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"Coordinated Actions to Improve Wolf-Human Coexistence at the Alpine Population Level"

Action A5

Technical Report

THE INTEGRATED MONITORING OF THE WOLF ALPINE POPULATION OVER 6 COUNTRIES

Monitoring standards and strategy to optimise the integrated monitoring of the status of the wolf alpine population

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The Wolf Alpine Group (WAG), who produced this document, is composed of the following representatives of each alpine country. In particular by:

ITALY: Francesca Marucco (University of Turin, Department of Life Sciences and Systems Biology - LIFE WolfAlps EU Project Partner), who coordinated the realization of this document; and Elisa Avanzinelli (Large Carnivore Center, Maritime Alps Protected Areas - LIFE WolfAlps EU Project Partner);
FRANCE: Christophe Duchamp and Ricardo N. Simon (French Biodiversity Agency (OFB) – LIFE WolfAlps EU Project Partner);
SLOVENIA: Hubert Potočnik (University of Ljubljana - Department of Biology - LIFE WolfAlps EU Project Partner);
AUSTRIA: Jörg Rauer and Felix Knauer (University of Veterinary Medicine Vienna - VETMEDUNI – LIFE WolfAlps EU Project Partner);
GERMANY: Ilka Reinhardt (LUPUS German Institute, DE);
SWITZERLAND: Fridolin Zimmermann and Ralph Manz (KORA Foundation).

The Scientific Committee which contributed at the LIFE WolfAlps EU workshop for the discussion of the monitoring standards in 2020 was composed by:

Francesca Marucco (University of Turin, Department of Life Sciences and Systems Biology – LIFE Project Partner),
Elisa Avanzinelli (Ente di Gestione Alpi Marittime - LIFE Project Partner),
Huber Potočnik (University of Ljubljana - Department of Biology - LIFE Project Partner);
Christophe Duchamp and Ricardo N. Simon (French Biodiversity Agency (OFB) – LIFE Project Partner)
Jörg Rauer and Felix Knauer (University of Veterinary Medicine Vienna VETMEDUNI - LIFE Project Partner)
Ilka Reinhardt (LUPUS German Institute, DE)
Fridolin Zimmermann (KORA, CH)
Valentina La Morgia (ISPRA, IT),
Olivier Gimenez (CNRS, Montpellier, France)
Guillaume Chapron (Department of Ecology, Swedish University of Agricultural Sciences, Sweden)
Luigi Boitani (University of Rome),
Achaz von Hardenberg (University of Chester, UK).

Summary

1. Introduction and objectives of the document

Wolves were effectively eliminated from the Alps during the early 20th century (Breitenmoser 1998) but the species was again recorded in the western part of the mountain range in Italy in the 1980s (Fabbri et al. 2007). Recolonization of the Alps was spearheaded by individuals dispersing from relic Italian subpopulations in the Apennines Mountains that began to recover in the 1970s following legal protection, widespread decreases in human density in the countryside, recovery of populations of wild ungulates and increase in forest cover (Chapron et al. 2014, Ciucci et al. 2009, Fabbri et al. 2007, Boitani 1992). From the western Italian Alps, the wolf population then expanded eastwards to the central part of the mountain range in Italy, and westwards and northwards into France and Switzerland (Valière et al. 2003). More recently, a similar process of recolonization began in the East as individuals from the Dinaric-Balkan population dispersed and reached the Alps (Fabbri et al. 2014). This expansion is exemplified by the case of a male wolf from a transboundary Croatian-Slovenian pack that travelled through Slovenia and Austria to finally settle and form a pack with a female of Italian extraction in the Italian Eastern Alps (Ražen et al. 2016). Dispersing wolves from the Central European lowlands and from the Carpathian Mountains further to the east can also be expected to eventually reach and settle in the Alps (Szewczyk et al. 2019, Falcucci et al. 2013), mainly through Germany, Switzerland and Austria. Wolf presence can therefore be expected to occur in the alpine range of all seven alpine countries (France, Italy, Austria, Slovenia, Switzerland, Germany and Liechtenstein) in the near future.

The continuing expansion and the transboundary nature of the wolf alpine population, combined with the species' generally elusive behaviour in landscapes dominated by human processes, such as in the Alps, represent a significant challenge for the species' management and conservation. These activities require an efficient and objective strategy for population monitoring at the appropriate biological scale. Yet current wolf monitoring in the Alps is still essentially conducted at the national or even regional level. Monitoring from one country or region to another is hence not standardised or performed at the same time, leading to mismatches in data that preclude an objective, overall view of the status of the wolf alpine population.

The objective of this document is to describe the current methods used for wolf monitoring in six alpine countries (Italy, France, Switzerland, Germany, Austria and Slovenia). We then propose the definition of standardised criteria and approaches for wolf population monitoring to allow for a common and coordinated evaluation of the conservation status of the wolf population within the species' entire alpine range.

The Wolf Alpine Group (WAG) - a team of wolf experts from alpine countries who have been working together since 2001 to homogenise monitoring approaches - have built a solid partnership over time and are well-placed to coordinate the monitoring of the wolf alpine population across its entire range. A significant effort will nevertheless be required given the ongoing expansion of the population and new challenges, such as the increasing density of wolves in some areas (to the point that it is becoming too difficult and expensive to count and distinguish packs), or wolf recolonisation of hill and plain areas with little to no snow cover during winter (making it harder to detect their presence). These new constraints mean that acquiring detailed knowledge of wolf abundance and distribution as done in the past might no longer be feasible, and hence that monitoring approaches need to evolve. This is evidenced by discussions taking place in every country on how to adapt the monitoring system to its current biological reality when the size of the wolf population becomes increasingly larger. However, it is fundamental that a minimum common denominator is maintained to allow data to be combined and synthesised at the population level if the overall trend of the conservation status of the wolf alpine population is to be assessed.

Building on this common understanding and in the framework of the LIFE WolfAlps EU project, the 10th WAG international workshop on wolf monitoring was held in 2020 to discuss the best cost-effective strategies to optimise the integrated monitoring of the species. The present document is the output of these discussions and follows from a second WAG workshop held in January 2022. We define here a set of standard monitoring criteria, definitions and timing, so that data obtained at the national and regional level can be combined to produce a coordinated and unified estimate of the status of the wolf alpine population.

2. Current national monitoring strategy in each country

Each country in the Alps has developed its own national wolf monitoring system and strategy, which is necessary to manage the species within its national boundaries. Understanding and highlighting the differences in monitoring systems is the first step to overcome the limits inherent to different technical protocols and to identify a common monitoring strategy that is feasible to all and that can take up the challenge of managing wolves as a unique biological entity in the alpine surroundings.

2.1 Wolf monitoring in Italy

Elisa Avanzinelli*, Serena Perrone** and Francesca Marucco**
** Centro Grandi Carnivori (CGC), Ente di Gestione Aree Protette Alpi Marittime*
*** University of Torino, Department of Life Science and Systems Biology*

Reference document – The wolf national monitoring system in Italy (in Italian) - https://www.isprambiente.gov.it/files2020/notizie/linee-guida-e-protocolli_monitoraggio_lupo.pdf

National coordination and technical references

In Italy, since 2000 we consider two wolf populations, the Apennine wolf population and the Alpine wolf population, as defined by the "Guidelines for Population Level Management Plans for Large Carnivores", approved in 2008 by the Directorate General for the Environment of the European Commission and by the Permanent Committee of the Bern Convention (Linnell et al. 2008). The spatial demarcation line between the two populations is arbitrarily fixed at the Colle di Cadibona, the boundary of the alpine territory given by the Alpine convention (WAG 2014). The two populations could be considered as one, both from a genetic point of view, since there is no clear genetic structure and sharing the same gene pool from southern Apennines to the Alps (Fabbri et al. 2007), and from a demographic point of view, being distributed over an almost continuous area. The difference lies rather in the ecological and management aspects, as the Apennine population is distributed entirely on Italian territory, while the Alpine one is shared among several countries (Italy, France, Switzerland, Germany, Austria and Slovenia). Given the distribution range of the alpine population an international collaborative approach was set up in the context of the WAG (Wolf Alpine Group) since the beginning of the wolf recolonization.

The first campaign of wolf monitoring in the Alpine Italian context goes back to the period 1999-2012 and it was realized in Piemonte, where the wolf alpine recolonization started in 1996. The Piemonte Region played an important role in coordinating wolf management activities at regional scale in the framework of a first regional project named “The wolf in Piedmont”. The “Large Carnivores Centre”, established by the Piemonte Region at the Alpi Marittime Natural Park, has been providing technical and scientific support from the beginning of the wolf recolonization in Piemonte

(Marucco et al. 2010). In parallel to the process of expansion of the wolf alpine population in Italy, the delegation to regional administrations of the activities related to wolf monitoring, and the lack of coordination at the national level, led to a high administrative fragmentation. In this fragmented context the implementation of a univocal, coordinated wolf monitoring system at national level was not easily achievable. The LIFE WolfAlps (2013-2018) set up a preliminary wolf monitoring coordination in the Italian Alpine context by setting up a homogeneous and standardized approach at national alpine scale (Marucco et al. 2014). In this framework, the conservation status of the species at Italian alpine level was assessed, providing the range of species occurrence, the number of packs and the minimum wolf estimate, during the 2014-2018 period (Marucco et al. 2018). As to the Peninsular Italian area, in the same years, despite the presence of high-quality data in many Apennine areas and the presence of numerous studies and monitoring projects, a homogeneous approach for monitoring the distribution and consistency of the wolf at a population scale was still lacking. For the lack of an univocal, coordinated and contemporary wolf monitoring system at national level (considering both the Alpine and the Peninsular populations), the Ministry of the Environment and Protection of the Territory and the Sea - MATTM (now the Ministry of Ecological Transition) in 2019 commissioned ISPRA (Higher Institute of Environmental Protection and Research) to define a national strategy, for setting a homogeneous national wolf monitoring, improving the coordination among the various Italian institutions operating in wildlife management. Therefore, as required by MATTM, the "Italian National Monitoring Guidelines for the national survey of the wolf populations" (Marucco et al. 2020) were drafted by ISPRA, to outline the operational tools for implementing the first experience of a simultaneous national survey to estimate wolf abundance of the species, that was implemented during the season 2020-2021. The monitoring approach were defined at 2 regional scales considering the 'Alpine regions' and the 'Italian Peninsula Regions' (Marucco et al. 2020), because the 2 populations have been increasing and expanding all over Italy, reaching lowland areas, and getting a continuous distribution over the regions.

In order to achieve this important goal, the collaboration of a dense network of operators' afferent to many regional and local Administrations was required, involving Regions, Provinces, Protected Areas, Environmental Police (Carabinieri-Forestali), research institutes and genetic labs, hunting districts and environmental Associations, Regional Health Services (A.S.L.), etc. The Network of collaborations has been activated and coordinated by ISPRA at national level for the first national wolf monitoring, and for the alpine regions it was coordinated in the framework of the LIFE WolfAlps EU project. Every operator of the Network received specific training and instructions following the national protocol provided by ISPRA (Marucco et al. 2020). More specifically, in the alpine regions, for resource optimization, the national wolf monitoring and the operators' training were performed as part of the LIFE WolfAlps EU Project, and coordinated by the Large Carnivores Center and University of Torino-DBIOS in support of ISPRA. As to the peninsular Italy, the 2020-21 sampling was directly coordinated by ISPRA in collaboration with Federparchi. In the alpine context, the organized network of different Institutions and operators is partly the result of a 20 years of consolidated collaborations and a strong coordination among Institutions, began with the first alpine campaign carried out by the first Project in 1999, and widened during the LIFE WolfAlps (2013-2018) towards the eastern Alps (Wolf Network). More recently the effort dedicated to the training of new operators was further extended to new Institutions and especially volunteers of several Associations, increasing the availability of operating personnel, also in new areas of recolonization. The training sessions organized in 2020 for the alpine regions, in preparation for the first national monitoring campaign (2020-2021), consisted of 23 events of training courses/workshops and 1 e-learning course realized in 2021. For the alpine regions about 1300 operators were trained in 2020 in the framework of LIFE WolfAlps EU.

Wolf Monitoring implementation in Italy

The monitoring of the distribution and consistency of wolf population is an essential tool to evaluate 1) the evolution of the conservation status of the species, and 2) the effectiveness of the management measures implemented. The sampling design adopted at national level, implemented for the first time during the fall-winter season 2020-2021, was provided by the already cited Guidelines (Marucco et al. 2020). The main aim of this first wolf national survey was to guarantee a population-level approach, to reach out a more rational and robust assessment of the conservation status of the species. The Guidelines define a robust study design to collect accurate data for the application of Occupancy Model (McKenzie et al. 2006) and Spatial Capture Recapture Model (SCR) (Chandler and Royle 2013; Royle et al. 2014) to estimate wolf distribution and abundance in the Alpine Regions and Italian Peninsular Regions. Additionally, the number of wolf packs is an important parameter to be estimated over time in the Alpine Regions, for comparison with previous years, considering the pack as the reproductive unit for the wolf population.
The sampling area is divided into a grid of spatial units, of a 10x10 km, and the sampling is conducted by stratifying the sampling units according to the probability of wolf presence based on previous knowledge on the species distribution (Boitani & Powell 2012).
Specifically, in the Alpine Region, due to the more recent recolonization by the species, the sampling was carried out in 100% of cells of possible presence, considering the last and more recent available data (2017-2019). The data collection is performed combining **an opportunistic sampling and a systematic sampling**, organized in scheduled surveys along transects and camera trapping. The estimation of the distribution and abundance of the wolf population at national level was obtained by a sampling strategy made up of two phases:

a. *extensive sampling*, which aimed to a contemporary estimation of the distribution of the species at national scale This approach was implemented organizing at least 3 consecutive and bimonthly systematic replicates to control effort, based on the patrolling of transects/camera trapping.

b. *intensive sampling*, which aimed to get the estimation of population density in the Alpine Regions, and in 11 sampling areas of the peninsular regions, through the application of Spatial Capture Recapture models, SCR (Royle et al. 2014) using the collected signs along transects aided by genetical analysis. This approach implied a greater effort, mainly due to a higher number of monthly replicates foreseen for the systematic monitoring, from October to March (i.e. at least 6 replicates, 1/month), but also for the higher density of transects detected in the intensive cells.

The year of monitoring is defined according to the reproductive cycle of the wolf, spanning from the 1st of May to the 31st of April. Overall, the protocol defined in the ISPRA Guidelines foresees the application of a non-invasive sampling strategy, based on snow-tracking, wolf-howling, camera-trapping and the genetic analysis of biological samples (especially scats). The standards criteria were based on the SCALP criteria, classifying observations according to their verifiability. In order to estimate population size and distribution, only C1 (certain) and C2 (confirmed observation) data were used (Marucco et al. 2020)

Alpine wolf population status in Italy (Alpine Regions)

In the framework of the first Italian national survey of 2020-2021, XX[1] wolf packs, XX pairs were identified in the Italian Alpine regions (Marucco et al. in progress[1]). We documented a higher density of packs in the Western part of the alpine regions, and new packs were detected in northern Piemonte, in central-eastern part of the Alps as well as in lowland areas (in particular in Piemonte) (Figure 1). Indeed, considering only the Italian Alps for comparison with previous years, the population grew in terms of reproductive units (packs and pairs) with average annual population growth of XX (Figure 1). The growth of the alpine population in Italy is also reflected in an expansion of the species' geographical range in the alpine regions (Figure 1) occurring now also outside of the Alpine range (XX[2] kmq).

Figure 1. Left: regular and sporadic occurrence of grey wolves in France under the European 10 x 10 km reference grid. Right: number of areas of permanent wolf presence in France at the end of winter from 1992/1993 to 2020/2021. [1]

Future perspectives and challenges in wolf monitoring in Italy

The positive trend of the wolf population in the Italian alpine regions has been confirmed both in alpine territories, where pack density is high, and in the lowlands, where new packs are settling. This new contest requires an understanding of the effort and economic resources needed for future sampling and resources. Some evaluation and analysis will be performed to achieve an optimization of the sampling effort, in order to obtain reliable estimates of the population, based on a rational commitment of resources. In conclusion, a best cost-effective strategy will be evaluated in Italy based on the results of the 2020-2021 survey to optimize the national monitoring of the wolf parameters on the long term.

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2.2 Wolf monitoring in France

Christophe Duchamp* and Ricardo N. Simon*
** Office français de la biodiversité (OFB)*

Reference document: Duchamp et al. (2012) Hystrix Vol *23*

National coordination and technical references

Wolf monitoring in France is implemented within the framework of a National Action Plan for the wolf and stock-rearing activities, currently in its fourth version (MTES & MAA 2018). Monitoring is based on a national network of trained observers (n > 4000) distributed across the whole country. Members of the network collect data on signs of wolf presence (scat, visual observations etc.) in their sampling area and report back to regional coordinators at the **Office Français De La Biodiversité** (**OFB**), the public agency responsible for monitoring the wolf population at the national scale. Data are individually checked against standardised technical criteria to state on their reliability. The data are then compiled and synthesised by the OFB in a single national database, and results are published regularly (https://www.loupfrance.fr/) following annual monitoring campaigns in both summer (new pack detection through provoked howling) and winter (population trend indexes and demographic parameter estimates using sign survey and non-invasive genetic capture-recapture estimates). The OFB also regularly provides training and workshops on wolf monitoring for new members of the network across the country.

Given that wolf distribution in France is still expanding, the network has also been growing, mostly towards the north and the west (wolf recolonization in France began in the southeast of the country, in the Alps, by wolves coming from Italy). The 2018-2023 Action Plan aims to diversify the prospecting effort in time and space to better monitor the expansion of the wolf population in the country. This action is on track, given that the distribution of the socioeconomic categories of members of the monitoring network is becoming more even, with an increase in the participation of hunters, farmers, breeders, conservationists and private individuals as a complement to the core group composed of wildlife professionals. Implementation of the monitoring network was performed throughout the whole country in 2020.

Wolf monitoring implementation in France

Wolf monitoring in France is described in detail in Duchamp et al (2012). It is at present based on a dual frame survey where:

1. Systematic reporting is done opportunistically over the whole area covered by the expert network. Members of the network report any signs of wolf presence they come across as they go about their daily business or professional activity. Data collected opportunistically are all validated by a standardised technical protocol to detect as early as possible the formation of new pairs and packs, as well as mapping all validated occurrences of wolf signs (including

depredations) gathered within a 2-year moving window (biological years) to monitor the temporal change in the species' distribution over time on the 10 x 10 km EU reference grid.

2. If and once wolf presence is considered permanent, surveying is stratified within each detected territory to better estimate pack composition and population parameters (number of individuals, reproduction events etc.). In this case, during winter, the survey is conducted via systematic snow tracking or through the use of camera traps to monitor pack sizes and composition. In summer, provoked howling protocols are (since 2013) implemented only to confirm the establishment of a pack in a new territory by documenting reproduction events. Finally, non-invasive molecular tracking has been conducted in France since 1995 to identify haplotypes, for genotyping and to monitor wolf-dog hybridization. This non-invasive monitoring is then used to model population trends and demography using dedicated capture-recapture models.

Alpine wolf population status in France

Projections based on non-invasive genetic CMR (Capture-Mark-Recapture) models built with data from 1995/96 to 2012/13 suggest that the wolf population in France is still increasing as of 2021, despite the derogatory regime under which some wolves are legally removed in a bid to reduce depredation to livestock, especially in depredation hotspots (97 and 100 wolves destroyed in 2020 and 2021 respectively, DREAL AuRA 2022). Most recent data from the winter of 2020-2021 provide an estimate of population size of about 620 individuals (n = 624, 95% CI: 414 – 834), with a mean growth rate switching from 1.13 to 1.08 during the last few years (OFB 2021). This growth in abundance is also reflected in **an expansion of the species' geographical range in the country** (Fig. 3) occurring mostly outside of the Alpine range (OFB 2021). Areas with permanent wolf presence have been estimated at 125 in the country, 106 of which have been identified as packs (OFB 2021). Almost all reproducing packs in the country occur in the Alps, the one exception being a transboundary pack in the Jura mountains at the border with Switzerland.

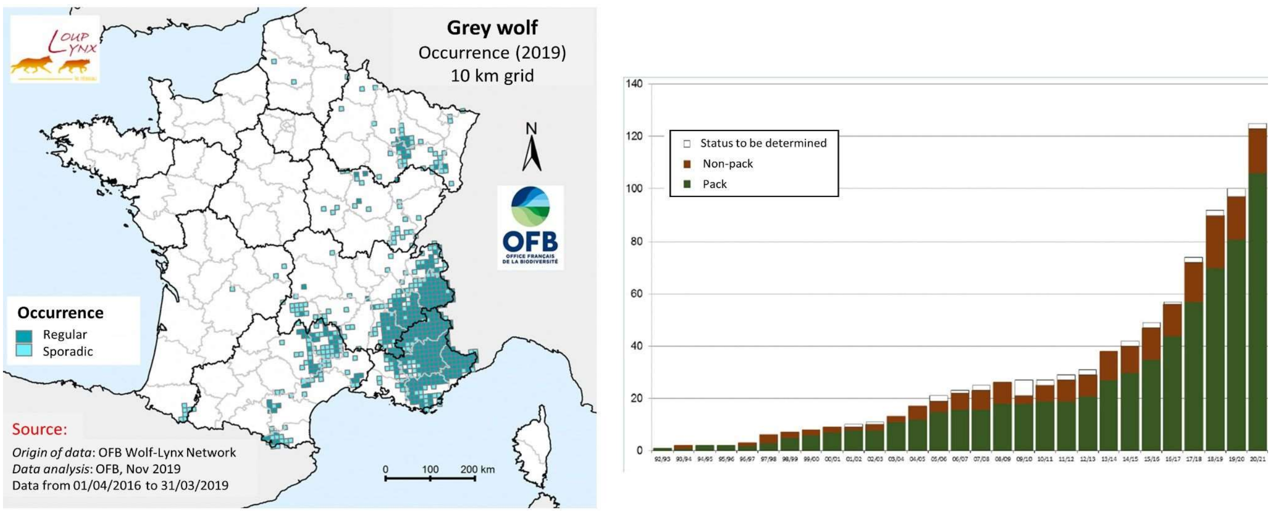

Figure 3. Left: regular and sporadic occurrence of grey wolves in France under the European 10 x 10 km reference grid. Right: number of areas of permanent wolf presence in France at the end of winter from 1992/1993 to 2020/2021.

Despite continued population growth, questions remain however over the viability of the population under a policy of predator control in which an increasing number of wolves is being removed each year. A viability analysis of the population conducted recently (Duchamp et al. 2017) quantified maximum thresholds for lethal control, depending on the rate of population increase, but also revealed large uncertainty on how population abundance is expected to change in the next few years (up to 2030) under the current management regime. Given the hypothesis that the wolf population in France is still growing exponentially, the trend is expected to remain one of growth, although confidence intervals become so large that it is impossible to predict with any confidence how many wolves will be present in the population by 2030 or even earlier. Under the hypothesis that the wolf population in France is reaching a plateau in abundance (i.e., logistic growth), confidence intervals become even larger to the point that it is no longer possible to ascertain whether the population will continue to grow or even decrease in the future. The authors of the analysis therefore advised the government to adopt the adaptive management of wolves in France, whereby population trend indexes (demographic and distributions) are updated after every winter to state on the demographic consequences of current management policy so that it can be adjusted to manage depredation hotspots while keeping the population in a favourable conservation status (Duchamp et al. 2017).

Future perspectives and challenges in wolf monitoring in France

It is becoming increasingly apparent that the current protocol for monitoring wolves in France is no longer adapted to the increasing range of the population in the country (Duchamp et al. 2019). Population abundance is, or at least could be, considered large enough (> 500 individuals) to guarantee the short-term viability of the species in the country, thereby reducing the need for intensive and fine scale monitoring of wolf numbers. Moreover, as the species expands to lowland areas without snow on the ground in winter, detection probabilities of wolf presence and numbers can be expected to drop sharply even if models can account for heterogeneous and imperfect detection. Even within the Alpine range, packs are now so closely imbricated with each other in some historical area of presence that it is becoming difficult if not impossible to distinguish them, requiring substantial efforts in collecting signs of wolf presence in the field and in conducting genetic analyses. There are also major logistical and financial costs to consider in keeping a monitoring network functioning at an increasingly larger spatial scale.

Efforts are therefore under way to identify and implement a new protocol for monitoring the wolf population in France based on patterns and changes in distribution rather than abundance (Duchamp et al. 2019). The metrics to be used should nevertheless be able to detect changes in population demography, particularly those resulting from changes in management. It should also account for imperfect detection, be fit to be implemented within an adaptive framework, be operational in the field and have an attractive cost-benefit ratio. Evaluation of methods used around the world to monitor wolves (e.g., in Spain, Italy, Scandinavia and the USA) suggests that no method is perfect and that compromises exist between these different requirements. However, occupancy models appear to be a metric that fulfils most of them (i.e., high sensitivity to changes in population size, accountability for imperfect detection, highly fit for adaptive management, even if costly in terms of field effort) (Duchamp et al. 2019). The appropriateness of applying this method to monitor the wolf population in France is currently under assessment.

At the same time, the current methodology used for wolf monitoring in France and the resulting estimates have been publicly questioned by national representatives of breeders and hunters (FNSEA et al. 2021). These stakeholders argue that wolf abundance and distribution are underestimated in the country. Among other demands, they have called for an increase in the monitoring effort on the ground and for this effort to be delegated to hunters. This request however is in direct contradiction to the assessment presented above that current monitoring methods in France are not sustainable over the long term given the increasing distribution and density of wolves in the country.

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2.3 Wolf monitoring in Switzerland

Fridolin Zimmermann*, Florin Kunz*, Luca Fumagalli** and Ralph Manz*

**Foundation KORA - Carnivore Ecology and Wildlife Management, Talgut Zentrum 5, CH-3063 Ittigen, Switzerland*

***Department of Ecology and Evolution, Laboratory for Conservation Biology, Biophore Building, University of Lausanne, 1015 Lausanne, Switzerland*

Reference website:
https://kora.ch/en/projects/large-carnivore-monitoring/what-is-monitoring/
Referenced document:
https://kora.ch/wp-content/uploads/2021/03/KORA_Bericht_91_E_25_years_of_wolf_presence_in_Switzerland.pdf

National coordination and technical references

The Swiss Wolf Plan (FOEN 2016) stipulates that the development of the wolf population, their distribution and abundance need to be observed and documented. The Foundation KORA is tasked by the Swiss Federal Office for the Environment (FOEN) and by the Office for the Environment of the Principality of Liechtenstein to monitor the development of large carnivore populations with scientific methods. According to the Swiss Wolf Plan (FOEN 2016), the management and monitoring of wolf and large carnivores is principally a duty of the cantons. Because wolves have large spacial requirements and can cover large distances very quickly, their management and monitoring must be done on a very large scale that crosses cantonal boundaries. To this end Switzerland has been divided into five main compartments for the management and monitoring of wolf (see Swiss Wolf Plan, FOEN 2016).
Monitoring is principally based on a national network of trained observers (mainly game wardens and a few trained volunteers, especially hunters in cantons with hunting grounds, representing about 220 people) distributed across the whole country. Members of the network collect and validate data on signs of wolf presence (sightings, tracks, scats, losses, damages to livestock) in their sampling area and report back either directly to KORA or in the respective cantonal database. The data are transmitted from the cantons to KORA on a regular basis, usually each quarter. Some observations are also reported directly to us by the general public by means of forms available on our website. Non-invasive genetic samples are sent by the members of the monitoring network to KORA where their further analysis is prioritized based on the needs of monitoring and management in the sampling area. The chosen samples are then anonymized by KORA and forwarded to the Laboratory for Conservation Biology (LBC; https://www.unil.ch/lbc/en/home/menuguid/contact-1.html). The following doctrine for the prioritization of genetic samples was used so far:

- Packs: genetic identification of all pack members. Genetic analysis is carried out until all individuals have been identified based on the information resulting from chance observations and camera-trapping (August to April as a suitable time window);

- Several neighboring single wolves: If there is a certain probability that the sample comes from an animal already detected in the same year, no further analysis;
- Transient and resident single wolves and non-reproducing pairs should be detected once every spring/summer. No analysis of further samples if no new individual is suspected.

As soon as the results of the laboratory's examination arrive, KORA informs the senders and the responsible cantonal hunting administrations.
All data are compiled and divided into three categories according to their significance and verifiability (see SCALP criteria; Molinari-Jobin et al. 2003) in a national database, and made available to the managers, interest groups and the general public through the KORA Monitoring Center (https://www.koracenter.ch) and specific reports. Results such as distribution maps, maps of single wolves, pairs and packs, losses and depredation including their evolution in time are regularly updated on the KORA website (www.kora.ch). KORA also regularly provides training and workshops on wolf monitoring for the game-wardens and volunteers, especially hunters, across the country.

Wolf Monitoring implementation in Switzerland

So far in Switzerland data collection relies on **passive monitoring** (collecting secondhand information), which includes dead wolves, damages to livestock, and chance observations (tracks, killed wild prey, pictures). In addition, **active monitoring consisting in the opportunistic collection** of camera-trap pictures/video and genetic samples is carried out all over Switzerland. The genetic and opportunistic camera-trapping is intensified in areas where (potential) pairs or packs have been documented (detection of reproduction and minimum pack size; e.g., Zimmermann 2019). On very rare occasions snow tracking is conducted in areas of packs (Manz et al. 2014). The feasibility to detect reproduction through passive recording by means of “songmeters” is currently assessed in selected packs in collaboration with Stefan Suter of the ZHAW (e.g., Suter 2016). In a next step the approach will be further developed to estimate the number of individuals in a pack and to identify individuals. Occasionally, single wolves were captured and fitted with GPS collars by the local game wardens of the canton of Grisons (N = 5) and Glarus (N = 1) to follow their movements more precisely. This would also enable to see if adverse conditioning is effective in case such measures have to be applied.

Alpine wolf population status in Switzerland

When considering genetic evidence, dead wolves and observed wolves that are temporally and/or spatially separated enough from genetic samples to consider them as s different individuals, 153 wolves (including juveniles) were detected during the calendar year 2021 in Switzerland. Between 2020 and 2021, the number of packs increased from 11 to 16 (five cross-border packs and 11 Swiss packs) in Switzerland, two of which are in the Jura Mountains (canton of Vaud).

The first pack, the Calanda pack, has formed in 2012 in the Grisons (GR). It was followed by the Morobbia pack in the Ticino (TI) in 2015 and the Augstbord pack in the Valais (VS) in 2016. In 2017 the reproducing female of the Augstbord pack (F14) disappeared. The male (M59) then roamed the Central Valais area with two of his daughters (F23, F24) and a newly immigrated male (M73). But there was no offspring in 2018. The Gantrisch pack established in 2017 in the border area of the Cantons Fribourg and Bern but disappeared the same year when the female was poisoned. Four wolf packs lived in Switzerland in the year 2018: Calanda, Morobbia, Central Valais and Ringelspitz (GR). In the following year the number was doubled: the Chablais (VS), Beverin (GR) and Val Gronda (GR) packs in the Alps and the Marchairuz pack (canton of Vaud VD) were added to those present in 2018. The Marchairuz pack in the Swiss Jura Mountains was the first in this area for at least 150 years after the eradication of the wolf. In 2020, three new packs have been formed (Stagias (GR), Muchetta (GR), Schilt (canton of Glarus GL)), so that at the end of 2020 there were 11 packs in Switzerland. In 2021, six new packs have been added (Val d'Hérens (VS), Kärpf (GL), Risoux (VD), San Bernardino (GR), Augstbord 2 (VS), and Onsernone (TI)) for a total of 16 packs including a second one in the Jura Mountains (Risoux pack). The Calanda pack was no longer detected in 2021 (the last reproduction has been confirmed in 2019). With the exception of five packs (Morobbia, Ringelspitz, Val Gronda, Muchetta and Schilt), all packs reproduced in 2021 resulting in a minimum of 48 pups of which at least four were dead at the end of the year 2021. The average litter size was 4.4 (1-7). In 2021, five juveniles, one subadult and one adult were victim of traffic accidents, one juvenile male was poached in the canton of Valais and three juveniles were legally shot in the frame of a pack regulation (Beverin pack), two adults, one male one female, were legally shot in the frame of measures against single wolves as foreseen by the Swiss Wolf Plan (FOEN 2016). An adult female died of bite wounds, two adult males had to be shot due to severe injuries, one adult male drowned in a compensation tank, one juvenile female fell off a cliff and one female died of undetermined cause.

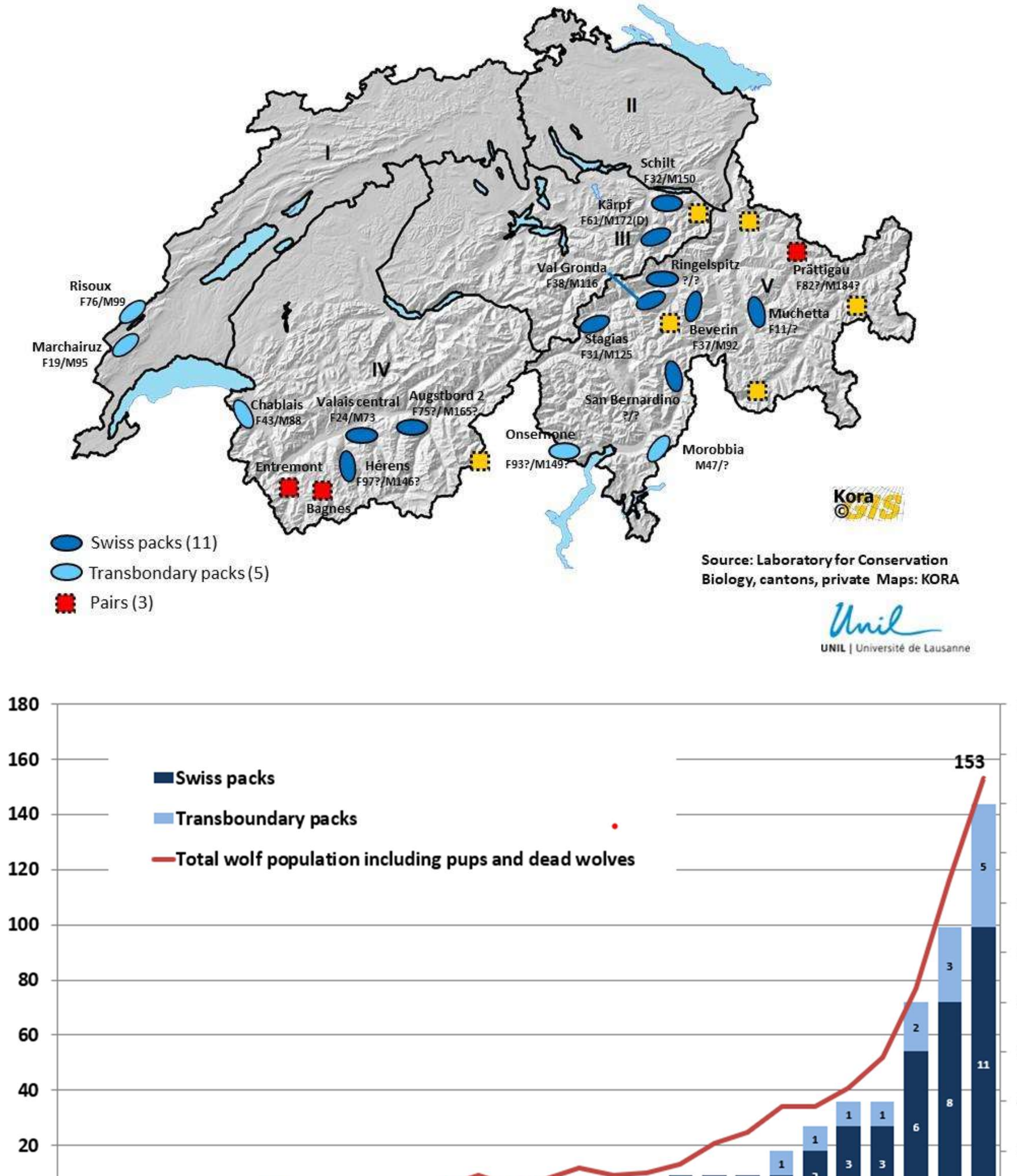
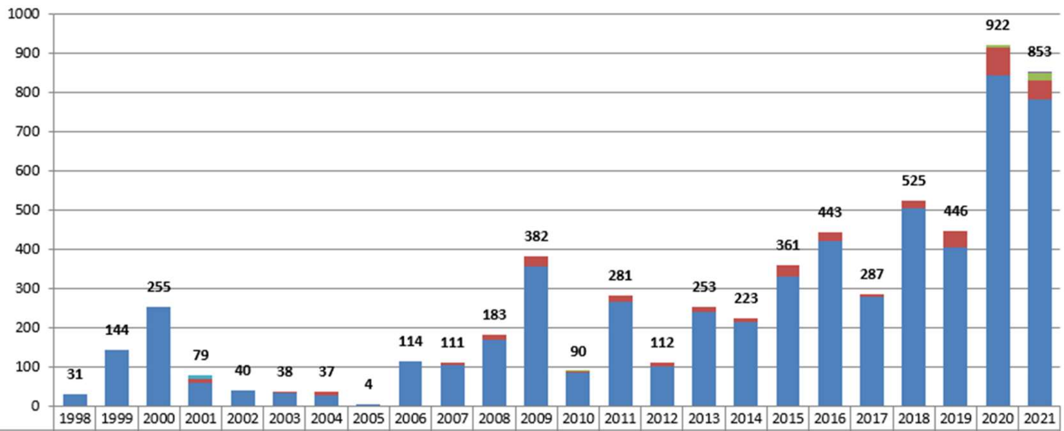


Figure 4. Top: Swiss (dark blue ellipse; N = 11) and transboundary (light blue ellipse; N = 5) packs and pairs (red squares); status February 2022. Below: Number of detected packs in Switzerland (dark blue), transboundary packs (light blue) and individual wolves per year (red = total wolf population). Adult and juvenile wolves are grouped in the number of individual wolves. This graph includes genetic records, dead wolves, as well as observations that are temporally and/or spatially separated enough from genetic samples to consider them as independent. Status 09.03.2022.

Since the start of the genetic monitoring of the wolf in Switzerland, 135 adult wolves have been analyzed for possible hybridization with a dog by high throughput DNA sequencing of 22 STR markers. The analyses did not detect any signal of recent hybridization with a dog (F1 or first-generation backcross (BC1)) for 132 wolves. Three wolves were detected as potential dog hybrids:

(i) Individual M10: analyses show that it is not a first generation (F1) hybrid, but a backcross (the highest probability (87%) is that it is a second generation (BC2) backcross);
(ii) Individual M87: analyses show that it is not a first generation (F1) hybrid, but a backcross (the highest probability (88%) is that it is a second generation (BC2) backcross);
(iii) Individual F41: analyses show that it is not a first generation (F1) hybrid, but a backcross (the highest probability (51.5%) is that it is a second generation (BC2) backcross).

Since the return of the wolf, the number of livestock compensated as wolf kills (mainly sheep) vary between 4 (2005) and 922 (2020). In the year 2021, 853 livestock were compensated as wolf kills. The number of registered damages for the year 2021 is not yet complete as it contains all cases sent to the FOEN by 31 October 2021. The number of compensated livestock per year is obviously not only dependent on the wolf population - individual years with a particularly high number of losses despite low wolf populations (and vice versa) stand out. This shows that other factors (e.g. the use of prevention measures) also play an important role in the development of damage to livestock. In 2021 the number of attacks on cattle increased. The affected regions are the Vaud Jura (N = 11) and the Grisons (N = 7).



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Others/unknown				10	1							1				1								
Equids																								3
Cattle													1										7	20
Goats				9		5	11			5	13	25	3	14	10	11	9	29	23	8	19	41	71	46
Sheep	31	144	255	60	39	33	26	4	114	106	170	356	86	267	102	241	214	332	420	279	506	405	844	784
Total	31	144	255	79	40	38	37	4	114	111	183	382	90	281	112	253	223	361	443	287	525	446	922	853

Figure 5. Development of damage caused by wolves and compensated by the FOEN and the cantons, broken down by livestock breed in Switzerland 1998 - 2021. Status 31.10.2021.

Future perspectives and challenges in wolf monitoring in Switzerland

KORA is currently elaborating a new concept for the wolf monitoring following as far as possible international standards. In view of the revision of the hunting ordinance and the evolution of the wolf population in Switzerland, genetics is becoming even more important. According to the Swiss Wolf Plan (FOEN 2016), the cantons can take measures against single wolves in case of significant damage to livestock. Furthermore, the cantons can regulate packs after consultation with the FOEN in three cases: 1) when they cause significant damages to livestock; 2) when they represent a concrete danger to humans; and 3) when they cause severe losses in the use of cantonal hunting prerogatives. In addition, according to the new hunting ordinance, a particularly harmful breeder (causing at least 2/3 of the damages to livestock over several years) may also be shot from November to January. In view of the management measures foreseen in the Swiss Wolf Plan, it is important to be able to assess which pack (or breeding pair), pair or single individual is responsible for the damages to livestock. It follows that it is necessary to continue working with population indices such as single wolves, pairs and packs. In recent years packs are getting closer to each other and often the reproducing females of adjacent packs are related to each other, making it increasingly difficult to distinguish neighboring packs from each other. Therefore, it will be important to have access to genetic marker sets with enough resolution to statistically assign with a high level of confidence an individual to a given pack and to distinguish between adjacent packs. This will only be made possible by an intensive sampling in the field, so that additional information, such as the identity of the presumed breeding pair or some of their offspring, can be introduced in the analyses.

The following requirements should be considered in the new monitoring concept:

- If possible, no abrupt transition from the old to the new system (backwards compatibility);
- Monitoring the development of the wolf population in Switzerland with a focus on packs (establishment, reproduction and development of packs);
- Assess the feasibility to estimate the wolf population size by means of capture-recapture analysis;
- More capacities for genetic analyses in the laboratory (increase in the number of samples & shorter deadlines if possible);
- To set up prioritization rules of (non-invasive) genetic samples by differentiating between management and monitoring relevant samples giving priority to the management relevant samples;
- For management purposes, the monitoring should enable to assess the situation as early as possible (packs with or without reproduction) to identify packs/individuals in the pack that kill cattle, equids or New World camelids, that kill livestock from a night pen, and to detect wolf-dog hybrids;
- Compatibility with the monitoring in neighboring countries (methods; definitions: packs, pairs, single wolves; necessary data for assessment; time window: biological year; harmonization of genetic methods);
- Management of bold wolves and hybrids;
- International cooperation in monitoring and management is required;
- Should remain within a realistic financial framework.

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2.5 Wolf monitoring in Germany

Ilka Reinhardt*
**LUPUS - Institute for Wolf Monitoring and Research in Germany*

Reference document – The wolf national monitoring system in Germany Monitoring standards for wolf, lynx and bear in Germany. (in German)
https://www.bfn.de/publikationen/bfn-schriften/bfn-schriften-413-monitoring-von-wolf-luchs-und-baer-deutschland

National coordination and technical references

Germany is a federalist country consisting of 16 federal states. Large carnivores are protected by federal laws (as well as by EU laws), and the Federal Government reports to the EU Commission in the frame of the Habitats Directive reporting. However, since implementation of large carnivore conservation is under the jurisdiction of the Länder, they are responsible for the monitoring of wolves. In order to make documentation and assessment of large-carnivore observations comparable and transparent across Germany, national monitoring standards for large carnivores were developed in 2009 (Kaczensky et al. 2009) and accepted by all federal states. These standards were updated in 2015 (Reinhardt et al. 2015) and are currently under revision.

Once a year in September the national monitoring meeting take place under the umbrella of the **Bundesamt für Naturschutz (BfN)**, the federal agency for nature conservation. On these meetings the persons responsible for LC monitoring within the federal states present the data on the previous monitoring year on the area of occurrence and population size estimates on state level. The data presented there are jointly discussed and evaluated and then compiled on a national level by the **Dokumentations- und Beratungsstelle des Bundes zum Thema Wolf (DBBW)**, the federal documentation and consultation centre on wolves (https://www.dbb-wolf.de) that also organizes the monitoring meetings. The DBBW publishes the results of the monitoring meetings in annual status reports and on the DBBW website. The DBBW is a scientific consortium that provides federal and state nature conservation authorities and was founded in 2016. It is technically supervised by the BfN and is supported by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB). The scientific institutions that are part of the DBBW consortium are the Senckenberg Centre for wildlife genetics that serves as national reference lab for wolf genetics, the Leibniz Institute for Zoo- and wildlife Disease (IZW) Berlin (national reference institute for dead wolf monitoring) and LUPUS – the German Institute for Wolf monitoring and research (data compilation and advice of authorities on all wolf related issues other than genetics and mortality). The administrative head of the DBBW is with the Senckenberg Museum for natural history Görlitz.
Besides the yearly meetings the DBBW advices the state authorities continuously on demand on all wolf related issues, including monitoring questions. New territories detected and territories known from previous years and confirmed within the current monitoring year can be published in between the yearly monitoring meetings after consultation with the DBBW. Up to date results of the current

monitoring year can be found on the website: https://www.dbb-wolf.de/wolf-occurrence/confirmed-territories.

In 2015 the CEwolf consortium was founded. The consortium consists of scientific institutions working on a harmonized genetic monitoring of the Central European wolf population (https://www.senckenberg.de/en/institutes/senckenberg-research-institute-natural-history-museum-frankfurt/division-river-ecology-and-conservation/cewolf-consortium/). In frame of this platform the genetic marker system has been standardized allowing for a harmonized trans-border genetic monitoring. For this regular ring tests are performed, common samples of wolves, domestic dogs and other canid species shared and genotype data exchanged. Currently member institutions come from Austria, Belgium, Czech Republic, Denmark, Germany, Poland, Luxemburg and The Netherlands.

Wolf monitoring implementation in Germany

The wolf monitoring in Germany is described in detail in the national monitoring standards (Reinhardt et al. 2015). Wolf surveillance is conducted annually with the goal of obtaining reliable area of occurrence and population size estimates at the national level each year. Uniform data evaluation and interpretation across administrative borders is ensured by the national monitoring standards. How the data are actually collected by the federal states. Which and how much personnel are deployed for this purpose, is their responsibility and differs from state to state.

The monitoring year follows the biological wolf year, spanning from 1^{st} May to the 30st April of the following year. The monitoring standards define the rules for estimating population size and area of occurrence and describe monitoring methods suitable for the collection of the necessary data. Signs of large carnivores are evaluated according to the SCALP criteria. Population size and area of occurrence estimates are based exclusively on C1 (hard facts) and C2 (confirmed observations) data. The annual estimate of the area of wolf occurrence is determined by the number of 10 × 10 km grid cells in which wolf presence was confirmed in the respective monitoring year (at least one C1 or three independent C2 per grid cell). The population size of the wolf is calculated as an index which results from the number of packs and pairs confirmed (minimum count). The number of single territorial wolves (wolves that are resident in an area for at least 6 months, but yet without a mate) is also provided. In addition, the number of mature individuals confirmed within the wolf territories is counted. No attempt is made to get a robust estimate of the total number of individuals, as this would again significantly increase the monitoring effort and associated costs. As packs and pairs form the reproductive units of a wolf population, this number is considered to be biologically more meaningful than the total number of individuals.

The monitoring standards provide definitions of packs, pairs and single resident individuals and set clear rules on how to distinguish neighbouring territories from each other. Especially in areas with widespread wolf occurrence it is often difficult to determine the number of territories as the spatial-social organisation of a wolf population changes permanently. New pairs try to establish themselves between existing territories and packs attempt to take over parts of neighbouring territories. Often all available evidence has to be taken into account to solve this dynamic puzzle. In particular, the genetic analyses done by the Senckenberg Centre for wildlife genetics play an outstanding role in this context. Due to permanent pedigree and pack reconstruction, it is often possible to distinguish neighbouring territories from each other by the identity of the territory owners.

In most parts of Germany winters are characterised by low snowfall. Therefore, monitoring methods have to be independent of snow and monitoring is conducted all year round with seasonal priorities. The main monitoring approach is an active monitoring with a combination of presence sign survey, camera trapping, and genetic analyses. While during summer the focus is on the proof of reproductions (mostly via camera traps) the priority in the winter month lies on the collection of genetic samples preferably of the breeding (marking) individuals.

Alpine wolf population status in Germany

In the monitoring year 2020/21, 157 wolf packs, 27 scent marking pairs and 19 single resident wolves were confirmed in Germany (DBBW 2021). The average annual population growth in terms of reproductive units (packs and pairs) was. 1.28 from 2000 to 2019, varying considerably among regions (Reinhardt et al. 2021). Most wolf territories occur in the North-West of Germany while in the South and South-West comparatively few wolf territories have been established so far. Immigrating wolves from the Alpine population are genetically proven in Germany every year. However, so far only one wolf territory of a single resident wolf was confirmed within the Alpine region of Bavaria (Oberallgäu). This wolf originates from the Central European population.

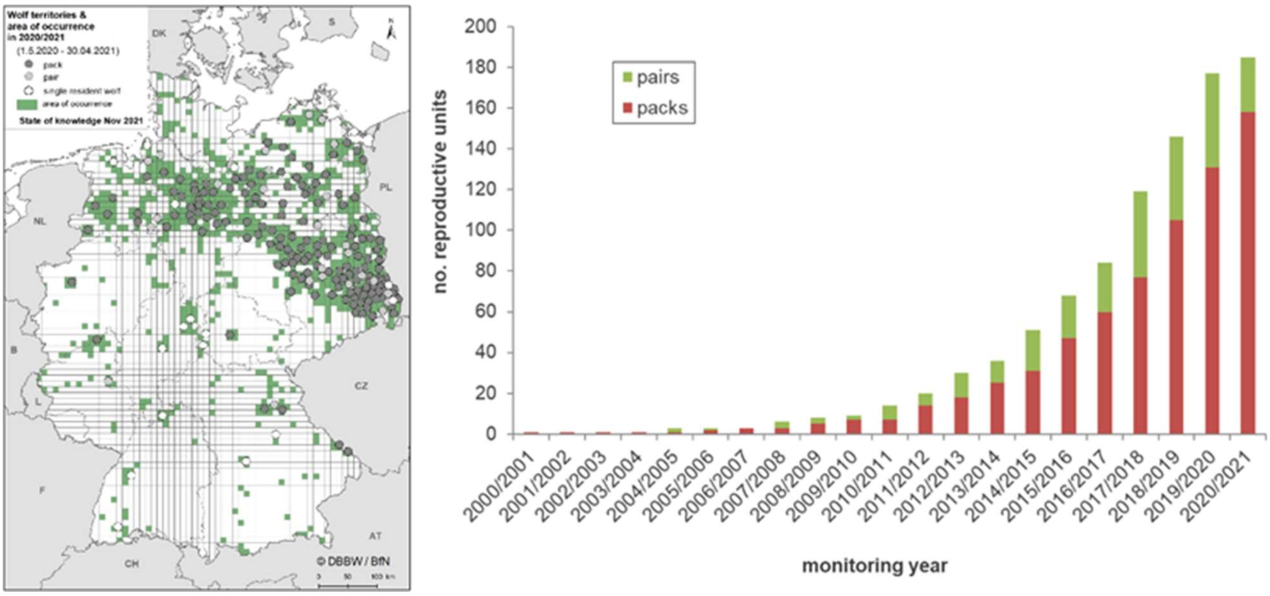

Figure 6. Left: Area of occurrence and distribution of wolf territories in the monitoring year 2020 / 2021. Right: Development of the number of reproductive units (packs + pairs) from the monitoring year 2000/2001 to 2020/2020. Source: DBBW.

Future perspectives and challenges in wolf monitoring in Germany

The rapid spread of the wolf in Germany pushes the monitoring system to its limits. New monitoring approaches need to be developed for the coming years that will allow us to keep track with the fast expanding population and still provide reliable data. The federal structure can have both advantages and disadvantages in this regard. Advantages as the area to monitor is already spatially subdivided and no single institution is responsible for the wolf monitoring all over the country. The challenges are that for a stratified monitoring approach the monitoring effort in the different regions would have to be comparable. The requirements for the federal states would then, unlike in the past, not only concern the expected results (survey of the number of territories and the area of occurrence), but also the monitoring effort to be provided. In addition, as population growth and expansion remain very dynamic, population saturation varies widely not only across Germany but also within each state, making a stratified monitoring approach no easy task.

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2.6 Wolf monitoring in Austria

Georg Rauer*, Felix Knauer* and Theresa Walter*
**Research Institute for Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria*

Reference document – National recommendations for wolf management (in German)
https://baer-wolf-luchs.at/download/OeZ_Wolfsmanagement_Empfehlungen_2021.pdf
Please be aware that these recommendations are not legally binding for the Austrian federal states.

National coordination and technical references

In 2019 the „Österreichzentrum Bär Wolf Luchs“ (Austrian Centre Bear Wolf Lynx) was established. This association of relevant administrations and stakeholder groups is supposed to harmonize the management of large carnivores within Austria and shall support its further development and implementation. Members of this association are the nine Austrian states, the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, the Federal Ministry for Agriculture, Regions and Tourism and stakeholders covering the interests of farmers, land owners, hunters, nature conservationists, and scientists. The states are responsible for large carnivore management and the Habitats Directive is implemented exclusively within the legislation of the states. Since January 2020 the Österreichzentrum pays for genetic data analysis of the passive monitoring (mostly swabs from livestock depredations and others). The genetics lab (head: Steve Smith) and scientific support and analysis of further passive monitoring data (Georg Rauer) are placed at the Veterinary University Vienna (Vetmeduni). The genetic analyses for active monitoring are currently mostly financed by the Vetmeduni, except for the military area.

Wolf monitoring implementation in Austria

Up to today, the wolf monitoring in Austria is mostly organized as passive monitoring. Every state has appointed several persons to investigate reported observations. The bulk of data are from kill inspections (livestock depredations and wild prey), pictures taken by camera traps of hunters or by local people in the course of random encounters. For the last years, a reduced form of active monitoring has been applied by the Vetmeduni in areas, where packs formed. This included camera trapping and active search for genetic samples (scats, urine, hairs, etc.). All data are categorized according to SCALP criteria.

Wolf population status in Austria

Starting in 2009 wolves were regularly recorded. The number of wolves genetically identified increased markedly from 2016 onwards. New wolves of the surrounding populations enter Austria each year, a total number of 70 different immigrant individuals could be identified between 2009 and 2020 (Österreichzentrum 2021).

The first pack was established in 2016 at a military training ground (“Allentsteig”) in the north of Austria. This pack is closely monitored by the military through camera traps and scat collection. Scats are then genetically analysed at the Vetmeduni. The Allentsteig pack reproduced successfully from 2016 through to 2020. In the monitoring year 2018/2019 two further packs developed also in the north of the country ("Karlstift" and "Litschau"), but they disappeared after one year. In 2019/2020 two new packs ("Harmanschlag" and "Gutenbrunn") emerged again in the same part of Austria and again reproduction could only be proven for one year. In the monitoring year 2020/2021 only the pack in Allentsteig could be verified. No packs have been registered in the Alpine part of the country so far.

Future perspectives and challenges in wolf monitoring in Austria

Due to the increasing populations in neighboring countries, wolf numbers in Austria are also bound to further increase in the future. However, currently the average residence time of genetically recorded individuals is less than one year (Österreichzentrum 2021). When interpreting this number, it must be taken into account that the actual residence time of many animals may be longer than the genetically recorded one. Nevertheless, one can justifiably deduce from the data that many wolves that reach Austria soon disappear again. We can only speculate about the causes, as the number of verified cases remains low. Wolves may move on into other countries (7 verified cases until the end of 2021), wolves may be killed in traffic accidents or by natural causes (5 verified cases until the end of 2021), and wolves may be killed illegally (2 verified cases until the end of 2021). To better asses the first cause, coordination with genetic labs in the neighboring countries would help. Partnering with the CEwolf consortium was a first step in this direction. Further exchange with labs in the Alps would be helpful.

The fact, that the turnover rate in the Alpine part of the country is significantly higher than in the non-Alpine part and that no packs could be established in the Alps has to be addressed in the future.

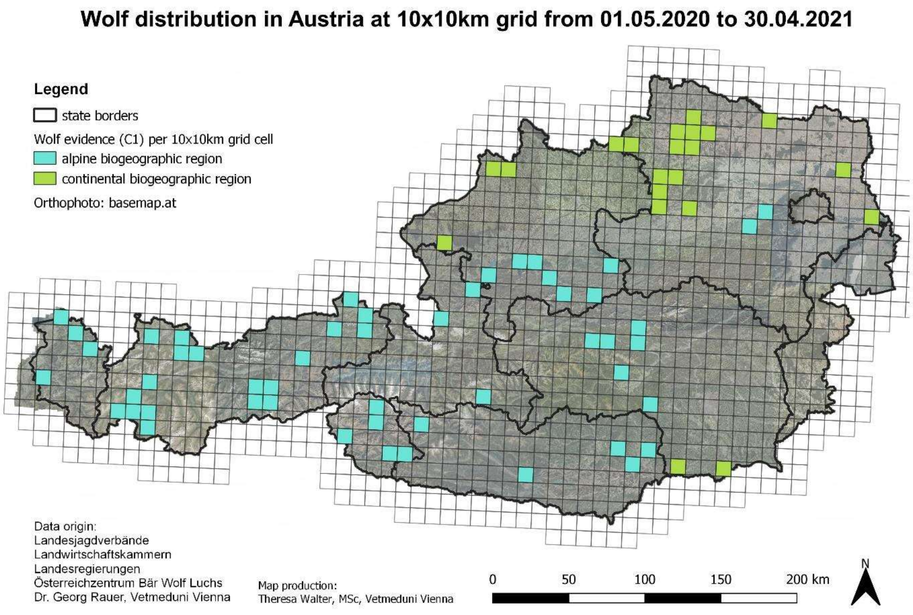

Figure 7. C1 evidence of wolves in Austria during the monitoring year 2020/2021 at the European 10x10 km reference grid. Colors differentiate for the two biogeographic regions present in Austria.

References:

Österreichzentrum Bär, Wolf, Luchs (2021). Statusbericht Wolf: Situation des Wolfs in Österreich.18 S. https://baer-wolf-luchs.at/download/%C3%96Z_Statusbericht_Wolf_2020_final.pdf

2.7 Wolf monitoring in Slovenia

Hubert Potočnik*, Matej Bartol**, Rok Černe**, in Tomaž Skrbinšek*
**University of Ljubljana, Biotechnical Faculty, Slovenia*
***Slovenia Forest Service*

Reference document – The wolf national monitoring system in Slovenia
[Link to the Action plan, including detailed monitoring methods]

National coordination and technical references

The Government of the Republic of Slovenia adopted the first Strategy for the Conservation of the Wolf *(Canis lupus*) in Slovenia and its Conservation Management in 2009 (Strategija… , 2009). Slovenia is currently implementing an extending period (2018 – 2022) of the first National Action plan for 2013-2017 that has been prepared within Life + Nature project "Protection and monitoring of the conservation status of the wolf (*Canis lupus*) population in Slovenia" – SloWolf (Akcijski načrt… , 2013). The main goal of the action plan is to establish a system of wolf protection management in Slovenia and thus increase the possibilities for its long-term preservation with as few conflicts between wolves and humans as possible. Communication between key stakeholders is extremely important to achieve the goal. The action plan identifies a number of measures, including monitoring and research of the wolf population, adequate protection of domestic animals to reduce damage, intervention in the wolf population and their prey species, education, information, public involvement and cross-border cooperation in wolf management.

Wolf monitoring in Slovenia is currently based on a national consortium of three bodies (governmental, public and NGO) consisting of Slovenia Forest Service, University of Ljubljana (Biotechnical Faculty) and Dinaricum society (Nature protection NGO). Steering board of the consortium is coordinating, planning and reporting all the activities and results of the monitoring to the competent Ministry of Environment and Spatial planning. A network of trained professional operators and trained volunteers consisted of hunters, farmers, breeders, conservationists, students and other individuals, actively working across the wolf range in the country. Members of the network collect data on signs of wolf presence (scat, urine, saliva) for non-invasive genetic analyses performed at the University lab, and volunteers for systematic howling tests are coordinated by Dinaricum society. All the damages to livestock are inspected and reported by Slovenia Forest Service. Given that wolf distribution in Slovenia is still expanding, the network has also been growing, mostly towards the north and the west since wolf recolonization of the Alps began from the southeast of the country, from Dinaric Mountains. Wolf population in Slovenia represents the most NW part of Dinaric-Balkan wolf population, however since 2018 immigrations of individuals with Alpine (Apennine) or mixed Alpine-Dinaric genetic population origin have been recorded.

Wolf Monitoring implementation in Slovenia

The methods used in the wolf monitoring were developed under the LIFE SloWolf project (LIFE08 NAT/ SLO/000244), updated within (LIFE WolfAlps (LIFE12 NAT/IT/000807) and are described in detail in the Action plan for sustainable management of the wolf (*Canis lupus*) population in Slovenia for the period 2013 – 2017.
A monitoring season follows the natural yearly reproductive cycle in wolves; from May to May of the next year. For the monitoring, multiple methods are used including established field-based protocols, laboratory tests, and quantitative methods to provide a holistic approach to wolf population monitoring in Slovenia.

1. The Howling method is used for detection of wolf litters to systematically survey the entire wolf range in Slovenia. Due to the natural expansion of the wolf population to the Alpine and pre-Alpine regions of Slovenia since 2018 the survey quadrant net was expanded to this part of the country by 113 quadrants, thus ensuring the possibility of systematic detection of the wolf litter occurrence across the entire area of permanent wolf presence in Slovenia. The current census grid for the systematic acoustic detection of territorial wolves and pups through howling survey thus comprises 605 3x3 km quadrants within which the forest (natural habitats) covers more than 65% of their area.

2. Non-invasive genetic monitoring. Field collection of non-invasive genetic samples are carried out between May and May of the next year. Collecting samples is mainly based on opportunistic collection of non-invasive samples on the entire wolf range. Additional samples are collected at “rendez-vous” sites after howling sessions and during inspection of damage cases on livestock, and tissue samples at examination of dead wolves. Based on the results of genetic analyses, the size of the wolf population (genetic mark-recapture method) in Slovenia is estimated and kinship relationships between animals as well as population measures of genetic diversity, structure and hybridization with dogs or other canids are estimated.

3. Damage case analyses. As part of their regular, routine work, Slovenia Forest Service inspectors inventories and, as a rule, assesses all damage cases caused by wolves. The inventory of damage cases is an important part of wolf population monitoring. With it, an insight into the conflicts between wolves and the local population is obtained and conflict hotspots identified.

4. Monitoring of health status and demographic characteristics by analysis of dead wolves. The analyses of dead wolves is systematically performed through biological and veterinary inspections, bio-chemical and patho-anatomical analyses at the Faculty of Veterinary Medicine, Slovenia Forest Service and Biotechnical Faculty. Routine analyses include:(1) biometric measurements of animals,(2) age assessment based on dentition, tooth wear and dentine tooth layers (I, P2), (3) DNA analysis (genotyping) and (4) Pathoanatomical section and parasitology (after indication of other necessary examination).

5. GPS telemetry. The method is a facultative method that is used combined within potential research/conservation projects. With GPS - GSM telemetry, we obtain high - resolution of wolves' spatial use as well as more general delimitation parameters between territories. Most of the captured animals are animals that are members of a pack, so with an individual monitored animal we get spatial data for the pack's spatial use. Telemetry also provides data on dispersal, insight into the survival of adult wolves and the possibility of estimating otherwise difficult to detect mortality (poaching and natural mortality), while at the same time enabling the prosecution of crimes.

6. Public attitudes toward wolves. The method is a facultative method that is conducted in 4-6 year periods among the general public or specific interest groups using questionnaires and is aimed to obtain attitudes towards the wolf and the management of the wolf population.

Alpine wolf population status in Slovenia and future perspectives

In the 2010/11 season, Slovenia's wolf population CMR size estimate was between 34 and 42 individuals lived in seven packs (Potočnik et al. 2014). From then on, the expansion and growth of the wolf population in Slovenia is well documented (Bartol et al. 2017, 2018, 2019, 2020). The last available population size estimate comes from the monitoring season 2020/2021. During this period, we collected 470 noninvasive genetic samples (304 scat samples, 127 urine samples, 32 saliva samples collected on natural wolf prey, 5 hair samples and 2 blood samples). Besides noninvasive genetic samples we also analyzed 8 tissue samples of dead wolves, one saliva sample collected from dead wolf (table I) and 6 blood or saliva samples collected during the wolf capture for telemetry. In the final estimate of the wolf population size and social structure we also included all working genetic samples (N = 44) of wolf saliva from livestock damages (genotipisation of these was financed through the public service). Altogether we gathered 317 working wolf samples. Based on the results of genetic analyses, we estimated the size of the Slovenian part of the wolf population (mark-recapture method) and analyzed kinship relationships between animals. For the season 2020/2021, we estimate that there are 12 wolf packs in Slovenia, 2 of which we share with Croatia. Five wolf packs were assessed as vital, four had "emerging" status, one "disintegrating" status and two "unknown status". This season results also indicate the disappearance of two wolf packs, which were still monitored in the 2019/2020 season. In addition, we have 18 wolves outside the territories of confirmed packs - eight immigrants of unknown pedigree, 10 dispersers with known pedigree.

The entire superpopulation, including all wolves detected in transboundary packs, was estimated at around 138 individuals (121–168, 95% confidence interval) but through the genotypes we detected 96 unique individual wolves 54 males and 42 females. Since the estimated average size of the wolf pack in Slovenia is around 6 wolves, and since 13 of the immigrants/dispersers are detected close to the border with Croatia and 5 elsewhere, all these 18 wolves will be considered as three additional packs, of which two are transboundary. According to the methodology from the previous years 4/15 (25 %) of the population are considered as cross-border animals. Also in accordance with the previous years' practice, half of the estimated cross-border animals are subtracted from the estimated population for management purposes. Thus, **in the season 2020/2021, we have 120**

(106-147) wolves for management purposes (after correction for cross-border animals) in Slovenia.

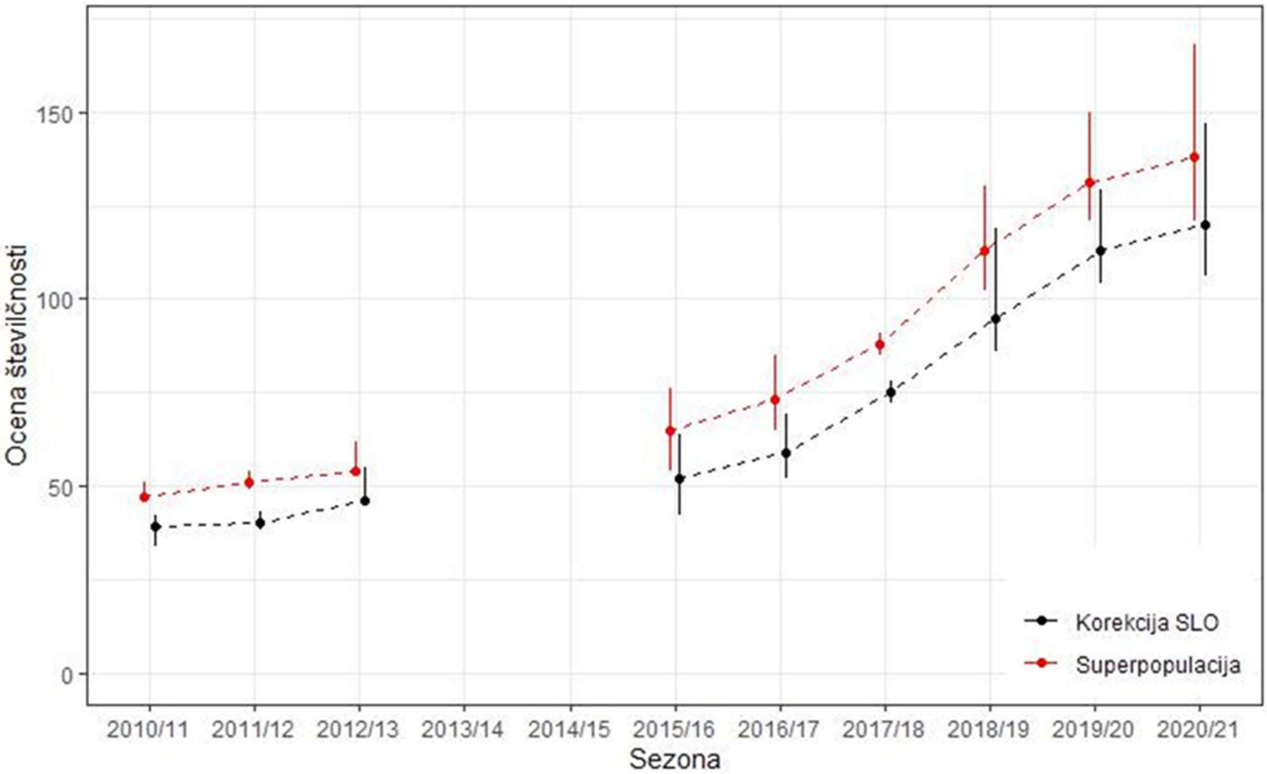

Figure 8. Multi-year dynamics of the wolf population in Slovenia. The points are mean population size estimates, the vertical lines indicate a 95% confidence interval.

During the howling survey we detected wolves in 14 quadrants. **Eight quadrants included the responses of pups.**

Since the beginning of the third wolf expansion wave in the nineties of 20th century, wolf pack presence was limited to the southern and south-western parts of Slovenia – Dinaric region. When the systematic monitoring started in 2010 there were just sporadic occurrences of single animals in pre-alpine and alpine regions of the country as result of the expanding process of Dinaric wolf population. The alpine wolf population in Slovenia is therefore ecologically-genetically a part of Dinaric wolf population, however fenced highway Ljubljana – Trieste is a delineating barrier that hinder demographic flux between the regions. First pack in the Alpine (Convention) area was established in 2012 (Potočnik et al. 2014) and until 2018 two to three packs were detected annually in the area (Bartol et al 2018). In monitoring seasons 2018/2019 and 2019/2020 there was a swift leap in spatial expansion of wolf population further into the Alps in Slovenia. First, three new packs were detected in the alpine and pre-alpine regions during the 2019/20 “howling test” and confirmed later by genetic evidence. Over the last three seasons, the situation has changed considerably in the Alpine region of the wolf range, where we now also have vital packs. In the monitoring season 2020/2021 »Trnovski gozd 2016« pack disappeared without the recorded mortality of the reproductive animal. Furthermore, in the »Pokljuka 2019« pack we noticed the disappearance of one of the reproductive animals (Bartol et al. 2021). We are concerned that there may be an increase in illegal cull in the population. Illegal killing is very difficult to prove and even more difficult it is to catch the culprit, so it is difficult to put more than speculation on the 'disappearance' of packs, but even if we consider only the recorded cases of illegal wolf killing, the current situation is worrying. Due to recurrent sampling, we can continue to monitor population dynamics. Because of differences in sampling intensity some estimators in the table I can be over or underestimated, nevertheless we get the overall picture of the population dynamics. The population shows remarkable dynamics that have been recorded since 2010.

Above diagonal: no. of animals in season Y caught again in season X.

Sez. X Sez. Y	15/16	16/17	17/18	18/19	19/20	20/21	Total animals	Loss	Growth	Imigration	Reproduction	Nett
15/16	49	15	13	8	6	2	49					
16/17	4	51	31	18	13	6	66	30 (61.2%)	51 (104.1%)	4 (7.8%)	47 (92.2%)	21 (42.9%)
17/18	2	3	53	38	26	13	87	31 (47%)	53 (80.3%)	3 (5.7%)	50 (94.3%)	22 (33.3%)
18/19	1	1	4	44	38	19	85	44 (50.6%)	44 (50.6%)	8 (18.2%)	36 (81.8%)	0 (0%)
19/20	0	0	1	2	67	37	110	41 (48.2%)	67 (78.8%)	5 (7.5%)	62 (92.5%)	26 (30.6%)
20/21	0	0	0	0	0	57	96	37 (33.6%)	57 (51.8%)	8 (14%)	49 (86%)	20 (18.2%)
Missed in season X	0	4	4	5	2	0	**Diagonal: no. of first catch**					

Under diagonal: no. of animals from the season X, not caught in season Y, but caught later.

Figure 9. Population dynamics table. Estimates are based on the actual detected animals, not model abundance. Based on the reconstructed pedigrees, we divided the total population growth into reproduction and immigration.

In the last decade, the wolf population in Slovenia has increased significantly. It seems that wolf abundance in Slovenia is now at the point where chance and mortality of each individual are becoming less important for defining the species conservation status. The wolf population shows a constant positive dynamic in both abundance and spatial characteristics, as it has been increasing and expanding spatially since 2010, ever since we have quality monitoring data**.** In season 20/21 we have two packs with “unknown” status and nine with active statuses (“vital” or “emerging”). Besides that, the population trend is still positive although it seems that population growth is slowing down.

The conservation status of the wolf in Slovenia can therefore be classified as favourable.

Additionally, cross breeding between a solitary territorial female wolf and domestic dog was detected in 2019, producing five F1 hybrid offspring in 2019 and three in 2020 and is worrying. However, hybrid pack from the area of Velika planina (The Savinja Alps) is mostly removed, including the alpha female wolf. However, two hybrid offspring have probably survived and possibly dispersed. We believe that in order to ensure long-term protection of the wolf population in Slovenia, confirmed wolf-dog crosses should be removed from the population, which is extremely difficult. An additional problem at the moment is the uncertainty in identifying animals that are not first generation (F1) hybrids, however there is no problem distinguishing animals coming from Italy to the Alpine region in Slovenia. (Fig. 2)

Wolf-dog hybridisation remains a concern. Although the wolf crossing with dogs on Velika Planina was culled, there are new reports of potential hybrids in the Alps at the end of this season. We believe that in order to ensure the long-term protection of the wolf population in Slovenia, it is necessary to remove confirmed wolf-dog hybrids from the population, which is extremely difficult. Nevertheless, we propose to continue removing hybrids and potential hybrids, as the introduction of dog genes into the wolf population is a much greater threat to the wolf population than potential culling errors.

Concluding remarks

All wolf monitoring data indicate that wolf conservation in Slovenia is successful, but it is possible that population growth is slowing down. Monitoring continues to provide a sound scientific basis for the management and protection of wolves in Slovenia. The multi-year and consecutive monitoring projects allow us to know the structure of Slovenian wolf packs on a "personal" level for several generations and to understand in detail the social structure, abundance and long-term dynamics of the population. Although most pedigree determinations, which are the main method for an in-depth understanding of population dynamics, are spatially and temporally meaningful this season, the number of individuals in the study is beginning to outstrip the statistical power of the set of genetic markers we are using. We will need to expand the set of genetic markers in the coming years.

Crossbreeding with dogs remains a problem that we will have to tackle seriously. Although it is not as widespread as in some neighbouring countries, the problem must be addressed with all seriousness. Since we have been monitoring the growth and spatial expansion of the population since 2010, we can non the less make a strong case for a favourable conservation status.

However, it should be remembered that the total number of wolves in Slovenia is by far too small for the long-term viable population, so it is crucial to maintain connectivity with other Dinaric wolves in Croatia, Bosnia and Herzegovina and Alpine wolves in Italy, Austria in order to maintain a favourable conservation status. In this sense, we should not forget about the fences at the border with Croatia and make sure that they do not cause isolation of the "edge" populations of large mammals in Slovenia.

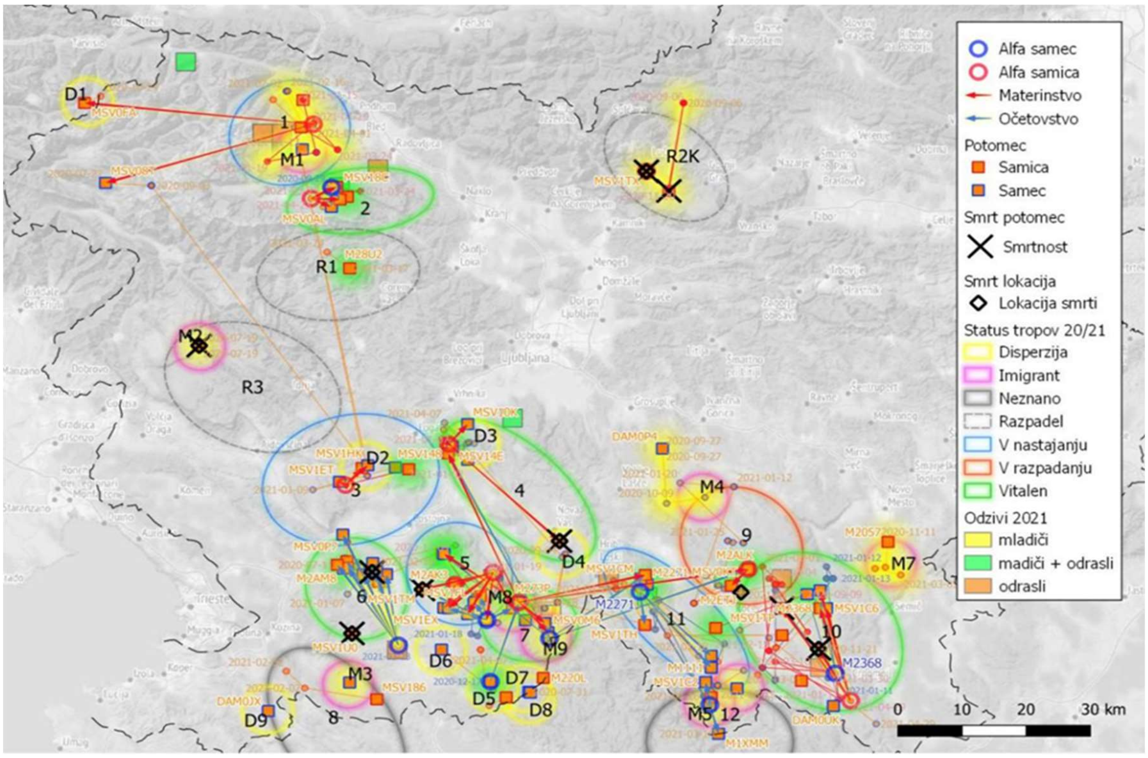

Figure 10. Family connections (pedigree) of wolves in the sampling season 2020/21, presumed pack territories, and tagged dispersers / immigrants. Pack territories are made on the basis of the locations of members of each pack, but are of a purely indicative nature.

Figure 11. A female wolf crossbred with a dog in 2019 and 2020. The female and five pups; 3 black and 2 black-brown from 2019 litter.

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Annual wolf monitoring reports - Slovenia

3. Wolf Alpine Group: goals and summary of activities

The Wolf Alpine Group (WAG) has brought together research and management experts from Italy, France, Switzerland, Austria, Slovenia and Germany in charge of wolf monitoring in the Alpine area since 2001. Associated research groups (especially genetic labs involved in wolf monitoring) also regularly contribute to the WAG workshops. The aim of the WAG is firstly to exchange biological scientific knowledge among countries on wolf distribution and demography over the Alps, at the population level. Secondly, we evaluate and implement minimum standards to produce a robust assessment of the status of the wolf population according to the available sources of data. Finally, the WAG aims to continuously improve methodological approaches designed to monitor distribution and demography of the alpine wolf population (WAG, 2008 and 2014).

In 2001, a first workshop on wolf monitoring organised in France gathered experts from France, Italy and Switzerland who were concerned about the recent recolonization by the wolf of western alpine areas. The main objective of the workshop was to set up an effective collaboration among the three countries in order to exchange scientific data to effectively monitor the wolf population in the Alps as a whole and to exchange about transboundary packs occurrences. Since then, the Wolf Alpine Group has continued to foster significant progress and strong collaboration among wolf experts, particularly regarding information exchanges and common/practical methodologies (WAG 2003). Common or compatible monitoring standards (e.g., definitions of wolf packs, minimum requirements to document pack presence, etc.) and genetic approaches have been defined, and exchanges of data have taken place regularly, while taking into account the differences between countries in data collection, institution organisation, levels of monitoring and specific objectives for population monitoring.

The WAG is an independent scientific group capable of addressing specific scientific requests from different platforms (see WAG 2008 for an example) and informing large carnivore management (e.g., WISO Platform of the Bern Convention, European Commission). Twelve years after the first discussions, the Wolf Alpine Group met for the 7th time in Jausiers (France) on the 19-20th of March, 2013, with the main goal of producing an update of the status of the wolf population in the Alps within the different countries. Moreover, some methodological approaches (especially exchanges of genotyping results) were discussed to solve the discrepancies between technological changes and result updates. After defining the population segment of interest and according to previous results and future goals, Austria, Germany and Slovenia joined the group to cover practically the entire alpine range. A WAG logo was defined in April 2014.

In 2015, the 8th WAG workshop was organised in Stelvio National Park, Italy, in the framework of the first LIFE WolfAlps project. On this occasion, the first transboundary monitoring standards, fundamental to producing reports on the status of the wolf alpine population, were considered. In addition, a discussion was held among the genetic labs involved in the genetic analysis of biological samples from wolves in the Alps, with the ultimate goal of continuing to have a joint genetic approach to monitor the wolf population over the Alps as techniques continued to evolve. In 2018, the 9th WAG workshop was held in Slovenia, and the discussion on both topics continued. The agreed transboundary monitoring standards for the wolf alpine population were finalised during the 10th and 11th WAG workshops, held respectively in May 2020 and January 2022. Both events were organised in the framework of the LIFE WolfAlps EU project and were held online due to Covid restrictions. The present document is the outcome of discussions from these last two workshops.

Table 1. Below is a table with the list of WAG meetings/workshops and the relative documents that were produced

YEAR of WAG Workshop	Location	Document produced
2001: 1st meeting	Briancon (France)	https://kora.ch/wp-content/uploads/2021/03/ONCFS_2001_First_alpine_wolf_workshop_Briancon.pdf
2003: 2nd meeting	Boudevilliers (Swiss)	https://kora.ch/wp-content/uploads/2021/03/KORA_18_E_2003_Second_alpine_wolf_workshop_Boudevilliers.pdf
2004: 3rd meeting	Entracque (Italy)	https://kora.ch/wp-content/uploads/2021/03/Marucco_2004_Wolf_Monitoring_in_the_Alps_3rd_WAG_Workshop_Italy.pdf
2005: 4th meeting	St Martin (France)	
2007: 5th meeting	La Fouly (Swiss)	https://kora.ch/wp-content/uploads/2021/03/KORA_41_E_2008_Fifth_alpine_wolf_workshop_La_Fouly.pdf
2010: 6th meeting	Entracque (Italy)	
2013: 7th meeting	Jausiers (France)	https://kora.ch/wp-content/uploads/2021/03/KORA_41_E_2008_Fifth_alpine_wolf_workshop_La_Fouly.pdf
2015: 8th meeting	Bormio (Italy)	https://kora.ch/wp-content/uploads/2021/03/WAG_report_2015_2016_final.pd
2018: 9th meeting	Podcerkev (Slovenia)	
2020: 10th meeting	On line	Present document
2022: 11th meeting	On line	Present document

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Figure 12. The wolf alpine Group in Jausier (France) during the 7th WAG meeting 2013 March, 19-20th

Figure 13. The wolf alpine Group in Stelvio National Park (Italy) during the 8th WAG meeting 2015, March, 19-20th.

Figure 14. The wolf alpine Group online due to covid restrictions during the 10th WAG meeting on the 22nd May 2020, extended to a Scientific Committee.

4. Standard criteria for classifying and interpreting data on wolf monitoring

Within the Wolf Alpine Group, researchers from each country aim to harmonise as much as possible the methodology used to monitor the wolf alpine population. First by setting common unit definitions (e.g., packs, pairs, area of occurrence), parameters (e.g., sampling units, data needed to confirm units) and then by defining standard criteria for classifying and interpreting data collection. A final version of standard criteria was defined and accepted at the alpine level after the LIFE WolfAlps EU workshops held online in 2020 and 2022, which are reported hereafter.

4.1 Standard criteria for classifying wolf observations

WAG scientists have agreed to adopt standard criteria for classifying wolf observations, originally developed by SCALP (Status and Conservation of the Alpine Lynx Population), a conservation initiative (www.kora.ch) that developed standardised criteria for the interpretation of data for lynx monitoring. Under SCALP, observations are classified according to their verifiability into C1 = hard facts, C2 = confirmed observation, and C3 = unconfirmed observations.
These criteria have been adapted to wolves with adjustments and adopted by several countries in Europe (Kaczensky et al. 2009, Reinhardt et al. 2015, Marucco et al. 2014, 2020, Zimmermann et al. 2010, Duchamp et al 2012).

In the following, we update the agreed SCALP criteria adapted to wolves for the standardised monitoring of wolves in the Alps.
Researchers from alpine countries set how the data is assigned to the different categories of verifiability.
A few preconditions nevertheless apply:

- For the evaluation of field data, at least one experienced person must be available.
- A person is considered "experienced" if he/she has extensive experience in the collection of field data on wolves, meaning that he/she is practised in recognising and interpreting signs left by the species in the field. Such a person must have recently taken part over relevant field work in the framework of national or internationally recognised scientific wolf surveys.
- All observations must be checked for genuineness to rule out the possibility of intentional deception.

The letter "C" stands for "category". The numbers 1, 2 and 3 below denote the level of validation for an observation. In Table 1, classification criteria for all cases of observations are reported.

C1: Hard evidence = Hard fact, i.e., evidence that unambiguously confirms the presence of a wolf, like animals captured or rescued alive, dead animals, genetic proof, good quality video/photo, telemetric or telemetry locations.

C2: Confirmed observation = Indirect signs confirmed by an experienced person as being caused by the target species, like tracks followed for at least 100 m, scats, kills and howls with wolf pups. The experienced person can either confirm the signs himself/herself in the field or do it based on documentation by a third party (documentation is country-dependent).
C3: Unconfirmed observation = All observations that are not confirmed by an experienced person or observations which by their nature cannot be confirmed. Examples include all signs that are unclear or incompletely documented; signs that do not provide a clear picture of presence (for example a track less 100 mt long, heavily eaten kills or kills not combined with other C2 data); and all signs that cannot be verified (all sightings not supported by photos or videos). False observations are not considered and are entirely ruled out.

Table 2. Standard Criteria for classifying observations of wolf signs.

Criteria Category C1
Animals captured or rescued alive
Dead animals
Whatever DNA evidence confirms the biological sample (i.e., scats, hair, blood, urine, saliva, regurgitated, bones)
Telemetry locations
Good quality video and photos
Criteria Category C2
Documented tracks with typical trend/pattern assessed by an expert and followed for at least 100 m
Documented scats checked by an expert
Predation signs with typical bites and/or consumption, if combined with other C2 data
Howl with wolf pups' presence, checked by an expert[3]
Criteria Category C3
Tracks followed for less than 100 m in snow or single footprint
Scats not confirmed by an expert and not associated with snow tracks
Heavily eaten kills, livestock depredations not technically documented, or not combined with other C2 data
Single howls
Sightings not supported by photos or videos
Bad quality videos and pictures preventing secure identification of species
Observation not categorised, excluded from database
Inappropriate documentation provided by third party

4.2 Definitions and criteria for data interpretation

The WAG agreed on specific unit definitions and common parameters used in wolf monitoring over the Alps, and have moreover defined criteria for data interpretation to combine results at the alpine level, updating definitions used in 2018 (WAG 2018) (table 4.2). Wolf biology, standard monitoring requirements under the Habitat Directive, and data needs for the reporting of Large Carnivore

[3] Recent studies with songmeters might give further insights on this

Initiative for Europe (LCIE), have all been considered in these criteria definitions (i.e., mapping wolf occurrence at European level). Given that the wolf population has been growing in recent years, WAG researchers decided to implement some parameters and criteria for monitoring wolf population over the Alps during the last WAG meeting in 2022 (table 4.2).

It has become ever more difficult to distinguish adjacent packs when an area becomes saturated with wolf packs. Therefore, new criteria for distinguishing adjacent packs have been defined at the international scale following Reinhardt et al. (2015). Intensive application of genetic methods, simultaneous camera trapping or wolf howling are necessary to distinguish one pack from another in case of high pack density. Two or more adjacent packs can be distinguished only with the genetic identification of each pack (pack pedigree) or through simultaneous evidence of pack reproduction in both areas (through pups' howls or videos/photo). Also, telemetry may be helpful to identify a pack's territory if wolves from adjacent packs are also monitored; however, it is not a method that could be applied at a large scale.

During the 2022 WAG meeting, the case of packs with multiple breeding was also discussed. Multiple breeding within a pack can occur when a maturing wolf, usually a daughter of the reproducing female, stays and breeds in its natal pack. Such a situation may appear when the breeding male of the pack is replaced by a new male. This new male can then breed with the mother as well as with a mature stepdaughter. Other constellations involve the young female breeding with an external male that may or may not be accepted into the pack by her parents. Multiple breeding are well known from North America (Mech and Boitani 2003, Stenglein et al. 2011; Stahler et al. 2020), but have rarely been documented so far in Europe. Multiple breeding in a pack can be detected through the intensive application of genetic methods to establish detailed wolf pack pedigree during a single breeding season or with photographic documentation of more than one lactating female and / or multiple litters in the same pack. When detected, multiple breeding must be highlighted and recorded for that biological year as originating from a single pack.

The basic social units of a wolf population are packs and pairs (Mech and Boitani 2003). A pack is defined by at least ≥ 3 individuals travelling together while holding a territory or by pup occurrence. A pair is defined as one male and one female who mark their territory. Dispersers or solitary individuals are not reported in the territories of the map or in the evaluation of the population trend as represented by the number of packs and pairs, but are included in wolf occurrences. Packs have been defined as "transboundary" (Tr) once hard evidence is documented with genetic matches in areas across national borders, or as "likely transboundary" (LTr) without hard facts but based on the interpretation of the spatial distribution of wolf signs (WAG 2013).

Table 3. Definitions used in wolf monitoring and agreed criteria for data interpretation at alpine level.

UNIT	DEFINITION	DATA NEEDED
monitoring year	Biological year for wolves (from reproduction to next reproduction)	From the 1st of May to the 30th of April
Pair	Only 1M +1F holding a territory and travelling together but not (yet) having reproduced	C1 that confirms the pair bonding together: ● video/photo/genetic ● or a track of the pair with genetic proof of the couple
Pack	Reproductive unit identified by either pup occurrences or by at least ≥ 3 individuals travelling together and holding a territory	● Reproduction confirmed with one C1 or C2 ● or at least 2 independent C2 showing the pack travelling together (tracks) ● or ≥ 3 individuals confirmed by C1 (genetics / photo / video)
Wolf Occurrence (Cell)	10x10 km cell (EU grid) where the species has been detected on the yearly basis	At least one C1 or two independent C2
Representation of the Territory	Area held by the resident wolf/wolves to point its approximate localization over space	Circle of about 200 km^2 centred on the centroid of the MCP constructed on the collected C1-C2 wolf signs
Adjacent packs	Two adjacent packs need to be clearly distinguished to be considered two units (or more) by either: ● genetic data for pack identification ● simultaneous proof of reproduction ● telemetry data from radio collared wolves belonging to one of the adjacent packs	C1 data needed

5. A common strategy to survey and monitor the alpine wolf population

5.1 Survey and monitoring: terminology and definitions

Monitoring is a very commonly used term, but it is often confused with census or survey. While a **survey** is defined as the collection of quantitative or qualitative information through standardised procedures to determine a status at a particular point in time, **monitoring** means "a regular and structured monitoring (series of surveys) to check the compliance of a measure with an expected objective (e.g. the recovery of an endangered population to a viable status", Hellawell 1991, cited in Breitenmoser et al. 2006). Monitoring is the systematic surveillance of processes based on parameters (e.g. population size, habitat conditions, threats, acceptance) that provide information on the status of the system and its change over time (Yoccoz et al. 2001).

Monitoring is a process of continuously comparing results with the intended target. Before designing a monitoring program, the objective of monitoring must first be defined. Secondly, the accuracy and precision required to assess whether the monitoring objective has been achieved must be known. Finally, both the objective and the required accuracy determine the monitoring methods to be used. The analysis and interpretation of the monitoring results in comparison to the target determines the adaptation of the methods in order to achieve the monitoring objective (Linnell et al. 1998, Breitenmoser et al. 2006; Williams and Brown, 2012). There are various reasons for carrying out monitoring (for an overview see Jones et al. 2011), e.g., to check whether conservation measures for a species are achieving their goal, or to trigger specific management measures, or to generate information that allows decisions to be made between alternative measures. Monitoring programmes can also help to involve stakeholders in the conservation or management of species (Jones et al. 2011, Dickinson et al. 2012).

In relation to the Habitats Directive, the conservation objective is to achieve and maintain a favourable conservation status of wolves. The parameters suitable for assessing the achievement of this objective are given by the reporting format, such as population size, population trend, distribution range and trend, habitat suitability, etc. Monitoring the population development does not require recording every single wolf. In order to evaluate the conservation status, data on the **reproductive units** are necessary, **i.e. packs and pairs** (possibly reproductive in the following year). For management reasons, however, it may be necessary to follow certain individuals intensively. This approach is accepted and implemented widely. Germany developed and implemented very clear monitoring standards (Kaczensky et al. 2009, Reinhardt et al. 2015b), similar to a cross-border approach with Poland (Reinhardt et al. 2015a). Sweden and Norway focus on the reproductive units as well (Liberg et al. 2012). In the framework of the WAG, this is the approach that has been adopted so far.

According to Breitenmoser et al. (2006) **passive and active monitoring** can be distinguished. **Passive monitoring** requires no original field work but mainly means the collection, evaluation and analysis of information that is provided by the public through chance encounters. This may include wolves found dead, damage reports or direct observations. When populations are hunted, this would also involve harvest data. Care has to be taken when analysing and interpreting this information since these methods can produce biased results. For example, some causes of mortality may be easier to detect (traffic kills) than others (illegal killing, natural diseases). Additionally, the data collected by passive monitoring might not be appropriate for all monitoring questions, e.g. the number of depredation events is not closely linked to wolf population size, but depends also on damage prevention measures in place (Kaczensky 1996). The existence of a single individual killing a disproportionate number of livestock strongly biases the data (Linnell et al. 1998).

Active monitoring means collecting data specifically for the purpose of a monitoring program (Gese et al. 2012). This includes field work, but also special studies or habitat analyses. Data are collected in a targeted and systematic way to minimize the bias, and the monitoring results can directly answer the questions asked (e.g., snow tracking).

Monitoring methods used in the Alpine wolf population

Snow tracking is the most common monitoring method for wolves when possible. The climate conditions in the Alps often allow a systematic application of this method. However, snow tracking also needs a lot of manpower. The availability of staff for this method is different from country to country. Thus, snow tracking cannot be the main method used for monitoring the Alpine wolf population. However, whenever conditions allow tracking, the opportunity should be used to gain as much information as possible (pack size, marking animals, new occurrences, etc.).

As snow conditions increasingly do not meet the requirements for snow tracking and wolves settle more and more in areas with little snow, alternative methods have to be sought. Detection dogs are dogs trained to detect clues (e.g., faeces) of certain animal species (see e.g. Long et al. 2007). They could be a good alternative to snow tracking, as they can be used in snowy areas outside the winter season. Testing this method in the framework of wolf monitoring in areas with permanent wolf presence as well as in areas with suspected new establishment is recommended (Reinhardt et al. 2015). Genetic analyses are standard nowadays in large carnivore monitoring. The collection of genetic material (from scat, hair, blood, urine and saliva collected at kills) can be done all year round. Snow is appropriate to collect samples of marking individuals (urine or estrus blood). Genetic methods should be applied widely in monitoring the Alpine population. Presence sign survey – the search for signs left by large carnivores like tracks, scats, scratch marks or kills – is probably the most common active monitoring method for wolves (Linnell et al. 1998) and very powerful in combination with genetic analyses. It can be carried out all year round as long as the snow conditions in winter allow and should be used as a basic monitoring method for this population in areas with territorial wolf pairs and packs. Applied randomly, present sign surveys provide presence / absence data for distribution maps.

Elicited howling is mainly used for the detection of wolf reproduction in summer in many wolf areas. However, the success (answering) rate is generally low with this method (Fuller et al. 1988).

Meanwhile, other methods like camera trap surveys or genetic analyses have also proven successful for confirmation of wolf reproduction (Fabbri et al. 2007, Galaverni et al. 2012). Nevertheless, cases using elicited howling might still be reasonable (Llaneza et al. 2005). A recent study shows that when analysing recorded wolf howling, individual identification is possible (Root-Gutteridge et al. 2013). New technical tools such as acoustic sensors (e.g., the "Songmeter") allow the systematic recording of spontaneous howling. Although the effort for fieldwork is considerably reduced since the acoustic sensors automatically record the sounds (Passilongo et al. 2015; Suter 2019), hours of sound recordings must then be analysed in order to find the wolf howls. However, considering the increasing automation of these types of data analysis (e.g., Stowell und Plumbley 2014), this method has a promising future (Zimmermann 2019).

For the monitoring of wolves, camera trapping has proven to be effective in documenting presence (Galaverni et al. 2012; Cozzi et al. 2021; Zimmermann et al. 2021). In addition, camera traps can be used to obtain data on reproduction, the minimum pack size, and the distinction between neighbouring packs if wolves are recognisable. Some information on individual body condition and disease symptoms such as mange can also be obtained with this method.

Telemetry, is a method that offers a wide range of possible applications which go far beyond monitoring. It can provide valuable information on territory size; habitat use or reasons for mortality that is otherwise difficult to obtain. Telemetry studies are often used to calibrate the results of a monitoring program and to define rules. For instance, without knowledge about the territory sizes in a certain area (or genetic data), it is difficult to distinguish between neighbouring pairs or family groups. Radio telemetry studies provide the most accurate data, but are mostly limited to small areas and few individuals (Breitenmoser et al. 2006, Fuller and Fuller 2012). Breitenmoser et al. (2006) recommend telemetry to calibrate local monitoring programs. Since territory size data collected from just a few individuals can vary widely (Reinhardt and Kluth 2011), an adequate sample size is necessary. Telemetry could be used for monitoring bold wolves, for better observation, for assessing their dangerousness and for targeting deterrence measures.

Data and information obtained without field work like chance observations reported by the public, animals found dead and livestock killed by wolves should also be collected in a common standardised way.

Stratified monitoring

Monitoring large carnivores is a difficult task because top predators are always rare and roam over large areas. In practice, these constraints make it very personnel and cost intensive to monitor large wolf populations with the same intensity over their whole distribution area like small populations. In consequence, many have adopted stratified monitoring programs (see Greenwood and Robinson 2006 for a detailed introduction). This means monitoring may differ with regard to intensity and methods on various scales in space and time. Whereas on a broad, long-term scale more general indicators such as distribution, trends in range and population size have to be estimated, on smaller scales the objective is usually to obtain more detailed information like home range size and pack size, habitat use, the proportion of floaters or data on reproduction and population size.

The precise data gained in comparatively small study areas are needed to calibrate and interpret the information obtained with less expensive methods and less intensive effort over a larger area (, Boitani et al. 2012). Monitoring coordination across administrative levels is a prerequisite for a stratified monitoring approach.

5.2 Defining the time scale of the international wolf alpine monitoring

Nowadays, given the effort needed to survey the wolf population in each country, it is for the countries with large parts of the alpine population economically and strategically not feasible any more to conduct wolf surveys every year. Countries are therefore moving to survey the wolf population every other year (e.g., Italy, Slovenia), or within specific time tables, to concentrate efforts in certain periods. The two main European programs that need to provide updates on the status of wolf populations at a large scale (LCIE status reports and Habitat Directive reporting) do not require annual species surveys, but compile data over certain time windows.

Article 17 of the Habitats Directive 92/43/EEC requires every country to produce Annex II species updates every 6 years. All Member States are requested by the Habitats Directive to monitor habitat types and species listed in its annexes and send a report every 6 years following an agreed format. The assessment of conservation status is based on information about the status and trends of species populations and of habitats at the level of the biogeographical or marine region. The last updated dataset was reported by Member States for the period 2013-2018. The next one will be for the period 2019-2024.

Considering these time frames and each alpine country's needs, it is fundamental to find common time windows to conduct the wolf alpine monitoring concurrently, in particular when monitoring selected population parameters through time (presence occurrence and pack distribution, see section 5.1 below). Here we define the common period of survey which will allow updates at the alpine population level, and in connection with the requirements by Habitat Directive (HD) and LCIE products.

Table 4. Timeline for the production of the grid of wolf occurrence per country and for the Habitat Directive (HD) and LCIE products.

	Italy	France	Swiss	Germany	Austria	Slovenia	HD	LCIE
2020-2021	x	x	x	x	x	x		
2021-2022	x	x	x	x	x	x		
2022-2023	x	x	x	x	x	x		
2023-2024	x	x	x	x	x	x	x	x

Table 5. Timeline for the production of the wolf pack distribution per country and for the Habitat Directive (HD) and LCIE products.

	Italy	France	Swiss	Germany	Austria	Slovenia	HD	LCIE
2020-2021	x	x	x	x	x	x		
2021-2022		x	x	x	x			
2022-2023		x	x	x	x			
2023-2024	x	x	x	x	x	x	x	x

5.3 Defining the study area: the spatial extent of the alpine wolf population

Following the Guidelines for Population Level Management Plans for Large Carnivores, the wolf population in the Alps has been identified as a unique population segment (Linnell, et al. 2008). Although it is genetically and demographically connected to the Italian wolf population in the Apennines (Fabbri et al. 2007; Marucco et al. 2018), this population segment of wolves in the Alps is considered autonomous because of its ecological and socio-economic contexts (Linnell et al. 2008) that strongly differ from those of other regions, defining it as a management unit. In fact, as they live in the same ecological region and because wolf packs roam over large territories of up to several hundred square kilometres, because packs may extend beyond administrative borders, and because dispersers are able to move over hundred kilometres, wolves living within the Alpine arch are therefore considered to be a single unit, the alpine wolf population, no matter in which of the 7 different Alpine countries they occur. Today, the wolf population in the Alps is expanding in every country beyond the alpine territory, towards the hills, along rivers and down to the plains. However, in line with the objective of monitoring the wolf alpine population as a single population, we will still demographically and spatially evaluate the population within the Alps territory (Figure 5.1.), if only to continue documenting comparable trends of the population expansion over the years. Every country will nevertheless count wolves at the country level beyond the Alps territory, which under the Alpine Convention is considered the spatial extent of the international alpine wolf population.

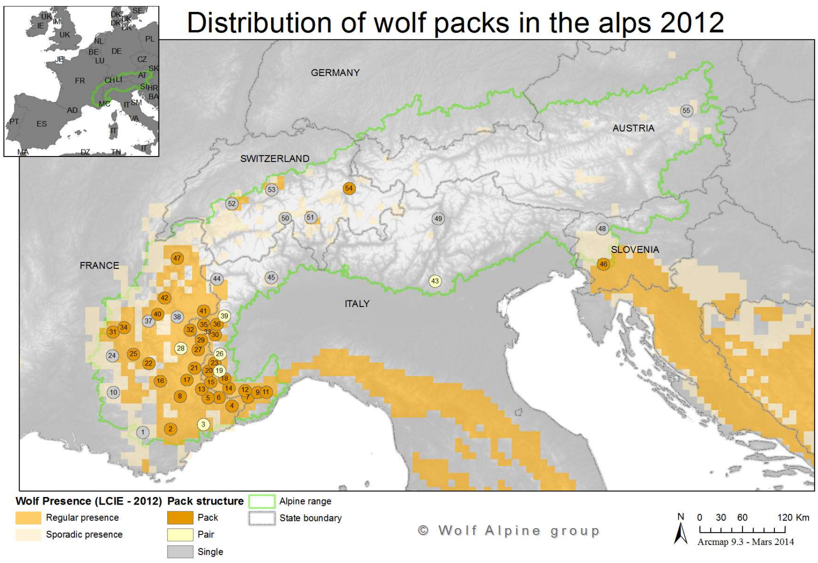

Figure 15. Wolf presence in the Alps as documented by WAG in 2012. The alpine range as defined by the Alpine Convention is indicated in green.

5.4 Defining the parameters to be monitored over time

Monitoring large carnivores is challenging given the low density of individuals over space and their ability for significant dispersal. The observation effort is also of concern to account for the imperfect detection of individuals (not all animals alive in a given year are "captured" by genetic evidence). Wolf monitoring therefore requires high and intensive fieldwork in order to detect first a possible occurrence, followed by more effort to assess the dynamics of the settlement of new packs and finally the overall trend of the demographic social units of the species. Whereas this monitoring methodology is largely implemented over each European country at the first stage of the wolf colonisation process (see Hystrix Vol 23 review), it becomes very challenging once the population and pack density increase. Distinguishing packs then requires high sampling effort and a mix of different methods to understand who is who over space and time.

At this advanced stage of transboundary wolf expansion over the Alps and to document trends (i.e. grid of occurrence, number of packs), we think it is more practical to track indexes of wolf presence over space and time instead of trying to estimate wolf population size, which would be too hard to conduct in terms of funding and effort. At the colonisation front, however, greater effort using sharper indexes of population monitoring will certainly be required and maintained. Therefore, hereafter, we define the indexes that we will use to monitor the expansion of the wolf population over the Alps.

5.4.1 Wolf occurrence: distribution and trend

Wolf occurrence will be defined by validated wolf signs, every year (Table 5.1.), considering the biological year (from 1st of May to the 30th of April). All validated wolf signs are projected on an EU 10x10 grid cell (LAEA89 datum). This validated dataset of wolf occurrence is regularly reported in WAG maps, following the criteria described in Table 4.2. Although the grid of wolf occurrence can be reported beyond the border of the Alpine convention (Fig. 5.1), the trend of the occupied area is calculated within the alpine range to focus on the demographic entity (*sensu* Linnell 2008), although some dispersals and gene flows have already been documented beyond that area (see WAG 2016).

For the year 2023-2024, we will produce a map of permanent vs. sporadic wolf presence within a 3-year temporal window to be consistent with the request of LCIE updates (Table 5.1). The criteria to use are:

- permanent presence: every cell occupied over the previous 3 years or in at least 1 of the last 2 years with proof of reproduction (C1-C2 data),
- sporadic presence: all other non-permanent occurrences.

The validated dataset on wolf occurrence will be reported in the WAG distribution map.

Over time, we monitor the following indexes of wolf distribution to detect trends:

- number of total cells of the map,
- number of permanent cells of the map (only for 2023-2024).

5.4.2 Wolf packs: distribution and trend

The Wolf Alpine Group reports considered changes in the number of "wolf packs" as the biologically meaningful index of population trend and distribution (WAG 2012 and 2016), such as in other wolf monitoring systems worldwide (Mech and Boitani, 2003). Also in this case, the biological year is defined from May 1th to April 30th the year after, corresponding to the wolf reproduction period.

Defining adjacent packs needs lots of data and genetic information (Table 4.2), so this exercise cannot be conducted regularly by every country, especially in high density areas. Hence, wolf pack distribution will be documented at the alpine scale not on a yearly basis, especially for Italy and Slovenia (Table 5.2), but only in years 2020-2021 and 2023-2024, to match the requirements of the Habitat Directive (HD) and LCIE products. For those selected years, we will update pack distribution on a common map, by indicating a circle of about 200km^2 (Table 4.2). We will also need to exchange genetic information whenever possible to document the transboundary status of some packs.

Over time, we monitor the following index of wolf presence to detect trends:

- minimum number of packs/pairs

5.4.3 Common alpine population report: indexes and distribution map

The WAG agrees to regularly produce a common report following the timing defined in Tables 5.1 and 5.2 and the criteria provided in Table 4.2. We will hence produce:

- a common map combining all presence data sets of wolf occurrence (10x10 grid) every year,
- a common map combining the distribution of pack/pair presence for 2020-2021 and 2023-2024,
- an evaluation of the number of packs/pairs as an index of demographic population trend,
- an evaluation of the number of occupied grid cells as an index of geographical population trend,
- an evaluation of documented hybrid packs whenever possible.

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