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Towards large-scale wolf population monitoring
Challenges and perspectives

Book of Abstracts

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"Towards large-scale wolf population monitoring-Challenges and perspectives"

Organized by:

University of Turin (UniTO), Protected Areas of Maritime Alps (APAM) and Metropolitan City of Turin (METO)

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Introduction

Quantifying abundance is fundamental for wildlife conservation and management. Indeed, reliable information on the number of individuals or wildlife population densities is key to support management decisions, harvest regulations, define conservation status, and further our understanding of ecosystems functioning. Large carnivores, and especially wolves, are highly controversial, and the assessment of their protection status or decisions about their management are often accompanied by intense political and public debate. This intense public scrutiny makes reliable and up-to-date population size estimates highly sought after by various government offices. Population size continues to be challenging to estimate in nature, especially when species are elusive, vagile, and distributed over large areas. This is because population sampling is never complete, making it necessary to use appropriate analytical methods that account for imperfect detection when estimating population size. Important advances have been made over the years in understanding imperfect detection in part due to the wealth of capture-mark-recapture data generated by non-invasive genetic sampling methods, whereby individual genotypes are identified from DNA extracted from samples deposited in their natural environment. Here, the strict connection with recent developments in genetic techniques. Despite the recent multidisciplinary approaches and methodological advances mentioned above, estimating the size of wolf populations is currently even more challenging due to the recent spatial and numeric expansion of the species at the European scale. Monitoring large scale wolf populations has become more costly and logistically demanding, as it requires investigations over large areas with multi-political jurisdictions, and the processing of numerous samples with harmonized protocols. Hence, this conference will focus on recent progress in estimating large-scale wolf populations in Europe and discuss challenges, highlighting experiences where large wolf populations have been estimated in Europe and future perspective.

Spatial capture-recapture and the Scandinavian wolf: mapping population density and beyond

Pierre Dupont, Norwegian University of Life Sciences

The Scandinavian wolf population has been monitored using non-invasive genetic sampling for over 10 years in both Norway and Sweden. Using this unique dataset, we developed and applied large scale spatial capture-recapture models to map wolf population density and dynamics throughout both countries. In this talk, I outline the different developments we proposed over the years and how they allowed us to go beyond population size and towards a fully spatio-temporal model of the Scandinavian wolf population. Most importantly, this enabled us to provide crucial information to managers, such as estimates of population growth and recruitment rates or spatially explicit mortality probabilities.

For more information on the research activity:

- *Bischof, R., Milleret, C., Dupont, P., Chipperfield, J., Tourani, M., Ordiz, A., ... & Kindberg, J. (2020). Estimating and forecasting spatial population dynamics of apex predators using transnational genetic monitoring. Proceedings of the National Academy of Sciences, 117(48), 30531-30538.*

For more information on the method developed by the team to estimate and map variation in survival throughout the wolf population in Scandinavia:

- *Milleret, C., Dey, S., Dupont, P., Brøseth, H., Turek, D., de Valpine, P., & Bischof, R. (2023). Estimating spatially variable and density-dependent survival using open-population spatial capture–recapture models. Ecology, 104(2), e3934.*

For more information on the status of the wolf population in Sweden and Norway:

- *Milleret, C., Dupont, P., Åkesson, M., Brøseth, H., Kindberg, J., & Bischof, R. (2021). Estimates of wolf density, abundance, and population dynamics in Scandinavia, 2012-2021.*

A multidisciplinary approach to estimating wolf population size for long-term conservation in the Italian alpine regions with sampling optimization

Francesca Marucco[1] and Virginia Boiani[1,2]

[1] DBIOS-University of Turin,
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As wolf population size estimate are increasingly demanded by administrations and wildlife management entities, we developed a system for comprehensive population estimation across the Italian alpine region (100,000 km2), involving 1513 trained operators representing 160 institutions. This extensive network allowed for coordinated genetic sample collection and landscape-level spatial capture–recapture analyses that transcended administrative boundaries to produce the first estimates of key parameters for wolf population status assessment. Wolf abundance was estimated at 952 individuals (95% credible interval 816–1120) and 135 reproductive units (i.e., packs) (95% credible interval 112–165) (Marucco et al. 2023). We also estimated that mature individuals accounted for 33–45% of the entire population. The monitoring effort was spatially estimated thereby overcoming an important limitation of citizen science data. We took advantage of the overall data collected to quantify how reducing the sampling and subsequent genotyping effort influence the estimate of wolf population size across the Italian Alps using spatial capture-recapture (SCR) methods. We investigated the effect of *(i)* decreasing the number of genotyped samples, *(ii)* decreasing the spatial extent of search transects and thus the number, and *(iii)* decreasing the number of search-transect repetitions on the SCR abundance estimates at the Alpine scale. By reducing the number of transects to 75% and fixing the number of search-transect repetitions to a maximum of 6, we obtained density estimates comparable to using the whole data set. While, neglecting the search effort and reducing only the genotyped samples resulted in higher estimates and had a great influence on the precision. This is an important approach for promoting wolf–human coexistence based on long term wolf abundance monitoring and an endorsement of large-scale harmonized conservation practices.

Marucco F., M. V. Boiani, P. Dupont, C. Milleret, E. Avanzinelli, K. Pilgrim, A M. K. Schwartz, von Hardenberg, S. Perrone, O. Friard, A. Menzano, F. Bisi, U. Fattori, M. Tomasella, S. Calderola, S. Carolfi, P. Ferrari, C. Chioso, F. Truc, G. Bombieri, L. Pedrotti, D. Righetti, P. L. Acutis, F. Guglielmo, H. C. Hauffe, C. Rossi, R. Caniglia, P. Aragno, V. La Morgia, P. Genovesi, and R. Bischof. (2023). A multidisciplinary approach to estimate wolf population size for long-term conservation. Conservation Biology. DOI: 10.1111/cobi.14132

Estimating wolf distribution and abundance with integrated population modelling: the first wolf assessment in south-central Italy

Vincenzo Gervasi, ISPRA-Italian Institute for Environmental Protection and Research

In 2020, a national wolf population estimation project was launched in Italy, as a result of a simultaneous and standardized demographic sampling of the two portions of the population. In central-southern Italy, given the vast area supposedly occupied by the species (about 150,000 km^2), the lack of previous knowledge in vast portions of the wolf distribution, and the limitations in the maximum achievable field effort, we adopted a design based on the demographic sampling of a portion of the whole population, identified through a stratified random sampling, and aimed at collecting both presence signs and non-invasive genetic data.

The data collection strategy was articulated into: *(i)* an extensive survey in 25% of the study area, aimed at collecting wolf presence data; *(ii)* an intensive survey carried out in 13 sampling areas, defined by a 3x3 arrangement of 9 cells, and aimed at collecting non-invasive genetic sampling. Both the intensive and extensive data collection took place from 1st October 2020 to 30th April 2021. A network of field staff from several institutions concerned with wildlife management (N = 344), volunteers (N = 431) and forestry service staff (N = 725) systematically collected field data on a network of transects, selected along roads and trails, and through photo-traps placed across the study area.

For the estimation of wolf distribution, we built and analyzed a single-season, multiple data-source, multi-event occupancy model, which accounted for the different types of sampling processes involved in data collection (transects and photo-traps) and for the possibility of species misidentification when collecting wolf scats in areas where also dogs where present. For the estimation of wolf abundance, we integrated the occupancy model with a Spatially Explicit Capture-Recapture model (SECR). The occupancy model estimated that 74.2% of the study area was occupied by the species, for a total extent of the wolf distribution of 108,534 km^2. The integrated model produced an estimate of total population size for the Apennine wolf population of 2,557 individuals (SD = 171.5; 95% CIs = 2,127 – 2,844), with an associated CV = 6.7%. By merging our estimate with the one produced for the Alpine regions, we estimated a total population size of 3,501 wolves (SD = 249.5; 95% CIs = 2,949 – 3,945) in the whole Italian peninsula.

Simulations showed that the integrated model was associated to an average tendency to slightly underestimate population size, with the average relative bias in the estimates being -12.9%. In future at least 30% of the study area should be sampled for presence signs and 30% for non-invasive genetic data, to provide a high probability of reducing bias below 10%.

Monitoring large carnivores over large scale: what's next for the successful recovery of wolves in France?

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[1]Office Français de la Biodiversité – Dpt. of Applied Research and Expertise – France
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Wolves naturally recolonized France in the early 1990s from the Italian population, now covering all the alpine range. The highly human-dominated landscape of the Rhone valley, west of the French Alps, has slowed down the recovery of the species beyond the alpine chain. However, this barrier is still permeable to some dispersers as new packs have indeed appeared west of the river since 2019.

About 3500 field experts are monitoring the wolf presence in France. This extensive network collects around 1800 biological samples per year which are then analyzed with microsatellite genotyping method. Using multi-event open capture-recapture models, population size is estimated at the end of each winter along with confidence intervals accounting for detection heterogeneity. Population size estimates are requested by authorities early spring to define the maximum number of wolves that can be culled to reduce depredation. Wolf population size in 2023 in France is expected to range between 1000 and 1210 individuals.

A national action plan aims to reconcile outdoor livestock rearing and wolves, while maintaining the wolf population in a favorable conservation status. Governmental authority promotes and funds prevention measures against wolf depredation, including the use of culling. Wolf survival decreased from 0.76 to 0.68 as culling increased from 10% to 20% of the estimated population size. While Mortality remained stable for scent marking individuals (residents) the survival dropped down from 0.63 to 0.28 for transient individuals, thus being probably less impactful for the overall population dynamics. Transition probabilities from resident-to-transient showed significant higher turnover rates as culling increased, suggesting the destabilizing influence of wolf removals on pack dynamics, both producing more transients as well as a higher propensity to set up new packs.

This high turnover associated with increasing pack density makes it very challenging to accurately monitor the population in space and time at the national scale, leading to greater uncertainty in population size estimates. Among the alternatives, patch occupancy models appear as a relatively cost-efficient metric, useful in adaptive management in order to detect changes in the population while also accounting for imperfect detection. We optimized these models to document changes in wolf pack dynamics across space and time in France. This metric appears reliable to identify pack occurrences and disappearance also avoiding false positives, but is less performant to identify pack disappearance in areas of high wolf density. Stakeholders and the general public often focus on the number of wolves in

the country, the hardest number to document accurately at large scale. The change in wolf occupancy as materialized through dynamic maps across years combined with studies on the underlying mechanisms driving population trends and livestock damages may become robust and cost-effective indicators to monitor the conservation status of the wolf population at the national scale as well as useful for local management issues.

Wolf monitoring in Germany – Keeping track of a fast-growing wolf population

Ilka Reinhardt, LUPUS – German Institute for Wolf Monitoring and Research

After 150 years of absence the first wolf pack was confirmed in Germany in 2000. From the Lausitz area in the German-Polish border region the wolf showed a rapid population growth and subsequent spread across western central Europe. In 2021 more than 200 wolf territories were confirmed in Germany, most of them in the North-Eastern part of the country. As Germany is a federal state wolf management including monitoring is under the jurisdiction of the 16 federal states. Wolf surveillance is conducted annually with the goal of obtaining reliable estimates for area of occurrence and population size at the national level. Population size survey is conducted as a minimum count of the number of packs and pairs. While the continuous generation of wolf monitoring data is funded, organized, and conducted on the federal state level, uniform data evaluation and interpretation across administrative borders is ensured by common national monitoring standards and yearly national monitoring meetings. The backbone of the current monitoring system is the genetic identification of wolf family groups, thus allowing genetic differentiation between neighbouring territories. In 2021 in about 75 % of the wolf territories at least one of the breeding individuals was genetically identified with large differences between the federal states. As the population is expected to farther increase alternative monitoring approaches are explored currently that are feasible for the German situation and meet the legal requirements as well as the public demand for information. It is obvious that there are no simple and cheap monitoring approaches that provide both reliable population estimates and detailed information on the current status of the wolf population for the public and the authorities, while at the same time providing the information necessary to carry out management removals in a meaningful way and to monitor the effects of such removals on the wolf population in a reliable way. As the country is for reasons of competence divided into 16 monitoring units (federal states) the current monitoring approach seems feasible also with a farther growing population, however ways for conducting monitoring and data evaluation in a more efficient way should be explored.

In order to support the wolf management and monitoring within the federal states several tools and resources are provided by the national authorities. In frame of the scientific consortium "Federal documentation and consultation centre on wolves" (DBBW) a monitoring data base was developed and is available for all states allowing for detailed data storage, exchange and analyses. The DBBW advises federal and state conservation agencies on all wolf-related issues upon request and compiles the wolf monitoring data annually on the national level. The results are published on the DBBW website https://www.dbb-wolf.de, providing timely and detailed information of wolf distribution and other aspects concerning the current recolonization process.

Large scale wolf monitoring without snow and genetics, and in a transboundary context. Some insights and challenges from Spain

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Estimating the size of wolf populations is a contentious issue, particularly when it comes to inform decision-making processes and to evaluate legal commitments. The number of wolf (breeding) packs is a reasonable target for wolf monitoring at large spatial scales, such as the case of Spain. This approach may make wolf population size estimates more homogeneous in a transboundary and regional context, and over time, as soon as the criteria used to confirm, or to estimate, a reproduction event are comparable. In Spain, the number of (breeding) packs as a monitoring goal is included in the two existing guidelines at the national level (from 2005 and 2022, non-legally binding), and is adopted at the regional level. But, the recommendation for the frequency of monitoring has varied between guidelines (2005: every 10 years, 2022: every 6 years in line with the Habitats Directive reporting period, following article 17 of the directive). However, wildlife conservation is under the jurisdiction of autonomous regions in Spain and, although a basic agreement on a common survey approach was reached in 2012 in the wolf working group, autonomous regions decide if to survey the wolf population, how, frequency of surveys, effort to invest, technical or scientific direction, and the collection and interpretation of field data. So far, the national wolf survey has been the outcome from the addition of regional surveys, coordinated by the national government, and avoiding double counting of transboundary (regional) packs. Political tensions at different administrative levels can make coordination difficult. Wolf monitoring in Spain is constrained by the lack of snow and, therefore, the monitoring of breeding packs is carried out in summer and early autumn. Different efforts have been carried out during the last decades to improve and to optimize the estimate of breeding events at that time of the year. Wolf monitoring based on the number of breeding packs is usually focused in confirming reproductions throughout the detection of pups in summer (e.g., using howling sessions, observations, or camera trapping). Additionally, different approaches to estimate reproductive events have been developed in recent years, such as linking the intensity of territorial marking (faeces and ground scratching) and the probability that a given pack has reproduced in a given area, or the implementation of multi-method and multi-state approaches (combining different sources of field information) to estimate a number of sites with wolf reproduction (within a credible interval). Additionally, efforts have been made to improve the use of sampling methods, like howling. Thus, since pup vocalizations are higher in pitch and shorter, compared to adults, and the acoustic energy is concentrated at lower frequencies in wolf choruses without pups, an increased effort have been made on the quantitative analyses of wolf choruses to estimate the probability of pup presence. Still, there is a need to improve the coordination in different aspects of wolf monitoring across autonomous regions, such as in the interpretation criteria for minimum number of

confirmed (breeding) packs, how to estimate reproduction events, or the use of different spatio-temporal criteria to avoid double-counting of packs (e.g., application of distance criteria among den or rendezvous sites, or temporal criteria such as simultaneous howling sessions in two potential neighboring rendezvous sites or to concentrate in time the use of howling sessions in summer).

Scaling up wildlife monitoring and estimation: reconciling the individual with the population

Richard Bischof, Norwegian University of Life Sciences

Applied wildlife ecology is often aimed at the management and conservation of animal populations. Yet, when we study wild animals, individuals tend to move into the foreground. This is not surprising, as populations are made up of individuals, and individual actions and experiences ultimately add up to the dynamics and fates of populations. On the other hand, a strong focus on individuals, especially small and nonrepresentative samples, can lead to skewed inferences about real systems, with potentially detrimental consequences for conservation policy and action. Using our group's research on carnivores as an example, I outline how modern wildlife monitoring methods and specialized models can connect information about individuals with studies of populations. The approach offers a comprehensive and mechanistic understanding of how individual life histories and movements propagate to the dynamics of populations. This, in turn, can facilitate scale-transcending population management and conservation.

For more information on wolves and spatial capture-recapture:

- *Bischof R, Milleret C, Dupont P, Chipperfield J, Tourani M, Ordiz A, et al. Estimating and forecasting spatial population dynamics of apex predators using transnational genetic monitoring. Proc Natl Acad Sci. 2020 Dec 1;117(48):30531 LP – 30538.*
- *Turek D, Milleret C, Ergon T, Brøseth H, Dupont P, Bischof R, et al. Efficient estimation of large-scale spatial capture-recapture models. Ecosphere. 2020;*
- *Bischof R, Milleret C, Dupont P, Chipperfield J, Akesson M, Broseth H, et al. Estimating the size of the Scandinavian wolf population with spatial capture-recapture and conversion factors. Norwegian University of Life Sciences. MINA technical report57. 2019.*
- *Bischof R, Turek D, Milleret C, Ergon T, Dupont P, de Valpine P. nimbleSCR: Spatial Capture-Recapture (SCR) Methods Using "nimble". R package version 0.1.0. 2020.*
- *Milleret, C., Dupont, P., Brøseth, H., Flagstad, Ø., Kindberg, J., Svensson, L., and Bischof, R., 2023. Estimates of wolf density, abundance, and population dynamics in Scandinavia, 2013–2023- MINA technical report 85. 34 pp.*

For more information on tracking techniques applied to cats and foxes:

- *Bischof R, Hansen NR, Nyheim ØS, Kisen A, Prestmoen L, Haugaasen T. Mapping the "catscape" formed by a population of pet cats with outdoor access. Sci Rep . 2022;12(1):5964. Available from: https://doi.org/10.1038/s41598-022-09694-9*

- *Bischof R, Gjevestad JGO, Ordiz A, Eldegard K, Milleret C. High frequency GPS bursts and path-level analysis reveal linear feature tracking by red foxes. Sci Rep . 2019;9(1):8849. Available from: https://doi.org/10.1038/s41598-019-45150-x*

Opportunities and implications of HTS STR genotyping for standardized genetic surveys and monitoring

Marta De Barba - Biotechnical Faculty, University of Ljubljana, Slovenia.

I presented about a new approach for genotyping microsatellite markers based on high throughput sequencing (HTS) technologies. Microsatellites, often abbreviated as STRs - short tandem repeats, are among the most widely used molecular markers in wildlife studies. The new approach entails sequencing of PCR amplified STR on an HTS platform, and bioinformatic treatment of the sequence data to obtain multilocus genotypes based on both length and sequence polymorphism. Compared to the current genotyping system, this method enables standardization and automation of the genotyping process, provides greater accuracy and power to discriminate individuals, and allows direct transfer of genotype data between laboratories. In addition, the massive parallel sequencing capabilities of the new technologies and the scalable workflow makes it highly cost-effective for large genotyping projects. The utility of the approach for genetic monitoring of large carnivores was illustrated with a non-invasive genetic study for brown bears in Slovenia-Croatia, and with a novel application to individual genotyping from snow tracks eDNA of wolf, lynx and brown bears.

Litigation on wolf policy in Europe

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The return of large carnivores in Europe's human dominated landscapes is an unexpected conservation success. The wolf, in particular, has experienced a remarkable recovery with the species now being present and breeding in most European countries where it had previously become extinct. The return of the wolf, however, creates conflicts with several human activities which feed demands to know how large wolf populations are. Many countries allocate substantial efforts to provide reliable estimates of their wolf populations, as the talks during the symposium have illustrated. Wolf population estimates are political numbers in the sense that they may trigger political decisions which themselves may have consequences on wolf populations. Specifically, if it is considered that the number of wolves exceed what is considered desirable, for whatever reasons, authorities may decide to enact wolf culling or hunting. However, the wolf is by law a protected species and killing wolves can only happen under particular conditions. In many EU countries, wolves are listed in Annex IV of the Habitats Directive which grants the strictest level of protection. In some other countries, wolves appear in Annex V of that Directive, which is more flexible. In any case, European legal protection must always be reflected into the national laws of the Member States.

When national or regional authorities allow wolf killings, interested parties such as environmental non-governmental organizations (NGOs) may challenge these decisions on legal grounds, arguing that these are not in line with the legal protection conferred to wolves and ask courts to carry a legal review. This is called public interest environmental litigation and it has become an integral part of environmental policy making in many countries. Importantly, litigation may also happen to oppose wolf conservation. Administrative litigation ("contentieux administratif" "contenzioso amministrativo" "Verwaltungsstreitverfahren") can take place in national courts (i.e. administrative courts, administrative courts of appeal, supreme administrative courts or constitutional courts) or at the European Court of Justice (through referral by the European Commission following an infringement or through a request for a preliminary ruling by a national court).

Litigation is a policy instrument that remains understudied. It may be seen by some in conservation academia as better avoided since it may be perceived to exacerbate conflicts. This is misleading as litigation may instead turn conflicts into disputes in a forum (the court) where parties agree on accepting democratic rules and the authority of the law. Litigation performs a diversity of additional social functions. It is a democratic practice where members of the public have the possibility to hold governing authorities accountable. Litigation clarifies what the law really means as laws are often purposely written in broad terms, with the courts being tasked to explain what the law implies in practice for the cases they handle. For authorities, litigation allows through trial and error to develop lawful policy:

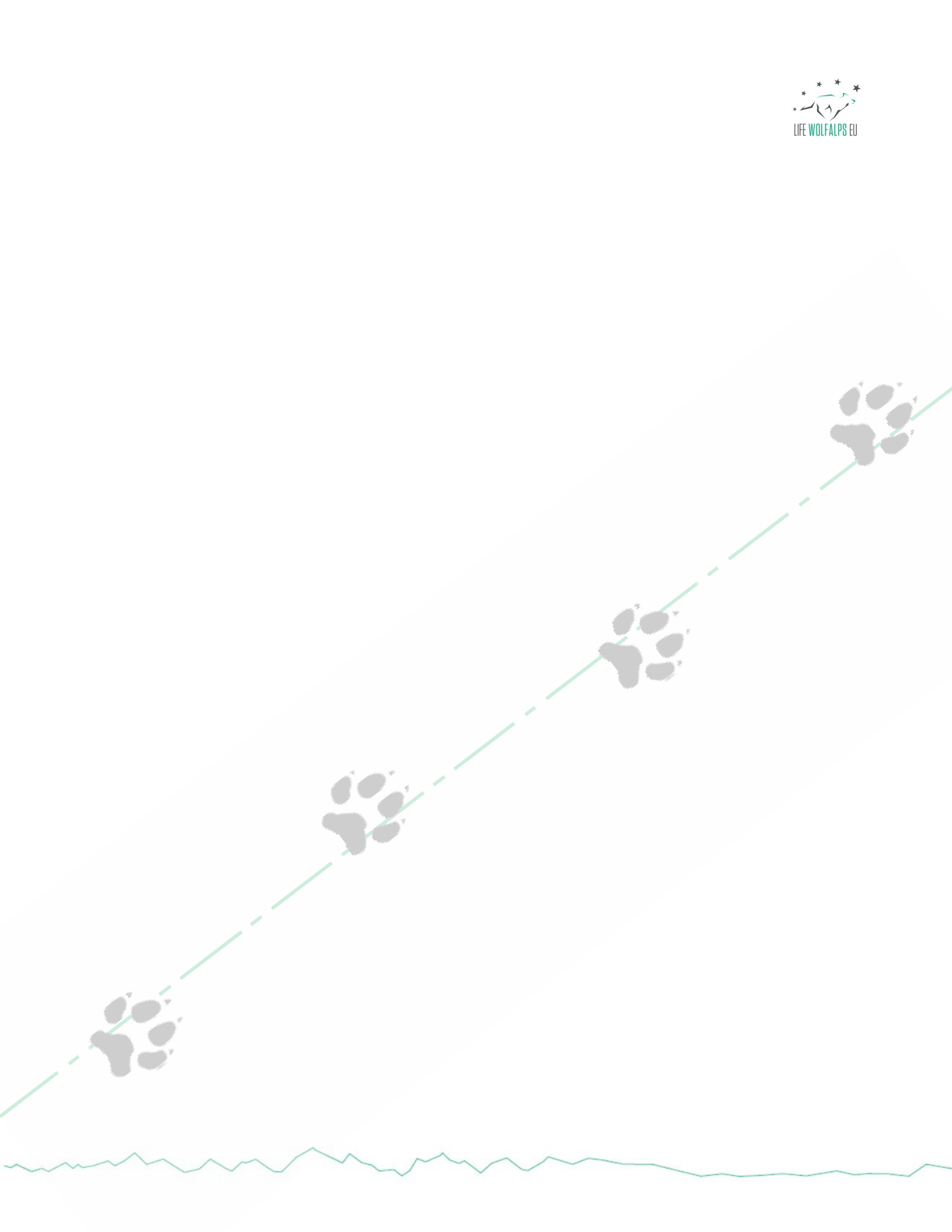
decisions rebutted by courts may be avoided in the future, while decisions validated by courts may be explored further. Finally, litigation may have a direct or indirect impact on wolf populations.

I present a research project funded by the Swedish research council FORMAS and aimed at developing a systematic mapping of litigation for species conservation in the European Union. We map the extent, scope, nature, and outcome of public interest litigation for species protection in the EU. More specifically, we map administrative, civil and constitutional court cases about the direct protection of wild animal species in the EU. The relevant laws are the Birds Directive and the Habitats Directive. We focus on litigation where members of the public, typically NGOs, take legal actions against local or governmental authorities for decisions, actions, or failures to act regarding species. I present preliminary results based on the wolf related court cases we have already collected and provide a deeper analysis of such court cases in France.

We collected a total of 275 French wolf related court rulings during the past 20 years. Unsurprisingly, we found that wolf litigation occurred more often in administrative courts located in regions where wolves first returned (i.e. South-East of France). Animal welfare or protection associations were the most active and successful plaintiffs. The State administration represented by its Préfets was also a plaintiff in lawsuits against illegal culling decisions made by mayors. The Préfet des Alpes Maritimes and the Minister of the Environment were regular defendants for decisions to cull wolves that were litigated by nature protection associations. These associations overall had a case winning rate higher than 50%. There were no immediately obvious inter-annual trends in wolf litigation. Our analysis did not allow us to quantify the total number of wolves that were effectively protected from culling decisions because court rulings made after the implementation of culling decisions did not specify whether the animals were already killed or not. Be it as it may, NGOs appear to conduct legally relevant litigation in view of the high success rate they achieve and conservation lawsuits belong to the portfolio of available conservation instruments.

Our project takes place while the legal landscape regarding wolves has become more dynamic, with legal changes to their protection being implemented or discussed. For example, in Italy, the province of Trentino has issued a culling permit for wolves for the first time. Austria has changed its legislation to fast-track wolf culling while limiting possibilities of appeal. The European Commission has recently launched a process to revise the wolf protection status. We may have now reached "peak wolf" in Europe and the coming years may see a reversal of the species recovery, with local re-extinctions. Legal aspects, including litigation, will be central.

https://www.clawsandlaws.org/courts-conservation/



The LIFE WOLFALPS EU project works to improve coexistence between the wolf and the people who live and work in the Alps and the Ligurian-Piedmontese Apennines by building and implementing shared solutions together with stakeholders to ensure the long-term conservation of the wolf in the Alps and along the Apennine corridor. LIFE WOLFALPS EU operates throughout the Alps and the Ligurian-Piedmontese Apennines, involving twenty Italian, Slovenian, French and Austrian partners and dozens of Institutions and associations that support the project.

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