Eurasian lynx (*Lynx lynx*) monitoring with camera traps in Slovenia in 2018-2019

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FOREWORD

In this report, we describe the results of the first year (season 2018-19) of the first systematic monitoring with intensive camera trapping of Eurasian lynx (*Lynx lynx*) population in Slovenia. We explain the underlying need for establishing a national-scale monitoring scheme for lynx and describe the approaches used to develop this scheme. We point out specific objectives that were set within the framework of three projects focusing on conservation of Dinaric-SE Alpine lynx population and set the ground for population monitoring activities. We argument the choice of methodology and sampling effort and suggest the potential improvements and optimization of monitoring in the next years.

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INTRODUCTION

Historically, Eurasian lynx (*Lynx lynx;* hereafter: lynx) experienced dramatic population declines in its continental range. In many European countries, prey base was seriously depleted and lynx populations were persecuted to extinction in the end of the 19th and beginning of the 20th century, including Slovenia and Croatia, which host part of the Dinaric-SE Alpine lynx population. After extinction, lynx was successfully reintroduced in Slovenia in 1973, followed by fast expansion and population growth during the following two decades (Čop 1990). However, after the 1990s the population trends reversed and the numbers started to decline (Kos et al. 2004, Potočnik et al. 2009, Kos et al. 2012).

The initial monitoring of the reintroduced lynx population was based on opportunistic observational data and mortality records (categorized using SCALP methodology; Molinari-Jobin et al. 2002). Although with high effort of recording lynx signs on the field and reporting lynx mortality, data were not collected systematically and were often originating from anecdotal and misunderstood information. Hunting quotas were based on population size estimates that were probably highly overestimated at the time (the estimates reached up to 200 animals (Čop 1994, Kos et al. 2012)). The uncertainty and bias in population estimates can lead to serious consequences for wild populations, especially if they are simultaneously under (lethal) management control (Saether et al. 2010). The legal hunting though stopped with last lynx being shot in 2003. Despite full protection of the species after that, the population distribution shrank and the estimated number of lynx dropped (Kos et al. 2012). The real effect of the lynx culling on the sudden decrease of lynx population size in Slovenia thus remains unexplained. Nowadays however, lynx in the Dinaric Mountains and SE Alps is facing extinction as the genetic analysis showed that population is highly inbred (Sindičić et al. 2013). Thus, a program of population reinforcement through translocation of unrelated lynx from the Carpathian population is taking course within the LIFE Lynx project.

Due to lack of reliable data, we recognized the need to establish a rigorous, systematic and intensive monitoring system of the remaining lynx population and implement it before, during and after the planned lynx reinforcement efforts. The monitoring was designed to allow us to i) choose and use the best available methodology for monitoring lynx, ii) estimate the Slovenian Dinaric lynx population size and distribution, iii) identify the local areas where lynx is still present and reproductive, iv) help guiding future population reinforcement efforts, v) follow population trends and vi) recognize the potential threats. The monitoring should enable harmonization of the data in the Dinaric Mountains (in Slovenia and Croatia) and provide the basis for their long-term collaboration. Importantly, the cost-efficient monitoring system was designed in a way that active involvement of stakeholders, specifically hunters, whose acceptance of lynx is crucial for long-term lynx conservation.

CHOOSING THE BEST AVAILABLE METHODOLOGY: CAMERA TRAPPING

Camera trapping is a widely used non-invasive scientific tool to study wild species of large to medium sized mammals and in certain variations also for smaller mammals and other vertebrates (Rovero & Zimmermann, 2016). It uses remotely triggered cameras that automatically take pictures and/or videos of animals passing in front of them. The records obtained with camera traps are objective evidence of animal presence (unlike sighting reports, for instance) and can provide a range of information about the biology and ecology of the studied species (see Rovero & Zimmermann 2016 for further details) as well as individual identification using individually distinct fur pattern in species such as lynx. Camera trapping has already been successfully used to monitor Eurasian and Iberian lynxes in Europe, e.g. Switzerland (Capt 2007, Zimmermann et al. 2013), Germany (Weingarth et al. 2012, Weingarth et al. 2015), Czech Republic, Slovakia

(Kutal et al. 2013), Republic of North Macedonia (Melovski et al. 2009) and Spain (Gil-Sanchez et al. 2011, Garrote et al. 2011).

Data from camera traps enable us to obtain information about the lynx identity and reproduction, as well as estimation of minimum population size. If performed intensively, it can also allow capture-recapture analysis and thus estimate population density with known uncertainty. If performed over a long time span, it allows collecting individual life history information, such as migration, reproduction, kitten survival, dispersal and minimum home range size. Therefore, camera trapping was chosen as one of the fundamental methods for systematic, long-term lynx monitoring in Dinaric and SE Alpine region.

Another method that will be used in parallel for population level monitoring is genetic monitoring, which will however be primarily used to determine the level of genetic diversity and the accumulation of inbreeding, rather than population size. Compared to the camera trapping, it is also a more labour intensive and costly method if used for monitoring rare and elusive species which DNA samples are difficult to find in the nature (lynx cover its faeces and it is only possible to collect DNA at marking spots during winter). However, the combination of genetic methods and camera trapping can yield optimal results. For that purpose, we installed hair-traps at some of the camera trapping stations. We expected the approach to enable us to get both visual and genetic data simultaneously for individual lynx even though it was shown as not the most efficient method for Canada lynx (*Lynx canadensis*) survey (Crowley & Hodder 2017). The hair traps we used were designed at University of Ljubljana within Dinaris project (Krofel 2008) and optimized prior to the start of the project (Smolej 2018). Part of the hair trap was designed a-novo, using a passive hair trap combined with an active coil spring. The idea behind it was that the lynx would get attracted to the hair-trap by the attractant (mix of catnip and beaver gland secretion in Vaseline; McDaniel et al. 2000) and then rub against the hair-trap. Method enables the active capture of hair with hair roots and individual hair capture of only one specimen. These hair traps gave good results during testing at Ljubljana ZOO (Smolej 2018).

In parallel to the systematic camera-trapping, we will continue to collect SCALP data about lynx (Molinari-Jobin 2012) and include them in the results of this report.

<u>SURVEY DESIGN</u>

Survey design for camera trapping needed to be planned carefully, taking into account the temporal and spatial attributes of the data about lynx presence, which was reported in the past. Following the experience of Weingarth et al. 2015 and Zimmermann et al. 2013, the best season for camera trapping lynx is from September to December and December to February, respectively. In autumn, the population is demographically closed, before the male lynx start to move more extensively in search for mates during pre-mating and mating season (i.e. December-January and February-March, respectively) and before the kittens from previous year separate from their mothers and disperse. Residential lynx start intensively marking their territory in the mating season, which is easy to detect with snow tracking and can help choose the location for a camera trap. In the same season, female lynx with kittens from previous year become more mobile and are easy to detect (kittens follow their mothers until late April).

Considering all these aspects, we installed camera traps in the field from late August until end of April to ensure highest possible detectability of lynx in the first year of monitoring. We performed intensive monitoring only from August to November (see Field work – Camera Trapping for details) over the entire lynx core range in the Slovenian Dinaric mountains (Figure 1). We considered the scope of the projects addressing lynx monitoring (Table 1) and the extent of available funding to appropriately distribute the available equipment (mostly number of cameras). Besides the LIFE Lynx project which aims to reinforce Dinaric SE-Alpine lynx population (www.lifelynx.eu), we were also involved with an international lynx project 3Lynx which aims to harmonize lynx monitoring in countries sharing the Dinaric - Alpine lynx population. The national annual monitoring of lynx funded by the Ministry of Environment and Infrastructure (MOP) was also running with the main idea to improve the existing monitoring system in state's special purpose hunting reserves (LPNs). All three projects provided us enough funding to survey a large area with a relatively high density of camera traps. We decided to implement 3Lynx and MOP funds within the state-owned hunting grounds as opportunistic lynx monitoring took place there since the reintroduction on 1973. Some opportunistic monitoring was already established in other hunting grounds but not to such an extent as in LPNs. We thus implemented the MOP and 3Lynx projects aiming to improve monitoring in LPN using the experience from abroad and to transfer the good practice of lynx monitoring in LPNs to other national areas while we surveyed lynx in other hunting grounds within LIFE Lynx project. We believe this approach will help establish a reliable long-term population monitoring on a national scale and we thus report the results of survey of all projects in all areas in this common document.

Table 1. An overview of the projects (funding) addressing lynx monitoring in Slovenia. A full list with hunting grounds involved is available in Table 1 in the Appendix.

Project (period)	**No of cameras installed**	**Type of hunting ground (no.)**	**Main objectives**
LIFE Lynx (2018-2024)	95	Other (31)	1. Pre-reinforcement survey of the potential release sites and the genetic and demographic status of residual lynx population (in Slovenia and Croatia) A.3. 2. Surveillance and directed management of the reinforcement process C.5.
MOP (2018-2019)	62	State's special purpose hunting grounds (5)	1. Improving the existing (opportunistic) monitoring of lynx in state-owned hunting grounds (LPN). 2. Transfer the experience from LPN to optimize the national level monitoring scheme.
3Lynx (2017-2020)	35	State's special purpose hunting grounds (5)	1. Harmonization and integration of lynx monitoring in Italy, Slovenia and Croatia (Dinaric-Alpine lynx population). 2. Transfer the knowledge and experience from more than 10 year monitoring of Bohemian-Bavarian-Yura lynx population.

FIELD WORK

COLLABORATION WITH HUNTERS

Prior to the start of the intensive monitoring season, we established or renewed contacts with hunters. Hunters from LPNs have been familiar with our work as they have been involved with other large carnivore related projects and were monitoring lynx opportunistically in the past. It was thus easier to communicate and reach the objectives of MOP and 3Lynx projects as they were addressing wider objectives than just surveying an area (optimization, harmonization of methods on a wider scale; see Table 1). Hunting clubs in the area of potential lynx presence were contacted via local hunting associations. We prepared presentations of our idea in their local environment and then proposed the collaboration individually to the head officials of each hunting club. The responses were really encouraging as all but one hunting club responded to our invitation positively. Thus 36 hunting grounds (including 5 LPNs) collaborated within the national lynx monitoring (Figure 1, Table 1 Appendix). Generally, hunters were eager to collaborate; some of them saw an opportunity to get to know this charismatic species and some were interested to get new insights about other game and non-game species in their hunting grounds. We also involved some local enthusiasts that wished to collaborate as they had good knowledge about lynx in their area. We assigned one coordinator of lynx monitoring at SFS and a few persons from SFS or

UL that were joining hunters/enthusiasts on the field. The entire coordination of monitoring and field work ran in close collaboration with the UL.

CAMERA TRAPPING

At the beginning of monitoring season (in the end of August 2018) we met with all the hunters that would collaborate in the monitoring. At least one person per hunting ground was chosen to be responsible for equipment maintenance, sending the data and communicating with SFS or UL. We accompanied 63 hunters in the field and together chose at least two locations for camera traps (and sometimes also hair-traps) per hunting ground. Joining their experience and local knowledge about lynx and our expertise in biology and ecology of the species enabled us to choose the optimal locations. In LPNs we choose at least two locations per district as the entire LPN is much larger in size than other hunting grounds (Table 1 in the Appendix). We planned to set up the cameras in LPNs systematically in 2.7 x 2.7 km^2 grid, following the system used in the central Europe (e.g. Zimmermann et al. 2013), however adjusting it to the 3x3 km^2 grid that is already used for wolf monitoring in Slovenia. For each camera trap, we noted the location details (GPS coordinates, the name and the district of the hunting ground), a brief description of the site, presence of a hair trap (yes/no), the hunter's contact details, the camera name and the set-up date and any additional remarks. If the nearest cameras were less than 25 m apart (Drosos & Malesios, 2016), we defined them as one camera trap station.

We used 3 types of camera traps (CuddeBack X-Change™ Color Model 1279 with white flash or IR flash, CuddeBack X-Change™ Color Model 1213 with black IR and StealthCam STC-G42NG with black IR) which were successfully used for lynx monitoring in other European countries (e.g. Switzerland (Zimmermann et al. 2013), Germany (Weingarth et al. 2015), Slovakia (Kutal et al. 2013)). We used cameras with white flash on remote locations (animal paths, natural stone walls, rocky terrain etc.) where lynx would just pass by and the best possible lighting would be needed to get a high quality photo of a moving animal. We used cameras with IR at locations which could be frequented by people (forest roads, paths, etc) so it is less visible for people (avoiding theft). We used cameras with black IR at potentially best locations where we could expect lynx to stay longer (marking spots), including anthropogenic marking locations (forest huts, abandoned houses, ruins etc) where the black IR light would not disturb lynx but the proximity to the marking site would still offer sufficient quality recordings despite lower quality lighting.

During the first three months of camera trapping, hunters checked the cameras and the hair-traps approximately every two weeks, replacing the batteries and SD cards, if needed, and collecting any lynx hair from the hair-traps and mixing the attractant to ensure its evaporation. They stored all recordings on an external drive that was mostly personally retrieved by SFS or UL personnel. The hunters also reported any other information about lynx in their hunting ground. After the 3-month period, cameras were left on the field until the end of April.

Camera traps were also installed opportunistically at found remains of prey or at sites where lynx was seen. Opportunistic camera trap footage with lynx was also sent to SFS as SCALP data. We thus considered all these additional data that was not collected within the systematic monitoring in the same time period as SCALP data and we report it separately.

ANALYSIS AND RESULTS

In total, we installed 191 cameras on 161 camera trap stations (Figure 2, Table 1 in the Appendix). Seven cameras were either moved to another location due to disturbance or were damaged or stolen during the monitoring period. Hair traps were installed at 53 of these locations (Figure 5). In total, we installed cameras in 100 out of 347 3x3 km^2 cells covering the entire area of monitoring (all hunting grounds). We did not distribute the cameras systematically over the grid (e.g. in every second cell in the grid) but rather set them on the appropriate locations in agreement with the hunters.

LYNX RECORDS

39 camera traps recorded 165 lynx recordings (113 photos and 52 videos) within 14 hunting grounds (Figure 2). The cumulative number of recordings was increasing almost linearly during the entire monitoring period while the number of individual lynx was increasing until the end of the year 2018 and then stabilized (Figure 1). Only two individuals appeared in 2019 that have not been recognized before, both in LPN Jelen during the mating season. Possibly they were males that made excursions outside of their usual home range in search of mating opportunities with additional females.

Most of the lynx records (all but the ones of poorest quality) were uploaded to a common database lynx.vef.hr, where we share our lynx-related data with researchers from Croatia.

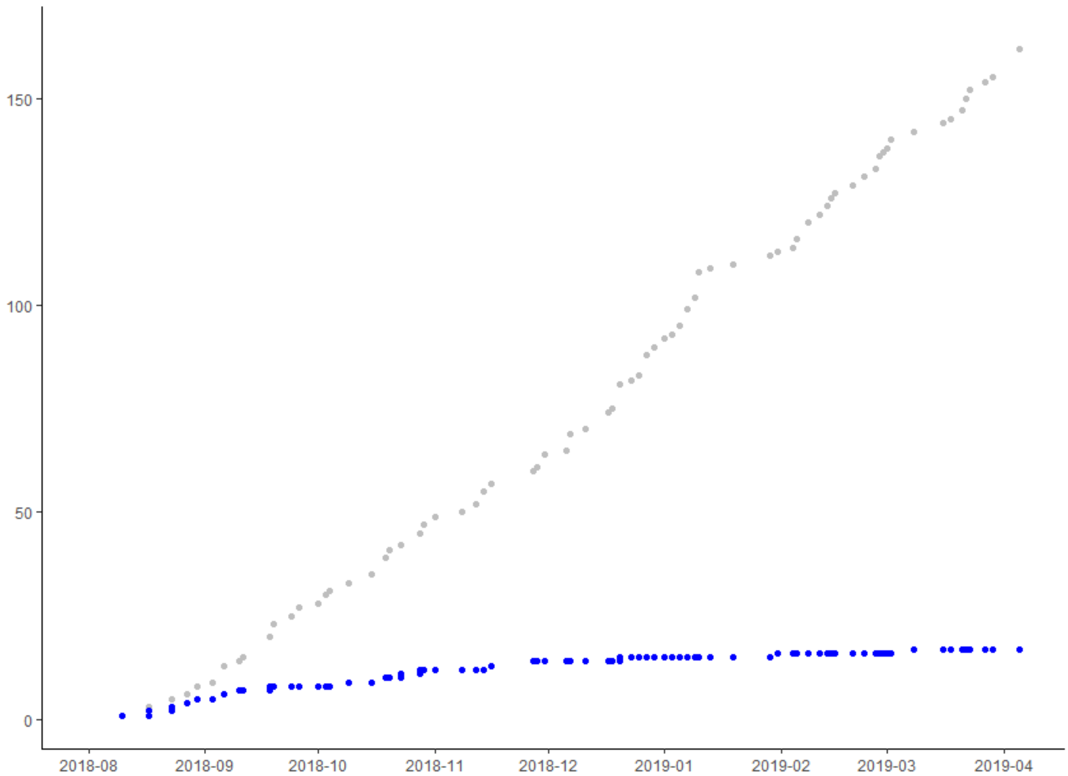

Figure 1. Cumulative number of lynx recordings (gray dots) and different lynx (blue dots) with increasing number of days of camera trapping during the entire monitoring season.

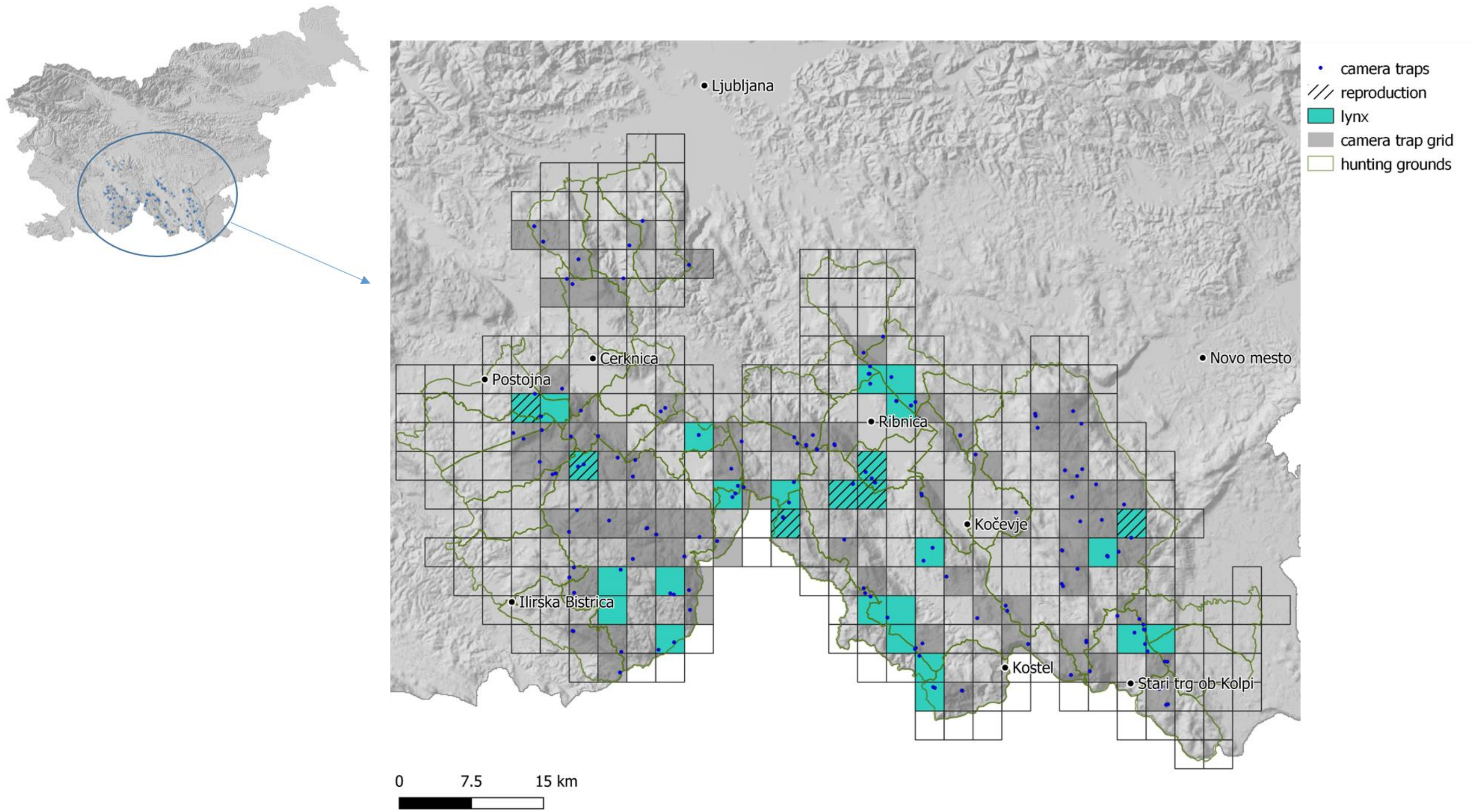

Figure 2. General area of lynx monitoring in Slovenia in season 2018/19 (top left) and the 3x3 km^2 grid (right, outlined with grey) covering all collaborating hunting grounds (right, outlined with green). The cells and locations of camera trapping stations are shown as grey cells and blue dots, respectively. The turquoise cells show where lynx was recorded and the hashed cells show where reproduction was detected.

Recordings of lynx were examined visually for identification purposes (Figure 3). Coat pattern was identifiable on roughly half of the recordings and we could distinguish minimum 17 individual adult lynx (Table 2, Figure 4). It is important to be aware that animals identified close to the national border may also have part of their territory in Croatia. Until now, we found two animals that were recorded in both countries, however cannot say whether they were in dispersion or making excursions outside their territories.

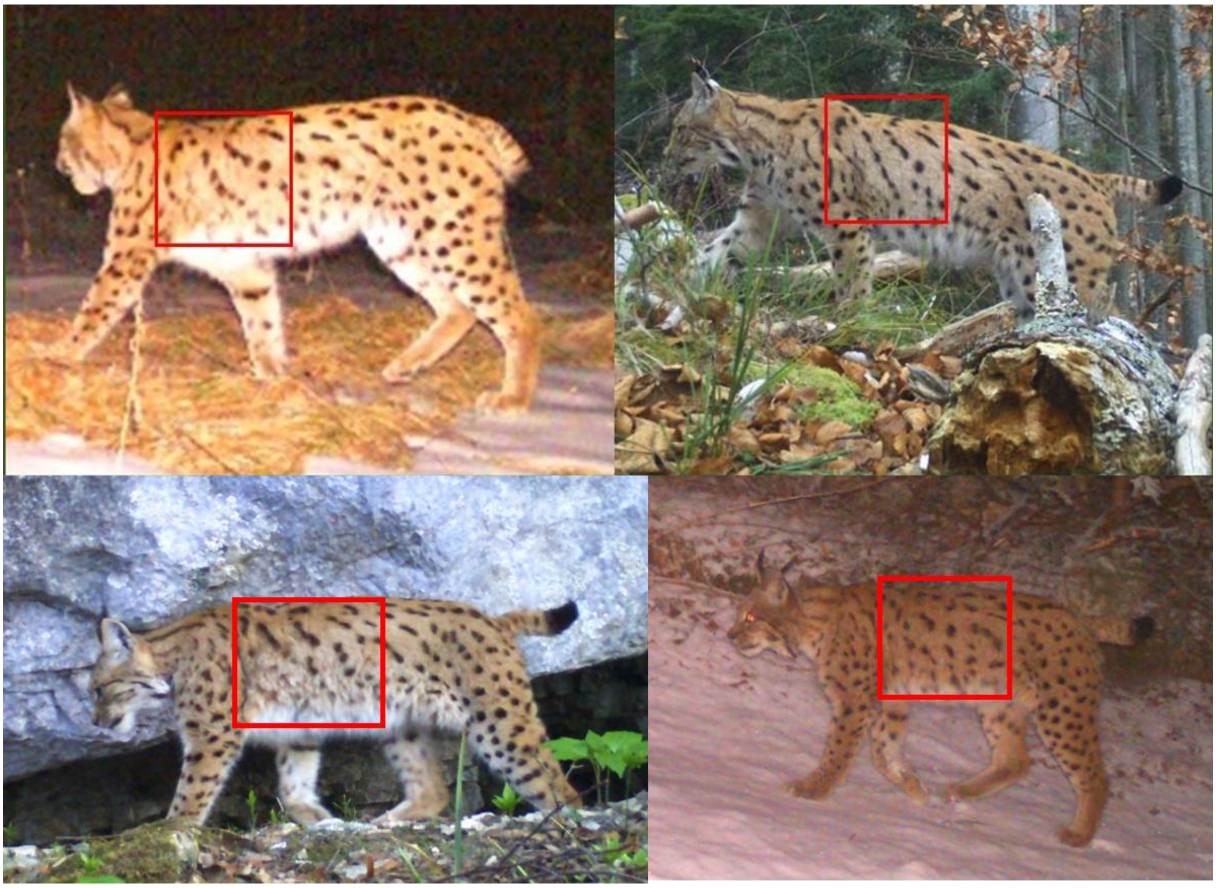

Figure 3. An example of visual lynx identification by the coat pattern. The red quadrant shows how we used certain patch of coat pattern to compare two records of the same (top; left and right) or different (bottom; left and right) lynx.

In most cases, it was impossible to sex the adult lynx; exceptions are females with juveniles (n=6) and certain recordings that show lynx exhibiting marking behaviour. Some individuals were recognized at more than one hunting ground (Figure 1 in the appendix) and at several camera trap stations so we can speculate about the minimal home ranges. Lynx was not recorded evenly within the monitoring area, with the most recordings at the core of the monitoring area and no recordings in the northernmost (just South of Ljubljana) area.

Table 2. An overview of number of cameras, recordings and individual adult and juvenile lynx in Slovenia the monitoring season 2018/19.

Hunting ground	Number of cameras that recorded lynx	Number of lynx recordings	Min. no. of adult lynx	Lynx ID (Sex)	Min. no. of juveniles
Babno polje	1	1	1	?	
Banja loka	1	2	1	?, Osilnica2	
Dolenja vas	2	9	2	?, ?(F), VelikaGora1	1
Draga	3	36	3	? (F), Draga1 (F), Draga2 (M), Glazuta2016 (F)	2
Javornik Postojna	2	3	1	? (F), Javorniki1	1
Loški potok	1	8	3	?, Draga2, Glazuta2016 (F), Stojna1 (M)	
Lož Stari trg	1	2	1	?	
Osilnica	4	14	3	?, Osilnica1, Osilnica2	
Predgrad	2	11	1	?, PoljanskaGora1	
Struge	2	10	1	MalaGora1 (F)*	
Velike Poljane	1	13	1	MalaGora1 (F)*	
LPN Jelen	9	43	6	? (F), Gomance1, Javorje1, Jurjeva1 (F), Jurjeva2, Jurjeva3, Kambrce1	1
LPN Medved	4	6	2	PoljanskaGora1, Rog1 (F)	1
LPN Snežnik Kočevska Reka	5	10	3	Glazuta2016 (F), Osilnica2, Stojna1 (M)	1

* the female lynx "MalaGora1" was later captured and collared and named "Teja".

CAMERA TRAP STATIONS

We categorized the locations of camera trap stations by their most prominent anthropogenic and/or natural characteristic. We defined 6 anthropogenic features; human objects (forest huts, ruins, houses), logging trails (muddy, less used by people), forest roads (gravel, more used by people), artificial water source and artificial feeding site (in vicinity). The 4 natural features were ridge, crossing of at least two game paths, a path through rocky terrain and a rock wall. We analysed the number of lynx recordings at each of these features, using only data from camera trap stations in areas with confirmed lynx presence, i.e. sites that were inside a 5 km buffer (representing roughly half of lynx home range (Krofel, 2012)) around stations which recorded lynx. In this way, we tried to get the most representative idea of what are the best micro-locations that a lynx would use in its home range. Lynx were most often recorded at game path crossings (33.3 %), rock walls (31.8 %), rocky passes (29.4 %) and human objects (28.6 %) (Figure 4).

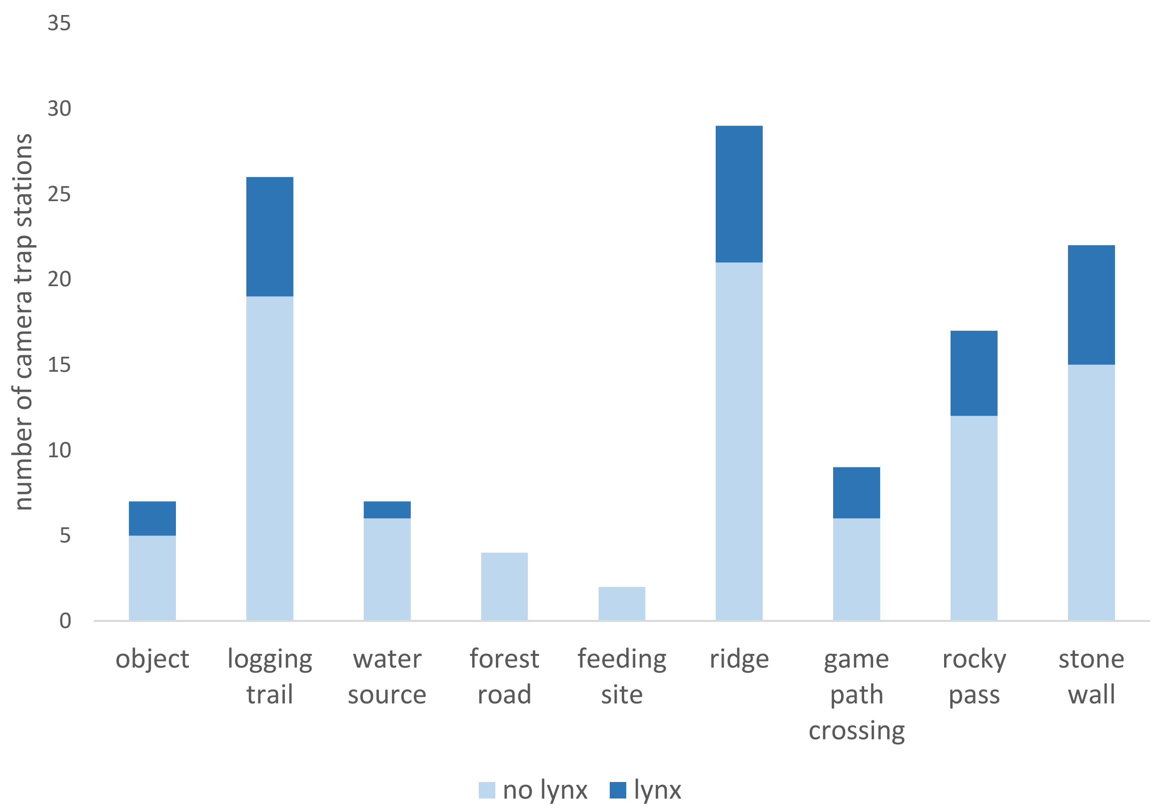

Figure 4. The number of camera trap stations with specific anthropogenic/natural characteristics where lynx was recorded.

<u>HAIR TRAPS</u>

On 11 out of 53 locations with hair-traps, we recorded lynx on 42 camera-trap recordings (Figure 5). On one recording, lynx only looked at the hair trap and then passed it while two different lynx on one recording each used them for marking (in LD Dolenja vas; recorded with white flash camera in beginning of February (about 5 months after the location set up) and LD Predgrad; recorded with Black IR camera in the end of September (about one month after the location set up)). An additional hair pole was installed with a camera trap in frame of SCALP monitoring, which was effectively used for marking by a female lynx that has later been also captured and collared. On all others recordings of lynx at hair-traps, lynx did not show any signs of detecting the hair-trap. Unfortunately, we could not control exactly if or how often the hunters were mixing the attractant to spread more scent and how that influenced the lynx choice of approaching the hair-trap. Since we only detected 2 events with successful lynx hair trapping within the intensive monitoring period we will have to change the approach in the next season, for example installing the hair traps only at already known marking sites (Crowley & Hodder 2017, Slijepčević 2018, pers. comm.).

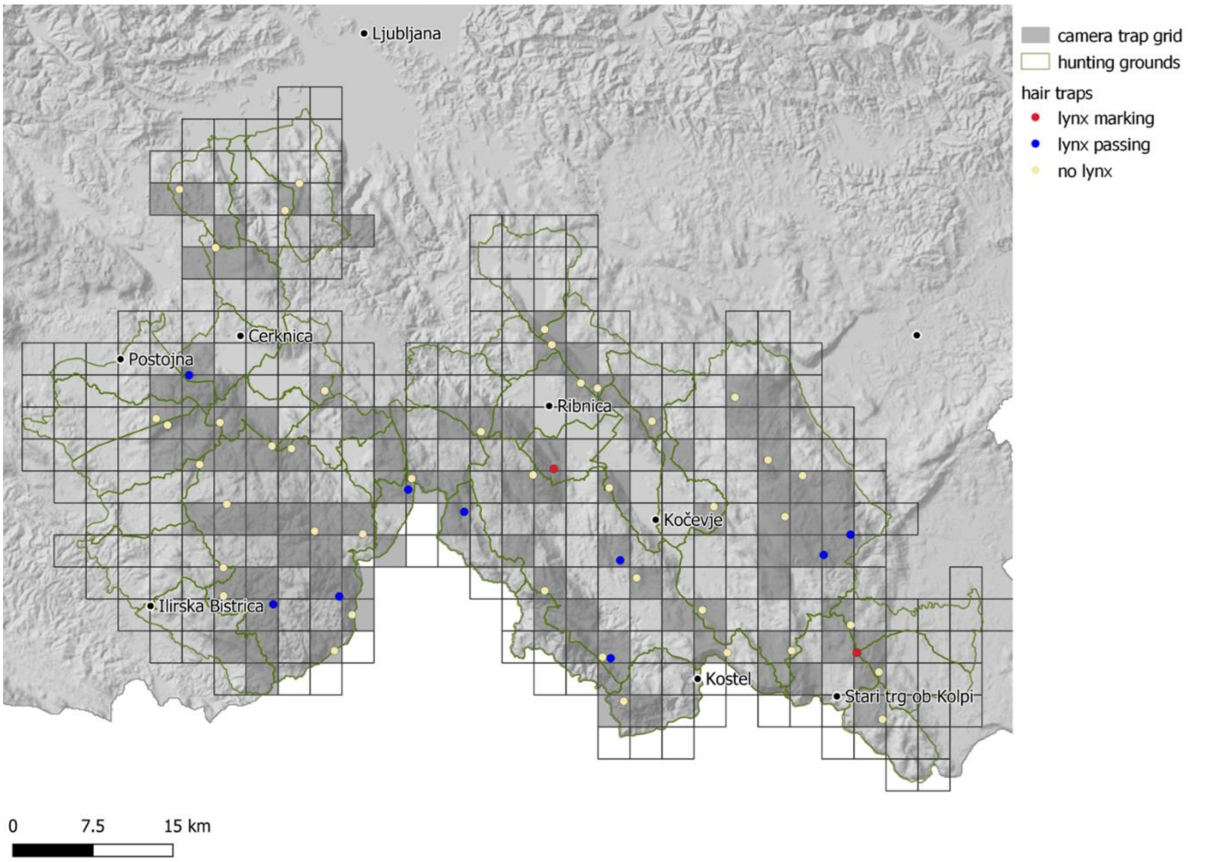

Figure 5. Locations of hair traps where lynx was recorded (blue dots) or not (yellow dots) and the locations at which it used the hair trap (red dots).

SCALP DATA

During the period of systematic lynx monitoring, we also obtained camera trap footage from 16 additional locations. We recognized four that were already identified within the systematic monitoring. Two lynx were new; one in LD Col and one in LPN Snežnik Kočevska Reka. One of them (in Col hunting ground, the area of Hrušica plateau) was recorded outside the area of monitoring, which is encouraging as we plan to extend the area for lynx monitoring in the upcoming season towards the SE Alps. Adding these two individuals to the 17 which were identified within the systematic monitoring, we can conclude that we have minimum 19 adult lynx in Slovenia (with some of them having their home ranges also in Croatia).

CONCLUSIONS

This report presented the results of the first systematic monitoring of lynx in Slovenian Dinaric mountains. Extensive camera trapping combined with data collection using SCALP methodology enabled us to get a reliable estimate of the minimum population size (19 individual adult animals) of lynx in this area, with two of them being also detected in Croatia. An important result of the first season of lynx monitoring is also a successful start of collaboration with hunters. This collaboration enabled us to obtain a sufficient amount of data over a longer (few month long) period at a national scale. In the neighbouring Croatia, they counted cca 40 lynx with the same method.

Many important lessons for long-term monitoring of lynx were taken during this season. The main ones include:

1. Joint teams of SFS personnel, UL researchers and local hunters should be a norm when setting up the camera traps. Constant communication between SFS, UL and hunters is vital for undisturbed data collection.
2. Choosing the camera trap with appropriate flash functions accurately for the situation in which it is set up. Even though we followed the guidelines for when and how to use different camera traps (Stergar and Slijepčević 2017), 50 % of all recordings were useless for identification purposes. We were unsatisfied with black IR cameras as they produced the worst quality images/videos, if set more than a few meters away from the expected point, where lynx would pass by. We thus plan to use them only at marking objects where we will be able to set them very close to the marking spot and where lynx typically stops for several seconds while marking, which results in sharp images even with lower intensity of lightning.
3. Finding additional objects that lynx use as marking spots, e.g. through snow-tracking for the upcoming season. Rock walls and animal path crossing should also be preferred over other natural characteristics as main camera trap location characteristics. The locations where lynx was recorded should be preserved for the next seasons.
4. The period of monitoring can remain as it is as the cameras stay operative without maintenance also in winter and spring. To have enough time for data processing, all cameras should be collected and returned to SFS in spring.
5. The use of hair traps should be carefully revised for the upcoming season.

To avoid overestimation of the minimum number of lynx in the entire range of Northern Dinaric mountains, recordings of lynx that were taken close to the border between Slovenia and Croatia should be compared between both teams. That should represent the first step for harmonization of population-level monitoring system (Table 1).

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APPENDIX

Table 1. List of hunting grounds that collaborated in systematic lynx monitoring in season 2018/19 with the number of locations, number of cameras per hunting ground and their surface areas. The hunting grounds where lynx was recorded are indicated in bold.

Hunting ground	No of camera trap stations	No of camera traps	Hair trap [no.]	Surface area [ha]
Babno polje	**3**	**4**	**1**	**2041.8**
Banja Loka	**4**	**4**	**1**	**5024.6**
Begunje	2	2	2	4562.3
Borovnica	2	2	1	4268.7
Cerknica	2	2	1	4571.7
Dobrepolje	2	2	1	6172.0
Dolenja vas	**3**	**4**	**1**	**3373.3**
Draga	**3**	**4**	**1**	**3512.2**
Dragatus	2	2	1	4714.7
Gorenje jezero	2	2	1	3561.2
Grahovo	2	2	1	4252.8
Iga vas	2	3	0	2760.9
Javornik Postojna	**3**	**3**	**0**	**5130.3**
Kočevje	1	1	1	5365.2
Kozlek	3	3	0	5859.9
Loka pri Črnomlju	4	4	1	5068.7
Loski Potok	**4**	**4**	1	**4987.5**
Loz Stari trg	**2**	**3**	1	**3200.6**
LPN Jelen	**24**	**35**	**8**	**27832.1**
LPN Ljubljanski vrh	3	6	1	4137.9
LPN Medved	**27**	**34**	**8**	**37951.6**
LPN Sneznik Kocevska Reka	**14**	**20**	**7**	**27135.7**
LPN Zitna gora	1	2	1	3473.4
Mala gora	2	2	1	3734.8
Osilnica	**4**	**5**	**1**	**3626.6**
Pivka	2	2	1	5832.3
Predgrad	**5**	**5**	**1**	**4977.3**
Prestranek	2	3	1	5627.2
Rakitna	2	2	1	6291.2
Ribnica	6	6	1	5448.3
Sinji Vrh	4	4	1	4283.7
Sodrazica	7	4	2	5236.2
Struge	**4**	**4**	1	**3715.6**
Tabor Zagorje	3	3	1	4076.2
Trnovo	2	3	1	6374.8
Velike Poljane	**3**	**3**	**1**	**2419.1**
TOTAL	*161*	*194*	*53*	*240602*

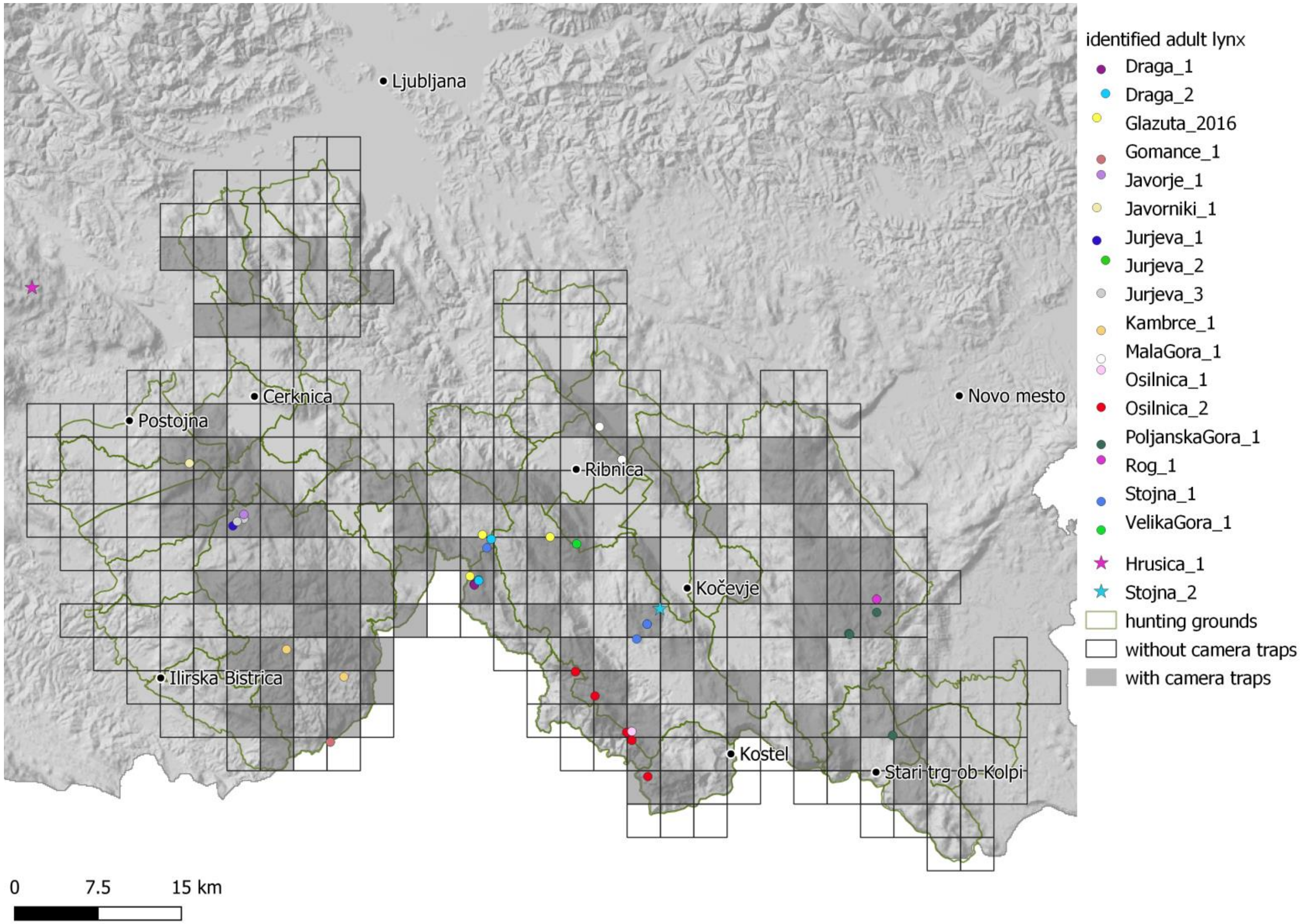

Figure 1. Locations where we recognized individual adult lynx (n=19). Each colour represents given lynx. Points of different colours are clustered at single locations, where more than one individual adult lynx was recognized. Two lynx that were recognized from records provided through SCALP methodology are shown with a star symbol.