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The Eurasian lynx in Continental Europe

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Guidelines for authors are available at www.catsg.org/catnews

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Cover Photo: Camera trap picture of two Eurasian lynx kittens in north-eastern Switzerland. 11 December 2014 (Photo KORA).

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EUROLYNX: Collaborative science for studying Eurasian lynx movement ecology at the range of its distribution

EUROLYNX (European Lynx Information System) is an open, collaborative project based on a spatial database that stores shared Eurasian lynx *Lynx lynx* data to investigate variation in behavioural ecology along environmental gradients or population responses to specific conditions, such as habitat changes, impact of human activities, prey densities, or livestock husbandry methods. EUROLYNX aims to promote comparative theoretical and applied research into Eurasian lynx behaviour and ecology at the European scale. The open, bottom-up and cooperative structure of EUROLYNX spurs proactive engagement of partners and assures that they are involved in all stages of research. Currently, 42 groups from 19 countries have joined the initiative and nine working groups have been established to address ecological questions, to prepare research protocols and to push methodological advances forward.

In recent years, advances in research methodologies, such as genetic analysis, camera trapping, bio-logging and remote sensing, have opened new research avenues in ecology and conservation biology. In particular, the introduction of satellite-based telemetry, so called GPS telemetry, has provided the opportunity to observe wildlife behaviour in their natural habitat in an unprecedented manner at low cost (Cagnacci et al. 2010). Aside from research on migratory bird behaviour, telemetry studies have mainly been performed in local study sites by single research groups providing spatially limited insights into the ecology of the target species. Reasons for this are manifold, but the most important are probably the huge effort required to establish telemetry projects and limited possibilities for single research groups to perform studies in multiple countries. However, a continental-scale approach is needed for a better understanding of the behavioural responses to climate and ecosystem changes, management practices, and human disturbance. This was the rationale underpinning the establishment of the EURODEER initiative twelve years ago (Cagnacci et al. 2010). Indeed, such large-scale research is particularly valuable in the case of large carnivores, since conservation planning for these species requires information crossing regional and/or national boundaries. To enable such research, multi-population datasets across environmental gradients are a prerequisite. Specifically, standardised animal and environmental datasets across large spatial extents providing high spatial and temporal resolutions are most useful. Satellite telemetry is well suited for such an approach as the data are relatively simple, consisting of just geographical coordinates and a timestamp at its most basic level. In addition, satellite remote sensing platforms such as the Landsat and Sentinel satellites can provide a variety of standardized products describing the habitat and environmental conditions across large areas, overcoming the limited comparability of local approaches (Oeser et al. 2019). Moreover, spatial databases are needed to store the data (Urbano et al. 2010). However, technical advancements are rendered unim-

portant when a close collaboration between different research groups is missing, which is able to take advantage of the opportunities provided by technology.

To overcome this shortfall, EUROLYNX was founded – a collaborative scientific initia-tive for data and knowledge sharing on movement ecology of Eurasian lynx. Its aim is to investigate variation in Eurasian lynx behavioural ecology along environmental and climatic gradients and to record population responses to specific conditions, such as habitat changes, impact of human activities, and different prey density and distribution.

EUROLYNX is part of EUROMAMMALS, an umbrella platform that coordinates species-specific projects on European populations of roe deer *Capreolus capreolus* EURODEER, red deer *Cervus elaphus* EUREDEER, wild boar *Sus scrofa* EUROBOAR, and European wildcat *Felis silvestris* EUROWILDCAT. Currently, EUROMAMMALS promotes collaborative science among 100 research groups from research institutes, wildlife offices, protected areas and NGOs with scientific purposes from 30 countries. EUROMAMMALS is supported by an external sponsor and by the voluntary contributions of each partner.

Structurally, EUROLYNX is a database that serves as a repository where data from partner institutions are harmonised, stored and shared for analyses. The EUROLYNX database is hosted on the server of Fondazione Edmund Mach – Centro Ricerca e Innovazione (Italy). The database is constructed to include data at the individual level (GPS and VHF locations, activity data, etc.), the site level (prey density, management, food composition etc.), population level (survival, mortality, genetic structure, etc.), and any other specific data partners believe necessary to be included in the dataset (e.g. body mass, reproductive success, personality, etc.). Furthermore, animal data are automatically annotated with environmental data within the database. These include the Normalized Difference Vegetation Index (NDVI), tree cover density, snow cover, human footprint index, road networks, and land cover. A detailed description of the database can be found in Urbano & Cagnacci (2014). The strength of the database's approach is the standardisation of data among the different research groups, allowing seamless analysis. Through the use of processing protocols and automated as well as manual quality checks, the standardisation also improves data quality. In addition, the database assures long-term data preservation. This is especially important for research groups or PhD students who do not work solely on lynx. In both cases, the data might disappear after a thesis or project report is written. Therefore, it is also on the agenda of EUROLYNX to recover old data and make it available through the database. Moreover, the database also allows collaboration with other large e-infrastructures such as Movebank (Kranstauber et al. 2011) and most importantly, strengthens the links between the different groups working on Eurasian lynx. To ensure this collaboration, each group must agree to specific rules which regulate the way the groups will work together. These "Terms of Use" must be understood and signed by every group that wants to join EUROLYNX.

Fig. 1. Participants of the second EUROLYNX workshop at the Mammal Research Institute Polish Academy of Science, Białowieża, Poland.

EUROLYNX Taking Action

The initiative was founded at a workshop, which took place at the Bavarian Forest National Park, Germany, 15–17 October 2018. In the first year, the activities were focused on setting up and preparing the web page and database as well as dealing with basic communication tasks, organising terms of use documents from partners, website account management, preparation of data templates, database table preparation and data collation. Furthermore, the data curators attended a training workshop at the Fondazione Edmund Mach to learn data curatorship from the core EUROMAMMALS team. The second EUROLYNX workshop was hosted at the Mammal Research Institute of the Polish Academy of Science in Białowieża, Poland 28–30 October 2019 (Fig. 1). Funding for the first year was secured from WWF-Poland and Bund für Umwelt und Naturschutz Deutschland (BUND). The third workshop was held digitally from 7–8 October 2020 due to the corona pandemia, but allowed attending to more than 70 members and students. Moreover, data curatorship was supported by a grant from WWF Germany through the Euro Large Carnivore Project.

During the two workshops, the following working groups have been established:

1) Drivers of survival and mortality of Eurasian lynx in European landscapes

The objective of this working group is to determine European-wide threats to lynx populations. Therefore the working group analyses survival and causes of mortality across ecological and human disturbance gradients The working group is led by the PhD student Joe Premier, University of Freiburg, Germany.

2) Assessing Eurasian lynx habitat in Europe using cross-population wildlife tracking data

The objective of this working group is to produce a continental wide habitat suitability map for Eurasian lynx. Therefore the work-

Fig. 2. Location of the 41 member groups from 19 countries of the EUROLYNX network (see also Supporting Online Material Table SOM T1).

ing group will test the usefulness of GPS telemetry data from lynx populations across Europe. The goal is to identify – based on a systematic model transferability assessment – habitat models that are transferable across ecological gradients while capturing local responses. The working group is led by the PhD student Julian Oeser, Humboldt-Universität zu Berlin, Germany

3) Home range selection of Eurasian lynx populations across landscape gradients

The objective of this working group is investigating the effect of sex-specific behaviour and population density on the 2nd order habitat selection. Specifically, they analyse if males are less selective as they need to cover larger areas, whereas females select higher-quality home ranges to raise and protect their kittens. Moreover they will evaluate if with the animals prefer lower human presence, in the home range core. The working group is led by the MSc student Lucia Ripari, Università degli Studi di Torino, Italy.

4) Harmonisation and standardisation of Eurasian lynx camera trapping

The objective of this working group is to standardise camera-trapping protocols for abundance and density estimates of Eurasian lynx to allow a straightforward comparison of estimates between study areas. Therefore, the influence of sampling design, variables recorded in the field, different analytical approaches, inclusion of covariates and telemetry data will be analysed. The working group is led by Fridolin Zimmermann, Kora Switzerland and Kirsten Weingarth, Habitat – Wildlife Services, Austria.

5) Machine learning (ML)-based pattern recognition via Convolutional Neural Networks in order to identify individual Eurasian lynx captured by camera traps on the basis of their distinctive coat patterns

Currently, thousands of photographs of captured lynx individuals are processed manually and require considerable human effort and time to be analysed visually. This method of individual identification is a tedious, time-consuming task, inducing bias related to the observer. Therefore, we plan to implement a ML-based approach by training a Convolutional Neural Network within the Python (KERAS/Tensorflow) programming environment. The resulting algorithm should assist in processing and analysing collected data and allow for accurate (semi)automatic individual image classification of Eurasian lynx. The working group is led by Robert Behnke, University of Veterinary Medicine Vienna, Austria.

6) Effects of human disturbance on lynx activity patterns

Understanding the activity and habitat requirements of large carnivores, in regard to human disturbance, is a fundamental piece of information for developing effective conservation and management actions. Therefore, we plan to analyse the spatial and temporal tolerance of lynx regarding human disturbance across Europe's ecological gradients. Our main objectives are to identify the forms of human disturbance with greater impact on lynx activity patterns across Europe and to establish if spatial or temporal patterns of lynx activity adjust to the existence of long-time disturbances. The working group is led by Julie Louvrier, Leibniz Institute for Zoo and Wildlife Research, Germany.

7) Movement ecology of Eurasian lynx in relation to foraging behaviour

The working group aims to analyse lynx movement patterns in respect of their foraging ecology at the continental scale, across different landscapes in Europe. Specifically, the questions addressed in this working group are: how does lynx kill rate, feeding and searching times change across Europe and what determines the temporal and spatial distribution of kill sites? The working group is led by the PhD student Teresa Oliveira, University of Ljubljana, Slovenia.

8) Movement ecology of Eurasian lynx during the reproductive season

Research on lynx ecology during the breeding season has mainly focused on den site selection, while less information is available about

changes in movement patterns during the mating and denning seasons. This working group will try to fill this knowledge gap by asking how sex-specific movement patterns change during the mating period and how females use space while nursing immobile kittens. PhD student Teresa Oliveira, University of Ljubljana, Slovenia.

9) Shall I cross? What drives spatiotemporal patterns of road crossings and vehicle collissions of lynx throughout Europe

The objective of this working group is to shed light on the poorly understood behavioural response of Eurasian lynx towards roads at different spatial scales. The working group wants to predict spatiotemporal road crossing behaviour and to compare these crossing sites with lynx-vehicle collisions. Therewith they want to provide knowledge on the habitat and roadside characteristics that influence the outcome of road crossings and to predict spatiotemporal "hot-spots" of felid vehicle-collisions. The working group is led by Matteo Bastianelli, Bavarian Forest National Park, Department of Visitor Management and National Park Monitoring, Germany.

10) The timing and synchrony of birth in Eurasian lynx

In contrast to most felid species lynx are strict seasonal breeders. The timing of birth is thus most likely crucial to match weaning with a period rich in resources. This working group is aiming to disentangle the mechanism behind the timing and synchrony of birth in lynx. They expect that lynx in northern latitudes will have a later timing and a shorter birth period due to more extreme climates than lynx in more southern latitudes.

11) Dispersal in human-dominated landscapes

For the conservation of large predators in human-dominated landscapes, understanding the process of dispersal is of great importance. This is especially true for Eurasian lynx, which still occurs in small isolated populations in much of its range. Dispersal plays a key role to achieve connectivity between these populations, allowing genetic exchange. This working group will analyse the movement of dispersers with step selection functions to obtain a better understanding about the requirements of subadult lynx towards human dominated landscapes.

Summing up, in the first years after establishment, we were able to establish the central infrastructure and motivate many groups to join the EUROLYNX-network (Fig. 2). The database contains 680 animals and over 390,000 GPS and 74,000 VHF positions. Also a data table to collect kill series and animals found dead is implemented. Now, EUROLYNX connects a large part of the European community working on Eurasian lynx, thus facilitating their cooperation. During the next years, the focus will be on the integration of further data sets such as genetics and food composition and on the funding of PhD students to facilitate the analysis of data and the cooperation with other cat networks world wide In parallel, we must secure baseline funding for the data curation and the development of the databases. In addition, the first scientific publications are expected for 2021. EUROLYNX will also work on the definition of protocols and standards for future data collection and will foster the identification of gaps in research knowledge to focus the next generation of fieldwork on filling these gaps to secure lynx survival.

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Supporting Online Material SOM Table T1 is available at www.catsg.org.

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Radio-collared lynx collecting data for movement analyses with the EUROLYNX network (Photo KORA).