OVERVIEW OF GOOD PRACTICES IN EURASIAN LYNX MONITORING AND CONSERVATION

FINAL REPORT

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SUMMARY

Eurasian lynx is the largest felid in Europe, where many populations still face extinction. Major threats include poaching, inbreeding depression, vehicle collisions, habitat loss and fragmentation. To preserve viability of these populations, further efforts are required, including an efficient monitoring that represents an important part of any successful conservation program. In this report we first provide an overview of methods used for lynx monitoring across Europe with their strengths, weaknesses, opportunities and threats, as well as differences in their implementation among the different regions. In the second part, we highlight several good practices in various conservation actions aimed to address the major threats to lynx populations.

Several field methods and analytical tools have been developed for monitoring of lynx populations. While opportunistic data collection can be efficient in terms of effort and cost, it can introduce bias and reduce the quality of final results. Therefore data should preferably be collected systematically using methods like camera trapping, snow tracking, hair trapping and other types of genetic sampling, systematic distribution of questionnaires, recording of mortality records, and telemetry. Based on the review of 125 publications and direct communication with lynx experts, we prepared an overview of monitoring programs in each country. Most countries use a combination of several methods and many are starting to conduct systematic monitoring. While some of the methods are an obvious choice for specific areas, there is no single method that could be generally recommended for all populations and every context. Camera trapping in combination with (spatial) capture-recapture analysis is currently the method of choice for obtaining robust estimates of lynx abundance in many regions, with the exception of populations with large proportion of unspotted individuals, which prevents individual recognition. Recent trends in monitoring programs also indicate increasing involvement of volunteers in monitoring programs and initiatives to synchronize lynx monitoring at the transboundary level.

Given threatened status of many populations and relatively poor dispersing abilities of the species, active conservation remains essential for long-term survival and recovery of the lynx in Europe. Reintroductions and reinforcement programs continue to play crucial role in lynx conservation and we describe two ongoing projects aimed to create vital populations in areas where lynx have become extinct or drastically reduced. Besides translocating lynx, it is essential that such projects also address other aspects, such as preventing poaching, involving stakeholders and increasing public support for lynx conservation. Such examples include creation of specialized police units, involvement of hunters in monitoring programs and creation of local consultative groups. Inspiring example of transboundary collaboration is the Balkan lynx Recovery Programme, where a group of leading experts from one country provided their expertise to establish a successful research and conservation program in another country with limited capacities. To successfully prevent livestock depredations it is important to test which methods are effective and which are not in order to provide knowledge that can be implemented when the need arises. Although many of these activities are costly and demand considerable effort, recent success stories show that such investments are well worth making. They help us to safeguard survival of lynx in human-dominated landscapes of Europe, where hopefully one day translocations and similar human interventions will no longer be needed.

GENERAL INTRODUCTION

Eurasian lynx (*Lynx lynx*; hereafter referred to as 'lynx') is the third largest carnivore in Europe after brown bear (*Ursus arctos*) and grey wolf (*Canis lupus*). It is also the largest extant member of the cat family (Felidae) in European fauna.

Currently, there are 10 lynx populations in Europe inhabiting 27 countries. Six populations are small (i.e. <200) and fragmented (Alpine, Balkan, Bohemian – Bavarian – Austrian, Dinaric, Jura, and Vosges – Palatinian forest) with Endangered or Critically Endangered status. Other four populations (Baltic, Carpathian, Karelian and Scandinavian) are larger (i.e. >1000) and categorized as Least Concern and Viable. Estimated number for the entire Europe (excluding Russia) for 2009-2011 was approximately 9.000 lynx (Kaczensky et al. 2013).

Most of the European lynx populations are protected under the E.U. legislation (the Habitats Directive), although lynx is regularly hunted in Sweden, Latvia, Estonia and Finland, where member states use derogations under article 16 of the Directive, which allows a limited cull. In Norway (a non-E.U. country), lynx is listed as a game species with annual hunting quotas (Männil & Kont 2012, Kaczensky et al. 2013).

Species description

Lynx is characterized by the ear tufts, round head, long legs, large feet, short black tail and flared facial hair. Three general coat pattern phenotypes were described: spotted (with small or large spots), rosette pattern and uniform pattern without spots (Gregorová 2002, Kubala et al. 2020). Each individual has unique coat pattern (exception to this are the unspotted individuals that occur in some populations), which can help scientist and researchers to identify individual lynx (e.g. from camera-trap recordings). Sexual dimorphism is also present, as males are on average larger than females (Breitenmoser et al. 2006).

Lynx is a seasonal breeding species and mating usually occurs in February and March. Gestation period lasts from 67 to 74 days, therefore most kittens are born in May or beginning of June. Kittens normally stay with their mother until the next mating season, when they start becoming independent. They often stay in their mother's territory for some time, but then they have to disperse and find an unoccupied territory with sufficient prey density. Males usually disperse farther than females, who often even establish home range that partly overlap with their mothers (Samelius et al. 2012). In this period mortality rate of the young lynx is very high (Kramer-Schadt et al. 2004).

The optimal lynx habitat in Europe is forest, but lynx can also survive in more open landscape, such as semi deserts, tundra and mountainous areas above the forest line (Breitenmoser & Breitenmoser-Würsten 2008). Lynx is a territorial species, but exhibits territorial behaviour only towards conspecifics of the same sex. Therefore there is usually large overlap between male and female home ranges. The average home-range size in Europe varies among the regions. In northern parts of Europe they range between 600 to 1400 km^2 (Saebø 2007), while in Central Europe and in the Balkans around 100 to 450 km^2 (Melovski et al. 2020). The home-range size in general varies in respect to the prey density with lower densities resulting in larger home ranges and vice versa. Lynx is mostly active during the night, with the peak of the activity at dusk and down (Heurich et al. 2014).

Eurasian lynx uses two techniques of hunting: ambush and stalking. It is mostly specialized on predation of small to medium-sized ungulates. In most of Europe, the main prey is roe deer (*Capreolus capreoulus*), while they also hunt red deer (*Cervus elaphus*), chamois (*Rupicapra rupicapra*) and rodents (Breitenmoser & Breitenmoser-Würsten 2008). In northern Europe, the main food source can also be hares (*Lepus europeus* and *L. timidus*) and reindeer (*Rangifer tarandus*).

Livestock depredation in continental Europe is relatively low, especially when compared to losses caused by brown bear and wolf (Kaczensky 1999). In Scandinavia, however, lynx often predates on sheep (especially in Norway) and semi-domestic reindeer, which graze unprotected in the remote areas. Compensation schemes for livestock breeders are often the main measure for conflict mitigation (von Arx et al. 2004).

Threats

Major threats to lynx in Europe include poaching, habitat loss and fragmentation due to infrastructure development, and vehicle collisions (Kaczensky et al. 2013). Additional threat to the several small, reintroduced and usually isolated populations is inbreeding depression (Ryser-Degiorgis et al. 2004, Sindičić et al. 2013b, Mueller et al. 2020).

Importance of conservation actions and monitoring programs

In recent decades, large carnivores are making comeback across the Europe as a result of change in public attitudes, favourable legislation, better ecological conditions and better management tools (Chapron et al. 2014). Thanks to several lynx reintroduction programs, lynx have recolonized areas where they were exterminated in the past. Such reintroductions or reinforcements (i.e. translocation of additional lynx to prevent inbreeding) were conducted from the early 1970s and some continue nowadays in Switzerland, France, Slovenia, Croatia, Austria, Italy, Germany and Poland. However in some early attempts of lynx reintroduction, when knowledge was less advanced than today, less attention was paid to some important aspects, such as number, relatedness and genetic origin of the released lynx, and large spatial demands for population viability, an there was often poor or no communication to general public and poor collaboration with crucial stakeholders (Linnell et al. 2009, Wilson 2018). Nowadays, these aspects are given more attention and several projects can be considered as good practice examples of lynx reintroduction or reinforcement. However, despite efforts to help lynx to recover, some populations are still declining and are considered to be critically endangered. To preserve viability of populations in the long term, further efforts are required, such as building partnership with the main stakeholders like hunters, conservationists, farmers and local public. Important part of any successful conservation project is also efficient monitoring that provides detailed insights into population status, trends and the effectiveness of conservation efforts implemented.

Goal of this report

Main goal of this report is to provide an extensive overview of lynx monitoring methods across Europe and highlight the good practices in various conservation actions. This will serve as a guideline for wildlife managers, authorities and practitioners when looking for most suitable way to approach lynx conservation and monitoring challenges in their region.

PART I. MONITORING

1. INTRODUCTION

Monitoring is defined as continuous observation of a population through a series of surveys, where results are continuously compared with a defined goal. That distinguishes it from surveillance (observing a process without a clearly defined goal) or a survey (defining a status at given time) (Hellawell 1991). It is an essential activity for any species conservation or management program and allows constant adjustments and efficiency evaluations, if being ran in a long term.

Monitoring of large carnivores is arguably one of the most difficult tasks of wildlife management. Large carnivores live in low densities, are long lived and have slow growth rates. In Europe, they have been persecuted for millennia, which has further decreased the populations, while habitat destruction has fragmented them into patches with low or no connectivity. Besides, large carnivores are very difficult to observe as they live a secretive, nocturnal lifestyle, especially when persecuted (Linnell et al. 1998). Nevertheless, populations of large carnivores in Europe have shown a remarkable capacity to recover (Chapron et al. 2014) and today monitoring programs have been adopted and adjusted in most countries with existing populations of large carnivore species.

Monitoring of large carnivores can involve passive or active approach to data collection, both of which then require actively handling, analysing and interpretation of the collected data (Breitenmoser et al. 2006). Therefore, we prefer to use terms “opportunistic monitoring” vs “systematic monitoring”. Opportunistic monitoring includes collecting all available data about a desired species from random sources or sources primarily serving another purpose and can thus involve a high degree of bias. While opportunistic data collection is a realistic and important part of many monitoring programs of large carnivores, systematic monitoring is the monitoring in the strict sense of the word. Only data collected in a targeted and systematic way can assure homogenous and unbiased sample (Breitenmoser et al. 2006). The quality and reliability of a monitoring programme depends on the investment, but it always needs to primarily consider the main objective of the monitoring before choosing the most suitable design with needed accuracy. Due to the protected status of Eurasian lynx under the Habitats Directive, periodic reporting (every 6 years) for the countries of the European Union is required to show the species is kept in a favourable conservation status (https://www.eea.europa.eu/).

Population distribution, size, trend, abundance, health and genetic status are the main parameters addressed by monitoring programmes. In case of Eurasian lynx, a wide array of methods is used to asses these parameters as lynx status varies among different European countries, as do the conservation goals, management plans, administrative systems, population characteristics, and environmental conditions (e.g. the duration of snow cover). Attempts to harmonize the data collection on a transboundary level were initiated already in the 20th century, such as collecting opportunistic and mortality records from Croatia and Slovenia to assess the status of reintroduced transboundary Dinaric lynx population (Čop & Frković 1998). This is continued nowadays, as in the transnational camera-trapping monitoring of the transboundary Bohemian-Bavarian-Austrian lynx metapopulation (Belotti 2020). Even wider and more structured harmonization of lynx monitoring programs among central European countries is the main goal of the Interreg 3Lynx project, while the countries sharing the Dinaric population are establishing the common monitoring guidelines within the LIFE Lynx project.

In the following chapters, we present review of all methods currently reported to be used for monitoring of Eurasian lynx across Europe. We focus on the similarities and differences of method implementations among different countries, regions or other entities and provide a list of strengths, weaknesses, opportunities and threats for each of the methods.

In preparation of this report, the baseline information on the status and use of the main methods for monitoring of lynx and other large carnivores in Europe prepared by Kaczensky et al. (2013) was particularly useful. However, the information provided in that document was limited in the scope of details provided for each country and method. Besides, the list is becoming outdated and needs an update with new information and references. An overview of the principles of monitoring and the options and problems of monitoring lynx published by Breitenmoser et al. (2006) compiled extensive experience with lynx monitoring and research, mainly from Switzerland, to assist the survey design for Balkan lynx. Although highly relevant, these guidelines needed to be expanded with experience from other European countries and recent methodological advances. An overview of methods used for monitoring large carnivores of Europe assembled by Linnell et al. (1998) included much valuable information about the theoretical background of methods for lynx monitoring for the time, but can now be complemented by more than two decades of practical experience of implementation of these methods in Scandinavia and elsewhere.

2. METHODOLOGY

To obtain the most recent and relevant information about existing lynx monitoring programmes, we established contact with experts from all countries within the lynx distribution in Europe (according to Kaczensky et al. 2013) via EuroLynx network or directly via personal contacts with lynx experts. EuroLynx provides a platform for networking, collaboration and data sharing of institutes and researchers who aim to investigate ecological aspects of Eurasian lynx (www.eurolynx.org). The main goal of the network is to produce knowledge and in particular to support a science-based sustainable management of environmental resources and conservation. Some members reported activities that have not been published yet (e.g. the lynx scat collection network), or provided the official monitoring reports in their national languages which would be difficult for us to find (e.g. Hurstel & Laurent 2019). For the countries from which we were not able to obtain information via the EuroLynx, we performed a thorough literature search and directly contacted the researchers or authorities involved in lynx monitoring or familiar with the monitoring program in the country. We asked them to direct us to the most recent publication available on the topic. If such publications were not available, we asked them to provide the basic information about the methods used based on their knowledge.

The chapters in this part of the report are organized according to the main field method used to collect data and structured to follow a course of data collection in the field, followed by obtaining population parameters of interest through appropriate analysis. Some of the chapters are partly overlapping, especially with the genetic sampling (chapter 3.7). We decided to keep the genetic sampling as a separate chapter because it involves different invasive or non-invasive sources of data, which can be collected with several of the field methods described earlier (hair trapping, snow tracking, opportunistic data collection, telemetry and mortality records), but these methods can be used also on their own without the inclusion of analysis of genetic samples. At the same time, there are certain specifics associated with genetic monitoring.

Each chapter provides an overview of the given method, including a general description, the aim and objectives (i.e. what the collected data is used for), the spatial and temporal details of the implementation of the method in various countries/regions/protected areas, with the information about responsible institutions and the available information about the required resources. Furthermore, the means of data processing are explained in each chapter, including information about data storage, data sharing and computing. The analytical approaches (the statistical analysis or other methods of calculating the population parameters of interest) are highlighted as they are an important indicator of the quality of the estimates obtained for a certain lynx population or its part (Gimenez et al. 2019) and since important part of the recent development of methodology for lynx monitoring deals with this aspect. Special focus is given to identifying the benefits and drawbacks of all methodological aspects considered.

Finally, a SWOT analysis was performed for each method and results are presented in a table at the end of each chapter, presenting the strengths, weaknesses, opportunities and threats of the given method. The SWOT analysis is a common approach used in business marketing and management, which allows compiling the favourable and unfavourable internal and external issues regarding the topic in question in an organized, easy to grasp, chart (Helms & Nixon 2010). This approach can help realize how internal strengths of an organization, or a program, can create new opportunities and how weaknesses can slow its progress. SWOT has been recently gaining attention also among wildlife managers and practitioners for evaluation of practices connected to management of protected areas, conservation policies and human-wildlife conflicts (Battisti & Amori 2016).

3. RESULTS

In total, we received 37 responses from the lynx experts providing information for lynx monitoring in 23 countries. With their help and our own search we collected and reviewed 125 publications, including peer-reviewed scientific articles, doctoral dissertations, master theses, conference proceedings, reports, action plans and various publications from the grey literature. We were also provided with or found 12 online sources for additional information on the implementation of lynx monitoring in some of the countries.

3.1 COLLECTION OF OPPORTUNISTIC RECORDS

Collecting opportunistic records (also referred to as 'chance records'; Breitenmoser et al. 2006) is an easy way of collecting data from the field, but a difficult element to interpret and integrate in detailed management or conservation schemes. Opportunistic records include direct lynx sightings, finds of dead lynx, hearing of lynx calls, coincidental photos and videos recorded by people or camera traps (set for other purposes), and various signs of lynx presence (tracks in snow, mud or sand, prey remains including killed livestock, resting sites, hair, scratch marks, faeces and urine). Opportunistic records are not collected in a systematic way targeting detection of lynx presence, e.g. via predetermined snow-tracking transects or grid of camera traps. Moreover, even though the type of data collected can be reliable (e.g. geo-tagged photos) or verified (e.g. re-visiting and inspecting a potential lynx kill) its reporting is still dependent on the (random) observer, who is not necessarily a member of a trained monitoring network. For example, a photo of lynx from a hunter's personal camera trap will be considered an opportunistic record, while a photo of a lynx from a grid of camera traps set up specifically to monitor lynx population will be considered a systematic record. Therefore the opportunistic records are by definition biased and can give an imperfect picture of species distribution. Often we also do not have available information on the effort invested in the field collection of this data, nor the proportion of recorded data that is reported to the authorities.

The effort of collecting opportunistic data may change considerably in time, depending on the motivation and information provided to the public, or the network members. Nevertheless, opportunistic records are often the first data to emerge about the species presence in an area and represent an important indication where systematic surveys should be conducted (Breitenmoser et al., 2006). When no systematically-collected data are available (e.g. due to lack of funding), opportunistic records can provide at least a rough impression on the distribution of species and in some cases about its relative abundance.

Figure 1: Coincidental finds of lynx prey remains represent important part of lynx opportunistic records reported by hunters (Photo: Lan Hočevar)

Hunters, game wardens, foresters and lynx experts often represent the majority of people reporting opportunistic data about lynx. Continuous training of the network members increases the quality of collected data (Müller et al. 2014). Students can provide an additional manpower and for example provided an important input during a Polish national survey of large carnivores (Jedrzejewski et al. 2002). In Germany, the Bavarian Environment Agency (LfU) collects all opportunistic data about lynx presence since 2004 and has established a "Large Carnivore network" of trained volunteers (hunters, foresters, naturalists, biologists). In some countries, data is also provided at online database to tje general public, e.g. in Czech Republic (*http://biolog.nature.cz/cz/Maps#1),* Switzerland (*http://www.kora.ch, http://www.luchsprojekt.de*), Slovenia and Croatia (https://www.lifelynx.eu), and several central European lynx populations (www.interreg-central.eu/Content.Node/3Lynx.html).

Since opportunistically-collected data have different level of reliability and verifiability about species identification, depending on the type of data, person recording it and material proof available, it is important to develop categorization that reflects this reliability and can be later used in the interpretation of the collected data. An important step forward in handling opportunistic data was the establishment of 'SCALP' criteria for categorization of lynx data (SCALP stands for the Status and Conservation of the Alpine Lynx Population; Molinari-Jobin et al. 2003). The goal of the SCALP project founded by KORA (Swiss Carnivore Ecology and Wildlife Management) is to bring together lynx experts across the Alpine arch and connect the main lynx populations in the Alps following the Pan-

Alpine conservation strategy. All Alpine countries (France, Switzerland, Germany, Liechtenstein, Italy, Austria, Slovenia) adopted this categorization and used it to monitor the development of lynx populations. In the recent years, the SCALP criteria are also being adopted by the non-Alpine countries (e.g. Northern Macedonia, Czech Republic, Germany, Slovakia) and for other carnivore species (e.g. golden jackal, *Canis aureus*). The data is collected at the national centres (such as environmental agencies or wildlife management services), which are also in charge of reporting the status of lynx to the European Commission under the Habitats Directive Article 17 (Molinari-Jobin et al., 2017). Data categorized according to the SCALP criteria are annually reported by each country to the KORA, where data are processed at the transnational level on 10x10 km grid and reported in annual reports. In the last years, the reports include in addition to the Alpine region also the neighbouring (sub)populations in the Jura and Dinaric Mountains. Note that in addition to opportunistically-collected data, SCALP reports also include the growing amount of systematically-collected data obtained by camera trapping, telemetry, snow tracking, hair trapping and genetic sampling (Molinari-Jobin & Fuxjäger 2015).

The SCALP categorization classifies lynx records according to their reliability and verifiability into three categories: category C1 – hard facts with material evidence, such as lynx carcass, live-captured lynx, photographs or video recordings of lynx, and all invasive and non-invasive genetic samples confirmed to belong to lynx; category C2 – records of lynx presence (e.g. direct observations, killed livestock, wild prey remains, tracks and scats) recorded or verified by trained individuals or lynx experts; and category C3 – non-verifiable records reported by the general public (Molinari-Jobin et al. 2003, 2012, 2017).

Standardized categorization of opportunistically-collected data allows comparability of data collected in various countries and provides a measure of quality for population parameters extracted, which can assist in interpretation of results. The largest potential of opportunistically-collected data lies in large-scale assessments (O'Connell et al. 2011), for example of distribution of lynx presence and reproduction (reproduction is determined based on records of lynx kittens). Such data can be used to study distribution dynamics over longer time frames at national (e.g. Stahl & Vandel 1998, Wolfl & Kaczensky 2001, Kos et al. 2012) or international scale (Molinari-Jobin et al. 2017). Moreover, by comparing the different proportions of verified (C1 and C2) vs. unverified (C3) records over time, we can detect improvements in the monitoring and identify the potential sources of error. For example, site-occupancy modelling revealed a higher probability of false positive records in the data (Molinari-Jobin et al. 2012). Nevertheless, it has been shown that even the least reliable data (C3) can improve the accuracy of determining lynx distribution, if included in the dynamic occupancy models that account for misidentification (Louvrier et al. 2019). The categorization is also a useful way to critically assess the collected data and find drawbacks of an existing monitoring network. Besides, it can provide important basis to design the systematic monitoring.

<table>
<tr><td>Strengths
- Can be collected over a large geographical range with relatively small effort
- Is an easy way to obtain the first reliable data about lynx presence and reproduction in a certain area to guide further systematic monitoring efforts
- If classified in SCALP categories, it is possible to account for difference in reliability of the records
- Allows comparability of collected data between countries
- Is inexpensive so it enables data collection even in situations where scarce resources are available</td><td>Weaknesses
- Provides poor quality data with high potential for biases
- Limited use to assess population parameters other than presence/distribution of lynx or reproduction
- Effort of data collection cannot be controlled and is difficult to evaluate
- Experts need to be strictly harmonized in evaluating C2/C3 records</td></tr>
<tr><td>Opportunities
- Can be used for long-term analysis of lynx distribution dynamics
- Categorization, data sharing and reporting, as is currently done for Alpine countries, could be expanded to other countries and species
- New analytical approaches may improve the usefulness of the opportunistically-recorded data categorized by SCALP criteria</td><td>Threats
- High potential for bias can lead to erroneous conclusions (including overestimation of lynx population) if not carefully interpreted</td></tr>
</table>

3.2 QUESTIONNAIRES

Questionnaires are another relatively simple and inexpensive method to obtain data about a species presence, but have advantage over opportunistically-collected data that they can be performed in a systematic way (an example of such questionnaire is presented in Appendix 1). Questionnaires can be distributed to a general public or to selected group of people that are expected to have better knowledge about the species and its local occurrence (e.g. game wardens or hunters). They can also be conducted in specific temporal and spatial frames. Although the results of questionnaires do not give objective information about the status of lynx, we can assume we are dealing with a consistent error if the target group has the same bias, or professional background. Moreover, if the network of surveyed participants remains unchanged over the course of the years (e.g. game wardens or park rangers), the results will allow a relative assessment of changes in lynx presence in space and time (Breitenmoser et al. 2006). Questionnaires are also the main tool to assess people’s attitudes towards lynx, or gather other human-dimension data. However, for the purpose of this report, we focus only to questionnaires that are at least partly focused on obtaining data about lynx presence.

In Switzerland, an annual inquiry among the game wardens by means of questionnaires has been established in 1993 (Capt et al. 1998) and is still ongoing as a part of a regular monitoring scheme (https://www.kora.ch). The questionnaires are sent once a year in a constant grid, with the rangers' districts acting as grid cells (Breitenmoser et al. 2006). The questionnaires are the main method to monitor the distribution of lynx and they complement the opportunistic records, especially since they allow differentiating between missing data and lynx absence. The questions ask about signs of lynx presence and reproduction (i.e. presence of kittens), as well as the population trends in the relevant region over the past year. The results from the questionnaires are projected on a map (e.g. https://www.kora.ch/index.php?id=83&L=1). To maintain the motivation of the members of the network, Breitenmoser et al. (2006) recommend regular feedback to participants via simple publication. In Switzerland, this has been done within annual KORA reports and newsletters, publicly available at (https://www.kora.ch).

Questionnaires were one of the first methods to be used for assessing the status and distribution of the Balkan lynx (*Lynx lynx balcanicus*) (Melovski et al. 2012, 2018). Up to eight people of various professional backgrounds (e.g. hunters, foresters, livestock breeders, beekeepers, farmers) were interviewed in each of the 207 grid cells (10 × 10 km) in the potential species range in Albania, Kosovo, North Macedonia and Montenegro. The questionnaire compiled of 55 questions including questions about lynx presence, site use and human-lynx interactions, such as the level of poaching. Probabilities of site use by lynx were shown on an occupancy map in three categories (low, medium, high), considering differences in level of knowledge of survey participants and detection probability due to specific environmental characteristics. Although estimates of number of resident lynx were reported in earlier studies (Grubač 2002), the latest interpretation of questionnaires were not used for this purpose anymore due to difficulties of obtaining reliable density estimates, but rather limited themselves to identifying lynx distribution and important areas for conservation, including a map of potential poaching areas (Melovski et al. 2018).

In Czech Republic, questionnaires have been regularly (every two years; Kaczensky et al. 2013) sent to hunting grounds and regional authorities for assessing lynx occurrence in State Nature Protection between 1993 and early 2000s. A standard mapping grid (11.2 × 12 km grid cells) was used to report the results of questionnaires and the lynx occurrence at national level. The amount of grid cells with reported lynx presence was counted and used as a measure of lynx distribution and estimate population size (Ćervený et al. 2001, 2002). Lynx occurrence was shown on a distribution map with three categories (no lynx, transient occurrence and permanent presence). Use of this data to estimate population size must, however, be interpreted with caution, or rather be used only as a measure of population trend (Ćervený et al. 2002).

Simple questionnaires were sent to local Forestry Administrations in Bulgaria (Spassov et al. 2006) to gain basic information about possible lynx presence and are still in use today as complementary to other methods (see Table 1). They are distributed within a grid of randomly selected 10 × 10 km cells and kept constant over the years (NATURA Bulgaria 2014). Interviews with locals were also held between 1980-2000 to gain records about lynx presence in Serbia (Grubač 2000, 2002) and personal interviews with representatives of hunting organizations and forestry companies (n=51) were held in Bosnia and Herzegovina (BiH) in 2017 to gain a first insight about the lynx presence in the country and estimate potential population size (Trbojević 2019).

In Hungary, systematic questionnaire surveys were used to inquire data about lynx from each game management units since 1987 (since 1997 using a unified survey). Data was considered to be of limited reliability, therefore field investigations were initiated to assess the information about lynx provided by questionnaires, peaking in intensity during a LIFE project on large carnivores (LIFE00 NAT/H/007162) (Miklos 2002). In Poland, questionnaires were sent to 431 forest districts and 17 national parks to obtain information about lynx presence (Jedrzejewski et al. 2002). Because response rate was low, it was important to supplement it with other data sources (opportunistically-collected data and systematic snow tracking). In Lithuania, questionnaires represented the only means of data collection between 2014 and 2017 because the conditions did not allow the official snow-tracking survey to be performed. The questionnaires targeted the major stakeholders (hunters, naturalists, biologists, etc.) to report opportunistic observations of lynx (and other large carnivores) with enclosed evidence. Advertising the survey on national media channels notably increased the number of responses to the questionnaires. All reports were verified by experts and the respondents were asked for additional explanation, if necessary. Changes in lynx group size (number of lynx reported per record) were the main population parameter extracted from the reports (Balciauskas et al. 2017).

Collecting data about lynx presence via questionnaires was also the first method to be used after reintroduction of lynx to Slovenia with a goal to monitor the progress of the population growth (Čop 1990; see also Appendix 1). The questionnaires were distributed to hunting areas every year and returned to the coordinating institution (Slovenia Forest Service) directly or via Hunting Association Slovenia (Staniša et al. 2001, Koren et al. 2006). At first, the data was collected at the level of hunting grounds, but since 1996 all data are recorded with geographic coordinates. The use of questionnaires is still in use with a purpose of detecting changes in lynx occurrence during the program of population reinforcement (LIFE Lynx, www.lifelynx.eu) and to identify new areas where systematic monitoring needs to be applied. Similar approach has been used in Croatia, where one-on-one interviews were conducted with local hunters, which brings an additional benefit of establishing collaboration with local stakeholders (Slijepčević et al. 2019).

<u>Effort and costs:</u>

Questionnaires are a method requiring relatively low cost and time investment. For example, distribution and evaluation of about 300 questionnaires needs a month of work of one person (Breitenmoser et al., 2006). The main investment is work by the coordinating institution that sends and collects the questionnaires, analyse the answers and prepare reports. As with opportunistic data collection, effort from the coordinator(s) is needed also in promoting the questionnaires, or maintaining responsive network of participants.

Strengths	**Weaknesses**
- Low cost and effort - Can provide an indication about lynx presence and distribution, sometimes even population trends - Enables differentiation between “missing data” and “lynx absence” records - Can help determining priority areas for other monitoring methods	- Information provided cannot be verified, causing risk of low reliability - Response rate can be low or decrease over years if network members are not motivated

Opportunities	Threats
- Can provide additional important info about the attitudes towards and lynx human-lynx interactions, including poaching - Can be complemented with verifiable records (e.g. photos) - The response rate can increase if the questionnaire is kept short and simple and if regular feedback to participants is provided - It can help establish a good relationship with the respondents for other work	- Dishonest answers may be obtained - Results are sometimes not trusted, e.g. if the surveyed public are hunters - Results may be oversimplified and used for unreliably estimating abundance of lynx

3.3 CAMERA TRAPPING

Camera trapping is nowadays one of the most important and widely used methods for lynx monitoring, as well as other feline species with spotted pelage. The records obtained with camera traps are objective and verifiable evidence of lynx presence, as well as a source of individually recognizable coat patterns. Lynx coat can have large spots, small spots, rosettes, or no spots and there are considerable differences in the frequency of these types of pelage among different populations. Because the pattern can be unidentifiable in some (unspotted) individuals, this can represent a major drawback for this method. For populations where this coat pattern prevails, other methods might be more suitable for monitoring, e.g. hair trapping in Poland (Schmidt & Kowalczyk 2006) or snow tracking in Scandinavia (Linnell et al. 2007a).

Where individual recognition is possible and camera trapping is done intensively, data can enable capture-mark-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 emigration/immigration, reproduction, kitten survival, dispersal, minimum life span and minimum home range size (Rovero & Zimmermann 2016). Besides, camera-trapping data when set at specific locations (e.g. marking sites or kill sites with fresh prey remains) can also provide a range of information about the behavioural ecology of lynx, such as marking behaviour (Vogt et al. 2014), feeding behaviour or interactions with other species (Krofel et al. 2019, Soyumert 2020).

The design of camera-trapping monitoring programs varies from simple field design of setting up cameras at specific locations with the aim to confirm lynx presence in certain area, like in Bulgaria (Zlatanova et al. 2009, Spassov et al. 2015), to population-level long-term systematic studies using large camera-trapping grid and advanced analytical approaches for obtaining high precision population parameters, like in France (Gimenez et al. 2019). It has been suggested that with proper design, camera-trapping represents the best balance of rigor and cost-effectiveness for estimating abundance and density of cryptic species that can be identified individually (Balme et al. 2010). This approach has so far also produced the most reliable density estimates for lynx in Europe (see Table 2).

The essence of this method is deploying remotely-triggered cameras, usually based on movement- or heat-detection sensor, which automatically record pictures and/or videos of animals passing in front of them. Most suitable camera traps for lynx monitoring have fast trigger, large detection zone, lowest possible latency, time lapse function and controlled flash intensity. Technological development of novel camera models is ongoing and very fast

(Rovero & Zimmermann 2016), often to the level that by the time peer-reviewed publications are published the knowledge is already outdated. In one of such studies involving laboratory and field tests the Cuddeback Capture camera-trap model was assessed to be the most suitable for CMR studies for lynx (Weingarth et al. 2013). The model most commonly reported to be used in actual monitoring programs in the recent years was the CuddeBack X-Change™ Color Model 1279 with white flash, which was successfully used in Switzerland (Zimmermann et al. 2013a, Pesenti & Zimmermann 2013), Germany (Weingarth et al. 2015, Middelhoff & Anders 2018), Slovakia (Kubala et al. 2017) and Slovenia and Croatia (Fležar et al. 2019). Camera trap models with black IR (e.g. CuddeBack X-Change™ Color Model 1213) work well for recording lynx from close distance (e.g. at marking sites or kill sites) and can be favourable for recording videos of specific behaviours (e.g. scent marking and feeding behaviour) because they are completely invisible for the animals and therefore do not interfere with their normal behaviour. Also note that recording videos at marking sites can be very useful for monitoring purposes, since it often enables to obtain coat pattern from both sides of the animal (Stergar & Slijepčević 2017). However, models with black IR are less useful for recording animals from greater distance (e.g. 5 m) or when moving (e.g. on trails or roads), as this results in blurring of the image, which reduces opportunity to recognize individual's coat pattern.

Figure 2: Camera trap (CuddeBack X-Change) deployed on the ridge frequently used by lynx in Slovenia (photo: Lan Hočevar)

Success of camera trapping often depends on choosing appropriate locations to set camera traps. When initializing camera-trapping surveys, this is often based on local knowledge and previous opportunistic records. Long-term monitoring programs can benefit from experiences in previous surveys and in time enable development of highly effective network of camera-trapping sites. There are several factors that determine probability of obtaining lynx footage. Landscape and terrain features which are likely to channel lynx movements to the more predictable paths should be prioritized. These features may differ between different geographical areas, e.g. high mountains or lowland forests, so specific local experience is required to find the optimal locations. Best results are often reported from rocky ridges, narrow valleys, trails on steep slopes, forest trails and forest roads in dense vegetation. Lynx scent-marking sites often represent the best locations, since they attract lynx to regularly visit them to renew the scent marks. In addition, lynx often stops at such locations and turns around, which enables to obtain high quality recordings from all sides of the body. Marking sites are often conspicuous objects, such as tree stumps or large rocks, (Allen et al. 2017) as well anthropogenic structures, such as forest cabins and edges of forest roads (Krofel et al. 2017). Additional opportunity to obtain lynx recordings are fresh prey remains, as lynx typically return to their kill sites for several days (Krofel et al. 2013).

Cameras should be set at suitable height in respect to lynx body size (approximately 40-50 cm above ground) and at appropriate distance (ideally 3-5 meters) to capture the entire animal and obtain clear image of the coat pattern. Important aspect to consider is the expected speed of the lynx (faster on trails and slower at marking or kill sites), which should dictate the type of illumination used (i.e. white flash, red IR or black IR in that order from faster to slower expected movements). If two cameras can be set per location, which is favourable in order to obtain images from both sides of the body, they should not be directed toward each other in order to not blind themselves. Cameras can be protected in robust housing to avoid damage caused by wildlife (e.g. bears) or humans, and locked if set up at locations with higher risk of theft. Locations frequented by humans (e.g. popular hiking trails and hilltops, roads or mountain huts) should be avoided in regions where risk of stealing is higher. Cameras should also be regularly checked and data extracted (SD cards and batteries replaced, if needed) and cleared of snow if set up during the winter. Further and more detailed recommendations on how to set up camera traps for lynx monitoring are available in several guidelines developed for some parts of Europe (Breitenmoser et al. 2006, Rovero et al. 2013, Stergar & Slijepčević 2017).

Besides technological advances in the equipment, camera trapping is developing also in the statistical approach used (TEAM Network et al. 2014, Rovero & Zimmermann 2016, Wearn & Glover-kapfer 2017). Earlier capture-recapture (CR) models (Karanth & Nichols 1998) were replaced by spatial capture-recapture (SCR; also known as spatially-explicit capture-recapture) in the early 2010s (Royle et al. 2014). Both models are suitable for estimating population densities and abundance of a species where individuals can be recognized. CR models account for the fact that not all animals in the study area are observed, and therefore allow a relatively accurate estimation of population density or abundance. However, in CR models, the area sampled is necessary to consider, as the population estimates are given per area effectively sampled. Traditionally, this area was estimated based on a polygon encircling the camera trap locations with an added buffer, which reflects the assumed additional area used by the trapped animals. The study design requires careful spacing of the cameras and sufficient size of trapping grid. Due to this drawback, models can provide biased density estimates, especially in direction of overestimation in smaller sampling areas (Zimmermann et al. 2013b). CR should therefore be chosen only if study design can be effectively implemented on the field to remove all potential sources of bias, which is rarely the case in reality. SCR allows obtaining more accurate population density estimates for lynx without any advances, but rather simplifications in the technical field design (Zimmermann et al. 2013a, Blanc et al. 2013, Pesenti & Zimmermann 2013, Burgar et al. 2018). While CR models rely on multiple detections of an individual (encounter history) within a pre-defined arbitrarily-set sample area (e.g. in a grid of cells), SCR incorporates spatial organization of both individuals and the observation mechanism, i.e. distribution of camera traps (spatial encounter history). The SCR does not rely on geographic closure of the surveyed population because it models the probability of detection for each trap as a function of distance between individual activity centre (from which the animal moves randomly) and the camera trap (where the animal was captured). Therefore, the use of SCR goes beyond estimating population density and can be also used for studying individual movement, resource selection, space use and population dynamics (Royle et al. 2014). SCR is becoming a standard method to estimate lynx densities in Europe, as seen by increasing number of publications (e.g. Kubala et al. 2017, Gimenez et al. 2019), and the same trend is observed in monitoring of the Iberian lynx (Sarmento & Carrapato 2019). SCR models are now being developed also for camera-trapping data of partially-marked or unmarked animals and it will likely be possible in the near future to use them for estimating density of populations of lynx with no distinctive pattern (Gilbert et al. 2020). Framework for SCR models is provided in R package oSCR (Sutherland et al. 2019).

All methodological approaches require an organized database of recorded lynx and the camera trap performance. Using software for saving and analysing the camera-trapping data enable prompt and controlled data collection. There are several types of camera-trapping software available, with new features and upgrades or even completely new software being developed constantly (Scotson et al. 2017). For example, in lynx monitoign in Slovenia and Croatia a user-friendly program “Camelot” is used (Hendry & Mann 2017), which automatically exports organized data frames, but also performs some basic camera trapping statistics, which can be directly imported to other software for further statistical analyses (e.g. to build SCR models). Additional manpower is required for data import and trained contracted students proved to be a good trade-off in these countries. As every database, Camelot should be installed so that regular backups are created periodically. Storing data in camera-trapping software enables to backup both photos and their annotations simultaneously, as well as keeping the framework of the database unchanged. Within the EuroLynx network, attempts to harmonize and standardize camera-trapping data collection and analysis are focused on development of program “TRAPPER” (Bubnicki et al. 2016). Moreover, an automatized way to identify lynx on the photos is currently being developed within 3Lynx project. The only tool reported so far to be used in assisting manual identification of lynx is the “extract compare” software (Gimenez et al. 2019; http://conservationresearch.org.uk/index.html). Since identification of individuals can yield errors and lead to overestimation of population density estimates (Johansson et al. 2020), it is important to be cautious and if possible, cross-check the individuals identifies with multiple observers.

Camera trapping has been successfully used to monitor lynx in many parts of Europe (see Table 1 for an overview). The first county to implement it for assessing lynx population was Switzerland in 1998 (Breitenmoser-Würsten et al. 2001, Laass 2001). They used analogous cameras combined with motion detector as commercial camera-trap kits were not yet available. In the beginning, cameras were deployed over the entire year, but later the monitoring period was shortened to winter months (December – February), when females make larger movements with their kittens and before juveniles disperse (Zimmermann et al. 2013b). This period was preferred also due to lower human disturbance (Zimmermann & Foresti 2016). A grid of 2.7 × 2.7 km was suggested (Laass 1999), which later became a reference grid for other camera-trapping deigns (Weingarth et al. 2012, 2015), although not everywhere. For example, grid of 2.5 × 2.5 km is used in Slovakia (Kubala et al. 2017), 10 × 10 km in Czech Republic (Kutal et al. 2013), and 3 × 3 in Harz, Germany (Middelhoff & Anders 2018). For reliable density estimates, Weingarth et al. (2015) recommend to prolong the period from late summer to early winter and space cameras 2.5-3 km apart in smaller areas (~300 km^2) and 5-6 km in larger ones (~750 km^2). In Switzerland, systematic camera trapping is performed every two or three years in nine reference areas across the lynx range. Camera-trap pairs are installed according to a predefined grid and they operate for 60 days. Lynx population density is calculated with capture-recapture statistics (www.kora.ch). Being the country with the longest period of practical experience, Breitenmoser et al. (2006) provided useful guidelines and recommendations for camera trapping in terms of survey design, effort and analysis, which have been adopted by many other countries using camera trapping as the main method for lynx monitoring.

In France, camera trapping was initiated in 2011 and the density estimates were based on SCR models (Blanc et al. 2013, Gimenez et al. 2019). Following the design used to monitoring lynx populations in the adjacent Alpine countries, the French use a standard 2.7 × 2.7 km grid and place two cameras to every trapping site for 2 months in winter (Feb-Mar), ensuring that at least one site was chosen in each potential lynx home range. Systematic camera trapping is undertaken annually in reference areas in Vosges and Jura mountains (Hurstel & Laurent 2019).

In Italy, camera trapping has been performed in a non-systematic way by a non-governmental organization Progetto Lince Italia (PLI) in the southeastern part of the Alps since 1996, with 15-20 cameras maintained at the best known lynx locations throughout the year. PLI provides equipment (camera traps) to its network of collaborators, who also use some of their cameras (hunters, naturalists and foresters from the Regional Forest office and National Forest Service) and provide lynx recordings to PLI. The recordings of lynx are only used as a source of C1 data (see chapter 3.1) and reported in annual SCALP reports (Interreg CE 3Lynx 2018). In 2019/20, camera trapping intensified and expanded to southern Julian Alps, where lynx immigration from Slovenia is expected. At least two camera traps were set up in every grid cell where lynx presence had been reported in the past two years, resulting in total 15 grid cells covered in the region.

In Slovakia, the first camera trapping study was conducted in 2013/14 in Štiavnica Mountains Protected Landscape Area and Vel'ká Fatra national park (Kubala et al. 2017) and the second in 2015/16 in Muranska Planina national park (Smolko et al. 2018), both following the design of Weingarth et al. (2012) and Zimmermann et al. (2013b). Small scale camera trapping is also taking place in the neighbouring Hungary, in Aggtelek national Park (Bakó 2014), however no population parameters were reported from there yet (http://www.anp.hu/en/mozgalmas-ejszakak-az-aggteleki-nemzeti-parkban).

In Czech Republic, camera trapping has been used in both areas of lynx occurrence in the country: Šumava national park in Bohemian Forest since 2007, and in Beskydy Protected Landscape Area in the Western Carpathians since 2009 (Kutal et al. 2013). In Šumava, systematic camera trapping started in 2009 and the design was developed together with the adjacent protected area in Germany, the Bavarian Forest national park. The area surveyed was about 300 km^2 on Czech and 500 km^2 on German side. In 2013, all three countries sharing the Bohemian-Bavarian-Austrian (BBA) population (Germany, Czech Republic and Austria) started with a common monitoring at the total camera trapping grid area of 7,600 km^2 as part of Interreg project. In Austria, lynx is present also in the Kalkalpen national park since 1998, where year-long camera trapping is undertaken by the park administration (Fuxjäger et al. 2012), however the data is kept separate from the estimates of the BBA population. In the Kalkalpen, the important distinction is that camera-trap deployment require prior approval of the respective landowner(s) and informing the hunting permit holder(s) (Interreg CE 3Lynx 2018). The three countries collaborating in monitoring of the BBA lynx population have been the first to collect the data and report the lynx densities on a transnational level (Weingarth et al. 2015). However, issues with storing and sharing data, coordinating the monitoring and developing new tools for secure, time-efficient and reliable identification of collected lynx images are currently the biggest challenges for the implementation of a coordinated camera-trapping method. Some differences still exist among the involved organizations, such as distribution of camera traps (e.g. one pair in each 10 × 10 km grid cell vs. one pair of cameras in every second 2.7 × 2.7 km cell) and camera deployment period (part of a year vs. whole year) (Interreg CE 3Lynx 2018).

In addition to the Bavarian forest, Germany hosts another reintroduced and isolated population of lynx in the centre of the country, in Harz mountains, where systematic camera trapping was implemented since 2014. They use a 5 × 5 km grid, with 2 cameras per grid cell, covering a reference area of 780 km^2. CR models are used to calculate lynx densities, however, the estimates have to be interpreted with caution because telemetry data showed that some lynx have most of their territories outside the reference area. In Harz, they have a high recapture rate with 8.17 photo events per lynx, which is exceptional due to intensive monitoring of reintroduced individuals from reintroduction onwards (Middelhoff & Anders 2018).

In Croatia and Slovenia, which are sharing the northern part of Dinaric lynx population, first camera traps were set opportunistically within an Interreg DinaRis project in 2007. Camera trapping intensified in Croatia in 2011 in several parts of the country (Huber et al. 2013), but without centralized coordination and data collection. The photos were primarily used to obtain C1 data and for individual lynx identification (Sindičić et al. 2019). Further development and expansion of camera trapping, which included also neighbouring Slovenia, occurred in 2018 with systematic use of about 270 camera trapping sites per year over the transboundary lynx range of 12,600 km2 (Fležar et al. 2019). Further expansion in camera trapping is expected in the next years with translocations of lynx and creation of stepping stone population in the Slovenian Alps. Coordination and harmonization of monitoring between Slovenia and Croatia and obtaining population density estimates is a priority for this camera-trapping program. In the southern part of Dinaric population in Bosnia and Herzegovina, the monitoring of lynx status and distribution of lynx is still in initial phase, including first pilot camera-trapping surveys (Kunovac et al. 2018, Trbojević 2019).

Intensive camera trapping survey of the Balkan lynx took place in North Macedonia (Mavrovo national park with its surroundings) in 2008 and 2010. An area of 432 km^2 was monitored from February to April with 32 camera trapping locations and 2 cameras per location, distributed according to the 2.7 x 2.7 km grid. This confirmed park as the stronghold for the Balkan lynx, while in adjacent areas only sporadic lynx presence was detected (Melovski et al. 2009, 2012).

Initiatives to start implementing the method in an extensive, systematic manner have been taken also in Romania in 2018 (Gazzola et al. 2018) and in Latvia in 2020 (Ozoliņš et al. 2017), however no estimates from these countries were reported yet. Camera trapping is recently taking place also in Anatolian part of Turkey (Soyumert et al. 2019).

Camera trapping has been recognized as the most robust and cost-effective method for monitoring lynx in most of Europe, especially when estimating density is the goal. Importantly, camera trapping is gaining attention in countries where traditional methods for monitoring lynx have failed in recent years due to external factors (e.g. reduced opportunities for snow tracking due to climate warming). In Norway, a pilot study has shown that camera trapping can provide a useful supplement or replacement method to snow-monitoring of lynx family groups as well as allowing estimates of lynx densities with precision measure (Odden 2015). However, in northern populations, as well as in Poland, this method has still limited applicability for estimating densities due to difficulties in recognizing unspotted individuals, which are frequent in these populations. As noted above, newer analytical approaches might overcome this problem in the future.

Effort and cost:

Camera trapping is a costly method, but considering the data, which can be obtained from visual records of lynx, the overall evaluation of the method suggested to be cost-effective in many studies listed above. The highest investment is initial purchase and to a lesser extent the later maintenance of the equipment. Cameras, which have been recently most frequently used in lynx monitoring (CuddeBack models with white flash) cost around 200 USD per piece, excluding accessories (batteries and SD cards, as well as optional housings and locks). If possible, the cameras should be protected in case of theft or damage caused by wildlife. Cost for work and travel required for setting the cameras and retrieving the data can be reduced by involving volunteers, however, initial training has to be provided in order to avoid missing data or improper setup of camera traps. Any changes in the equipment (e.g. introduction of a new camera-trap model) need to be communicated and another training session for the collaborators should be encouraged by the monitoring coordinator. A good solution is collaboration with hunters, who are often already experienced with the use camera traps and familiar with terrain. It proved to be beneficial to provide them with basic funding, such as paying for travel expenses. Including them in monitoring programs can also reduce theft and sabotage, thus minimizing the costs for replacement of the equipment lost. The cost for coordination and motivation of the volunteers must be taken into account. The cost of camera-trapping data analysis depends on the quality of the estimates we aim to obtain and what personnel is involved in processing and analysis of the data (from student technical assistance to statisticians).

Strengths	**Weaknesses**
- Enables individual identification, if coat pattern is spotted or with rosettes - Detection history of an individual can be used to calculate population densities with high precision using SCR models (or CR models, with lower precision) - Does not need any special field equipment apart from the cameras and accessories - Cameras are easy to deploy on the field and can be operated by almost anyone - Small-scale camera trapping surveys can provide reliable confirmation about lynx presence in an area	- CR or SCR statistics are only useful for lynx populations with dominant spotted or rosette coat patterns - The equipment needs active maintenance and data retrieval - Collaboration with volunteers requires intensive coordination, some training, communication and centralized data storing and analysing - It is a relatively expensive method in terms of equipment required and effort (personnel needed) - Some camera models are not intuitive to use (simple models should be used if volunteers are deploying them) - When deployed in the field, cameras need to be regularly maintained and checked and the data extracted - When used over several years, camera traps are prone to failure, requiring frequent repair or replacement

Opportunities	Threats
- A good way to initiate collaboration with stakeholders (e.g. hunters) - Attractive method for volunteers, which can be used to substantially reduce costs - Provides a feasible alternative to other traditional methods, e.g. snow-tracking - Photos are an easy tool to communicate the science behind wildlife monitoring and give feedback to the collaborators - With no extra effort, valuable lynx behavioural data and data about non-target species are collected - Future development in SCR models could enable to calculate population densities also in populations with predominant unspotted lynx	- Cameras can be sabotaged or stolen - Cameras can be destroyed by wildlife (e.g. bears) - Logging or environmental factors (e.g. windstorms or bark beetle outbreaks) can destroy a good location for a camera trap site for many years - Cameras can suddenly break and cause data loss - Collaborators have to be continuously motivated by providing them with timely feedback; if not, the quality of the collected data may decline - Population parameter estimated may be biased if errors are made during individual identification - Lack of coordinated and intensive sampling effort prevents estimating density and inferring trends - Long-term funding might be difficult to secure and many current monitoring efforts rely on short-term project funding

3.4 RECORDING LYNX MORTALITY

We categorized collection of mortality records as an opportunistic monitoring method, however, this type of data can be very important for monitoring of any population, as it provides an insight into crucial part of population dynamics, as well as into the potential threats. Although mortality records are usually characterized with small sample sizes (exception being some countries with intensive culling programs), data collected over longer period can indicate population trends, especially when combined with data from other monitoring methods. Besides, lynx carcass can be a source of several parameters and samples, which provide information on health status of the population, main mortality causes, demographic structure of the population and genetic status (Breitenmoser et al. 2006). For example, dead lynx provide source of information for morphometric studies (Marti & Ryser-Degiorgis 2018), coat patterns (Thüler 2002) and teeth condition, which is the basis for age estimation (Marti & Ryser-Degiorgis 2018). Understanding the main causes of lynx mortality also gives a crucial insight into population dynamics and evolutionary processes acting upon them (Bischof et al. 2009, Nilsen et al. 2012, Sindičić et al. 2016). Nevertheless, caution is needed, as these records can be biased (e.g. age groups can differ considerably in survival probability and detection of mortality can depend strongly on the cause of death, especially when not used in combination with telemetry). As mentioned in chapter on opportunistic records, mortality records are also important source of C1 category records (Molinari-Jobin et al. 2003), although this is losing importance in the recent years with increase in the use of camera trapping and collection of non-invasive genetic samples.

Lynx mortality records can be collected from hunting or from opportunistically found dead lynx. In many countries, where hunting is/was performed, protocols are established for systematic collecting of certain measurements and samples from the carcass. In some countries, especially where populations were regularly hunted, mortality records can serve as the main monitoring method (Bagrade et al. 2016), which was also the case for most other countries in the past, including monitoring the expansion of the first reintroduced populations, like in Slovenia (Čop 1987). For many game species, hunting quotas are prescribed in respect sex and age structure, but that is usually not the case with lynx. One of the reasons is that it is very difficult to estimate sex and age during hunting (exception being females with kittens). In Norway, where there hunting quotas are not specified by age or sex, harvest mortality of lynx is male-biased and mortality increases with age among males, but not among females (Nilsen et al. 2012). The only limitation that is specified is the maximum number of adult females (Linnell et al. 2010).

In Latvia, collecting mortality records is the main monitoring method for population size estimation and range distribution (Bagrade et al. 2016). Lynx hunting season is open from 1st of December to 31st of March or until fulfilment of the quota within the hunting season. Every shot lynx must be reported and information about date, location, sex and estimated age must be delivered on the next day working day (Bagrade et al. 2016). 40 – 50 % of shot lynx are further analysed in lab to determine exact age and female fecundity (Interreg CE 3Lynx 2018). Virtual population analysis method developed by Fry (1957) is used to back-calculate the cohort sizes and estimate population size. This method assumes constant survival and hunting as the main reason of mortality. Based on the results, cull is planned for the next years and population dynamics are analysed.

Figure 3: In some countries where populations are regularly hunted, like Latvia, hunting records serve as the main monitoring method (Photo: Miha Krofel)

In areas with no hunting, collection of the mortality data is mostly opportunistic, but nevertheless forms a part of the monitoring system in many countries (e.g. Croatia; Sindičić et al. 2016). When lynx carcass is found, several institutions wildlife and forestry services, police, hunters, veterinarian need to be involved. Breitenmoser et al. (2006) provided guidelines on how to proceed with collection of carcass. Each case should be documented with pictures, notes and morphometric measurements. For pathological research, it is necessary for fresh carcasses to be cooled and transported to pathological institute. For genetic analyses blood or soft tissue must be stored in alcohol.

Effort and costs:

Effort can vary between years as it is dependent on number of culled or found dead lynx. Also organization effort of specialized institutions like pathological, veterinarian institutions and zoological museums should be considered. For detailed analyses (e.g. pathological examinations) effort and costs can be considerable and may require specialized laboratory equipment (Breitenmoser et al. 2006).

Strengths	Weaknesses
- Provide hard evidence for lynx presence - Provide important data on population structure and unique insights into the health status of the population - Provide mortality factors of the lynx, which indicate major threats to the population	- Sometimes mortality records are hard to interpret, as high mortality can be connected with increasing population or increased threats (and therefore decreasing of population) - Sample sizes can be too low to be relevant in small populations - Usually provide useful data only over longer time period - Many specialized institutions must be involved in the process to obtain several data types - Some of the analyses can be connected with high costs and expensive laboratory equipment might be required
Opportunities	**Threats**
- Can be used to obtain samples for genetic analyses, body condition, health status, biometrics, and morphology - Can be used for identifying pathological threats - Can provide an understanding of the impact of hunting on population	- Population estimates using only dead lynx data may be misleading - If relying only on mortality records, results might become available too late to prevent population decline

3.5 SNOW TRACKING

Snow tracking was one of the first methods to be used for lynx monitoring and has been used in various forms across Europe, especially in northern latitudes. Lynx track found by experienced tracker provides information about the presence of the species (C2 category according to SCALP categorization). When done systematically or in combination with other methods, it can provide semi-quantitative information about the lynx population (Ryser et al. 2005). Snow tracking can be also used for collecting non-invasive genetic samples, such as lynx scats, urine and hairs. In addition, snow tracks can provide information about the lynx behaviour and habitat use (Haglund 1966). Thus it can help in finding suitable locations for camera-trapping monitoring or specific sites that can be used to study lynx behavioural ecology, such as marking sites, resting sites and kill sites.

In several countries snow tracking was or still is the main method of systematic monitoring aimed to estimate population size, for example in Scandinavia, Finland, Russia, Baltic countries, and north-western parts of Poland (Breitenmoser et al. 2006). Snow tracking monitoring for estimating population size is limited to areas with stable snow conditions. Waiting for tracks to accumulate in two to three days after the fresh snowfall increases the chances of finding tracks. But waiting for too long can cause confusion due to tracks of other animals, which can overrun older lynx tracks. However, ideal conditions are usually very rare, especially in countries with warmer climate or less stable weather conditions, like large part of Central Europe. Therefore, in these areas snow tracking is often performed only opportunistically or in combination with other monitoring methods.

Transects for searching for lynx tracks could be random or predefined. The latter option is usually preferred as transects can be set in the areas where chances are higher to encounter lynx tracks, like ridges, trails or natural corridors known to be frequented by this species. In Scandinavia, transects are typically located along the valleys or in steeper areas where lynx are resting during the day time (Linnell et al. 2007a). In Dinaric mountains, lynx often use forest roads and forest cabins for scent-marking (Krofel et al. 2017), so checking these locations often leads to good results. Besides, searching for lynx tracks along forest roads enables person to cover more ground, especially when snow is shallow enough to allow looking for tracks while slowly driving with car. Snow mobiles can be used in similar way in deeper snow.

Figure 4: Lynx track in the snow (photo: Miha Krofel)

When lynx track is found, the location, number and direction of tracks are recorded. Then the track is usually followed, for which a minimal distance of 3 km of tracking is recommended. It is also recommended to record entire track with a GPS device. This can help with interpretation of data to avoid double-counting of the tracks made by the same animal. Even more reliable way to avoid this is to collect non-invasive samples and use genetic analysis to identify individual that was tracked.

Best period for snow tracking is in the mating season, between February and April, when lynx increase their movements (Breitenmoser et al. 2006). However, in this period it can be difficult to separate between females with kittens and mating pairs of adults. This is the reason why all the systematic monitoring using snow-tracking method with counting family groups of lynx in Scandinavia starts in December and ends before the mating season in February.

In Slovenia, snow-tracking is conducted primarily with the aim to collect non-invasive genetic samples. After fresh snow, experienced researchers and trained volunteers use forest roads in known lynx territories to search for lynx tracks, either walking (in case of deep snow) or driving. Once a track is found, it is followed on foot and recorded in GPS. Usually the track is followed until at least 2-3 samples of lynx urine, scat or hair are collected. The aim is to every year obtain genetic samples from each occupied lynx territory with favourable snow conditions. At the same time, snow tracking is used to study lynx behaviour and ecology, e.g. sent marking and interspecific interactions (Krofel & Kos 2006, Krofel et al. 2017).

In Scandinavia, Poland, and Finland, where snow tracking is used for estimating lynx population size, two different approaches are used: counting reproduction units and one day snow-tracking censuses.

<u>Family group counts</u> is a method used for counting the minimal number of females with kittens in northern Sweden and Norway (Andrén et al. 2002). This method has been used since 1995, starting in Norway. As noted above, observations of lynx family groups are made before the mating season to avoid confusion with mating pairs. All the observations of animals, tracks or other signs of lynx presence are reported to the Norwegian Nature Inspectorate, which sends authorized personnel to the field to investigate the evidence. The personnel of the Norwegian Nature Inspectorate also determine whether the tracks originate from a family group of lynx or not. Based on all confirmed observations, both documented and verified, the minimum number of family groups in Norway and Sweden is calculated, before the hunting seasons begins in February. The calculations are based on distance rules that are used to separate family groups from one another.

Once the data are collected, a standardized set of distance rules are applied to observations. There are two rules, static and dynamic distance rule, which are based on maximal home range size and maximal distances travelled by lynx in known time periods (Linnell et al. 2007b). According to the static distance rule, two tracks are treated as different animals, when they are recorded at a distance greater than the maximum home-range length (from data obtained through telemetry). This is based on the fact that females are very territorial and have small territory overlap among them. Dynamic distance rule is a method to separate observations made within the same week. Again, telemetry was used to determine the distances over which lynx move in single night. Because of the variation in home-range size and movement distances in different parts of Scandinavia, different distances are used for different regions (i.e. maximum home-range lengths varied from 28 to 54 km, and average maximum daily distances varied from eight to 16 km; Linnell et al. 2007b). The minimum count of family groups can then be extrapolated to estimate the total population size based on factors developed from survival and reproductive rates of radio-collared lynx (Andrén et al. 2002, 2006). Different extrapolation factors have been developed for the different regions that take into account regional differences in demographic parameters and main prey type (Linnell et al. 2007b).

The second method used is referred to as <u>one day censuses of lynx snow tracking.</u> This is used in central and southern Sweden, some smaller parts of Norway, north east Poland, and across Finland. It is also used annually in the Bavarian Forest national park in Germany. In Scandinavia, hundreds of volunteers (mostly hunters) search for lynx tracks simultaneously, one or two days after the fresh snowfall. They try to distinguish among tracks by backtracking until the track meets up with another track or they arrive to a daybed. Since the goal is to count the total number of animals, large number of people is required for this method, which thus relies on the help by volunteers. In some areas, this census is focused only on family groups (Andrén et al. 2002). Linnell et al. (2007a) showed that for this methods using pre-defined transects is more efficient than random transects. In Poland, snow tracking surveys are conducted in the first half of the winter by employees of the state forests and national park services. The surveys are organized by the Mammal Research Institute, once or twice per season, 12 hours after the fresh snowfall, across all forest inspectorates. Transects usually start in areas where frequency of lynx movement is highest, based on previous year-round observations (Interreg CE 3Lynx 2018).

<u>Effort and costs:</u>

Snow tracking is a time-consuming method and requires considerable manpower, especially for one day snow-tracking censuses. Also organization effort should not be overlooked. Effort depends on the length and number of transects and how many times per winter they are performed. Effort can vary considerably among regions due to variable field conditions, man power and area size. In countries that perform simultaneous snow-tracking surveys like in Scandinavia, many people need to be involved to cover large areas in a very short time window. On the other hand, in countries that have small areas to survey, manpower and personnel cost is usually not the limitation. One of the important factors is also terrain accessibility, including forest road network density, which can help covering larger areas in shorter time. The method is more suitable for areas with reliable and long period of favourable snow conditions, like Scandinavia.

Snow-tracking methods can be relatively cheap when volunteers are involved. No special equipment is needed except for winter field equipment, cars and (optional) GPS devices. While looking for lynx tracks, collecting data for other wildlife species is also possible and this is regularly done for example in Slovenia and Scandinavia, where genetic samples of wolves and wolverines are also collected at the same time (Linnell et al. 2007a).

Strengths	Weaknesses
- Relatively accurate monitoring method to determine minimal population size or number of breeding females - If monitoring is systematic and on a large scale with high manpower, results can be achieved in a short time - Relatively low cost if involving volunteers	- Good snow conditions required over entire survey area - High manpower and organization effort - Gathered data is limited for only specific part of the season - Global worming may reduce snow cover and thus opportunities in the future
Opportunities - Provides possibility to find good locations for setting camera traps. - Provides opportunities to find fresh kill sites, scent-marking sites, and to collect genetic sample material like urine, scats and hair. - Enables collection of data on other wildlife species and their interspecific interactions with lynx. - Allows stakeholders to be included in the fieldwork. - Snow tracking is a good way to educate people about lynx and other wildlife. - Provides information about lynx behaviour and ecology that is difficult to obtain otherwise.	**Threats** - Less experienced trackers can misidentify the species. - Interpretation of data can be challenging and double-counting of animals can occur. - It can be dangerous, as trackers are exposed to harsh winter conditions, especially when conducted in remote areas. - Can cause disturbance to lynx or other wildlife

3.6 HAIR TRAPPING

Rubbing behaviour is common type of scent marking behaviour used for scent communication among felids (Saebø 2007). While rubbing, usually with the head, neck and side of the body, lynx often leave their hair on the rubbed surface. Hair can then be inspected morphologically under a microscope (based on the structure and pattern of coticular scales) or with the use of genetic analyses, if the sample is fresh enough, to determine the species. Thus hair-trapping can be used to confirm lynx presence in the region or as part of the non-invasive genetic monitoring scheme (Schmidt & Kowalczyk 2006). Degradation of DNA in hair is usually slower compared to DNA in scats and in general provides more consistent results at lower costs (Kendall & McKelvey 2008). Still, it requires frequent collection of material (e.g. every week or two weeks). Collecting hair can be also combined with other monitoring methods, especially with camera trapping at the frequently visited scent-marking sites. In this way, lynx coat pattern can be linked to the individual genotype.

Collection of hair samples can be enhanced using simple device called hair-trap, which often includes certain chemical compounds that attract lynx and/or stimulate rubbing behaviour in felids. This approach was first used on the Canadian lynx (*Lynx canadensis*), for which a combination of catnip and beaver castoreum was reported to be most efficient compound (McDaniel et al. 2000). The beaver scent attracts the lynx to the hair trap, while catnip stimulates rubbing behaviour in cats. Similar attractants were more or less efficiently used also on Eurasian lynx in Europe (Schmidt & Kowalczyk 2006, Krofel 2008). Vaseline can be added to the mixture to prevent scent evaporation and washing out (Krofel 2008). Besides attractant, hair trap includes part that catches hair. This can be a passive hair trap, which collects hair that falls off the lynx coat during rubbing, or it can be an active hair trap, which includes a mechanism that grabs the hair and pulls it from the lynx coat. Active traps are expected to provide better genetic samples, as they increase the chances that hair will contain the follicle and prevent collecting mixed hair samples (i.e. samples with hair of several individuals or different species), but there is a risk that they may cause lynx to start avoiding the hair trap.

Heurich et al. (2012) tested five different types of passive hair traps, each attached to the 130x6x6 cm wooden post: 'carpet hair snare' (carpet size 10x30 cm with forty roofing nails pushed through a carpet with a length of 2cm above the carpet surface), 'rubber band hair snare' (household rubber bands wrapped around the post), 'wildcat hair snare' (wooden post roughened with a wire brush and with 2-3 mm deep horizontal and diagonal ridges), 'doormat hair snare' (textile doormat wrapped around the posts, with a knobbed rubber mat above and a piece of sandpaper), and 'wire brush hair snare' (wire brush with four rows of brass wire, with the brush head surrounded by a 30-cm wide piece of high-pile). Based on their results the most efficient hair traps were the wire brush hair snares, although lynx tented to rub longer on models without sharp edges and nails. In Poland, carpet hair snare was used (Schmidt & Kowalczyk 2006) and in Slovenia first the passive hair trap with barb wire and velcro tape was used (Krofel 2008) and later an active hair trap was developed using a coil spring, which triggers when animal rubs against it and pulls the hair from the lynx coat (Smolej 2018).

Figure 5: Hair trap installed in Dinaric mountains, Slovenia including combination of passive (carpet hair snare) and active hair trap (coil spring) with attractant including beaver castoreum and catnip located in the lower part (photo: Lan Hočevar)

Hair traps can be set randomly in an area or at specific locations. Best results are obtained when hair traps are set at the existing lynx scent-marking locations (Schmidt & Kowalczyk

2006). However, this is usually not possible when lynx monitoring is initiated in area without previous knowledge of lynx marking sites. Two studies in Slovenia compared frequency of lynx rubbing at hair traps set at four types of locations (none of them where previously known marking sites): gravel forest roads, logging dirt tracks, randomly in the forest, and at conspicuous landscape features (e.g. large rocks, cliffs, and rock shelters). In both cases best results were obtained from hair traps set at the forest roads, although frequencies of lynx rubbing were low (Demšar 2005, Krofel 2008).

Best period for setting hair traps is a mating season, when lynx movement and scent-marking activity is at its peak (Schmidt & Kowalczyk 2006). Winter time is also more suitable for hair trapping because lynx have longer hair in this period (Heurich et al. 2012) and because degradation of DNA material is slower in cold condition and with less ultraviolet light (Kendall & McKelvey 2008). However, possible limitation for installing hair traps and collecting samples in winter could be snow, as it can cover the entire hair trap (Davoli et al. 2013) and limit access to the hair-trapping site.

Hair trapping was used in several countries, but mainly as pilot studies to assess its potential for lynx monitoring. So far it was met with limited success. In Białowieza, Poland, Davoli et al. (2013) showed that with hair trapping it was possible to genetically identify individuals and monitor their spatio-temporal relocations. Here, hair trapping system was based on a network of 153 known lynx scent marking sites, which were previously identified with snow tracking. Hair traps were installed directly on the scent-marking objects and distributed along the forest roads. In Šumava and Bavarian forest hair traps were placed in proximity of the camera trapping sites along the Czech-German border between 2010 and 2012. The aim was to photograph individual lynx and link the photo with genetic material. Hair traps and camera traps were checked every two to three weeks in order to minimize the risk that more than one individual used hair trap between the sessions. Several models of hair traps were used, but the method was not successful as only a few samples were collected (Belotti 2020). In Slovenia, hair traps were tested as alternative to snow-tracking and were therefore at first not deployed at the known marking sites. In 2006-2008, 145 hair traps were active for 6-12 months and checked once a month. This resulted in small number of detections (0.8 per 100 hair traps per month) and none of the collected samples could be successfully genotyped (Krofel 2008). In the next attempt, active hair traps, which were successfully tested on the captive animals (Smolej 2018) were deployed mostly away from known marking sites in combination with camera-traps, but again resulted in low number of samples despite several recordings of lynx passing by hair traps (Fležar et al. 2019). In future, more targeted distribution of hair traps is planned in Slovenia, focused primarily on known marking sites. Similar to Poland, this approach worked better in Croatia, where hair traps were installed only at already known marking sites (V. Slijepčević, pers. comm.). This method was also tried in Bulgaria and Scandinavia, but was not successful (D. Zlatanova and J.D.C. Linnell, pers. comm.).

In conclusion, it appears that this method can be successfully used only when hair traps are placed at the known scent-marking locations. These are mostly located with the help of snow tracking, therefore suitable snow conditions might be a limiting factor also for the use of hair trapping. Potential alternative might be to use camera traps set at conspicuous objects in the landscape, including forest cabins and other human objects or next to vertical objects along the forest roads, which seem to attract lynx for scent-marking (Allen et al. 2017, Krofel et al. 2017) and try to identify marking sites that can be then used for hair trapping. However, feasibility of this option still needs to be tested, before it could be recommended for broader use.

Effort and cost:

Materials for hair traps are relatively cheap compared with other monitoring tools (Kendall & McKelvey 2008). Therefore the main cost of this method is associated fieldwork (and genetic analyses, if used), which could require considerable personnel effort, since hair traps need to be checked regularly to obtain useful samples for genetics. This is another reason why smaller number of hair traps set at previously established marking sites might be better than larger number of hair traps set at unknown locations.

Strengths	**Weaknesses**
- Method can be used systematically - Equipment costs are relatively low - Can survey large, remote areas and locate cryptic species - Is less dependent on snow conditions than snow-tracking	- Unless used at the known marking site, probability of lynx using the hair trap is low - A hair sample is not always reliable source of information, if it is too small or degraded or contains hair from more than one animal - Requires frequent checking in order to obtain useful genetic samples, which can result in considerably personnel effort - Genetic analysis of hair samples cause additional costs
Opportunities	**Threats**
- Hair sampling can provide genetic samples, which can be used to estimate abundance, inbreeding, kinship relatedness, animal origin etc. - Can provide information about other species - Combination with camera-trap can enable to establish link between the lynx ID according to its coat pattern and its genotype	- Despite the non-invasive nature of hair collection devices, some animals may avoid hair traps and introduce bias - Active hair traps may cause lynx to start avoiding the site - Hair traps can be covered in snow during the winter - Hair traps could be a victim of vandalism, especially on forest roads and human objects

3.7 GENETIC SAMPLING

Molecular genetic methods are becoming increasingly used as non-invasive tools to survey populations of wildlife (Heurich et al. 2012). Besides estimating population size, these methods enable insights into many parameters and processes essential for successful management and conservation of lynx populations. So far, genetic methods have been mostly used to assess the health status and genetic structure of a lynx population of interest (Sindičić et al. 2013b). That is especially important for small, reintroduced and usually isolated populations, where genetic drift and level of inbreeding need to be carefully monitored in order to retain favourable genetic and demographic status (Garner et al. 2005). Kinship relationships offer an insight to the wild animal pedigrees and are vital for understanding the changes in reproductive success, selection and gene flow

(Sindičić et al. 2013a). Moreover, genetic analyses can play a vital role in assessment of anthropogenic activities, such as (un)regulated hunting on gene flow between adjacent lynx populations (Bagrade et al. 2016). Even in growing populations, genetic status should be evaluated regularly as it may reveal a negative trend in genetic diversity despite increasing population abundance (Mueller et al. 2020). If combined with other methods, such as telemetry, genetics can also provide data for estimating effective population size and spatial organization of lynx population (Davoli et al. 2013, Holmala et al. 2018). Understanding the past relationship between remnant lynx population in Europe is crucial for proactive conservation activities, such as population reinforcement (Gugolz et al. 2008) or can help guide management decisions (Hellborg et al. 2002). Phylogenetic relationship among extinct and/or remnant populations is also used to guide translocation efforts in order to select the most suitable donor populations (Skrbinšek et al. 2019).

Genetic samples, which can be collected in an invasive (tissue of dead lynx or blood/hair samples of captured lynx) or non-invasive manner (from hair, faeces, urine, blood, saliva and skin cells found in the environment). Finding these samples can be achieved via opportunistic collection (chapter 3.1), snow-tracking (chapter 3.5), hair trapping (chapter 3.6), from dead lynx (chapter 3.4) or live captures for telemetry studies (chapter 3.8). Detailed and clear protocols for sample collection and storage should be developed and members of the network for collecting samples should be properly trained and informed about the protocol. Any changes or advances in the sampling techniques need to be communicated to them in real time in order to ensure samples are collected correctly.

Non-invasive genetic samples are generally more difficult to obtain for lynx compared to some other carnivores (e.g. wolves and bears). This is mainly connected to more secretive behaviour and less obvious scent-marking in lynx. Scats, which are often the main source of non-invasive genetic samples for other carnivores (e.g. Hindrikson et al. 2017, Skrbinšek et al. 2018), are typically covered by lynx and therefore difficult to find. They can be reliably found only in during snow tracking or with the use of detection dogs. While the use of detection dogs to obtain non-invasive samples from scat has been successfully practiced in North America, e.g. for bobcat (*Lynx rufus*; Clare et al. 2015) and Canada lynx (Mumma et al. 2015)), it has only recently started to gain attention in Europe for surveying Eurasian lynx (Hollerbach et al. 2018). This approach is estimated to be 3-times more expensive than camera trapping in terms of purchase, logistical support, lab cost and field labour (Clare et al., 2014). However, detection dogs perform better than camera trapping when confirming lynx presence in an area and allow collecting sufficient amount of non-invasive samples for systematic genetic monitoring of lynx, especially in areas where the lynx population is expanding and where snow conditions are poor (Clare et al. 2015, Hollerbach et al. 2018).

Other sources of non-invasive genetic samples can be obtained from saliva at kill sites (collected from bite wounds on wild prey or domestic animals), hair at daybeds or den sites (mainly located with the help of snow tracking or telemetry; it can be especially useful for collecting samples from different animals in a family groups, whose genetic samples are otherwise difficult to find, as juveniles do not exhibit territorial marking behaviour yet), hair at marking sites (regular checks of known marking sites, where also hair traps can be installed to increase the probability of collecting hair) and urine (usually collected from the snow during tracking of lynx).

A newly emerging technique for genetic monitoring of lynx is collecting environmental DNA (eDNA), found in animal footprints in the snow. eDNA sampling has been already established as promising technique for recognizing species (Franklin et al. 2019), but further development is needed to be able to identify individuals, which is usually the main goal of lynx genetic monitoring. Sampling footprints for individual identification requires uncontaminated collection of snow from footprints of single lynx in a sterile container. Once a sample is collected, snow is melted and filtered through specific “micro-filters” prior to the genetic analysis. DNA extraction and PCR follow the same steps as for other non-invasive samples. The technique is still undergoing the testing phase and fine-tuning of the method is needed in order to make it feasible, especially in terms of determining how much snow needs to be collected to provide enough DNA and which factors increase the success of obtaining useful samples (Hellström et al. 2019, T. Skrbinšek, pers. comm.).

Figure 6: Sampling eDNA from lynx footprints might be a future method in genetic monitoring (photo: Miha Krofel)

All collected samples need to be stored as soon as possible to prevent degradation of genetic material due to environmental factors, such high temperatures, ultraviolet light, and microbial activity (Kendall & McKelvey 2008). Samples should be desiccated with silica gel (hair, saliva or scat), stored in 96% ethanol (urine or scat) or frozen (tissue samples or snow from footprints). Research institutions are often in charge of laboratory work (genetic analysis and data interpretation), while samples can be collected by national lynx monitoring centres, if genetic sampling is coordinated at a regional level, or individual organizations involved in monitoring schemes (Davoli et al. 2013, Holmala et al. 2018, Krojerová-Prokešová et al. 2019, Skrbinšek et al. 2019). Given transboundary nature of many lynx populations, it is important to ensure international collaboration and comparability between marker panels (i.e. by the use of common minimal panel of genetic markers), if samples are analysed in different labs. This may also require careful consideration to which genetic lab the samples are sent. Alternatively, samples might be split to more parts and each sent to different lab, although this approach is not the most economical.

<u>Effort and cost:</u>

Genetic monitoring is generally the most costly method due to large effort needed to obtain lynx genetic samples in the field (the most expensive being the approach using detection dogs) and relatively high costs of laboratory analyses, although the latter are decreasing with the technological advances. Similar to camera-trapping and snow-tracking, fieldwork for genetic sampling can be assisted by network of volunteers. Maintaining and motivating such network requires similar cost than this activity performed in the scope of other monitoring methods involving volunteers. In respect to motivation, it has to be kept in mind that for volunteers collecting genetic samples might be less interesting than camera trapping or snow tracking.

Strengths - Is the only option for studying genetic structure, level of inbreeding, gene flow, effective population size and pedigrees - Allows individual identification - Samples can be stored for many years and reused when technology advances in the future	**Weaknesses** - Relatively expensive - Not all samples are successfully genotyped, thus the sample size decreases - High effort in the field needed to collect a relatively low amount of samples
Opportunities - Scat detections dogs are a promising tool for systematic genetic monitoring programs, however they come with a high cost - New methods for sampling are emerging (e.g. eDNA sampling) and appear promising for the future genetic studies - Intensive sampling could provide datasets that enable capture-recapture analysis of lynx densities	**Threats** - In poor snow conditions or in unsuccessful hair trapping surveys, DNA samples are very difficult to obtain

3.8 TELEMETRY

Telemetry is primarily used for studying lynx ecology and behavior, such as habitat use, movement (including dispersal), circadian activity, predation, feeding, survival and reproduction (Schadt et al. 2002, Krofel et al. 2013, 2014 Heurich et al. 2014). Information obtained from telemetry studies (e.g. home-range size, population density) can be used to estimate population size or regional abundance (Molinari-Jobin et al. 2006), although it is not an optimal method for lynx monitoring in larger areas (Kaczensky et al. 2009). More importantly, it can provide information that is required for correct interpretation of data collected using other methods and to assist in designing suitable monitoring programs in given area. For example, telemetry data on daily movement rates and home-range size was essential for analysis of data collected by snow tracking in Scandinavia (Andrén et al. 2006; see also chapter 3.5). Information on home-range size, micro-habitat use and seasonal activity patterns can also help with designing camera-trapping surveys.

For telemetry, capturing and sedation of live animal is required, before collar is fitted. This provides opportunities to also assess animal health and body condition, reproductive status, conduct morphometric measurements, collect genetic and blood samples, and photograph the coat pattern for potential later identification during camera-trapping surveys. Also the capture itself provides a C1 record for opportunistic collection of lynx records.

There are two main methods of telemetry. Older is radio (typically VHF) telemetry, where collar emits radio signal, which can be located with radio receiver and directional (yagi) antenna. When direction is established from several locations, animal location can be estimated with triangulation (Mech 1983). Alternatively, location of the signal can be pinpointed from the air using airplane or other aircraft. Newer type is GPS (global positioning system) telemetry, in which GPS collar directly communicates with satellites and automatically saves locations of the collared animal at pre-defined times. Collar stores the data, which can be retrieved 1) after the collar drops off, 2) by downloading the data remotely through portable terminal, 3) or the collar sends the data via GSM, GPS or GPRS networks (Interreg CE 3Lynx 2018). GPS telemetry is much superior to the VHF option, since it provides considerably more precise information (accuracy of GPS is about 10 meters, while error in VHF telemetry is typically several hundred meters) and it does not require fieldwork, which enables much higher frequency of obtained fixes and is not dependent on accessibility of terrain or weather and light conditions. Often also GPS collars include VHF transmitters, which can help locating animal/collar in the field (e.g. in case of failure of the GPS unit, mortality event or after collar drops-off).

All types of collars can be equipped with activity sensors, which measure acceleration in several axes and can provide useful information on animal activity patterns and to certain level enable interpretation of it behaviour (Heurich et al. 2014). Some collars can also include other types of sensors (for example to measure temperature, animal heartbeat, proximity to other collared animals or detect mortality) and video camera. The latter has so far limited use for the lynx, because relatively small size of this species prevents use of heavy batteries with higher capacity, which is required to obtain video footage.

Telemetry of lynx is currently widely used across Europe (see Table 1 for list of countries), where it assists other monitoring methods.

Photo 7: Sedated male lynx, equipped with GPS telemetry collar (photo: Lan Hočevar)

<u>Efforts and costs:</u>

Telemetry is an expensive method, both in terms of costs for the equipment, as well as the effort needed to collar each animal (and to track them in case of VHF telemetry). This is the main reason why usually only small fraction of a population is collared. First, animal must be captured, which require specialized equipment, drugs and (in most countries) involvement of a professional veterinarian. Lynx is a very elusive species and to capture it can be a challenging task connected with considerable efforts in the field. To monitor collared animals, receivers and antennas are needed for VHF telemetry, which is also associated with considerable costs for personal and travel expenses. GPS telemetry often does not require special equipment, although with some producers researchers must purchase terminal or GSM station for remote download of data. Certain costs are also required for transmission of GPS data (amount depends on the type of signal used).

Strengths	**Weaknesses**
- Provides very precise data on lynx movements, home range size, habitat use, dispersal, activity patterns, survival, predation and reproduction (among others). - These data can help with designing monitoring programs and might be essential for correct interpretation of data collected with other method. - Information about home-range size can be used to predict population densities. - Enables collection of detailed information on locations of den sites, kill sites and resting sites - After capturing, it enables studying animals and their behaviour remotely, with limited disturbance	- Expansive equipment (GPS telemetry) or high costs for fieldwork (VHF telemetry) - Relatively small size of lynx limits the battery capacity and therefore life span of the collar - Considerable effort required to capture each lynx - Usually sample size of collared lynx is small
Opportunities	**Threats**
- Various data of animal behaviour and ecology can be obtained, which are essential for research, conservation and management - During capturing many types of data and samples can be collected for other purposes - Collars can deter poachers from shooting the lynx - Enable to follow life histories of individual lynx, which can be used for education and promotion of lynx	- Capturing and tranquilizing animals can be risky for them in terms of possible death, injury and stress - Especially in younger animals, extra care is needed in respect to the size and weight of the collar - Drop-off system is not always reliable, which presents risk that collar will stay on animal for life - Some people may find collaring animals unethical, which can create controversy

3.9 OVERVIEW OF METHODS USED ACROSS EUROPE AND ESTIMATED LYNX POPUALTION DENSITIES

The most frequently used methods for lynx monitoring in Europe include camera trapping, questionnaires, mortality records and collection of opportunistic records (Table 1). Most countries use a combination of several methods and increasing number of countries are starting to conduct systematic monitoring. However, there are still areas without lynx monitoring and in some countries developing of lynx monitoring is still in very early phases.

As noted above, the most reliable density estimates available so far come from surveys using camera-trapping and (spatial) capture-recapture analysis. Such data are so far available from several regions of five countries, where estimated densities range between approximately 0.5 to 3 independent lynx per 100 km^2 (Table 2).

Table 1: Overview of lynx monitoring methods used in countries across Europe within the lynx range. Red colour indicates that given method is not reported to be used in the country, yellow colour means only opportunistic or sporadic use in the past, and green colour represent that method is regularly used.

Country	Opportuni-stic records	Questionnaires	Camera trapping	Mortality records	Snow tracking	Hair trapping	Genetic sampling	Telemetry	Source
Albania	Yes	In 2006-2007 and 2012-2013	Opportunistic	Yes	Opportunistic	No	Opportunistic	No	D. Melovski, pers. comm.
Austria	Yes	Yes	Yes	Yes	Yes, regionally	Yes, regionally	Yes, regionally	Yes, regionally	K. Weingarth, pers. comm.
Belorussia	Yes, regionally	No	Yes	No	Yes, regionally	No	Yes, regionally	Yes, regionally	Sidorovich et al. 2018, V. Sidorovich, pers. comm.
Bosnia and Herzego-vina	Yes	Yes	Yes	Opportunistic	Opportunistic	No	No	No	Trbojević 2019, I. Trbojević, pers. comm.
Bulgaria	Yes	Yes	Yes	Opportunistic	No	Tried but not successful	No	No	D. Zlatanova, pers. comm.
Croatia	Yes	Yes	Yes	Yes	Opportunistic	Yes	Yes	Yes	Kaczensky et al. 2013, Sindičić et al. 2016
Czech Republic	Yes	Yes	Yes	Yes	Yes	Tried, but not successful	No	Yes	Kaczensky et al. 2013, M. Dula, pers. comm.
Estonia	Yes	No	No	Yes	Yes	No	No	Yes	P. Männil, pers.comm.
Finland	Yes	No	No	Yes	Yes	No	No	Yes	Finnish Ministry of Agriculture and Forestry, 2007
France	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Gimenez et al. 2019, Louvrier et al. 2019
Germany	Yes	No	Yes, regionally	Yes	Yes, regionally	Yes, regionally	Yes, regionally, using detection dogs	Yes	Weingarth et al. 2012, Heurich et al. 2012, Kaczensky et al. 2013, Hollerbach et al. 2018, Port et al. (manuscript in review), M. Herdt-felder, pers. comm.
Hungary	Yes, regionally	More than 20 years ago	Yes, regionally	Yes, regionally	Opportunistic	Tried, but not successful	Yes, regionally	No	S. László, Á. and L. Szabó, pers. comm.
Italy	Yes	No	Yes	Yes	Opportunistic	No	Yes	Yes	Kaczensky et al. 2013
Kosovo	Yes	In 2013	Yes	Yes	No	No	Opportunistic	No	D. Melovski, pers. comm.
Latvia	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Kaczensky et al. 2013, Bagrade et al. 2016, Ozoliņš et al. 2017

Country	Opportuni-stic records	Questionnaires	Camera trapping	Mortality records	Snow tracking	Hair trapping	Genetic sampling	Telemetry	Source
Lithuania	Yes	Yes	Yes	Yes	Yes	No	No	No	Kaczensky et al. 2013, L. Balciauskas, pers. comm.
Monte-negro	Until 2017	In 2013	No	No	No	No	No	No	D. Melovski, pers. comm.
North Macedonia	Yes	In 2006-2007, 2009 and 2018	Yes	Yes	Opportunistic	No	Opportunistic	Yes	D. Melovski, pers. comm.
Norway	Yes	No	As pilot study	Yes	Yes	No	Opportunistic	Yes	Andren et al. 2002, Odden 2015, Linnell et al. 2007, Mattisson et al. 2014
Poland	Opportunistic	In 2002	Yes	Opportunistic	In the past	Regionally in the past	In the past	Yes	Schmidt and Kowalczyk, 2006, Davoli et al. 2012, Jêdrzejewski et al. 2002, K. Schmidt, pers. comm.
Romania	Yes	No	Yes, regionally	No	Yes	No	Yes	No	M. Pop, pers. comm.
Serbia	Opportunistic	Opportunistic	Opportunistic	Opportunistic	No	No	No	No	D. Ćirović, pers. comm.
Slovakia	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Kaczensky et al. 2013, Smolko et al 2018, Kubala et al. 2019,
Slovenia	Yes	Yes	Yes	Yes	Opportunistic	Yes	Yes	Yes	Krofel 2008, Fležar et al. 2019, Skrbinšek et al. 2019
Sweden	Yes	No	No	Yes	Yes	No	Yes	Yes	Andren et al. 2002, Linnell et al. 2007, Kaczensky et al. 2013
Switzer-land	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Thüler 2002, Pesenti and Zimmermann, 2013, Zimmermann et al. 2013, Vogt et al. 2018, Marti and Ryser-Degiorgis, 2018
Turkey	No	No	Yes, regionally	No	No	No	Yes	Yes	Soyumert 2020, Mengulluoğlu et al. 2019
Ukraine	No	Opportunistic	Opportunistic	No	Yes	No	No	No	M. Shkvyria, pers.comm.

*Table 2: Overview of estimated lynx densities in Europe based on camera-trapping data and capture-recapture (CR) or spatial capture-recapture (SCR) analysis. Surveys using other means of calculating densities are not included (e.g. there are density estimates for Serbia and Mavrovo, but they are not based on CR or SCR approach). Densities refer to the number of independent lynx (i.e. kittens that accompanied their mothers were not included). When several surveys were repeated in the same area, the results from the latest survey are presented. *Estimates are given either as a 95% confidence interval or as average with or without a standard deviation (SD) or standard error (SE). ** R package used for SCR analysis is provided in the brackets.*

Area	Season	Density per 100 km^2 *	Method**	Reference
Bavarian NP + Šumava NP, Germany/Czech Republic	2018/19	1.77	CR	Heurich et al. 2019
Muranska planina, Slovakia	2015/16	1.47 ± SD 0.37	SCR (SPACECAP)	Smolko et al. 2018
Štiavnica Mountains, Slovakia	2013/14	0.58 ± SD 0.13	SCR (SPACECAP)	Kubala et al. 2017
Veľká Fatra NP, Slovakia	2014/15	0.81 ± SD 0.29	SCR (SPACECAP)	Kubala et al. 2017
Harz NP, Germany	2017/18	2.9	CR	Middelhoff & Anders 2018
Jura-Vosges, France	2011-2016	0.64 ± SE 0.03	SCR (oSCR)	Gimenez et al. 2019
Southern Jura, Switzerland	2017/18	2.16-4.80	CR	www.kora.ch
Rhône nord, Switzerland	2019	2.55-4.03	CR	www.kora.ch
Simme-Saane, Switzerland	2017/18	2.54-3.78	CR	www.kora.ch
Bernese Oberland Ost, Switzerland	2016/17	2.31-3.95	CR	www.kora.ch
Northern Jura, Switzerland	2018/19	1.91-3.19	CR	www.kora.ch
North-eastern Switzerland	2017/18	1.94-3.13	CR	www.kora.ch
Mid-Central Switzerland	2016/17	1.47-2.33	CR	www.kora.ch
Western central Switzerland	2018/19	1.37-1.50	CR	www.kora.ch

4. DISCUSSION

There is a large diversity of methods used for lynx monitoring in Europe, each with its advantages and drawbacks. Some of the methods are an obvious choice for specific areas with specific conditions (e.g. snow tracking in high latitudes with good accessibility and good snow cover), but generally there is no single one-fits-all method that could be generally recommended for all populations and all purposes. Therefore it is essential that priorities are set and clear monitoring objectives defined before any monitoring scheme is initiated. Moreover, one has to keep in mind that the objectives can be redefined with time, in response to changes in conservation or management priorities. This should guide authorities to decide whether it is enough to collect opportunistic data, to perform small-scale study to assess lynx status in certain regions (mostly in terms of confirming presence of lynx in a certain area) or if there is a need for a targeted systematic monitoring, which will provide reliable data about the status of the local lynx population and, ideally, enable to estimate absolute densities. The trend in recent years shows that systematic monitoring schemes, at least in reference areas, are increasing across Europe. To obtain sufficient information about the status of lynx as a protected species, at least one reliable monitoring method should be regularly deployed for monitoring on a national or population level. Finally, it has to be kept in mind that there is a rapid technological and methodological development of data-collecting and analytical approaches. Therefore frequent re-evaluation and adaptation of monitoring programs is advised in order to continuously improve the efficiency and quality of information obtained.

The experience and recommendations from a number of countries indicate that camera trapping is the method of choice to obtain robust estimates of lynx abundance in many regions (exception being populations with large share of unspotted individuals). However, it depends whether there is a justified need to obtain precise population density estimates and if sufficient funding is available. Therefore, when choosing the most suitable method for lynx monitoring in a specific area, it is important to consider that the choice does not depend only on the external factors, such as terrain or size of the area with suitable lynx habitat, but also on the resources and personnel available. It is alarming to know that funding remains a main constraint even for monitoring lynx populations with years of successful transboundary collaboration, such as Bohemian-Bavarian-Austrian metapopulation. Moreover, local constrains which can hamper the implementation of any method, should be taken into account (e.g. hunting system, land ownership or attitudes of local communities). In some cases, a combination of different methods represent an optimal monitoring design. Such example is the efficient monitoring scheme used in Switzerland where opportunistic data is collected all year long, questionnaires to game wardens are distributed annually and systematic camera trapping is conducted in reference areas every 2-3 years (www.kora.ch).

Optimizations of methods in use should be encouraged using experiences from other countries, e.g. which models and how many camera traps per what grid size, and how to best collect non-invasive genetic samples. Experience exchange in lynx monitoring is encouraged also thanks to international platforms and networks, such as EuroLynx and SCALP platform, which reach beyond specific international funding schemes with limited duration (e.g. Interreg or LIFE projects). Sharing of experiences is vital for countries that are initializing systematic lynx monitoring for the first time or that need to adapt their methods due to changing environmental effects, for example influence of climate change on possibility of snow tracking.

We realized during the preparation of this review that information on effort and costs is difficult to obtain and interpret for most methods. There is an obvious lack of publications providing information about investments needed for implementation of different methods, including estimates of number of required (trained) personnel, amount of working hours, type and quantity of equipment used, travel costs, etc., which represents an important knowledge gap that needs to be filled in the future. Such data would make it easier to estimate their capability in terms of finances and personnel and help decide which monitoring method to implement on a national or regional level, especially for institutions or countries with limited previous experience in lynx monitoring.

Regardless of the method used for collecting data in field or data analysis, one needs to consider also other work required for effectively running a monitoring programme. Good coordination of the monitoring activities, organizations or regionally-specific entities is a prerequisite for obtaining good quality data, especially when combination of several methods is used. There should be sufficient time allocated to coordination of monitoring, especially if the program involves external collaborators (hunters, foresters, naturalists and other volunteers). While involving volunteers can significantly reduce costs of a monitoring program and enable large-scale surveys, it requires more effort from the coordinating institution. This includes providing regular feedback to collaborators, effectively communicating the potential changes to the program, and building a trustful long-term relationship, which keeps the collaborators motivated. Regular sharing of results from the completed surveys is often the most important part of ensuring future collaboration. It also needs to be taken into account that the means of communication should be tailored specifically for different groups of stakeholders, as different groups need, or are interested in different types of information (Breitenmoser et al. 2006). Besides, the coordinator of lynx monitoring should report main results of monitoring regularly and in clear messages also to the managers, decision-makers and funding institutions.

As animals do not know national borders, transboundary cooperation and synchronization of monitoring methods and data is necessary for monitoring on a larger scale, as well as for population-level management and conservation of lynx populations, which is especially relevant for Europe, where most populations are shared among several countries (Linnell et al. 2008). It would be also useful to ensure comparability of lynx population statuses on the European level, for which population parameters of interest should be selected (e.g. number of reproductive females, population density, minimal population size, or effective population size). However, this would require synchronization of methods used, which does not seem feasible at the moment given the diversity of environmental, cultural, and population-specific factors influencing the design of monitoring programs. Therefore, a more realistic scenario is using novel analytical approaches, such as SCR, to increase the precision of the population parameters of interest, where suitable data are available. Often advanced statistical computing would not necessary require adaptations in existing monitoring design to allow direct comparability of results among different countries, regions or reference areas.

PART II. LYNX CONSERVATION PRACTICES

5. INTRODUCTION

Large carnivores are returning to many parts of Europe, where they have been exterminated in the past (Chapron et al. 2014). This can create challenges for their conservation and ensuring coexistence with local people. In this part of the report we present examples of good practice in lynx conservation, which address the main threats and conservation challenges that lynx populations are facing in Europe nowadays: low population numbers and inbreeding, insufficient knowledge, conflicts related to livestock depredations, and low support for lynx conservation or mistrust in lynx management, which can present an incentive for illegal killings.

Lynx is currently present in 27 European countries and separated into 10 populations (Kaczensky et al. 2013). These include several large and vital populations (e.g. Scandinavian and Carpathian), as well as several small, isolated and threatened, which represent remnants of once larger populations (e.g. the Balkan lynx) or new reintroduced ones (e.g. Alpine and Dinaric), many of which could be endangered due to inbreeding. Some of these small populations are so threatened that they are likely to go extinct without direct human assistance and some parts of the historic lynx range are unlikely to be re-colonized by lynx in foreseeable future without translocations. Therefore reintroduction and reinforcement programs play crucial role in supporting recovery of lynx in Europe. We will describe two ongoing projects that are dealing with lynx translocations aimed to create vital populations in areas where lynx have become extinct or drastically reduced. Besides translocating lynx, such large projects often include other activities which address other aspects of lynx conservation, such as preventing poaching, involving stakeholders and increasing public support for lynx conservation.

Good knowledge about the local population, including its status, ecology, distribution and attitudes of local people towards the lynx, is a basis for any successful conservation efforts. Obtaining such knowledge can be challenging in regions, where local researchers have limited experience or capacity for studying this elusive species. In such case, international collaboration, capacity building, sharing experiences and providing funding can be instrumental to establish effective research and monitoring programs. Good example of such international collaboration is research and monitoring of the Balkan lynx, which was for a long time the least known population of lynx in Europe.

Although lynx live primarily in forest habitats, their home ranges are large and because many of European forests are fragmented, lynx interactions with people or domestic animals are inevitable. This can result in conflicts, which creates a need for efforts that promote coexistence and mitigate potential conflicts. Important aspect of promoting coexistence is close collaboration with main stakeholders in the lynx area (e.g. farmers, hunters, foresters, general public, environmental NGOs and local community representatives), who should be included in the lynx management and provided with reliable information about status of lynx populations, their behaviour and ecological effects. One approach to improve attitudes of local people towards lynx and build their trust in lynx management is to involve local stakeholders into lynx monitoring, management and conservation activities. For example, in Scandinavia hunters are regularly involved in snow tracking censuses, which represent the main source of data for lynx monitoring. Similar is done in Slovenia as part of the population reinforcement project, which also created local consultative groups that provides local stakeholders with opportunity to get actively involved in the lynx management and obtain updated information, which is then shared within their communities.

Although lynx is not as problematic species in terms of human-carnivore conflicts as grey wolf or brown bear, lynx can kill livestock. This is especially true for Scandinavia, but lynx is now making a comeback also to some regions where it was extinct for long periods, and local livestock breeders may have lost knowledge on how to deal with predators. Therefore, there is an increasing need for effective preventive measurements against livestock depredations. This aspect was given considerable attention in Switzerland, where several approaches have been tested. This knowledge of what is effective and what not can now be shared with other parts of Europe, where similar conflicts are starting to become a problem.

6. EXAMPLES OF GOOD PRACTICES IN LYNX CONSERVATION

6.1 REINTRODUCTION AND REINFORCEMENTS CONSERVATION ACTIONS

Reintroduction and reinforcement programs have significantly contributed to recovery of lynx populations in Europe. These programs started in the 1970s as a result of advanced conservational thinking. More than 110 lynx were translocated to Western and Central Europe, including Switzerland, Italy, Slovenia, Austria, Germany, Czech Republic, Poland and France (Vandel et al. 2006) and there are several more projects continuing today.

LIFE Luchs: Reintroduction of lynx to Palatine forest (Germany)

LIFE Luchs project (https://snu.rlp.de/de/projekte/luchs) is one of the recent reintroduction projects, which started in 2015 and will last until end of September 2021 with the goal to reintroduce lynx into Palatinate Forest in Germany and re-establish reproducing lynx population in this region. Like in many parts of the Europe, lynx disappeared here in the 18th century. By 2020 project achieved the objective to release 20 lynx into from Slovakia and Switzerland. All of the released lynx were equipped with telemetry collars and monitoring of the new populations and evaluation of the reintroduction process has been established.

Besides translocating lynx, the project established the central office in the project area where professional training for staff and volunteers is taking take place. In addition, cooperation with stakeholders on German and French side of the border has been established and public-relation work and educational activities are conducted to help to increasing lynx acceptance by the most important interest groups in the area.

LIFE Lynx: Reinforcement of Dinaric-Southeast Alpine population

The main goal of the LIFE Lynx project (www.lifelynx.eu) is to prevent the extinction of the reintroduced Dinaric-SE Alpine lynx population, which is threatened due to very high level of inbreeding. This is being accomplished with the reinforcement of population by translocating the lynx from the Carpathians (Romania and Slovakia) to the northern Dinaric Mountains and southeastern Alps (Slovenia and Croatia) in parallel with other conservation actions, such as building local support for lynx conservation among stakeholders and general public (see chapter 2.2), preventing illegal killings (see chapter 2.3), and maintaining habitat connectivity.

Lynx became extinct in the Dinaric Mountains in the beginning of the 20th century, but were reintroduced to Slovenia in 1973, when 6 lynx were translocated from the Carpathians. The population spread across large part of the Dinaric range and into Southeastern Alps and reached its peak in the 1990s. Then population started declining, most likely due to high level of inbreeding and possibly also due to intensive legal hunting, which was partly connected with overestimated population size. Genetic research confirmed that level of inbreeding is reaching critical level (Sindičić et al. 2013b, Skrbinšek et al. 2019), which triggered action to prevent the second extinction of lynx in the region. Within the 7-year LIFE Lynx project 14 lynx from Romania and Slovakia are planned to be included in the Dinaric-SE Alpine population and prevent the inbreeding depression. Five lynx have already translocated to Dinaric forests of Slovenia and Croatia until the end of May 2020 and further releases are planned in the following years, including the creation of stepping stone population in the Slovenian part of the Julian Alps, which is hoped to later expand to the neighbouring Italy and Austria. All translocated animas are equipped with telemetry collars, which enable to track their movement, and intensive genetic and camera-trapping monitoring was initiated to follow and assist the reinforcement process. The first successful mating between translocated male and resident female was already confirmed in the first year of translocation efforts in 2019.

In addition, the project aims to develop science-based management tools to assist strategic planning to ensure long-term viability of the lynx in this part of Europe and improve lynx population connectivity with the long-term vision of connecting this population with other reintroduced populations along the Alpine arch. Since the population is shared by several countries, also international collaboration in conservation efforts, monitoring and management is essential and given high priority in the project activities.

6.2 BUILD SUPPORT FOR LYNX CONSERVATION AMONG LOCAL COMMUNITIES

Establishment of local consultative groups in Dinaric Mountains

One of the main objectives of LIFE Lynx project (www.lifelynx.eu) is also to maintain the support among the local people during the lynx population recovery. One of the innovative approaches used was creation of local consultative groups (LCGs), which consist of local community members, such as local hunters, farmers, mayors and other municipality representatives, school teachers, members of local environmental associations and LIFE Lynx project members. In total, four LCGs have been established in Slovenia and two in Croatia. Members of the LCGs take part in special events with moderated round table meetings, in which members are regularly informed about all aspects of the reinforcement process and included in decision making of further activities. Another topic relevant for local communities is eco-tourism, which provides them with economic benefits from coexisting with large carnivores. Special role is given to local hunters, who are also responsible for building and maintaining soft-release enclosures (where lynx are kept for a few weeks after translocation from the Carpathians and before they are released into the wild) and inform other LCG members about their activities through presentations.

So far experiences of working with public and stakeholders in the scope of LCGs are very promising and members show great interest to be part of the discussions of potential and actual problems, as well good practices. In addition to the organized events and round tables, there is frequent one-on-one communication with several members, which takes place via e-mails, telephone or personal conversations. LCG members also have access to promotional material on the lynx and project and then serve as local information points to other members of their communities (some of which may trust better the information obtained from his neighbour villager, rather than from a project employee that comes from the capital). They also participate in public awareness-raising activities on local media outlets and collaborate with local schools to present project and the lynx to younger population.

6.3 PREVENTING ILLEGAL KILLING

Establishing specialized police unit to fight poaching and other wildlife crime in Slovenia

Illegal killing is one of the biggest threats to wildlife worldwide and the same is true for several lynx populations in Europe (Kaczensky et al. 2013). However, illegal killings are very difficult to detect and authorities are often lacking knowledge and motivation to deal with this type of crime.

Human-dimension studies from Slovenia indicated that lynx have a strong support among general public and hunters, nevertheless small proportion does not share the same opinion and they hold negative attitudes towards the lynx (Mavec et al. 2020). Hunters often see lynx as competitor for prized ungulates, such as chamois, roe and red deer, which can lead to poaching illegal killing (Breitenmoser et al. 2010) and several confirmed cases of illegal killing of the carnivores, including lynx, have been reported in the past in this region. With the expected recovery of lynx population, chance for illegal killing are also expected to increase. Before, cases of illegal wildlife killing have rarely been solved by police. This was partly connected with the limited capacities and with the fact that procedure of documenting illegal killing was not regular routine for the field personnel. Such shortenings could to mistakes which can later be irreversible for successful solving of crime cases.

To overcome these limitations, a specialized police investigation unite for fighting wildlife crime and more efficient persecution of illegal killings of the lynx and other animals was established within the LIFE Lynx project (www.lifelynx.eu), led by the Slovenian Hunting Association in collaboration with the national police. A group of 20 policemen (many of which are also hunters) received specialized training for solving wildlife-crime cases with the help of criminal law experts and wildlife experts from University in Ljubljana, Slovenia Forest Service, Hunting Association of Slovenia, and Slovenian Environmental Agency. A protocol with detailed procedures on how to deal with cases of suspected illegal killing of wildlife was established. This will serve not only to police employees, but also to other field workers that could possibly detect cases of wildlife crimes, such as hunters, game wardens, wildlife managers and foresters.

Additional educational seminars for field personnel were organized on local scale with instructions on how to react and proceed in cases of suspected illegal killings and distribution of promotional material. Experience exchange meetings were organized, where all members shared and discussed their wildlife crime investigation experiences. Such sharing of information and experiences will continue in the future, with the aim to revise the protocol if needed, increase or maintain the knowledge and keep everybody involved motivated. Furthermore, a leaflet was produced and sent to every Slovenian hunter to increase awareness about the problem of illegal killings, together with basic instructions on how to proceed in case of suspected wildlife crime and contact information to report detected illegal killings. The leaflet was also distributed to foresters, and other field personnel, with intention to reach out to people that could detect cases of illegal killings of wildlife.

While the direct purpose of this action is to improve sanctioning of the offenders, indirect intention is to send a clear message to potential offenders that such crimes will no longer be tolerated, with the ultimate goal to reduce illegal killing of lynx and other wildlife.

6.4 CAPACITY BUILDING

Developing monitoring and research of the Balkan lynx in North Macedonia

The Balkan lynx is considered to belong to a separate subspecies of the Eurasian lynx (*Lynx lynx balcanicus*) and is today it is considered to be the most endangered subspecies and non-reintroduced population of the Eurasian lynx in Europe with estimated number of less than 50 mature individuals (Melovski et al. 2012). The latest data show that population size is decreasing in North Macedonia and reproduction is confirmed in only one area, which makes it a conservation priority. In Albania population trend cannot be assesed, due to lack of knowledge (Melovski et al. 2015). The species is fully protected by law in all range countries (Melovski et al. 2012, 2015), but remains threatened due to lack of wild prey, habitat destruction and fragmentation, as well as illegal killings due to poaching, poisoning and snaring. Also expanding populations of Eurasian lynx from Dinaric and Carpathian ranges can pose a threat to the genetic uniqueness of the Balkan lynx population, although some admixture may be beneficial to reduce possible threat of inbreeding depression.

Critically endangered status of the Balkan lynx necessitates sound knowledge obtained through scientific data, which are essential to guide conservation effort. However, until recently there was very limited reliable information on the population status, distribution and basic ecology of this population (Melovski et al. 2020). To address these knowledge gaps, provide capacity building for local experts and stimulate research, a three-phased conservation plan for the Balkan lynx recovery was established by the Swiss carnivore-expert team at KORA in 2001. After each phase, decision making process was predicted for the next phase in terms of funding and next steps that need to be taken (Breitenmoser-Würsten & Breitenmoser 2001). In 2006, the first phase of the "Balkan Lynx Recovery Programme" was initiated with the goal to combine the lynx protection in the sustainably managed protected area system in North Macedonia and Albania and to build capacities on a local level for long-term monitoring and conservation of the Balkan lynx, as well as to raise awareness in nature protection. The first phase of the project lasted for 3 years under supervision of experts from KORA and was funded by the Swiss-based MAVA foundation (Melovski et al. 2012). First camera-trapping survey was conducted in National park Mavrovo (730km^2) in the northern part of Macedonia with the aim to determine distribution and minimal number of lynx in the national park. In total, 29 lynx photographs were obtained, which indicated that at least 7 to 10 lynx individuals were present in Mavrovo and confirmed that this area represents the core of the remaining Balkan lynx population (Melovski et al. 2009). Parallel to these efforts, a human-dimension project was initiated and supported by Norwegian experts and funded by the Research Council of Norway (Melovski et al. 2015). This showed that one of the hindrances for lynx conservation in Albania and Macedonia is also lack of local knowledge about the species, probably due to the cryptic nature of the lynx. Since limited knowledge, which is mainly based on myths and rumours, can create negative attitude towards the lynx (Lescureux et al. 2011), this stressed the need to start working with local people to increase awareness and provide reliable information about this species.

In 2010, a second phase of the Balkan Lynx Recovery Programme started. Since reliable information on Balkan lynx ecology was missing, a research project "Status, ecology and land-tenure system of the critically endangered Balkan lynx in Macedonia and Albania" was initiated. The project was supported by the Swiss National Foundation under the SCOPES foundations and it lasted for 2 years until 2012 (Melovski et al. 2015). During this period, first three Balkan lynx were captured and equipped with GPS telemetry collars. In addition, wildlife monitoring network was created and intensive camera trapping survey was conducted in the core area.

The third phase of the Balkan Lynx Recovery Programme started in 2013 and lasted for three years with the main aim to continue with research and population monitoring, develop an action plan for the core areas of the Balkan lynx distribution, and to expand project activities to Montenegro and Kosovo. In these two countries, first baseline surveys were conducted and in 2013, distribution and conservation status of Balkan lynx was assessed at the population level (Melovski et al. 2015). The results indicated critical status of population, with pessimistic scenario pointing to only 20 – 44 independent individuals, which are mostly distributed within the western part of North Macedonia and eastern Albania. No evidence of lynx presence in Kosovo or Montenegro could be found at that time (Melovski et al. 2012). However, in 2015 Balkan lynx was confirmed in Kosovo for the first time in thirty year by three photos made with a camera trap (KORA 2015). Educational and awareness actions on a local, national and international level were performed with the goal to educate people about Balkan lynx and its important role in the ecosystem (Melovski et al. 2015). Also four primary schools in Mavrovo were involved with the goal to increase the knowledge about the Balkan lynx among 280 primary school pupils (KORA 2015).

Efforts to collar additional animals continue today and based on telemetry data from seven lynx, it was possible to provide the first reliable estimates on the home-range size and foraging ecology of the Balkan lynx (Melovski et al. 2020). Contrary to some previous assumptions, it was discovered that home-range size and foraging ecology of the Balkan lynx is similar to lynx populations in Central Europe. However, data indicated that kill rates of ungulates (on average 31-53 ungulates per year) are relatively low, which probably reflects low availability of wild ungulates. Therefore, improving prey availability, especially roe deer and chamois, will be one of the crucial aspects of future conservation.

Melovski et al. (2018) identified three main conservation priorities for the Balkan lynx recovery on a local and wider geographical scale: 1) In situ protection of the remaining population, their habitat and their prey base. In this respect, law enforcement and management actions should be included in the conservation of identified areas, with designation of newly protected areas. 2) Active involvement of the stakeholder groups in the conservation is crucial for long term survival of the species. Especially hunters should be involved in the conservation processes, as they can play important role in reducing poaching, helping with the lynx monitoring and raising awareness among other hunters and local people about the lynx' importance in the ecosystem. 3) Improving the legal framework for more efficient lynx protection.

The Balkan lynx Recovery Programme is example of good practice in transboundary collaboration, where a group of leading experts from one country provided their expertise, capacity building and help with securing funding to establish a successful research, monitoring and conservation program in another country that had previously limited capacity and experience in lynx research and conservation.

6.5 INTERNATIONAL COLLABORATION

SCALP: Developing common criteria and central database for opportunistic collection of data (Alps)

Another good practice example in international collaboration on lynx monitoring is the establishment of harmonized categorization of opportunistically-collected data and common database of lynx distribution developed within the long-term SCALP project (Status and Conservation of the Alpine Lynx Population; see also chapter 3.1 in the first part of this report). So called “SCALP categories” of lynx records were first proposed and defined within the Pan-Alpine conservation strategy for lynx, aiming to re-establish and maintain, in coexistence with people, a vital lynx population covering the whole of the Alpine arc (Molinari-Jobin et al., 2003). The initiative was founded by the KORA (Swiss Carnivore Ecology and Wildlife Management) and set the goals to connect the main lynx populations in the Alps and develop an Alpine-wide strategy to meet the goal.

Within the initiative, the status and distribution of lynx in the Alps had to be assessed. All Alpine countries (France, Switzerland, Germany, Liechtenstein, Italy, Austria, Slovenia) adopted a common categorization of opportunistically and systematically collected data on lynx presence. Three main categories were proposed (C1, C2 and C3 – see chapter 3.1 for details), accounting for the level of verification of lynx records. Standardized categorization allows comparability of data among countries and enables quality assessment of collected data. The data is collected at national centres (such as Environmental Agencies or Wildlife management services), which are also in charge of reporting the status of lynx to the European Commission under the Habitats Directive Article 17 (Molinari-Jobin et al. 2017). SCALP categorized data is annually reported by each country to the KORA, where data are processed at the transnational level on 10x10 km grid and reported in annual reports (www.kora.ch).

In the recent years, this good practice was expanded to include also data from Jura and Dinaric mountains, and SCALP criteria are being adopted also by the non-Alpine countries (e.g. Northern Macedonia, Czech Republic, Germany, Slovakia) and for other carnivore species (e.g. golden jackal).

6.6 INVOLMENT OF HUNTERS IN LYNX MONITORING

Well-planned monitoring system can significantly contribute to success of conservation and management actions. With limited resources from government to monitor wildlife, there is a need for scientist and wildlife managers to use cost-effective methods for data collection. Monitoring is primarily done by the professional personnel, but in some cases help by volunteers can play important role to obtain data from the field. Recent review reported that hunter-based monitoring of wildlife exists in 32 out of 36 European countries for at least one species (Cretois et al. 2020). Data provided by hunters include body parts of shot animals, as well as non-invasive (e.g. genetic) samples, which can be used for estimating population trends, monitoring health status, detecting spread of invasive species, etc. In most of the European countries hunters have to go through education and pass the exam, which makes them especially suitable for involvement in wildlife monitoring activities (Cretois et al. 2020). Besides, they often possess detailed knowledge about their area and can spend considerable amount of time in the field. This increases chances of finding tracks or signs of rare species and can provide critical input for selection of optimal sites for camera trapping. Thus including hunters can provide considerable advantage and allows large area to be covered and considerable number of samples to be collected.

Important side-effect of involving hunters in animal monitoring is that in this way they feel included in the monitoring and management, which may increase their trust in the results of monitoring programs or management decision-making. It may also increase their interest in species that can otherwise be threatened by negative attitudes or even poaching. This suggests that collaborations between hunters and wildlife experts are promising and should be considered as a standard partnership in monitoring programs and conservation actions (Cretois et al. 2020).

Hunters and lynx monitoring in Scandinavia

One of the best examples of actively including hunters in lynx monitoring comes from Scandinavia. There huntersy are regularly involved in snow tracking censuses and counting the minimal number of family groups, which also provides the basis for setting lynx hunting quotas. In snow-tracking surveys, hunters search an area for lynx tracks 1 or 2 days after fresh snowfall (Andrén et al. 2002) and local hunters put in a good deal of time to search for a lynx tracks (Linnell et al. 2007a) (see also chapter 3.5). Although sometimes hunters misidentify lynx tracks for fox or a wolverine, their knowledge of the wildlife species is generally better than other volunteers (Linnell et al. 2007a, Cretois et al. 2020). All the observed data and counted records of the lynx tracks from hunters, game wardens and other volunteers are reported and tracks of lynx family groups are then verified by the authorized personnel, which reduces the problem of potential misidentification or deliberate erroneous reporting (County Administration Boards in Sweden and State Nature Inspectorate in Norway). After verification, the data is included into monitoring database called Rovbase (https://www.rovbase.no/?SprakID=4). According to national regulations, hunters are also required to deliver lynx carcasses for post-mortem examination, which provides important additional source of data (Nilsen et al. 2012).

6.7 PREVENTING LYNX CONFLICTS WITH FARMERS

Human-carnivore conflicts are a one of the major threats for large carnivore survival in Europe and lynx is no exception. There are two main causes for conflict between lynx and people: livestock depredation and predation of valuable game species (primarily roe deer, red deer, reindeer, chamois and mouflon). Out the three widespread species of large carnivores in Europe, lynx is the species that causes least conflict due to livestock depredations (Stahl et al. 2001). The conflict is greatest in Fennoscandia, where lynx regularly kill unprotected sheep and semi-domesticated reindeer that graze freely within the lynx habitat (Pedersen et al. 1999, Odden et al. 2002, Linnell 2013). There the conflict is attempted to mitigate by paying high compensations for livestock losses and by lethal control of lynx populations. Although this has limited effects on preventing depredations (Herfindal et al. 2005), it appears to increase the acceptance of lynx to the level that enables population to maintain favourable conservation status and even increase. Depredation of livestock can represent a problem also in other parts of Europe and in this chapter we describe problems and preventive measures that helped to reduce damages caused by lynx on domestic animals in Switzerland and improve our knowledge of which methods are effective in reducing livestock depredations and which are not.

Preventing livestock depredation by lynx in Switzerland

There are several factors that influence the probability of livestock depredations. This is increased when livestock is grazed freely away from village or in forested areas with lower densities of wild prey (Kaczensky 1999). In such cases it is essential that effective measures are put in place to prevent further conflicts (Treves et al. 2016). When large carnivores have been missing in the region for longer period, most of the livestock protection measures also disappear, as do the experiences of how to deal with large predators. For example, in the Alps there was a widespread practice of large herds of livestock to be left unattended in the mountain pastures for extended periods (Schnidrig et al. 2016). After lynx was reintroduced to Switzerland in the 1970s, these created high risk for livestock depredations (Vandel et al. 2006). Until 1994, sheep attacks by lynx in Switzerland were rare, but soon number of attacks started to increase and in 1996 first applications were received for permits to shoot a lynx suspected of killing the sheep. Several lynx have been shot in the following years, but analysis of damages cases revealed that removal of the problem animal did not resolve the problem, as damages continued on the problematic pastures also after the shooting, as new lynx often took over the vacant territory and started to kill sheep on the same pastures (Stahl et al. 2001, Angst et al. 2002, Breitenmoser et al. 2005). Nevertheless, according to the current system, permit to shoot the lynx can still be issued in Switzerland, if lynx kills more than 15 sheep within given area per year (Schnidrig et al. 2016).

Increasing problems and need for more effective ways to reduce depredations led to the initiation of several projects that aimed to analyse temporal and spatial distribution of the damages, as well as to develop and test various preventive non-lethal measures for protecting livestock (including captive game species) from lynx attacks. Results of the analyses showed that the losses of the livestock connected with the lynx were minimal considering other sheep mortality factors and that lynx attacks were more often to occur in the specific pastures with specific local condition. For example, vicinity of the forest near pastures, number of lynx in the area and availability of wild prey were revealed as factors that influenced the frequency of attacks (Angst et al. 2000). In respect to non-lethal methods to prevent depredations, at first mechanical protective measures, such as protective collars, were tested on 1200 sheep in 18 flocks, but several of the sheep equipped with these collars were still killed by lynx. In the next step, protective collars with repellent were developed, however, also these proved non-effective. Optical and acoustic deterrents (e.g. flashing lights and explosives) were also tested and were observed to be successful, but the effects were short-term. Some lynx were captured at the affected pastures as a form of aversive conditioning to give lynx negative experience in the vicinity of pastures in order to attempt to change future behaviour. This seemed to be successful, as treated lynx never returned to the pasture where they have been caught. However, this method requires a lot of effort and experienced people, besides it does not assure that lynx will not kill livestock on neighbouring pastures. Next, electric fences were also tested, and they proved very successful in stopping lynx from killing captive game animals (Angst 2001). Livestock guarding animals, such as dogs, donkeys and llamas also seemed to be successful; however, young animals of some of this species can also be potential prey for lynx. Also use of shepherds was observed to be an effective method as no sheep was killed during the shepherding. However, from economic point of view and given rarity of lynx attacks on livestock, this method does not pay off to be used systematically over large areas.

In summary, the best approach according to experiences from Switzerland is to focus prevention measures on hot-spot pastures, where attacks occur regularly, and use electric fences or shepherding in combination penning the sheep at night to protect them from lynx where risks are high (Angst 2001, Angst et al. 2002).

Additional way to mitigate conflicts is to provide financial compensation to the owners that lost livestock to lynx. In Switzerland, killed livestock is compensated up to 100 % if predated by the lynx. This approach can form important part of lynx conservation and lessen the economic burden of coexisting with lynx, but must be used carefully, as poorly designed compensation system can lead to opposite effect by increasing the level of conflict and lower the acceptance of the large carnivores (Interreg CE 3Lynx 2018). It must also be kept in mind that compensation does not reduce the number of attacks on livestock.

7. DISCUSSION

Given threatened status of many populations, active conservation remains essential for long-term survival and recovery of the lynx in Europe. This includes variety of activities, including reintroductions, reinforcements, public education and awareness raising, prey management, prevention of poaching, and mitigation of conflicts. Some methods are more effective than others and not all approaches are effective everywhere and in all contexts. Sharing experiences, especially about the best practice examples, can therefore importantly facilitate conservation efforts, especially in regions where no such work has been attempted before.

Because lynx was in the past exterminated from most of Europe and due to relatively poor dispersing abilities, reintroduction and reinforcement projects will continue to play important role in the future of lynx conservation in Europe. In the past decades, such projects usually focused only on the translocation of animals. Advances in conservation science made it clear, that human dimension of such activities should not be neglected, as this often determine whether the efforts will be successful in the long term. According to this, modern reintroduction and reinforcement projects involve also several parallel activities designed to ensure support of local communities, such establishment of local consultative groups within the LIFE Lynx project.

Public education is not limited to projects dealing with lynx translocations, but is often needed also in regions where lynx populations have been established for a long time, but local communities remain poorly informed about this elusive species. Many projects across the Europe are now successfully working on education of local communities using traditional and novel approaches. This includes creation of consultative group meetings and using local opinion makers and trusted individuals to spread reliable information about lynx or involving important stakeholders, such as hunters, in monitoring activities.

Success of conservation projects, which result in increasing lynx numbers and distribution range, can also lead to increase in conflicts, like livestock depredations. This necessitates that lynx managers must be prepared to deal with conservation success and start thinking about the best ways to prevent conflicts form escalating to levels that might negatively affect public support or even result in illegal lynx persecution. Therefore helping the livestock owners with preventive measurement is essential. Also compensation for their losses of livestock could be a way to mitigate negative tendencies toward the lynx and help to buy time before effective preventive measures are implemented. Also here sharing experiences with other countries can greatly facilitate the process. This makes knowledge of what works and what does not in protection of livestock extremely valuable and many countries could for example benefit from years of testing already done in areas like Switzerland.

International collaboration has already provided several positive examples, including great improvements in research, monitoring and conservation of the critically endangered Balkan lynx highlighted above. Recently, EuroLynx network has been established in Europe, which is expected to further promote collaborative science based on knowledge and data sharing to investigate the ecology of the Eurasian lynx and support science-based management (https://www.eurolynx.org/).

Finally, it should not be forgotten that large carnivores can be used as very effective umbrella species, thus conserving lynx can be beneficial for conservation of many other species with which they coexist and habitats they live in.

FINAL CONCLUSIONS

Lynx is making a successful comeback in many parts of Europe and we are observing an increasing number of recovering populations throughout the regions where it was once exterminated. Many countries have made considerable progress in the past decade in terms of studying and monitoring their lynx populations. This includes implementation of robust systematic monitoring programs, using advanced technology and up-to-date analytical approaches, often at transboundary level with the help of international collaborations. They adapted the existing monitoring schemes to assess relevant population parameters for their resident lynx populations or optimized the way monitoring programs are implemented in response to changes in policy or the state of the environment. Moreover, international projects and funding schemes (e.g. Interreg and LIFE programs) have enabled development and implementation of monitoring programs, as well as facilitated sharing of good practices among countries with decades of experience and countries that are only starting to explore the status of their lynx populations. While not so long ago population-level monitoring was rare, nowadays transnational cooperation is becoming a standard for populations that span across national borders. Also with the help of the EuroLynx network, we can expect further standardizations in monitoring of lynx populations and promotion of data sharing.

Various threats still remain for lynx to prosper in Europe and some challenges are evident and inevitable. Conservation activities should be connected with efficient monitoring programs, which can provide feedback to lynx conservation and management programs. Even in stable populations, monitoring of their status has showed to be important for identifying newly emerging threats. It was also shown that in some areas lynx have difficulties spreading outside protected areas, primarily due to unsustainable levels of poaching, which represent a major challenge for the future. Hunter associations, police, farmers and spatial planners should be the targeted stakeholders to participate in reducing illegal killing and improving ecological connectivity, as well as increasing lynx acceptance. Elsewhere lack of sufficient prey base necessitates that more attention is given to conservation and management of wild ungulates. In this respect, collaboration with other sectors would be highly beneficial to improve the efficiency of conservation activities.

In recent years, participatory approaches and good communication with local communities and key stakeholders seems to be a prerequisite for any conservation program to succeed. With some good examples, like Scandinavia and Dinaric Mountains, long-term conservation and acceptance of lynx seem possible. Unfortunately, building of relationships is a long process without any immediate tangible results and can be quickly ruined if improper decisions are taken. Still, it seems that it could be the investment worth making to safeguard the lynx persistence in a human-dominated landscape of Europe, where hopefully one day human interventions in the form of reintroductions and reinforcements will no longer be needed.

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APPENDIX 1

Translated questionnaire from lynx monitoring in Slovenia in 1990

Institute for Forestry Management
Department for hunting
Večna pot 2, 1000 Ljubljana, Slovenia
Phone number: 263 -363

LYNX SURVEY

Goal of the survey is to monitor lynx in Dinaric Mountains after the reintroduction of 6 individuals (3 females + 3 males) in Kočevsko in 1973. Ecology, biology, movement, abundance, population growth, mortality, diet and the cull of the lynx will be monitored. We are kindly asking hunters and foresters, to inform us regularly where lynx have been tracked (A), seen (B) and heard (C), especially in the mating season which is early spring, although lynx can be heard throughout the year. Your information is a valuable contribution to Department for Hunting and will serve for research and monitoring of the lynx after the reintroduction.

(A) INDIRECT SIGNS

DATE:

HUNTING GROUND:

HUNTING DISTRICT:

1. Snow tracking? - yes - no
2. Tracks in the mud? - yes - no
3. Scat? - yes - no
4. Prey remains? - yes - no
5. Detailed location:
6. Were lynx tracks present at the game trails?
7. How many lynx were tracked?
8. Was there any difference in the footprint size (female + kittens)?
9. Lynx resting site description:

(B) DIRECT OBSERVATION

1. Description of the location
2. Date and time:
3. One or more lynx observed:
4. Difference in the size of the animals (female – kittens):
5. Did the lynx stand, rest or run:
6. Distance from lynx:
7. Lynx was seen in: - forest, - open area, - at the feeding site, - at the kill site etc.

(C) VOCALIZATION (in the mating season from 20.2 to 10.4)

1. Hearing of the mating calls: – once, - multiple times
2. Location, date and time:

Name, surname, address:

Please send the questionnaire immediately after the fulfillment and send it to the Institute address (upper left corner).