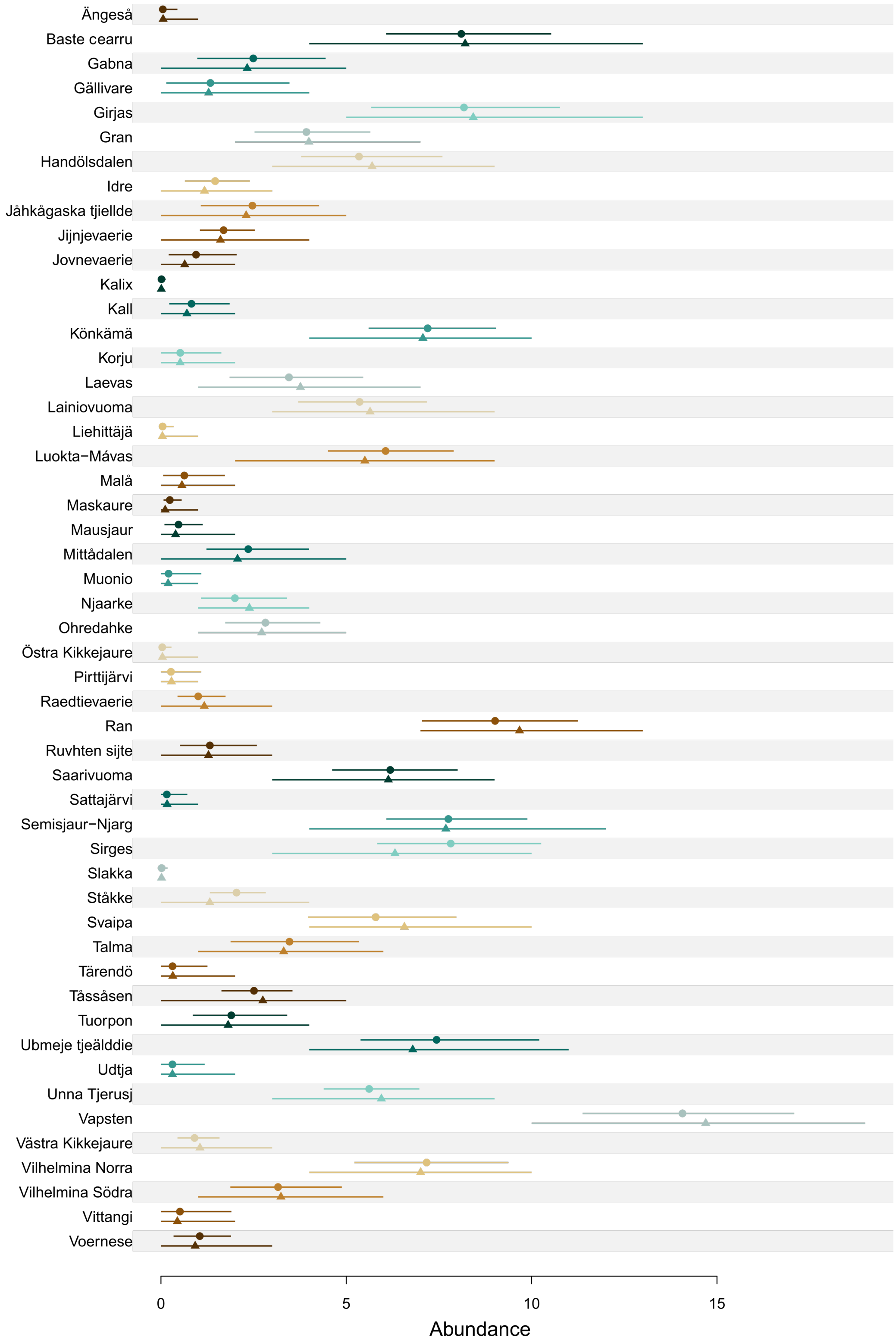

Figure 4: Comparison of wolverine abundance estimates for the different Sámi reindeer calving areas in 2019 based on estimated activity center locations (colored triangles, AC) and estimated space use (colored circles, UD). Filled shapes represent the mean estimate, associated segments represent the 95% confidence interval. This comparison, as well as similar comparisons for the other shapefiles and other years, showed no systematic differences between AC and UD-based estimates.

Cautionary note

The primary motivation behind the analysis presented here was to provide information to guide the allocation of compensation for damages inflicted by wolverines to reindeer herding operations in Sweden. Thus, estimates provided here may have direct policy implications and we feel obligated to note the following:

1. Many of the regions for which estimates were generated are small compared to wolverine home range sizes, and certainly small compared to the area used by the wolverine population. At such fine spatial scale, the ability of the model to make unbiased and precise inferences is limited. Mean estimates for very small areas will be disproportionately small relative to the associated uncertainty, making inferences unreliable. We urge users of the information provided here to focus on the upper and lower credible intervals, instead of the point estimates.
2. Use of our region-specific abundance estimates for disbursement of financial compensation also assumes that there is no overlap between different polygons/regions; overlap will lead to double-counting of animals and thus duplicate compensation (i.e., more than one jurisdiction receives compensation for the same wolverine's activity in the same area).
3. In this analysis, we only estimated region-specific abundances of wolverines and did not take into account actual damages inflicted. The relationship between wolverine abundance and risk of damages to reindeer husbandry operations will depend both on large carnivore activity and on the presence of reindeer and their vulnerability.
4. Our model makes a number of simplifying assumptions, the impact of which would need to be further evaluated. Among these assumptions are: circular home ranges and negligible variation in space use between individuals of the same sex. Again, the finer the spatial scale for which estimates are derived, the greater the expected impact of violations of these and other model assumptions.

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