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LYNX MONITORING REPORT

for the Bohemian-Bavarian-Austrian Lynx Population in 2019/2020

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Lynx Monitoring Report for the Bohemian-Bavarian-Austrian Lynx Population in 2019/2020

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Cover photo: Cover photo shows the lynx female “Leila”. Photographed by © Thomas Engleder with a camera trap. This female established a home range near Bärnstein mountain in the Austrian-Czech borderland, where she was camera trapped during lynx years 2019 (this report) and 2020.

Content

Summary

This report presents monitoring data of the BBA lynx population for the monitoring period 1.5.2019 – 30.4.2020 (lynx year 2019, hereafter: LY19) and is one of three monitoring reports prepared for this population within the 3Lynx project (Interreg CENTRAL EUROPE Programme). Our study area stretched along the border region of Germany, Czech Republic and Austria. Camera trapping was applied on an area of 13,200 km^2 (i.e. an area larger by 1.5% compared to the 2 previous years), with 2-8 camera traps per 10x10 km EU grid cells installed year-round. Lynx presence has been verified in 10,400 km^2.

We identified 133 independent lynx (subadults and adults, one of which immigrated from the Harz population), including 34 reproducing females, who produced 74 juveniles. The maximum population size was estimated at 143 independent lynx.

We registered 7 cases of mortality (5 road accidents, 2 illegal killings), and 4 cases of orphaned lynx, one of which was released back to the population during LY20 and is thus not considered a population loss. Therefore, in LY19, altogether the loss of 10 individuals was confirmed in the study area.

We examined the survival of 121 independent lynx from LY18 to LY19. 19.7 % (n=15) of adult lynx which were recorded in LY18 were not recorded anymore in LY19: in two cases it was due to proven illegal killing, in two other cases it was due to road mortality, in 11 cases (14.5%) the fate of these adult lynx was unknown. Based on the level of annual natural mortality estimated for another lynx population, on the different detection probability of mortality events related to different causes, and on the extent and intensity of camera trapping in the study area, we assume that the majority of these cases, where fate remains unknown, are probably representing the dark figure of illegal killing. 46.3% (n=19) of subadult lynx and 75% (n=3) of “lynx whose age only could be determined as more than one year old, i.e. subadult or adult” recorded in LY18 were no longer recorded in LY19: in only one case (subadult lynx) this was due to proven natural mortality, in all other cases the lynx disappeared. Most probably due to these (proven and probable) losses, the growth rate of the BBA lynx population was rather moderate with $\lambda = 1.10$ (10 % growth rate from LY18 to LY19).

These results are similar to those obtained for the previous lynx year (available here for LY18) thus further supporting our previous assumptions that illegal killing seems to be the most important threat to the Bohemian-Bavarian-Austrian (BBA) lynx population, and road mortality has gained in importance. Future conservation efforts must emphasize on taking effective measures against both threats.

Camera trapping proved to be a very valuable monitoring method and provided us with robust data on lynx distribution and population size. However, an ongoing and continuous approach is needed to monitor population dynamics effectively.

1. Introduction

Monitoring data is the base for decision-making in lynx conservation and management. Therefore, a lot of effort has been invested in improving and harmonizing monitoring methods for the Bohemian-Bavarian-Austrian (BBA) lynx population on a transboundary scale since 2013. The population-based monitoring stretches along the borders of Czech Republic, Germany and Austria. It includes almost the entire range of the current lynx population in these three countries, with about 13,200 km^2 stably covered with camera-traps, which to our knowledge is an exceptional case in Europe (the only comparable population-based monitoring has just recently been enforced in the Dinaric-SE Alpine area (Krofel et al. 2021)).

The harmonisation of data collection, data evaluation and data analysis started in 2013 during the TransLynx project, and is an ongoing process that continued with further methodical refinement within the 3Lynx project.

The present report is one of three monitoring reports in the scope of the 3Lynx project and represents collected monitoring data for the BBA lynx population for the lynx year 2019 (1.5.2019-30.4.2020, hereafter LY19). The monitoring reports of lynx year 2017 (hereafter LY17, Mináriková et al. 2023, updated from 2019), lynx year 2018 (hereafter LY18, Wölfl et al. 2023, updated from 2020) and lynx year 2019 represent the achievement of a fundamental goal of the 3Lynx project, the assessment of the BBA lynx population, which is part of the lynx conservation strategy prepared in the scope of the 3Lynx project.

2. Study Area

The study area (Fig. 1) stretches across the border triangle of Czech Republic (Bohemia), Germany (Bavaria) and Austria. Its boundaries are determined by the Danube River in the South, Krušné hory and Frankenwald in the North, Waldviertel and Vysočina in the East and Fränkische Alb in the West.

The study area was defined for the purpose of lynx monitoring and habitat modelling in 2013 during the TransLynx project. It was delineated by experts based on the knowledge of lynx habitat use, the large-scale occurrence of signs of lynx presence over the previous 15 years and in accordance with the habitat models of Schadt (1998), Schadt et al. (2002), Rudolph & Fetz (2008), and Romportl in Anděl et al. (2010). Besides core habitat areas, it also includes adjacent suitable habitat patches where lynx is supposed to occur only sporadically. The study area was defined big enough to consider long-distance dispersers, migrants, habitat features and a possible future expansion of the BBA population.

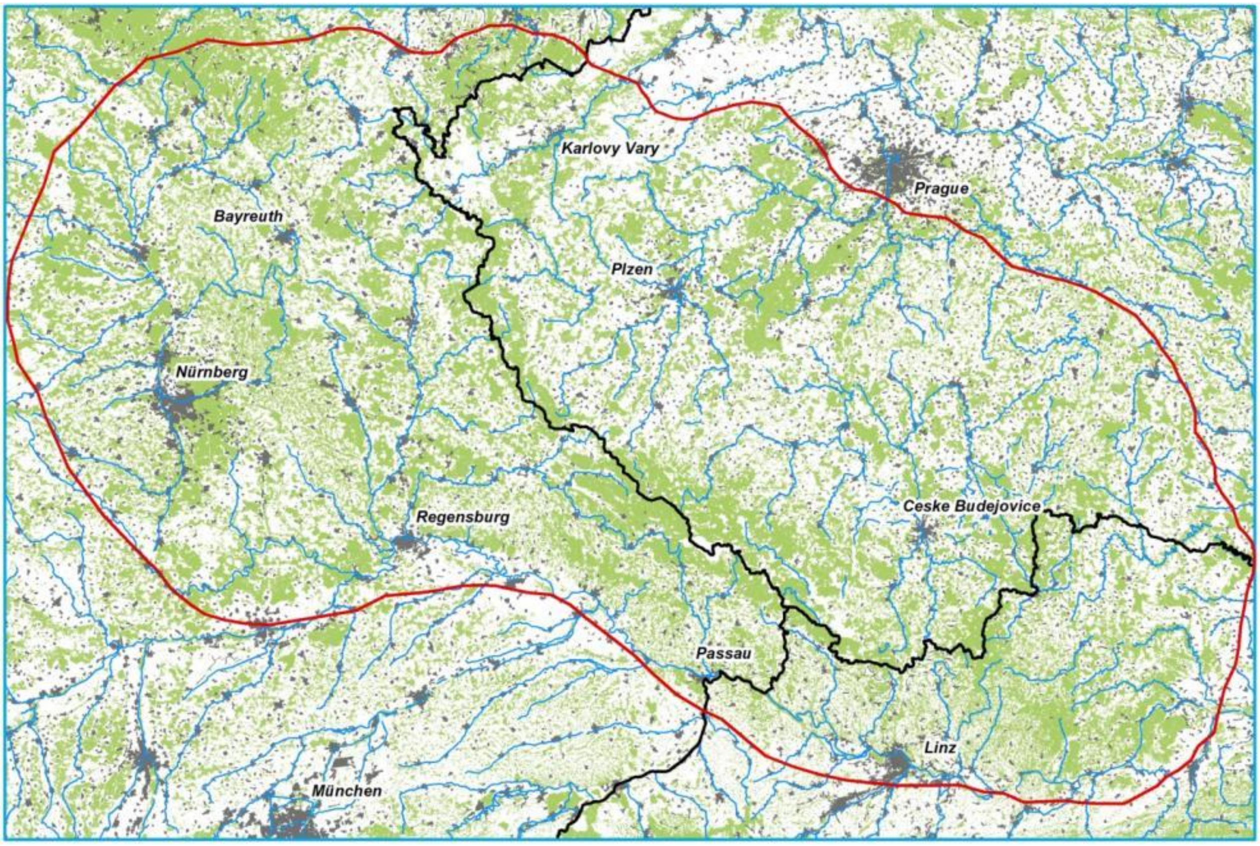

Fig. 1: Study area

Area monitored with camera traps

During LY19, the area monitored with camera traps consisted of 132 10x10 km ETRS89 grid cells, with 2 additional grid cells on the Czech side compared to the two previous lynx years. Therefore, the total size of the area monitored by camera traps was 13,200 km^2 (Fig. 2).

Generally, monitored grid cells were selected based on

a) existing lynx habitat models (Schadt 1998, Schadt et al. 2002, Rudolph & Fetz 2008, Romportl 2015),
b) the protection status of the area (protected landscape area, Natura 2000 sites),
c) the probability of lynx occurrence in the area (given mainly by distance and connectivity to the known core area of the population), and
d) the willingness of hunters and forest owners to cooperate.

In the Czech Republic, the National Park Šumava (680 km^2) and the protected landscape areas (PLA) Šumava, Blanský les, Český les, Slavkovský les and Brdy were monitored together with unprotected areas between PLAs and in the Czech-Austrian border region and north from PLA Šumava. In Bavaria, the Bavarian forest region with the Bavarian Forest National Park (240 km^2) and part of the Bavarian Forest Nature Park, the Oberpfälzer Wald along the Czech-German border and the Steinwald were monitored. In

Austria, Mühlviertel and Waldviertel along the Czech-Austrian border and some suitable habitat patches along the Danube were monitored.

These areas cover the core of the range of the population with the largest patches of continuous lynx habitat (national parks Šumava and Bavarian Forest, PLA Šumava and Bavarian Forest Nature Park). They also cover other significant patches of suitable habitat, stepping-stones and corridors in the outskirts which are inhabited by lynx or which bear a high chance of lynx presence.

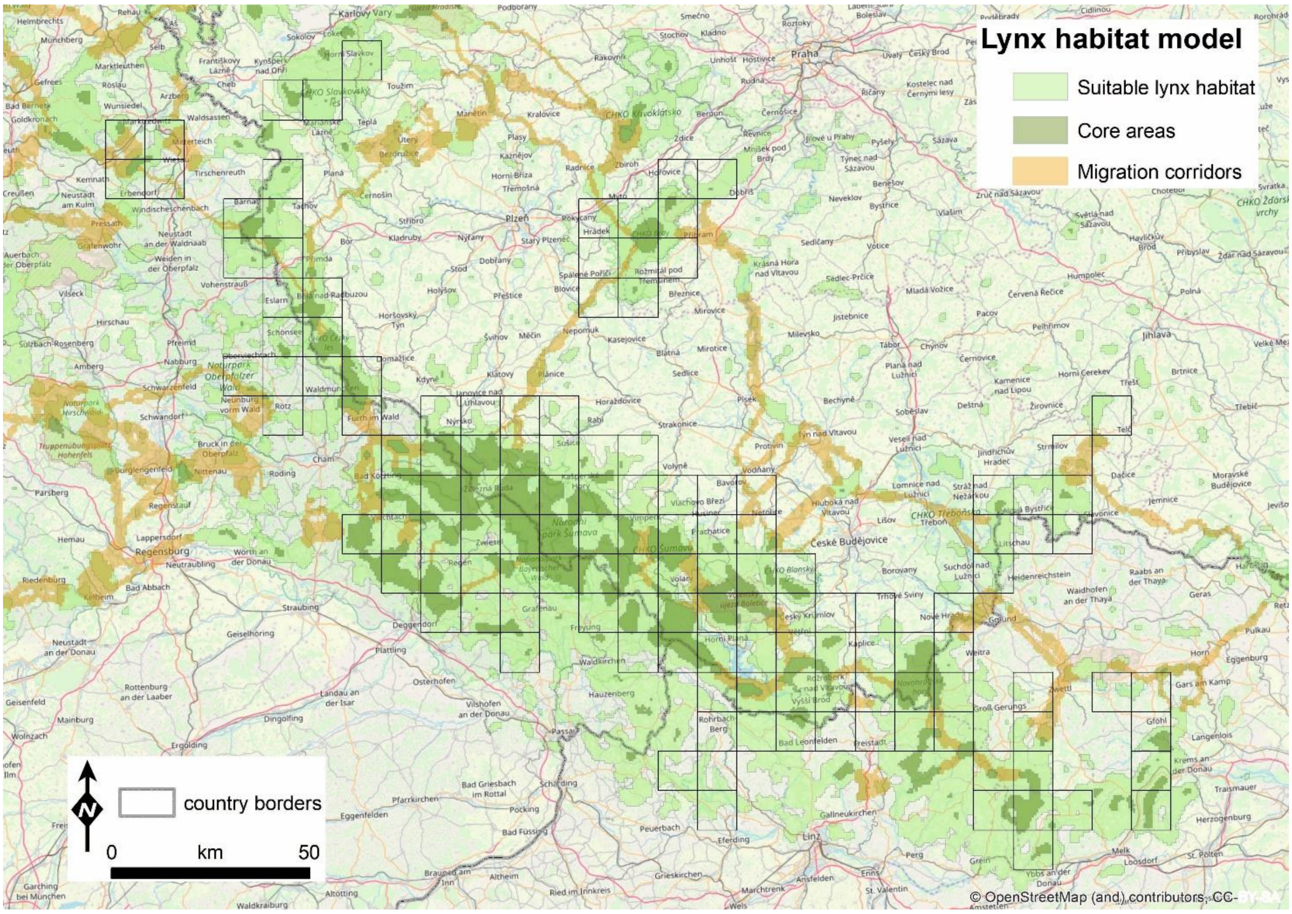

Fig. 2: Lynx habitat map with the 10x10 km ETRS89 grid cells monitored in lynx year 2019, based on lynx habitat model (Romportl 2015).

3. Monitoring Methods

3.1. Standards for data analysis and evaluation

3.1.1. Evaluation of monitoring data according to the SCALP criteria

All collected monitoring data was classified according to criteria described by the SCALP expert group (Molinari-Jobin et al. 2003, Molinari-Jobin et al. 2012). The classification was carried out according to the verifiability of records. This requires the standardized documentation of findings and verification by an expert with several years of field experience.

Three categories are distinguished:

- Category C1: represents 'hard fact' data (e.g. dead lynx, georeferenced lynx photo, genetic proof).
- Category C2: includes confirmed data (e.g. kills or tracks, verifiable due to a substantial documentation and verified by an expert).
- Category C3: summarizes unconfirmed data (e.g. direct visual observation and calls; kills, tracks which are not sufficiently documented but seem probable).

Data analyses (i.e. distribution, population size) were based only on data of the categories C1 and C2 (for technical reasons, for the Austrian part of the BBA population range, for this report, only C1 data were considered).

3.1.2. European grid

For scaling of lynx monitoring effort and for spatial data analysis, the 10x10 km ETRS89 grid in the ETRS LAEA 5210 projection was used.

3.1.3. Reporting period: Lynx year (LY)

The reporting period in which the data were analysed was chosen according to the lynx life cycle, i.e. the birth of lynx kittens in spring (May/June) and their separation from their mother in late winter (April/May) of the following year. By definition the "lynx year" therefore begins on 1st May and ends on 30th April of the following year. This ensures correct population size assessment, as females with kittens are only counted once per monitoring period.

3.1.4. Terminology

Lynx	Eurasian lynx (*Lynx lynx*)
Juvenile lynx	Lynx in the first year of life (also called “kitten”). From birth until 30th of April of the following year (0-1 year of age).
Subadult lynx	Lynx in the second year of life. After separation from its mother until sexual maturity (1-2 years of age).
Adult lynx	Lynx older than 2 years, sexually mature.
Independent lynx	Lynx no longer dependent on its mother, i.e. subadult or adult (>1 year).
Resident lynx	Lynx staying for at least 12 months in the same area
Reproducing female	Female who had offspring/kitten(s) in the respective lynx year
Lynx family	Reproducing female with juvenile(s)
Orphaned lynx	Juvenile who was separated from its mother because (1) its mother died, (2) it was abandoned, or (3) it was captured by humans because of true or assumed absence of the mother
Turnover rate	Percentage of individuals who were recorded in the previous lynx year but not recorded in the current lynx year, thus either died or vanished from one lynx year to the next

3.2. Data collection

For lynx monitoring we used the following monitoring methods:

1. Camera trapping
2. Collection of observational data and chance findings (dead lynx, photos, kills, tracks, scat, hair, etc.)
3. Genetic monitoring
4. Snow tracking

3.2.1. Camera trapping

Camera trapping was the fundamental method of the BBA pilot lynx monitoring system developed during the 3Lynx project and was applied extensively, i.e. on a large scale. A minimum of 2 camera trapping sites per 10x10 ETRS89 grid cell were selected. At every site, 1 or 2 camera traps were installed, depending on terrain and available number of camera traps. In most areas with known or assumed cases of reproduction, 4 to 8 camera trapping sites were selected, to both record natality (number of kittens) and obtain enough good quality pictures of the juveniles for later identification. As mentioned above, during LY19, on the Czech side 2 newly monitored grid cells were added to the area covered by stable camera trapping (i.e. an area larger by 1.5% compared to the 2 previous years, see chapter 2 and Fig. 2). Besides, in some already monitored (edge-) grid cells on the Czech side, camera trapping was intensified by installing few additional camera-trapping sites.

Thanks to the long-term and year-round installation of the camera traps also data on abundance, survival and dispersal, as well as changes in dispersion, age and sex structure in the course of the year could be collected. Thanks to the multiple year-round installation of camera traps, similarly as in our previous report (Wölfl et al. 2023, updated from 2020), we could calculate the "turnover rate" for adult and subadult lynx from LY18 to LY19, i.e. the percentage of individuals who were camera-trapped till LY18, and were not recorded anymore in LY19 (see chapter 3.1.4). Furthermore, it was possible to detect areas where a number of adult lynx suddenly disappeared, leaving unoccupied home ranges.

At most locations, in order to get good quality pictures, white flash camera traps of the brand Cuddeback were used. Infrared or black-flash camera traps were mostly used at kill sites or scent-marking places. At these locations, lynx generally move relatively slowly so that these camera trap types can also produce focused pictures with recognizable coat pattern.

Camera trap sites were chosen according to expert knowledge of lynx habitat and spatial use as well as information from snow tracking or past radio-telemetry locations (if available). They were installed at forest roads, hiking or wildlife trails and in rocky terrain to maximise the detection probability. Camera traps were equipped with information sheets about the owner and the objectives of the study. Due to logging activities in areas with bark beetle calamities or rolled lumber, thefts, sabotages or objections by landowners or hunters not every suitable camera trap site could be equipped with camera traps, which led to gaps in the otherwise even spacing of camera trapping sites.

3.2.2. Collection of observational data and chance findings

Observational data and chance findings (tracks, killed prey, hair, calls, camera-trap pictures from hunters, foresters, general public or nature conservationists) were collected and evaluated according to the SCALP criteria. These types of data were collected from the entire study area. They serve as additional data set and can assist and complement data gathered with systematic camera trapping. They can point out areas where it would be valuable to increase monitoring efforts, especially if these data originate from outside the area of extensive and systematic camera trapping.

As camera traps are increasingly commonly used by hunters and foresters, they sometimes also record lynx by chance at ungulate feeding sites or at lynx kills. This produces an increased number of camera trap pictures which can help to complement or fine-tune our established monitoring system.

3.2.3. Genetic monitoring

Samples of lynx scat, hair, urine, saliva, blood or tissue were collected in the field at known marking places, during field surveys specifically organized for this purpose or when found by chance. Saliva was collected from freshly killed prey and blood or tissue samples were collected from lynx carcasses. All these samples were sent to a specialized lab for DNA extraction (Institute of Vertebrate Biology, Czech Academy of Sciences in

Brno). The results of the genetic analysis are presented in a separate report (Krojerová and Turbaková 2020, Gajdárová et al. 2023).

3.2.4. Snow tracking

Following lynx tracks in the snow helps to adjust suitable camera trapping sites and to find lynx kills, scats or urine, also enabling genetic examination. However, snow tracking depends on persistent snow cover. Due to unreliable snow conditions in the study area in the last years, it was not systematically applied on transects but rather as a complementary method.

In winter 2019/2020, snow tracking was mostly applied by the associated project partner Hnutí DUHA Šelmy with their trained volunteers, so-called 'Lynx patrols'. The selected area for snow tracking was chosen at the edge of known lynx range, where insufficient lynx data existed, or where camera trapping was not fully implemented. In total, 160-day-long tracking walks were carried out. All findings (tracks, scat, hair, urine) were documented and evaluated according to the SCALP criteria.

On 24th March 2020, the Šumava NP Administration also organized a single day of snow-tracking with 63 tracking trails walked mostly by NP employees, for 613 monitored kilometres. Although the main aim of this activity was to monitor the dynamic situation with wolf (*Canis lupus*) occurrence within NP and PLA Šumava, every detected lynx track was also accurately documented and evaluated according to the SCALP criteria.

For LY19, all snow tracking data came from grid cells where lynx occurrence was also confirmed by camera traps. Thus, the data from snow tracking were mostly used for detecting potential new camera trapping sites and gaining genetic samples rather than confirming lynx presence in the area.

3.3. Data analysis

Collected camera trap pictures were exchanged on a regular basis via online-cloud and underwent a final overall review by all monitoring partners to avoid double-counting of the same individual. Each lynx individual was coded using a code system with characters and numbers, e.g. B33 or B500 or B020AT ("AT" stands for Austria). The code system was differentiated into number blocks for the Czech and Bavarian side of the study area. In this way, the given number revealed the country of first registration of the respective individual, too. If sex of the identified lynx was known, the animal got a name, which facilitated memorization of the individual lynx in daily work.

Camera trapping data were pooled in 60-minute-events, if more than one picture was taken during this time period, e.g. at kill sites. If more than one lynx was photographed in one picture, e.g. lynx female with two kittens, every identified lynx was recorded as a separate data line. These data, together with additional C1 (and C2) data obtained with other methods, were used for distribution maps and assessment of minimum and maximum population size, as described in the "Results" chapter later.

Distribution maps

We defined a grid cell of 10x10 km as "occupied" if at least one C1 or one C2 data was located and confirmed in the respective grid cell. Generally, grid cells with C1 data are differentiated by colour from grid cells with C2 data, because of the reasons mentioned above (see chapter 3.1.1).

Furthermore, because lynx year 2019 was the 3rd consecutive year of whole-population monitoring, performed more or less in the same way, for this report we were also able to prepare a "cumulative" distribution map based only on C1-positive grid cells of the 3 consecutive lynx years (2017, 2018, 2019). Even though in the study area the monitoring effort since 2017 has increased enormously compared to any of the lynx years until 2016, lynx occurrence may still be more difficult to detect at the margins of this area compared to its core. In fact, the number of camera trapping sites per monitored grid cell is generally lower at the margins than at the core of the study area. Thus, a given grid cell at the margins may still result negative in a single year only due to a temporally unfortunate combination of local conditions, accidental camera failures or camera-thefts, (not only because of possible locally more sporadic lynx presence). Furthermore, at the margins of the population's distribution some potentially suitable grid cells are not permanently monitored with camera-trapping yet. Only chance-C1 data can come from such grid cells, and obtaining chance data is "by definition" depending on several circumstances, which can vary enormously between years. Therefore, by overlaying the C1-positive grid cells from three consecutive monitoring years into one map, we aimed to limit these potential effects and give a more compact picture of lynx occurrence in the entire study area.

Assessment of minimum and maximum population size

We assessed the minimum and maximum population size in two ways and named them i) documented minimum population size and ii) theoretical minimum and maximum population size.

The documented minimum population size was assessed by counting all independent lynx, which could be identified individually by their coat pattern (all lynx coded as B-animals). The animals which were recorded only from left side or only from right side (coded as L- or R-animals) were partly taken into account, also depending on their general coat pattern type (spotted versus marbled). The reasoning behind this is: animals which were recorded from only left side could be the same animals which were recorded from only right side, therefore we only took into account the higher number of animals recorded from only one side (either R- or L-animals). However, an individual recorded as „marbled" from one side cannot correspond to an individual recorded as „spotted" from the other side. Thus, we obtained the documented minimum population size by summing the B-animals and the higher numbers of marbled and spotted individuals recorded only from one side (either left or right).

The approach to assess the theoretical minimum and maximum population size is based on the share of reproducing females applying the results of the Population Viability Analysis (PVA, Poledníková et al. 2015) performed within the TransLynx project.

The data compilation necessary for the PVA revealed that the long-term share of reproducing females from the whole population was 17.5 % with 19 % standard deviation and was stable over the years. Thus, based on the recorded number of families and the calculated age structure of the population within the PVA deterministic model, size of the whole population including all animals of all age categories (adults, subadults, juveniles) can be re-calculated. This simple method is used for a rough but objective assessment of the BBA population size. It is partly similar to Andrén et al. (2002)'s method used in Scandinavia, where the share of reproducing females out of all independent individuals is used to calculate the total number of independent animals.

4. Results

4.1. Distribution and range

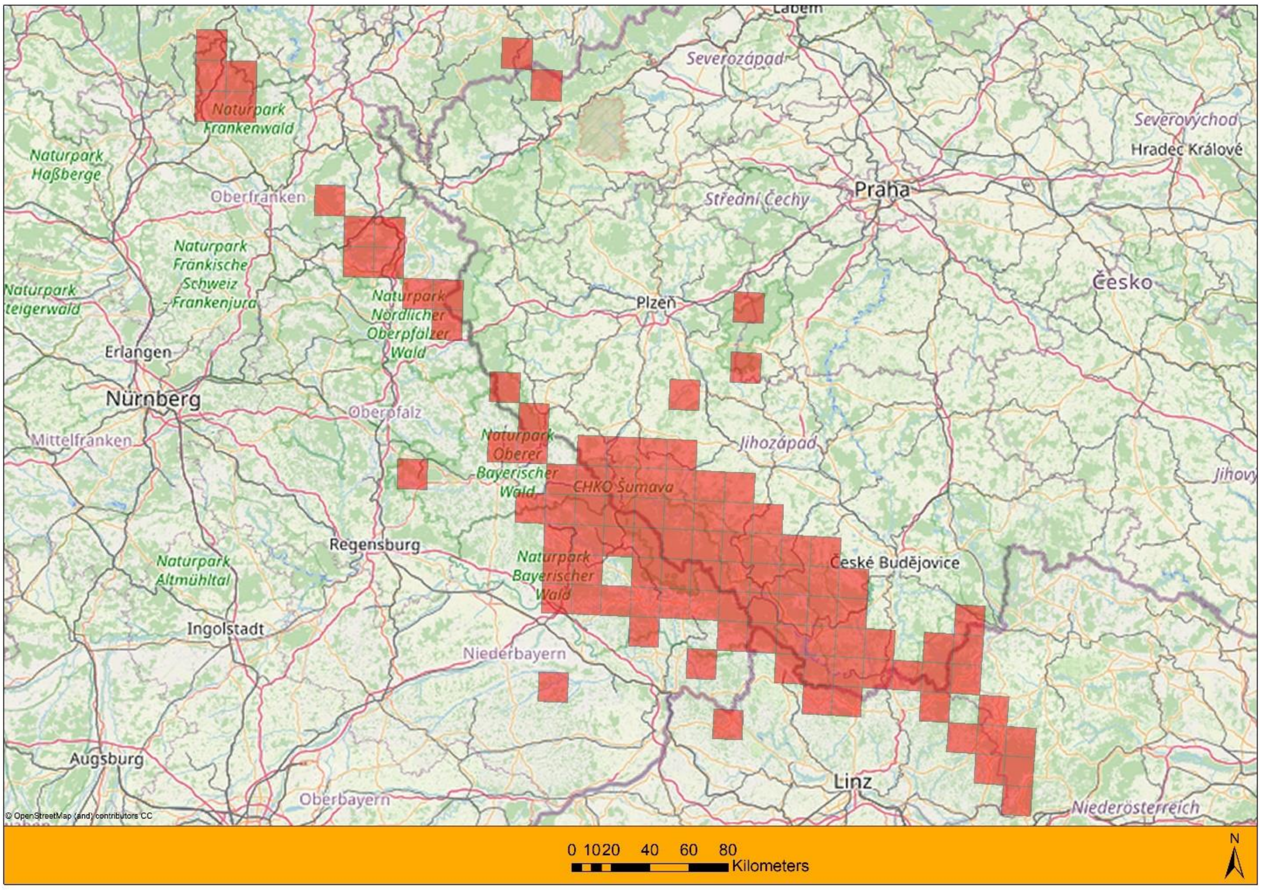

Fig. 3: The occupied 10x10 km grid cells projected in ETRS89 show the lynx distribution in the study area in lynx year 2019. Grid cells in red colour are occupied by at least one C1 data.

In the study area, in LY19, in total 104 grid cells of 10x10 km size were occupied by C1 records (including 2 grid cells in Erzgebirge/Krušné Hory - Fig. 3). For this report, as mentioned in chapter 3.1.1., for the Austrian part of the study area only C1 data were provided. Furthermore, all collected C2 data for the Czech and Bavarian part of the BBA population range were located in already C1 positive grid cells, which at least for the Czech side may be partially related to the minor improvement in camera-trapping coverage for certain regions in the outskirts of the population distribution described in chapter 3.2.1. Thus, the BBA distribution map for LY19 (Fig. 3) did not include any “only C2”-positive grid cells.

These 104 grid cells comprise an area of 10,400 km^2 with permanent or sporadic lynx presence, which represents a slight increase compared to the distribution range confirmed in the previous lynx years (LY17: 86 C1 and 12 C2 grid cells; LY18: 85 C1 and 6 C2 grid cells, Tab. 1).

When overlapping the distribution maps based on C1 data for the 3 consecutive lynx years 2017, 2018 and 2019, we obtained a total area of 12,100 km^2 (121 grid cells that proved C1-positive for at least one of these lynx years) with (permanent or sporadic) lynx presence confirmed by data of the highest quality category (Fig. 4).

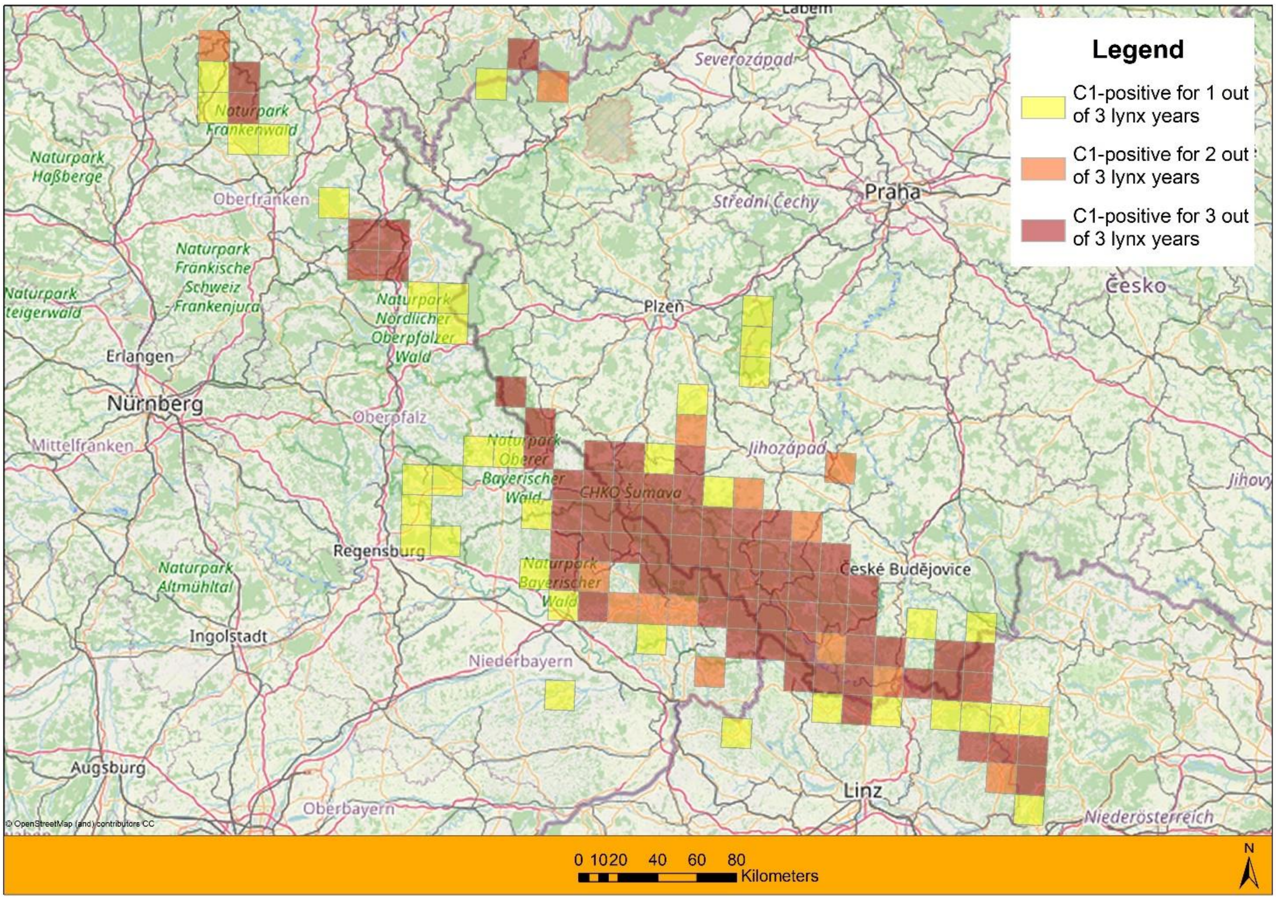

Fig. 4: The occupied 10x10 km grid cells projected in ETRS89 show the lynx distribution in the study area in lynx years 2017 + 2018 + 2019 (only based on C1-positive grid cells for each year). The darker the colour, the more years the grid cell was C1 positive – i.e.: darkest = all 3 year the grid cell was C1 positive, middle = 2 years, lightest = only 1 year).

Tab. 1: Number of C1 positive grid cells in BBA monitoring area according to lynx years (LY)

	N. of permanently monitored grid cells	N. of C1 positive grid cells	Corresponding area in km² and in hectares
LY19	132	104	10,400 km² or 1,040,000 hectares
LY18	130	85	8,500 km² or 850,000 hectares
LY17	130	86	8,600 km² or 860,000 hectares
LY17+LY18+LY19 summarized	**132**	**121**	**12,100 km² or 1,210,000 hectares**

4.2. Population information

The following population information was updated in 2022 due to new data and the changed consideration of lynx in Steinwald and Erzgebirge/Krusne Hory. Despite isolated from BBA population these lynx were newly integrated in the population information (see Wölfl et al. 2023, updated from 2020). Generally, data which might be provided later (sometimes up to three or more years later) can cause minor changes in population information.

Lynx occurrence in northern Bavaria - region of Steinwald and Frankenwald

The lynx occurrence in the Steinwald region was established in 2016 and 2018 by the translocation of two lynx who were found orphaned in the Bavarian Forest region. Since 2016 the Steinwald region has been inhabited by a female lynx, called „Fee“. She was captured as an orphaned kitten in 2015 in the Bavarian Forest and released in August 2016 in Steinwald. In 2017 another orphaned male juvenile, called „Hotzenplotz“, was captured in the Bavarian Forest and released in April 2018 in the Steinwald, too. At the end of calendar year 2018 a third lynx appeared in the area, displacing „Hotzenplotz“ and injuring him severely during a territorial fight. „Hotzenplotz” was then found dead in March 2019. The origin of the third lynx, called „Ivan“, could be proved by comparing camera-trapping pictures to be the Harz mountains, 220 km beeline from Steinwald.

In the Frankenwald region several lynx records have been registered since LY17. These records stem from a single roaming unidentifiable male lynx who was genetically tagged as coming from the Harz Mountains. The last genetic proof of this lynx was in December 2017. In autumn 2018 another male lynx appeared in Frankenwald. By comparing camera-trap pictures, his origin was proven to be the Bavarian Forest. This lynx B55, called „Bartl“, was lastly camera-trapped on 26th June 2018 in the Bavarian Forest and on 1st September 2018 he was first camera-trapped near Tschirn in Frankenwald, 190 km beeline from his last record in the Bavarian Forest. He was recorded during LY18 and LY19 by camera-traps installed by foresters in the Nordhalben forest district. This lynx showed interesting dispersal behaviour by travelling 190 km beeline in two months and by crossing three highways between Bavarian Forest and Frankenwald. However, without encountering female conspecifics such a lynx is most probably lost for the source population, although he contributes to the enlargement of the registered lynx range in the study area.

The situation in the Steinwald differs insofar as the translocated lynx female “Fee”, who established a home range there, could initialize an occurrence outside the current BBA lynx population by binding the translocated male “Hotzenplotz” (dead at the end of LY18) and the migrating male lynx “Ivan”. It needs to be stressed that this occurrence is still isolated from the BBA lynx population as up to now a natural dispersal from the BBA population has never been documented, i.e., the Steinwald occurrence is not yet connected with BBA population by regular dispersers coming from BBA population. This also leads to specific management implications for the further development of this occurrence.

However, the Steinwald occurrence contributes to the northward expansion of the registered lynx distribution in the study area and despite the Steinwald occurrence is still isolated from the BBA lynx population, we considered these lynx in the population information and in the following results about abundance and survival.

Lynx occurrence in Erzgebirge / Krušné Hory

The border region between Saxony and Czech Republic is included in our study area in order to consider long-distance dispersers, migrants (immigrants/emigrants), habitat features and a possible future spreading of the BBA population. In the western part of Erzgebirge / Krušné Hory around Johanngeorgenstadt and Oberwiesenthal lynx has been recorded since 2013 (Zschille et al. 2020). Zschille et al. (2020) assume that the records stem from one single lynx. A genetic sample collected in December 2017 on the Czech side revealed the origin of this male lynx to be the Harz mountains, appr. 180 km beeline from Erzgebirge / Krušné Hory (Gajdárová et al. 2021). The combination of the unspotted coat pattern, blurred pictures and/or only single-sided recording suggested to classify this lynx as unidentifiable. Therefore, this lynx – despite most probably the same lynx – was excluded from the minimum count of LY19 and the turnover calculation from LY18 to LY19.

4.2.1. Lynx families

4.2.1.1. Number of documented lynx families

In total, **34 reproducing females with 74 juveniles** were proved in the BBA lynx population (Tab. 2, Fig. 4; previous LY18: n=33 reproducing females and 66 juveniles, see also Tab. 6). All these numbers have to be taken as minimum counts.

11 (32.35 %) lynx families occupied a transboundary territory, 12 lynx families (35.3 %) lived entirely on the Bohemian side, 11 families (32.35 %) lived entirely on the Bavarian side. There was no lynx family using a territory located entirely on the Austrian side.

Tab. 2: Lynx families in lynx year 2019 (1.5.2019-30.4.2020) in the Bohemian-Bavarian-Austrian lynx population (C1 data only).

No.	Reproducing female (LynxCode_LynxName)	No. of proven juveniles	Country	Notes
1	B013AT_Boure	2	CZ/AT	
2	B014AT_Marylin	2	CZ/AT	
3	B026AT_Medvedice	3	CZ/AT	
4	B24_Tanja	2	DE/CZ	Motherless rescued kitten "Julchen" was most probably the 2nd kitten of Tanja, and most probably got separated from her mother (who survived).
5	B255_Hawei	2	CZ/DE	2 juveniles killed in 2 subsequent car accidents in September/October 2019 near Strážný (CZ), in Hawei's territory.
6	B271_Nika	2	DE	
7	B272_Julia	2	DE	Julia vanished during LY19 - orphaned case "Lea" was most probably one of her 2 juveniles, the 2nd juvenile was also observed together with Lea but could not be caught and was never recorded again.
8	B283_Elisa	2	CZ	
9	B30_Hope	2	DE	
10	B302_Malu	3	DE/CZ	
11	B31_Geli	3	DE/CZ	
12	B35_Vroni	1	DE	Vroni vanished during LY19, she had (at least) one juvenile which was never recorded again
13	B41_Hanna	1	DE	
14	B47_Marie	1	CZ/DE	
15	B525_Misa	2	CZ	
16	B556_Hvezda	3	CZ	
17	B567_Terka	2	CZ	
18	B569_Caramela**	1-2**	DE	**One or possibly 2 juveniles: Caramela shifted her HR during lynx year 2019 to the front part of B.F. near the area where a juvenile was overrun by a car (community Schaufling). This juvenile could thus possibly be a 2nd juvenile of Caramela.
19	B577_Anezka	2	CZ	

No.	Reproducing female (LynxCode_LynxName)	No. of proven juveniles	Country	Notes
20	B583_Kassandra	1	DE/CZ	
21	B585_Iris	2	CZ	
22	B591_Bonnie	2	DE	
23	B593_Sara	3	CZ	
24	B595_Zoe	2	CZ	
25	B598_Betka	3	CZ	
26	B60_Frieda	3	DE	
27	B62_Holly	2	DE	
28	B706_Svetlana	2	CZ	
29	B718_Nela	2	CZ	
30	B727_Viola	3	CZ/AT	
31	B731_Lee	3	CZ/AT	
32	B745_Anna	3	CZ	
33	B78_Hedy	2-3*	DE	*A 3rd juvenile, camera-trapped in March and much smaller than the other 2, was recorded in Hedy's territory and attributed (with uncertainty) to this family group.
34	N.N.	1	DE	Orphan "Karlchen" found almost starved in the territory established since October 2018 by female B77 Hedwig. It is not known if Karlchen was a kitten of her or of a previously resident, unknown female who vanished and was then replaced by Hedwig.
-	Road-killed_juv. Schaufling	1**	DE	**It is unclear if this was a juvenil of Caramela or of an unknown, resident female who vanished and was then replaced by Caramela. Considering the available hints, we believe it is more likely that this was a second juvenile of Caramela (see also note in the description of B569_Caramela's family) but there is no available proof that can clarify this case.

In Bohemia, 23 lynx families were documented during LY19 (previous LY18: n=26 lynx families including 1 case of orphaned juvenile from unknown mother). 5 of these families were also documented in Austria, 6 in Germany.

In Bavaria, 17 lynx families (including 1 case of orphaned juvenile from unknown mother) were registered (previous year: n=15); 6 of these families were also documented in the Czech Republic (previous year: n=7).

In Austria, 5 lynx families were documented (previous year: n=5). All these families had cross-border territories with the Czech Republic.

Looking at the lynx families only from a national perspective without transnational cooperation would lead to a double counting of the single families.

4.2.1.2. Map of lynx families and resident females in LY19

The following map schematically shows the approximate location and shape of home ranges of lynx families, resident females without proven reproduction and orphans that were considered as most probably "new, otherwise undetected reproductions" (Fig. 5).

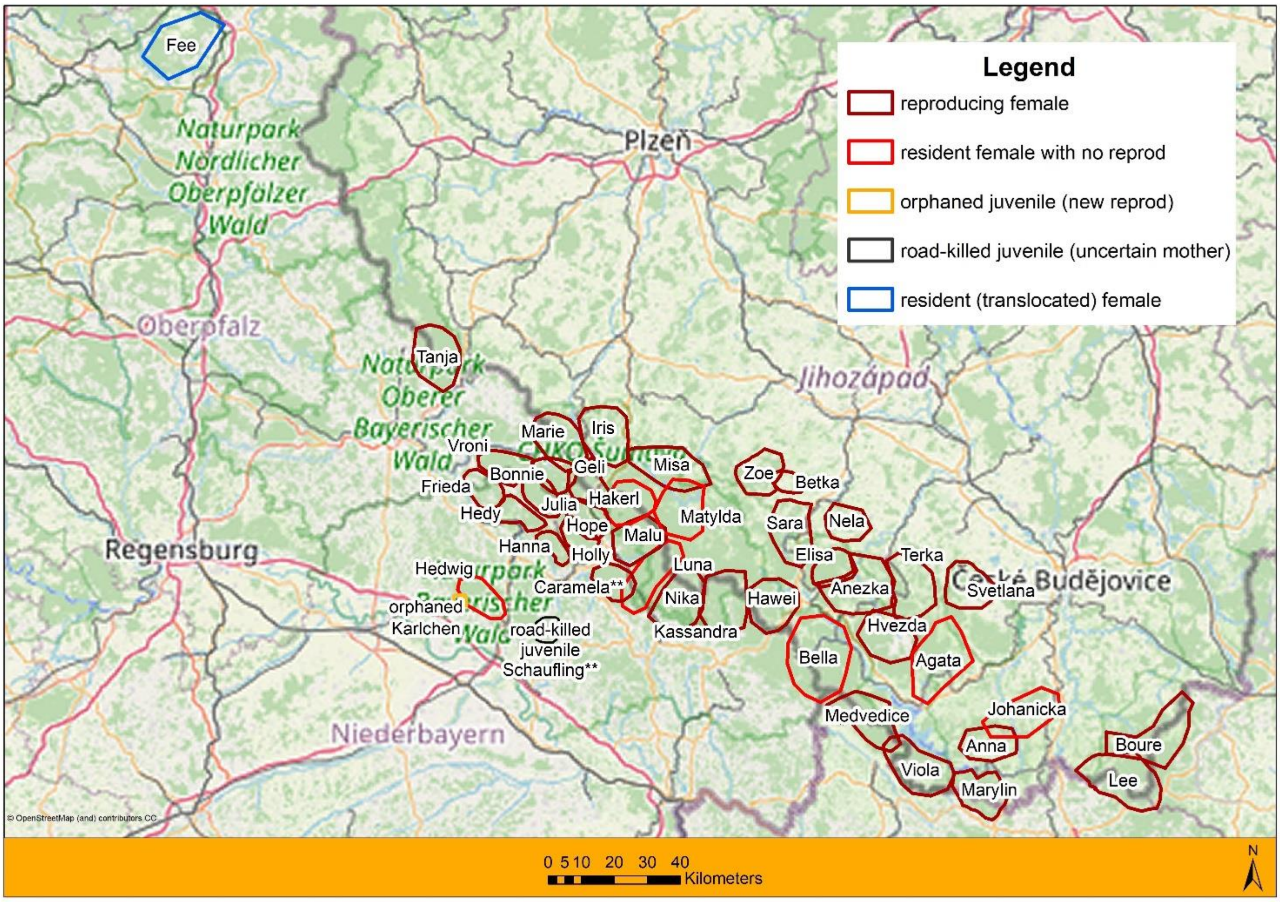

Fig. 5: Lynx year 2019 schematic map of reproducing females with kittens (dark red polygons), resident females without proven reproduction (light red polygons), resident (translocated) female (blue polygon), one orphan from unknown mother (orange polygon, case No.8 in Tab. 3) and one road-killed juvenile possibly belonging to a known but poorly documented family, where the female switched her home range during the year (black polygon, see description of "B569_Caramela" and "Road-killed_juvenile Schaufling" in Tab. 2, and case No.6 in Tab. 3). Size and shape of home ranges is approximate and based on available camera trapping and mortality data. **The approximate home-range of female "Caramela" was drawn only based on her camera-trapping records for May-October 2019, for the remaining part of LY19 data on her movements are lacking or too scarce to draw a home range polygon, but based on available data, she probably shifted her home-range more southeast and was recorded in the surroundings of "Road-killed_juvenile Schaufling" location.

Home ranges were drawn based on the available information about a given female during the given lynx year. Especially in the case of some females living at the periphery of the population, it is important to note that the actual home-range size might be bigger, as females might have also used surrounding areas without being detected.

Fig. 5 clearly shows that the noticeable gap in the (proven) presence of resident females (with or without kittens) in the region of the central Šumava high plateau (Modrava-Kvilda region) that appeared in LY18 mostly persisted also during LY19. In fact, in LY18, this gap extended over an area of approximately 250 km^2, and was probably mainly due to the disappearance of two adult females (Otis, Majka) holding their home ranges in the area till the end of LY17. In LY19, the size of this gap partially reduced thanks to partial rearrangements of the home ranges of the neighbouring resident females. Furthermore, we recorded the presence of 3 subadult females who dispersed into this area during LY19. Because of their age and behaviour, they could not be evaluated as resident yet, thus they were not considered in the map for LY19. Two of them settled during the following lynx years 2020 and 2021, almost completely closing the aforementioned gap.

4.2.2. Lynx mortality and population losses

In the previous two BBA lynx population status reports, we distinguished the causes of mortality into natural (starvation, disease, deadly interaction with other lynx), road mortality, illegal killing, probable illegal killing and unclear causes (the lynx death was proven but the cause could not be determined). For LY19, we also report mortality cases according to this categorization.

Altogether, 7 cases of mortality were documented in LY19 (Tab. 3, Fig. 6). Three cases of assumed orphaned juveniles add to the list of confirmed population losses for LY19 (see section 4.2.2.1): two of them were caught and died in a rehabilitation centre, one could not be caught and never showed up again. Another orphaned juvenile female, “Julchen” (most probably lynx female Tanja’s juvenile born in 2019), was found on a road and brought to a rescue station in July 2019; this animal could however be released again (19th June 2020 in Fichtelgebirge) and is therefore not considered as a loss for the population (see “Lynx orphans” chapter).

Tab. 3: Registered and confirmed population losses in lynx year 2019

No	Date	Country	District, Community	Coordinates	Individual	Sex	Age	Cause of death
1	25.1.2020	CZ	Mnichovice	48.5984300N 14.2891069E	Probably B032AT_Sara _juv.18-1	m	subadult	Illegal killing (probable)[a]
2	23.9.2019	CZ	Strážný - Dolní Silnice	48.8898100N 13.7218281E	Probably Hawei_juv. 19-1	m	juvenile	road mortality

No	Date	Country	District, Community	Coordinates	Individual	Sex	Age	Cause of death
3	2.10.2019	CZ	Strážný - Dolní Silnice	48.8898100N 13.7218281E	B631_ Probably Hawei_juv.19-2	m	juvenile	road mortality
4	16.7.2019	DE	Bischofsmais	48.9152710N 13.0301740E	B79	f	subadult	Illegal killing
5	2.12.2019	DE	Zwiesel	49.018991N 13.250069E	Zwieseler Stadtluchs (possibly a juvenile of Malu)	m	juvenile	road mortality (motherless juvenile)
6	9.12.2019	DE	Schaufling	48.8743530N 13.0852540E	- (possibly a 2nd juvenile of female Caramela)	f	juvenile	road mortality
7	31.1.2020	DE	Bodenmais	49.0600820N 13.0600110E	-	m	juvenile	road mortality (probable)[a]
8	5.9.2019	DE	Schwarzach	48.932682N12.845945E	Karlchen	m	juvenile	Orphaned raised in rescue station, later euthanized
9	26.9.2019	DE	Drachselsried	49.107537N 13.026721E	B26_Lea (Julia_juv.19-1)	f	juvenile	Orphaned brought to rescue station, later died of feline leukemia virus infection
10	26.9.2019	DE	Drachselsried	49.107537N 13.026721E	L108 (Julia_juv.19-2)		juvenile	Orphaned second juvenile, sibling of Lea, observed with her but not caught. It never showed up again (probable)[a]

[a] In cases n. 1, 7 and 10, the lynx's body could not be retrieved. However, given all the circumstances (see descriptions below), we consider that in all these cases the animal's death was extremely probable.

Two subadult lynx were illegally killed during LY19 (cases No. 1 and 4).

In case No. 1 (Tab. 3, Fig. 6), during snow tracking in the Czech part of the BBA population range, a spot near a hunting high seat was found, where a lynx was most probably killed. The dead animal's body wasn’t there, but the dead animal's imprint in the snow, blood and hairs were present and could be duly documented. Genetic analysis confirmed that biological samples came from a male lynx. The criminal police investigated this case, but the perpetrator was not identified. The lynx identity in this case was assumed based on the region of occurrence and on the time of disappearance of subadult male B032AT (Sara_juv.18-1), which both corresponded well with the time and location of this chance finding.

Case No. 4 (Tab. 3, Fig. 6) was a documented case of illegal killing of known subadult female B79 in the Bavarian part of the BBA population range. Forensic investigation revealed that this lynx was injured at the front paw at the age of appr. 8 months. Because of this damage of the front paw the lynx could not hunt on her own and starved to death after the dissolution of the family group at the end of LY18.

Five lynx juveniles died in vehicle collisions on roads (cases No. 2, 3, 5, 6, 7; Tab. 3, Fig. 6); one of them was a juvenile who most probably had got separated from its mother (case No. 5 of Tab. 3, see chapter 4.2.2.1 “Lynx orphans”).

Cases No. 2 and 3 took place in the same place and just a few days apart. In case No.2, the body was retrieved but no coat pattern could even be documented, because the juvenile was totally run over, probably by a heavy truck. In case No.3, the collision took place in the early morning and a spotted female mother was observed staying in the close surroundings of the site half a day (information from local road maintenance staff, no photo documentation available). Because the location of both accidents lies in the home-range of spotted female Hawei, who was only camera-trapped without kittens for the rest of the lynx year 2019, it was assumed that these 2 juveniles were most probably her (only) 2 kittens for this lynx year.

Case No. 6 was an overrun juvenile lynx in the lower part of the Bavarian Forest north of Schaufling. This area was less densely covered by camera-traps and proves of reproducing females were never obtained before. The situation with lynx reproduction in lynx year 2019 was unclear for this area (see also Fig.5 –“lynx family map for LY19” and Tab. 2). This dead juvenile was sufficiently well documented to determine it was not any of the known lynx juveniles coming from the surrounding documented lynx families, and it could not be attributed with certainty to any known lynx family. However, the accident location was approximately 13 km south of the area where female “Caramela” was monitored, also together with one juvenile, until October 2019. Caramela probably shifted her home range during LY19 as she never showed up again in the area where she was formerly recorded. She established her new home range in the area surrounding the location of mortality case No. 6. It is not clear if this juvenile was a kitten of Caramela or of an unknown, resident female who vanished and was then replaced by Caramela, although based on available information the first possibility seems more likely.

In case No. 7, a juvenile lynx was severely injured by a car when it tried to cross the road with its mother. Based on the report of the accident perpetrator it was assumed that this animal most probably could not survive the accident, although the body could not be retrieved. Hair was collected at the car and genetic analyses confirmed it was a male lynx. The location of this car accident, on the Bavarian side of the BBA population range, was in an area that in LY19 was fully covered by the home ranges of reproducing females with kittens. Therefore, this unidentified juvenile was considered as certainly belonging to one of the known lynx families from that region.

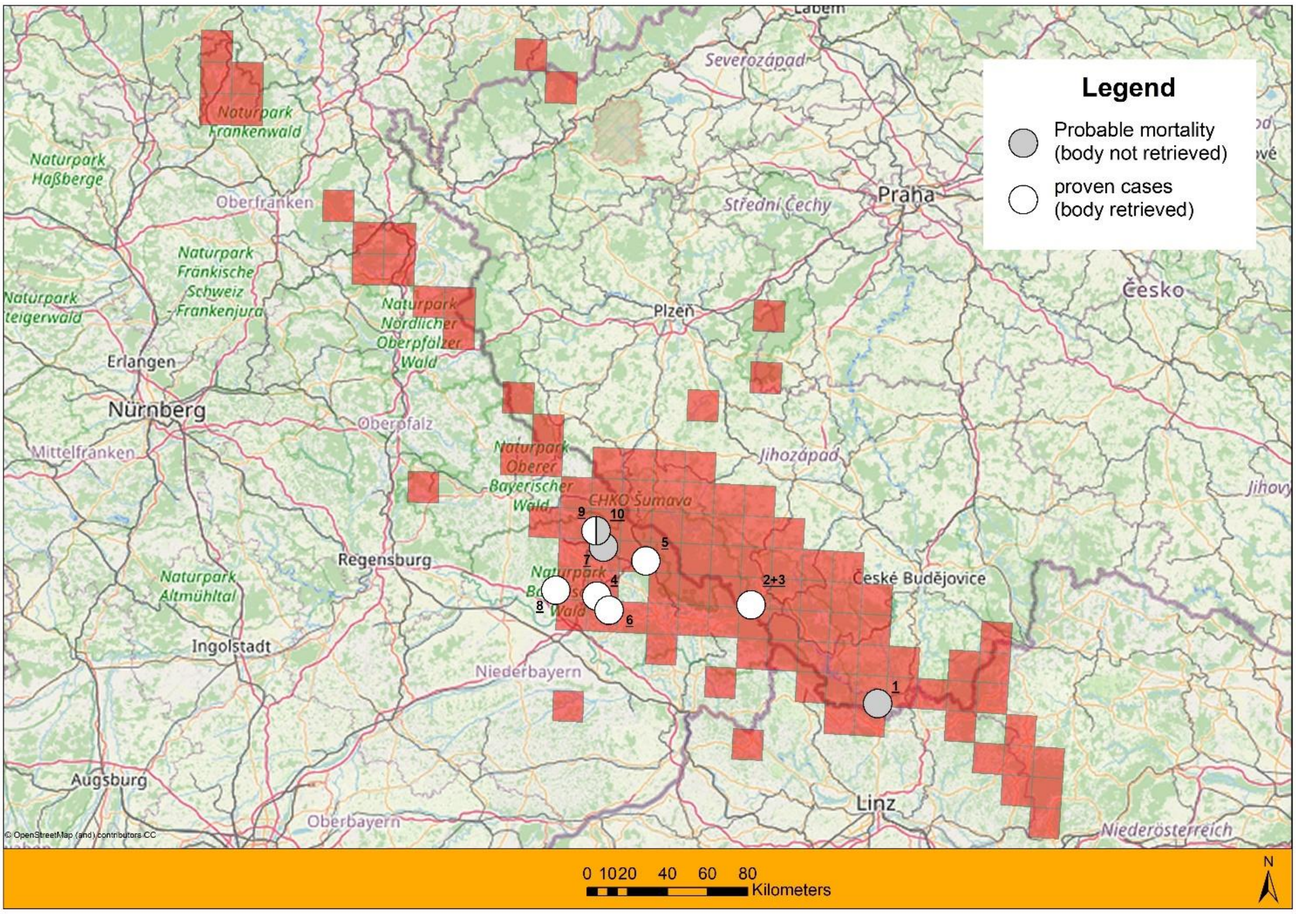

Fig. 6: Map of registered population losses in lynx year 2019 plotted on the background of C1 positive grid cells (red). Numbers refer to Tab. 3.

4.2.2.1. Lynx orphans

In LY19 we recorded five lynx juveniles that were found alone without trace of their mother (one of which could only be retrieved after having been killed by a car).

The first juvenile („Julchen“) was found running on a road in the community of Waldmünchen. It was picked up by animal welfare activists on 15th July 2019. Two days later it was transferred to a private rescue station where it was fed and raised. It was finally released on 19th June 2020 in the Fichtelgebirge where it still lives (July 2023). Based on all available information, we assumed that “Julchen” got separated from her mother, who was most probably the resident female Tanja, who is still alive and also had one more kitten during LY19 (see Tab. 2). Because “Julchen” could be released back to nature, we did not consider her case as a “permanent population loss” and therefore did not include it into Tab. 3, either.

A second juvenile („Karlchen“, case No. 8 in Tab. 3) was found on 5th September 2019 near a farmhouse almost starved to death. It was transferred to a private rescue station where it was fed and raised. However, “Karlchen“ could not be released because he severely broke his hind leg in February 2020 and finally had to be euthanized on 25th July 2020 due to health problems. “Karlchen” was either a juvenile of an unknown female who vanished and was replaced by Hedwig or a juvenile of female Hedwig.

A third lynx juvenile („Lea“, case No. 9 in Tab. 3) appeared at a farmhouse preying on cat kittens and rabbits that were kept in an enclosure. It was accompanied by a sibling (L108, case No. 10 in Tab. 3). A larger lynx was observed there once, too, together with both siblings, suggesting that this might have been the mother. The approaching of settlements by lynx is very unusual and generally happens for exceptional reasons (e.g., injured or diseased individuals). The two lynx kittens were already observed one week earlier at a house near the edge of the forest. Presumably, their mother was not able to feed her kittens anymore and approached the edge of the village to catch easy prey like chickens or rabbits. As the farm yard lies in the home range of resident female „Julia“, who went missing right after these observations, it was assumed that she most probably might have been the mother. “Lea” was captured on 26th September 2019 and was transferred to a private rescue station. Before she could be captured, she managed to kill several rabbits and one of the many domestic cat kittens living in the farm yard. Blood examination revealed later that „Lea“ was infected with FeLV (feline leukemia virus infection). FeLV is very rare in wild felids but was observed to occur in cougars, leopards and tigers (Ryser-Degiorgis 2001). She might have been infected by the domestic cat kitten she fed on at the farm yard. Unfortunately, there is no information about the health status of this domestic cat population in the farm yard. Lea later died of this disease.

The fourth lynx juvenile was L108 (case No. 10 in Tab. 3), “Lea”’s sibling, whose case is already described together with Lea’s. This (most probably) orphaned juvenile could not be captured, and never showed up again, as well as the assumed mother (most probably the vanished female Julia). Especially given its extremely young age, we assume this juvenile most probably died soon after its mother vanished. Therefore, although the body could not be retrieved (similarly as in cases No. 1 and 7, see Tab. 3), we include this case as a very probable further population loss for LY19.

The fifth juvenile („Zwieseler Stadtluchs“, case No. 5 in Tab. 3) showed up on 26th November 2019 in the eastern part of the town of Zwiesel (9,300 inhabitants). The juvenile lynx managed to catch rabbits in the garden of a house. This 5-6 months old male lynx was observed at several places in town (e.g. at the riverbank in the middle of the town, at a basement garage and at the cemetery). The attempts to capture him (repeatedly between 26th and 30th November 2019) were not successful. On 2nd December 2019 he was killed by a car when he tried to cross a ring road east of Zwiesel. Since the kitten was in a good physical condition, we assume it was probably not a true orphan but was possibly separated from his mother recently. Based on available hints, we hypothesize that the most probable mother could have been female Malu (whose 3rd kitten in LY19 was only very poorly documented).

4.2.2.2. Turnover rate and survival of lynx

The survival of 121 independent lynx, which were recorded (and included in the minimum count) in LY18, was examined. Those lynx were known to be adult (n=75, Tab. 4), respectively most probably adult (n=1, Tab. 4), or subadult (n=36), respectively most probably subadult (n=5) in LY18. For the remaining independent lynx (n=4) included in the minimum count in LY18, we were not able to determine whether they were adult or subadult in LY18 (category "lynx whose age only could be determined as more than one year old, i.e. subadult or adult").

Tab. 4: List of adult lynx recorded and included in the minimum count in LY18 and their fate from LY18 to LY19. Within the column "Fate from LY18 to LY19", "DEAD" indicates all cases of documented death within LY18 (described in Wölfl et al. 2023, updated from 2020); "MISSING" indicates all cases of lynx individuals whose last record alive was during LY18, thus the animal is not included anymore in the list of recorded independents for LY19, and it most probably also disappeared within the end of LY18.

No.	LynxCode	LynxName	sex	age class in LY18	Born (LY)	Fate from LY18 to LY19
1	B012AT	Blesk		adult	2016	MISSING
2	B013AT	Boure	f	adult	2016	Recorded
3	B014AT	Marylin	f	adult		Recorded
4	B015AT	Horecka	f	adult		MISSING
5	B017AT	Roman		adult		Recorded
6	B018AT	Eos	f	adult		Recorded
7	B026AT	Medvedice	f	adult		Recorded
8	B11	Kika	m	adult	2008	Recorded
9[a]	*B111*	*Fee*	*f*	*adult*	*2015*	*Recorded*
10	B23	Hakerl	f	adult	2011	Recorded
11	B238	Rico	m	adult		Recorded
12	B24	Tanja	f	adult		Recorded
13	B252	Luna	f	adult	2011	Recorded
14	B255	Hawei	f	adult	2011	Recorded
15	B271	Nika	f	adult	2014	Recorded
16	B272	Julia	f	adult	2014	Recorded
17	B274	Sancez	m	adult	2014	Recorded
18	B275	Kristof	m	adult	2014	MISSING
19	B281	Milo		adult		Recorded
20	B283	Elisa	f	adult	2016	Recorded
21	B286	Olina	f	adult	2016	DEAD (ROAD KILL)

22	B287	Moritz	m	adult		Recorded
23	B288	Robert	m	adult	2015	Recorded
24	B290			adult	2016	MISSING
25	B295	Ingo	m	adult		Recorded
26	B30	Hope	f	adult		Recorded
27	B31	Geli	f	adult	2013	Recorded
28	B32	Gestiefelter Kater	m	adult		Recorded
29	B35	Vroni	f	adult	2014	Recorded
30	B37	Zdenek	m	adult		Recorded
31	B38	Stefan	m	adult		Recorded
32	B39	Veit	m	adult		Recorded
33	B41	Hanna	f	adult	2014	Recorded
34[a]	*B0040*	*Ivan*	*m*	*adult*	*2016*	*Recorded*
35	B47	Marie	f	adult		Recorded
36	B508	Ctirad	m	adult	2010	MISSING
37	B510	Matylda	f	adult	2009	Recorded
38	B514	Julien	m	adult	2010/2011	Recorded
39	B52	Gerald	m	adult	2015	MISSING
40	B525	Misa	f	adult	2013	Recorded
41	B534	Agata	f	adult		Recorded
42	B537	Ludek	m	adult	2014	MISSING
43	B538	Michelle	f	adult		DEAD (POACHED)
44	B54	Justus	m	adult	2016	Recorded
45[a]	*B55*	*Bartl*	*m*	*adult*		*Recorded*
46	B556	Hvezda	f	adult		Recorded
47	B565	Bartho	m	adult	2015	Recorded
48	B567	Terka	f	adult	2016	Recorded
49	B568	Vanda	f	adult		DEAD (ROAD KILL)
50	B569	Caramela	f	adult	2016	Recorded
51	B577	Anezka	f	adult	2016	Recorded
52	B580	Zofie	f	adult		DEAD (POACHED)
53	B581	Pepik	m	adult	2014	Recorded
54	B582	Ludva	m	adult	2016	Recorded
55	B585	Iris	f	adult	2011/2012	Recorded

56	B588			adult	2016	MISSING
57	B593	Sara	f	adult		Recorded
58	B595	Zoe	f	adult		Recorded
59	B598	Betka	f	prob_adult		Recorded
60	B60	Frieda	f	adult	prob. 2016	Recorded
61	B610	Fernet	m	adult		Recorded
62	B62	Holly	f	adult	2016	Recorded
63	B64	Siegfried	m	adult	prob. 2016	Recorded
64	B68	Bobby	m	adult	2016?	Recorded
65	B7	Cora	f	adult	2009	DEAD (ROAD KILL)
66	B706	Svetlana	f	adult	2016	Recorded
67	B711	Bertik	m	adult	2015/2016	MISSING
68	B716	Karlos	m	adult		Recorded
69	B718	Nela	f	adult		Recorded
70	B719	Radim	m	adult	prob. 2016?	MISSING
71	B724	Hracicka	f	adult	FR 04/2017, adult?	MISSING
72	B726	Kukulin	m	adult		Recorded
73	B727	Viola	f	adult	prob. 2016	Recorded
74	B742	Eliska	f	adult	before 2017	Recorded
75	B745	Anna	f	adult	prob. 2016	Recorded
76	R507 probably =L514	Alzbeta	f	adult		MISSING

* The age class “prob_adult” means that these lynx were judged as most probably adult.

[a] These three animals (Fee, Ivan, Bartl) belong to the isolated occurrences of Steinwald or Frankenwald (see beginning of chapter 4.2.).

This analysis showed that 14.5 % (n=11) of adult (plus most probably adult) lynx which were recorded in LY18 were not recorded anymore in LY19. Adding the cases of proven mortality, this number increased to 19.7 % (n=15). The survival rate of independent lynx was 0.69. Separated by age class the survival rate of adults was 0.80, that of subadults 0.54 and that of “lynx whose age only could be determined as more than one year old, i.e. subadult or adult” was 0.25 (Tab. 5). A larger proportion of the losses took place outside of the National Parks.

Tab. 5: Types of losses and survival rate* from lynx year 2018 to lynx year 2019 for adult, subadult and "altogether independent" lynx, respectively. The calculation is based on 121 independent lynx (76 adults, 41 subadults and 4 "independents whose age only could be determined as more than one year old, i.e. subadult or adult") recorded and included in the minimum count in lynx year 2018. The percentages refer to the respective age class.

	Road mortality	Illegal killing	Natural mortality[a]	Missing in LY19	Total dead+missing (turnover rate)	Survivors	Survival rate[b]
Adults (> 2 years) (n=76)	2 (2.6%)	2 (2.6%)	0 (0%)	11 (14.5%)	15 (19.7%)	61 (80.3%)	0.80
Subadults (1-2 years) (n=41)	0 (0%)	0 (0%)	1 (2.4%)[a]	18 (43.9%)	19 (46.3%)	22 (53.7%)	0.54
Indep-either adult or subadult (n=4)	0 (0%)	0 (0%)	0 (0%)	3 (75%)	3 (75%)	1 (25%)	0.25
Independents altogether+ (n=76+41+4=121)	2 (1.7%)	2 (1.7%)	1 (0.8%)	33 (27.7%)	37 (30.6%)	84 (69.4%)	0.69

* The survival rate is calculated as N(t) / N(0), where N(t) is the number of lynx at the end of the time period and N(0) is the start of the time period. Survival rate for independent lynx is calculated as λ = 84/121 = 0.69, for subadult lynx λ = 22/41 = 0.54, for adult lynx λ = 61/76 = 0.80.

[a] See the BBA population status report for lynx year 2018 (Wölfl et al. 2023, updated from 2020) for details.

[b] In the case of subadult lynx, calculation of survival based on the number of animals that vanished from the study area according to camera trapping data can theoretically be more affected by bias than in the case of adults (see Discussion for details). However, data about subadults are required in all calculations for the category "independent lynx" altogether, and all these calculations are also of interest in the frame of an overall evaluation of the BBA population's development.

4.2.3. Documented minimum population size

In LY19, in total **133 independent lynx** were documented in the study area (as outlined in Fig. 1), including the 2 individuals recorded in the Steinwald region in north-eastern Bavaria (B111 Fee, translocated from the Bohemian Forest region in 2016 and B0040 Ivan, immigrated from the Harz population in 2018) and the individual recorded in the Frankenwald region (B55 Bartl, emigrated naturally from the Bohemian Forest region in 2018 – see beginning of chapter 4.2.).

For 129 lynx, both flanks were well documented, for 4 lynx only the right flank (all spotted individuals), and for 3 lynx only the left flank (all spotted individuals). As L- and R-animals could be identical, only the higher number of the animals documented from one side were taken into account (n=129+4).

Based on this number and on the documented minimum population size we obtained for LY18, when 121 independent lynx individuals could be documented, we also calculated the population annual growth rate, based on λ (λ= N(2019) / N(2018)). From LY18 to LY19, the population growth rate was 10% (λ = 133/121 = 1.10), which is the same growth rate value calculated from LY17 to LY18 (10%, see Wölfl et al. 2023, updated from 2020).

Table 6 summarizes the documented minimum numbers of lynx independents, families and juveniles for the study area for LY17, LY18 and LY19.

Tab. 6: Documented minimum numbers of lynx independents, families and juveniles for the study area for LY17, LY18 and LY19.

	Independents (including reproducing females/families)	Reproducing females/families	Juveniles
LY19	133	34	74
LY18	121	33	66
LY17	110	32	62

4.2.4. Theoretical minimum and maximum population size derived from number of families

The steps for estimating the theoretical population size for LY19 based on the share of reproducing females are shown in the table below (Tab. 7). See chapter 3.3 for information about the estimation of the theoretical minimum and maximum population size.

Tab. 7: Estimation of maximum population size in lynx year 2019.

Calculations	Explanation
34 / 17.5 * 100 = 194.3	34 = number of lynx families recorded in lynx year 2019 17.5 = long-term share [%] of reproducing females out of the whole population 194.3 = theoretical population size including all individuals (juveniles, subadults, adults)
194.3 - 74 = 120.3	74 = number of juveniles recorded in lynx year 2019 120.3 = theoretical population size incl. independent individuals only (subadults, adults)
120.3 * 1.19 = 143.2	143.2 = theoretical population size incl. independent individuals only, plus standard deviation of 19%
120.3 * 0.81 = 97.4	97.4 = theoretical population size incl. independent individuals only, minus standard deviation of 19%

Based on the number of families recorded by C1 data in LY19, the number of independent individuals in the population has been calculated as 120 animals ±19% [97-143]. The number of independent lynx (n=133) we were able to document lies well within this range. However, the calculated theoretical population size (incl. independent individuals only, i.e. adults and subadults) for LY19 was lower than the number of independent lynx we could actually document (120 calculated vs 133 documented). This suggests that either we might have missed some reproducing females in LY19, or the long-term share of reproducing females out of the whole BBA population (obtained based on long-term data till 2014 from the BBA region - see Poledníková et al. 2015) might need to be updated.

5. Discussion

The monitoring system established during the 3Lynx project in the border region of Germany, Austria and Czech Republic up to LY19 has been the most comprehensive and large-scaled monitoring approach in Central Europe: in LY17 and LY18 it covered 13,000 km^2, in LY19 the area was slightly extended and covered 13,200 km^2. The same monitoring standards are applied in all three countries; therefore, the data are comparable and produce a valuable and robust data set. Lynx year 2019 was the third consecutive year during which this entire area could be monitored, with a comparable monitoring effort between years. However, it must be noted that the location of several monitoring sites was further refined and few new monitoring sites were added at the margins of the population range from LY17 to LY19.

The area with confirmed lynx presence was calculated based on C1 and C2 positive grid cells for LY17 (86 C1 and 12 C2 grid cells, for a total of 9,800 km^2, see Mináriková et al. 2023, updated from 2019) and LY18 (85 C1 and 6 C2 grid cells, for a total of 9,100 km^2, see Wölfl et al. 2023, updated from 2020). For LY19, the fact that only C1 data were processed for the Austrian part of the study area does not allow to fully compare the occupied area calculated in this way between years. Considering only C1-occupied cells, there was a visible increase in the occupied area from the previous lynx years to LY19 (104 C1-positive grid cells in LY19, i.e., +18/19 cells compared to LY18/LY17, respectively). However, it has to be noted that several grid cells (n=5) which were C1-positive newly in LY19 were already C2-positive in at least one of the two previous lynx years. Furthermore, on the Czech and Bavarian side, collected C2 data were processed also during LY19, but did not influence this year's distribution map, because they were all in already C1-positive grid cells. These two facts suggest that a part of the increase in the occupied area is most probably due to the above-mentioned improvement in the lynx monitoring at the margins of the population range. However, we believe that a small but genuine increase in the occupied area is indeed visible, and it corresponds well with the further slight increase in the number of recorded lynx from 121 independent lynx in LY18 to 133 independent lynx in LY19 (λ = 1.10, 10 % growth rate, i.e. the same growth rate observed from LY17 to LY18, see Wölfl et al. 2023, updated from 2020). Clearly, also the increase in the total number of independent lynx from year to year could have partially been influenced by a further (small) improvement in the monitoring at the margins. However, minimally in Bavaria and in parts of Austria, where the monitoring effort has been kept (almost exactly) the same over the 3 considered lynx years, a minor expansion was indeed recorded, with lynx settling and even reproducing in some areas without past lynx presence.

The number of reproducing females changed from 33 in LY18 to 34 in LY19 (λ = 1.03, same as from LY17 to LY18). The number of juveniles increased from 66 juveniles in LY18 to 74 juveniles in LY19 (λ = 1.12, while it was only λ = 1.06 from LY17 to LY18).

As already discussed in our previous report (Wölfl et al. 2023, updated from 2020), comparing current data with data collected at the population level during the previous transboundary assessments in LY13 and LY14 (done in the scope of the TransLynx project, Wölfl et al. 2015a, Wölfl et al. 2015b) would only be feasible by applying advanced statistical methods and having a precise calculation of the monitoring effort for each lynx year for the entire study area, which is currently not available. In fact, the approximately halved values of all calculated numbers obtained in LY13 and LY14 were most probably mainly due to the fact that in that period the size of the study area was 7,600 km^2, i.e. approximately a half of the area monitored between LY17 and LY19 (13,000-13,200 km^2). Only after compiling the available data for the current report we finally have at least three lynx years in a row since LY17, with comparable monitoring effort in an area covering almost the entire BBA population distribution. This allows us to obtain a more sound evaluation of the (short term) evolution of the population status.

The observed slight increase in the number of independent lynx and in the occupied area could be caused by regional higher survival rates of kittens and subadults in recent years. Subadults represent the most variable part of the lynx population. They do not yet have their own territories, but are dispersing through territories of resident animals. Dispersing subadult lynx can compensate for losses among the resident lynx and, on the other hand, induce a range expansion, if they manage to establish home ranges in formerly uninhabited areas. In the latter case (and if the slight increase continues) we would expect a measurable further range expansion during the next few years. Furthermore, the increase in the number of kittens from LY18 to LY19 was more pronounced compared to the increase from LY17 to LY18 (λ = 1.12 and λ = 1.06, respectively). This may indicate that a few more subadults were able not only to survive until adult age, but also to settle and reproduce. Although the only slight increase in the number of females with proven reproduction from year to year rather does not support this interpretation, it must be noted that in the list of lynx juveniles 2019 there are indeed a few cases of single kittens evaluated as “most probably” belonging to a known family, which might instead represent further undetected reproduction(s). In addition, as mentioned, the presence of a few undetected reproductions is one of the possible explanations for the fact that, in LY19, the theoretically calculated population size (row 2 of table 6) was lower than the observed numbers. Minimally, these data from LY19 indicate an endurance of the slight positive trend already observed in our previous report. However, a longer time series of data (e.g. more lynx years of monitoring with comparable effort) would be needed to see if this trend is only temporary or will continue and lead to substantial improvements in the whole population status (e.g. in terms of documented reproductive units, i.e. lynx families, and permanent range expansion).

On the other side, data on proven population losses for LY19 and the calculation of turnover rate of independent lynx from LY18 to LY19 provided further hints on how the BBA population dynamics can be influenced by different sources of mortality, especially those which have long been considered as the main threats for lynx: illegal killing and road mortality.

Illegal killing can only rarely be proven, because the body of a shot or poisoned lynx is most often not found. However, two indirect indicators for the magnitude of illegal killing can be (a) the number of juveniles found orphaned, and (b) the turnover rate in the population, although of course not all cases of orphaned juveniles or vanished independent lynx have necessarily to be related to illegal killing. Indeed, quantifying the probable illegal killing out of the turnover rate is difficult, because a lynx's disappearance can also have several other reasons: natural death, long-distance dispersal beyond the study area and missed detection by camera traps. On the other hand, in the case of adult lynx, especially reproducing females usually do not leave their home ranges and start long migrations. Sometimes, adult lynx (especially males) shift their home ranges due to changes in the social organization of neighbouring conspecifics, which is often detected by our dense network of camera traps. Of course, natural death, e.g. due to high age or disease, occurs in adult lynx and is hard to detect. According to Breitenmoser-Würsten et al. (2007), the probability that natural death of a lynx not equipped with any telemetry collar will be proven (i.e., the body will be found) is indeed extremely low. In Scandinavia (i.e. practically the only European region where hundreds of lynx individuals were collared during past telemetry studies), the mean annual natural mortality rate in radio-collared adult lynx was 1-2% (Andrén et al. 2006).Although similar datasets are (almost) unavailable for single Central European lynx populations, based on the different climatic conditions and on observations from single study areas, it could be expected that lynx natural mortality in this region could be higher than in Scandinavia. Specifically this could be related to (a) a more prominent role of possibly deadly parasites and illnesses, e.g. sarcoptic mange (see e.g. Anders 2023); (b) congenital malformations possibly emerging in small, reintroduced populations as an effect of inbreeding (Ryser-Degiorgis et al. 2004, Breitenmoser-Würsten et al. 2007), e.g. skeletal deformities (Ryser-Degiorgis et al. 2004), heart deformities, pathologies, malfunctioning (Ryser-Degiorgis et al. 2020, Fležar et al. 2023). On the other hand, out of the several thousands of lynx photos and videos obtained in our study area, no visual hints of sarcoptic mange infection has ever been recorded so far (till the end of LY19). Skeletal deformities and heart malfunctioning considered to be an effect of a strong genetic variability loss has been observed in the Jura, Alpine and Dinaric lynx populations (Ryser-Degiorgis et al. 2020, Fležar et al. 2023), but not in the BBA population. Besides, a recent study suggests that the level of genetic variability of this population in the latest years has not decreased significantly (Gajdárová et al. 2023), although the same study suggests that the situation should still be kept closely monitored. Therefore, we do not expect that the level of natural mortality in the BBA lynx population would be manifold higher than that recorded in

Scandinavia. Finally, it is worth mentioning that also different types of human-induced mortality of non-collared lynx are likely characterized by a different detection probability, with cases of road mortality much more likely to be reported/proven than cases of illegal killing (Schmidt-Posthaus et al. 2002; Breitenmoser-Würsten et al. 2007). Thus, based on these considerations and on the intensity and extent of lynx monitoring in the study area in recent lynx years, it is reasonable to assume that the majority of cases of vanished lynx adults will actually be related to undiscovered illegal killing events (similarly as how this matter is treated by Andrén et al. (2006) and interpreted by Heurich et al. (2018)).

Accurately quantifying the relative importance of the different possible causes of the vanishing of subadult lynx is much more difficult than for adults, especially without telemetry data from a representative number of individuals. In fact, subadult lynx are known to disperse long distances until they find an empty territory, conveniently with connection to conspecifics. They might settle down at the edge of the known lynx range or even migrate beyond the monitored study area. Subadults are more prone to starvation and other causes of mortality than adult lynx, subsequently their survival is also naturally reduced. Due to their specific dispersal behaviour they are confronted with a greater risk of dying and it can be more difficult to monitor their fate by camera trapping. Nevertheless, the number of subadult lynx which were not recorded the following year is of interest itself, and it is required to estimate the value of turnover rate for all independent lynx, which is also of interest.

For these reasons, we estimated the turnover rate separately for adult and subadult lynx, the latter mainly as a component of the overall turnover rate of independent lynx. In both cases we distinguished known mortality cases from the cases of individuals which in the following year(s) were not recorded anymore in the study area.

Out of 121 independent lynx documented in LY18, 34% were subadults or most probably subadults (n=41), while for 4 independent lynx we had no sufficient information to determine (nor guess) whether they were adults or subadults. 43.9% (n=18) of these subadults and 75% (n=3) of the independents “either adults or subadults” were not recorded anymore in LY19. The total percentage of subadults that were not recorded anymore in the study area (including known/documented road mortality) was 46.3% (n=19), which approximately is in line with the percentage calculated for the period from LY17 to LY18 (44.2%, see Wölfl et al. 2023, updated from 2020) and with the findings from other populations in Central Europe (e.g. in Switzerland, 50% loss are reported for subadults, including assumed cases of illegal killing, Breitenmoser & Breitenmoser-Würsten 2008).

In the case of adult lynx, in our study area more than 14 % of the adult lynx disappeared from LY18 to LY19. Even hypothesizing a double or triple incidence of natural mortality in the study area compared to Scandinavia (annual natural mortality of adult lynx = 1-2% - Andrén et al. 2006), this suggests that a relevant percentage of adult lynx in the BBA population disappears every year because of “other reasons”. Together with the cases of mortality with known causes, the turnover rate reached almost 20 % of all adult lynx recorded in the study area.

Finally, it is worth considering the overall turnover rate for all independent lynx (including both proven losses and disappeared individuals of all lynx categories) calculated from LY18 to LY19, that was almost 31%. This value is slightly lower than what we calculated for the period from LY17 to LY18 (32.7% Wölfl et al. 2023, updated from 2020) and lower than the values for Western Carpathians (46.3 ± 8.06% for all independent lynx, 37.6 ± 4.22% for adults - Duľa et al. 2021) and Switzerland (survival rate of 76%, thus turnover rate = 24% for adults, survival rate of 53%, thus turnover rate = 47% for subadults, Breitenmoser-Würsten et al. 2007). Nonetheless, the turnover rate values in the BBA population remain (unnaturally) high.

Although all these calculations regarded just a restricted time period (LY17 to LY18, presented in Wölfl et al. 2023, updated from 2020, and LY18 to LY19, presented in this report), it is worth remarking that a high turnover of adult or resident lynx in the BBA population range was already revealed during the first population-wide assessment in the TransLynx project from LY13 to LY14 (Wölfl et al. 2015b, Wölfl et al. 2023, updated from 2020). In Bavaria, a population viability model developed for lynx predicted that if the mortality among adult resident lynx exceeded the threshold of 20 %, it would correspond to a 74-100% probability risk of extinction in combination with a moderate (10-35 %) mortality rate in subadults. In combination with a high mortality of subadult dispersers (> 30 %) the risk of extinction would be even 82-100 % (Kramer-Schadt 2004).

Thus, data from LY19 provide further support for our previous conclusions, that illegal killing and road mortality together still have the potential to bring the BBA population to the brink of extinction. They are likely the main cause of the population stagnation in numbers and range during the last 25 years, and they seem most likely responsible for the still limited growth and expansion of this population in most recent years. However, we are aware that 3 years of comparable population-wide lynx monitoring in a row are just the minimum required to reveal actual trends. For more robust estimations and predictions, data from several consecutive monitoring years would be needed (e.g., 6 to 12 according to the European Union’s Habitats Directive - Council Directive 92/43/EEC). Such data would better allow detecting possible changes in the turnover rate in the BBA lynx population, identifying the hot spots of mortality (i.e., the areas where the turnover rate of adult lynx is highest) and better determining the long-term effects of these findings.

In conclusion, we recommend that future conservation efforts should be based on a continuously and closely monitored BBA lynx population, and more effective measures against the main threats for this population’s long-term survival should be developed and applied based on the result of such population-based monitoring.

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