LIFE DINALP BEAR

Population level management and conservation of brown bears in northern Dinaric Mountains and the Alps

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Cost benefit analysis of different monitoring approaches and guidelines for optimized monitoring of brown bears

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Summary

In the rich history of bears research and management, the number of different monitoring methods for the surveillance of the status of the brown bear population, its impact on space and interactions with humans has been steadily increasing. For example, population size dynamics can be monitored with non-invasive genetic sampling, harvest-based reconstructions and stochastic models; data from systematic counting of bears at counting sites (such as practices in Slovenia) have great potential as well, and the dynamics of damage are also in principle associated with population size dynamics. Duplication of estimates may create problems: (i) redundant monitoring is expensive, (ii) divergent predictions leave room for conflicts and misinterpretations, which can be detrimental to the quality of management and research, (iii) perhaps the most problematic aspect thereof is the impact on the credibility of the profession, since the public does not understand the differences between monitoring activities and the media may even depict such differences as abuse. On the other hand, certain management-relevant signs are not formally included in any monitoring. It is therefore logical to optimize the entire bear monitoring scheme at the national and population levels. In this report, we prepared an overview of past and present monitoring schemes, analysed their strengths, weaknesses and scope, and identified indicators that are poorly covered, yet important for bear management and research. All analyses and descriptions have been made using the data for Slovenia, where thedata is the most abundant and the monitoring is particularly diverse. However, the key findings apply to the entire Alpine-Dinaric population and more broadly.

Europe is dominated by anthropogenic landscape which leads to bear- human encounters, which cause conflicts. Human tolerance to bears also depends on the efficiency of resolution of damage and other conflict cases. Conflict resolution requires a good overview of the types of damage, their spatial and temporal dynamics, and the factors that influence their occurrence. These indicators are monitored in the context of the **monitoring of damage by brown bear**, which has been carried out in Slovenia with some changes since 1994. Damage is also recorded in other parts of the project area. Human-bear conflicts are resolved by a rapid reaction team in the event of a threat to the lives of people and property by large carnivores, an **Intervention Group** operating under the auspices of the Slovenia Forest

Service since 2000; similar task forces operate in other countries in the project area. Data on the damage and measures by the Intervention Group are important for evaluating when socio-economic carrying capacity of the environment has been reached or exceeded, and when to take action. We propose that the following indicators are developed and reported on the basis of the data of both monitoring activities: (i) spatial occurrence of conflicts, (ii) number of conflicts, (iii) financial extent of conflicts, (iv) conflict types and (v) *conflict index*, which represents the weighted sum of all types of conflicts and is therefore especially suited for spatial and temporal comparisons at population level. Spatial data on conflicts also provides complementary information on bear occurrence, but it is biased. In order to understand the dynamics and mechanisms underpinning human-bear relations, it is also necessary to have (vi) **opinion polls**. We estimate that at least one poll modelled on the last poll (which was carried out as part of this project) should be conducted per action plan period, that is, every 5 years.

In the north-east Dinaric range and most other countries with vigorous bear populations, one of the basic management measures is culling. Data on all recorded mortality types are routinely recorded. Since recorded mortality represents a large part of all mortality, bear **mortality monitoring** data is an excellent starting point for reconstruction of a range of population parameters and processes. In Slovenia, for example, within this monitoring activity, each harvested animal is sexed, weighed and aged with teeth section analysis; date, time, location, cause of death and a number of other morphometric data is recorded, and tissue samples taken for further genetic, health or dietary analysis. Mortality monitoring data are key to monitoring (vii) absolute and relative bear mortality, and, despite certain limitations (e.g. time delay, correction for spatial openness of the population), provide a useful insight into absolute/relative natality, spatial distribution, distribution of reproductive females, sex structure and non-anthropogenic brown bear mortality. In combination with censuses based on non-invasive genetics, they also provide quality reconstructions and predict population size dynamics. Monitoring should be maintained in its current form to ensure regular analysis of age on the basis of grinding of teeth (model forecasting for missing samples).

Systematic counting of bears on the network of permanent counting sites is the oldest bear monitoring carried out for bears in Slovenia. In the framework of LIFE DINALP BEAR it was also introduced in Croatia. In its present form, it has been implemented in Slovenia since 2004, but its beginnings date back to the early 1990s. Within the framework of the monitoring, three times a year, always on the last Friday before the full moon, once in spring and twice in autumn, from an hour before dusk to midnight, all present bears are recorded, with separate recording of cubs of the year (0+), cubs of the previous year (1+), females with cubs and other bears. The data, collected at 167 counting sites points (feeding sites), that systematically cover the entire bear range in the country, are entered into a digital database. Using this data, we can monitor the dynamics of relative natality, litter size and structure, relative bear density across the country, and, to a certain extent, demographic links between parts of the population. By considering the effects of certain environmental factors (e.g. beech masting and weather on counting day), this monitoring activity also provides good surveillance of relative population size dynamics and forecasting of absolute population size. Of the three annual countings the first two provide good data, while the last one is redundant and less informative. We therefore recommend that it be discontinued, while the monitoring as such be maintained in its current form with minor changes.

One of the key bear monitoring activities in Slovenia and in neighbouring countries is based on analyses of a large number of **non-invasive genetic samples** collected over a short period. In Slovenia it has been carried out twice, in 2007 and 2015, in Croatia in 2015 and in Italy at different times in different parts of the country. The method facilitates currently the most reliable estimate of population size and sex structure; it also provides insight into local densities, distribution of females, genetic diversity and functional integrity of the population. However, it also has weaknesses: (i) it is expensive compared to other methods and requires a lot of preparation and organization, (ii) without the involvement of volunteers, it could not be implemented in Slovenia (the situation is similar in Croatia), and it is probably not possible to incite volunteers to participate every year, also (iii) due to long laboratory and computational analyses, results have been delayed by 1-2 years post-sampling. Due to all of these limitations, this monitoring method can be used only at intervals of several years; so far, it has been carried out at eight-year intervals. Taking into account the scope of two complementary monitoring activities (calibrated harvest-based forecasts and monitoring at permanent counting sites), it makes sense to keep this interval in the future. In the interim period, however, two above-mentioned methods for determining population size, both calibrated to genetic estimates, should be used. In exceptional circumstances or years (e.g. increase in poaching, longer suspension of regular hunting, drastic change in feeding), the interval should be shorter or, provided there is a clear mismatch in forecasts from complementary methods, monitoring must be carried out as soon as possible. Overall, the monitoring activity is maintained in its existing form, with the intensity of sampling adjusted to the state of the population. In areas where the population is expanding, population parameters change faster and densities are smaller (e.g. SE Alps), adapted monitoring with shorter time intervals is used.

Genetic monitoring of tissue samples (invasive genetics) is also based on molecular methods. Samples have been collected systematically from all harvested bears in Slovenia since 2003 (and in Croatia since 2008). These samples have higher quality than non-invasive samples, and the likelihood of contamination is lower. This is the only monitoring method that enables the calculation of the effective population size and the preparation of lineages, which has significant research value and management potential, especially at the population level. The indicators provided by this monitoring method were assessed as medium important at the workshop of managers and researchers in Slovenia. It is therefore advisable to carry it out insofar as there is sufficient funding and at the same interval as the census based on non-invasive sampling.

Feeding is one of the most important, but also the most controversial management measures, for bears as well as other species. It is intensively used in Slovenia and in many other countries. The measure is, for example, important in terms of reducing human-bear conflict, it facilitates monitoring and hunting, and reduces the likelihood of hunters wounding bears and such bears attacking hunters. However, it has several adverse effects on target and non-target species, and it is also controversial in terms of some aspects of conservation dogma. Therefore, the bear management strategy in Slovenia strives to reduce feeding in general so as to mitigate its adverse and preserve its positive effects. At present, the most appropriate method for assessing the importance of feed in bear diet is analysis of stable isotopes in tissue samples. The method was introduced in Slovenia as part of this research. We propose that it be introduced as an **independent monitoring of the content of anthropogenic sources in bear diet** and that the samples of all harvested bears be analysed during the duration of the current action plan, whereupon sampling should be optimised for best results with least resources.

Since 2014, samples have been taken routinely in Slovenia to **analyse bear health**. A pre-determined number of harvested bears are sampled for parasitological, microbiological, molecular and histopathological analyses, which allows monitoring of the general health of the bear population. The sampling is spatially and numerically limited to harvested bears. Since analysis is expensive, we recommend that this monitoring be continued, but with a focus on cases of mortality with unexplained causes of death or suspected pathological causes.

In addition to biological influences, population size of any species may be affected by socio-political and economic carrying capacity. The latter is determined by expenditure (e.g. compensation for damage) but also by direct and indirect income from the species. Data on the value of individual activities are thus important for realistic evaluation. Therefore, we recommend that in addition to the various damage indicators, the following **indicators of income** related to bear management are also collected: (i) extent of eco-tourism (number of guests / day / observatory), (ii) income from eco-tourism (income from visits), (iii) hunting income (trophy and meat). Knowing the extent of eco-tourism by location will be also important for understanding the impact of this activity on bear behaviour (habituation).

The report first presents the principal past and present bear monitoring activities carried out in Slovenia and other countries covering the Alpine-Dinaric population of brown bear and the derived indicators of the state of the population and its interactions with the environment, in particular human-bear interactions, facilitated by these monitoring activities. For each indicator (for individual monitoring) we identified the strengths and weaknesses, and indicated which analyses are optimal to maximise utility. We organized a national workshop with representatives of researchers, managers and the competent ministry, and ranked all indicators that we need in bear research and management by importance. Informed by the results of the workshop, we compiled a preliminary set of urgent and recommended monitoring activities and defined the intensity of their implementation for optimal results. The selection was made for Slovenia, but it is by and large applicable to other parts of the project area. The syntheses are presented in Tables 3 and 5 of this report, which also includes are of implementation since, some of the parameters are important on a transboundary level, some only for Dinaric population of bears and some on a national level.

One of the key aims of LIFE DINALP BEAR is to establish an optimised and coordinated monitoring scheme for the entire project area – a large portion of the Alpine-Dinaric population. As part of the project an international workshop was held (23-24 May, 2019) and its results formed the foundations for guidelines for such a monitoring scheme. The long-term vision – and the only reasonable vision – is to establish a uniform monitoring scheme of all minimally required indicators to monitor the entire population (which includes Bosnia and Herzegovina, Montenegro, Serbia, Switzerland and Lombardy in Italy).

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Tables

1. Introduction

Knowledge of population parameters and processes is a cornerstone of high-quality conservation management of animal species. Often the most important management parameter is population size, in particular for (smaller) populations of endangered species such as brown bear. Population size monitoring is typically demanding, various methods may be complementary and each has its own advantages and weaknesses. Non-invasive genetic sampling is one of the more precise methods, but due to high cost it is unrealistic to conduct it every year. Nevertheless, management increasingly requires annual estimates. It is therefore necessary to find a middle ground between costs, which extend the interval between samplings, and the desire for accuracy, which reduces this interval. Interval may also be affected by complementarity of the results of non-invasive genetic sampling and other, cheaper methods for estimating population size. In Slovenia we have developed a method for estimating brown bear population size that is based on harvest data. Despite certain limitations, its results are very useful when combined with non-invasive genetics (which allows calibration) (JERINA & POLAINA 2018). Accuracy may potentially be improved with a third method of estimating relative brown bear population size, i.e. counting on permanent counting sites. Depending on situation, various methods can be cost-optimised to arrive at an optimal balance between cost and accuracy of population size estimating.

Bear management studies in Slovenia have an impressive track record, and the number of different types of monitoring of bear population status and its impacts on space has gradually grown. Size dynamics can thus be described / measured with non-invasive genetic sampling, harvest-based reconstruction and stochastic models; data from systematic counting of bears on permanent counting sites has great potential as well, and damage dynamics are also in principle related with size dynamics. Even though it may seem that duplication of data / estimates cannot hurt, it can result in certain problems and thus requires improvement: (i) redundant monitoring is expensive, (ii) divergent forecasts leave room for conflict and misinterpretation, which can harm the quality of management and research, and (iii) potentially its most problematic aspect is the impact on credibility of professions in the field, as the public does not understand the differences between different types of monitoring and the media may even depict it as abuse. On the other hand, certain signs relevant for management are not formally included in any monitoring. For example, monitoring of the effectiveness of individual management activities (e.g. feeding) is particularly insufficient. It therefore makes sense to optimise the entire bear monitoring scheme at national and population level.

The final objective of this Life DinAlp Bear action is to develop an optimised scheme for monitoring the Alpine-Dinaric brown bear population that would cover the entire brown bear population distribution range on the territory of all partner countries. The action is important from the aspect of research, management and cost of brown bear management.

2. Overview of monitoring schemes

2.1. Monitoring of damage by brown bear

There is no longer real wilderness in Europe, the continent is dominated by anthropogenic landscapes. Except for parts of Scandinavia, most brown bears thus live close to humans. This inevitably leads to conflicts, which are a key threat to the future conservation of the species. The success of conflict management will therefore define the future success of conservation of large carnivores. Damage to human property caused by bears is one of the most common conflict situations. Cohabitation, and hence human tolerance of bears, relies to a significant extent on appropriate resolution of damage cases. Insufficient knowledge about the causes of damage and inability to resolve damage cases leads to dissatisfaction among people and consequently lowers tolerance of the species. Appropriate resolution of damages thus requires knowing the types (category) of damages, their spatial and temporal dynamics, and factors that impact their occurrence.

2.1.1. Description of monitoring

Each damage event allegedly caused by bears to human property is examined on-site by experts from the Slovenia Forest Service. For each confirmed case they collect basic data and enter it in the national database of damage events; date, location (coordinates), type of damage, scope and estimated value of damaged property data is collected. The most common categories are damage to livestock (in particular sheep), orchards, beehives and crops. Organised and systematic collection of data was launched in 1994, along with a compensation scheme. Once the system became more widely known in 1999, reporting of damage events surged. In their present form, collection of data on damage events started in 2003: since then the exact location of each individual damage event is recorded in a dedicated national database.

2.1.2. Utility and scope of the monitoring

Data on damage events is collected on an ongoing basis at the annual level and is therefore up-to-date. It is collected in an electronic database of damages maintained by the Agency of the Republic of Slovenia for the Environment. The data is analysed annually at minimum with basic descriptive statistical analysis. Most importantly, temporal (seasonal) and spatial dynamics of damages and their financial scope can be monitored at the annual level without significant additional investment. Analysis of the total damages is used in reporting (e.g. ZGS, 2016).

The collected data on damage by bear is important for monitoring the saturation of socio-economic carrying capacity, i.e. the (approximate) number of bears the local population is willing to cohabit with. This is because damage (conflict) dynamics are generally dependent on the dynamics of bear population size and density (A.1 report, Jerina *et al*., 2015). Damage data may be used as an approximate indicator of spatial distribution and the dynamics of relative population size. Finally, it also provides insight into the dynamics of seasonal activity in the vicinity of human settlements.

As part of action A.1 (Jerina *et al*., 2015) a comparison of damage in individual countries involved in the project was conducted. One elegant possibility of displaying damage cases that we presented was *weighed conflict intensity*, which includes also the work of the Intervention Group and collisions with vehicles (Jerina et al., 2015). *Weighed conflict intensity* makes it possible to sensibly combine all types of conflict into a single variable (instead of multiple individual variables), which is useful for analysis and presentation.

2.1.3. Shortcomings of the method

Monitoring of damage cases is important as an indicator of socio-economic saturation of carrying capacity. But it is of very limited use in the presentation of parameters and processes of bear population, since it only partially evidences bear presence (damage only occurs where there is property to damage; bears do not damage all potential property).

Correct interpretation of data also requires knowing environmental factors that influence damage dynamics. Beech masting is one such factor: more intense masting reduces the number and gravity of damage cases (Jerina *et al*., 2015). It is also possible that not all damage cases are reported, which is especially likely if damage is small.

2.2. Bear mortality monitoring

Brown bear is a long-lived species with comparatively high reproductive potential. The biggest danger to cubs early in life are males, especially at the peak of mating season. But except for infanticide, natural mortality is low. Humans thus account for the bulk of bear mortality in Europe, which includes hunting as well as mortality due to road and rail accidents. In Slovenia and other comparable European countries where culling (hunting) is one of the key management measures for keeping population size in line with socio-economic carrying capacity, recorded mortality represents a large part of total mortality. Allowing for certain limitations and assumptions, mortality data may be used to reconstruct population structure, size and dynamics. Additionally, measurements of biometric data (weight, size, share of fatty tissue) and autopsies of dead bears produce basic information for monitoring the general health of the population.

2.2.1. Description of monitoring

In Slovenia brown bear has been a protected species since 1994. Since then every removal must be recorded according to law. Population size has steadily increased in the last several decades (Jerina and Polaina, 2018). Throughout this period culling was carried out because one of the principal soft (unwritten) management goals was to stabilise population growth. Every year a bear expert group determines a harvest quota (which includes culling, projected accidents and other mortality events). Within this quota it sets the weight and spatial structure of the harvest, with the final document (rules) confirmed by the Government of the Republic of Slovenia. Data on harvested bears and other mortality has been recorded since 1994 in a single database kept by the Slovenia Forest Service. Since 1998 the database has been complete in that for each harvested bear, data on location and time of harvest, sex, age, mass and biometric size data (e.g. paw length and width, head diameter, etc.) is recorded. Since 1998 this data has thus been useful for all kinds of analysis, especially population size reconstruction and the sex and age structure of the population. Additionally, teeth (typically the P1 premolar) are extracted for ageing and some tissue samples, whose relevance to bear monitoring is explained in detail in chapters 2.2.1.1 and 2.2.2, are removed as well.

2.2.1.1. Teeth analysis, health and invasive genetic sampling

In 1991 we started to age individuals with tooth grinding, initially randomly, but since 1998 efforts have been made to obtain samples from all removed animals. The samples (premolars) are sent to a reference laboratory in the US Matson's Laboratory, Montana), where age is determined by counting cementum annuli (Jerina and Krofel, 2012). For some bears it is impossible to get a tooth sample (human factor, inability to get tooth). In such cases age is determined using a model (Jerina and Krofel, 2012) based on regression trees that uses sex, body mass, time of year (standardised body mass) and age estimated visually by hunting grounds managers as independent variables. The model produces very accurate results in younger animals (to within a year) but with age the estimates become progressively less reliable. This is a means of achieving age completeness of data for all removed animals, which is important for multiple subsequent analyses and monitoring.

Since 2003 a tissue sample (typically skeletal muscle) is taken from each removed animal for the purposes of genotyping invasive genetic samples, and since 2014 selected bears (animals showing signs of poor physical fitness or adult bears that died of natural causes) are sampled for heath analysis. Starting in 2015, we have been collecting multiple tissue samples (liver, muscle, hair, fatty tissue) to research diet profiles of bears from stable isotopes (in particular to estimate the importance of maize in bear diet). All this data is combined at the level of individual animal.

2.2.2. Utility and scope of the monitoring

Bear mortality monitoring provides very good insight into one of the most important population parameters – mortality. The data can be directly used to analyse relative scope, sex and age structure, and causes of mortality. With age (premolar analysis) and sex analysis, it is possible to use statistical methods to recursively reconstruct the age and sex structure of the bear population. These methods are underpinned by certain assumptions, but in the long term they provide accurate estimates of population trends (Jerina and Polaina, 2018). Population dynamics is one of the things that can be modelled with the data: calibrated with genetics data, it provides good results on population size, especially over a period of several years after calibration (perhaps up to 8 years). Data on harvest location may be used to partially monitor the spatial distribution of brown bear (Jerina *et al*., 2013). The database of harvested tissue samples, systematically managed at the Biotechnical Faculty (departments of biology and forestry), and the biometric data are, among other things, an important source of information on diet, general fitness and health of brown bears.

2.2.3. Shortcomings of the method

The rules on brown bear culling determine the weight structure of the cull (e.g. 65% of individuals up to 100 kg) and ban the culling of females with cubs. Hunting mortality (and consequently a portion of recorded mortality) of individual sex and age groups is not the same or even proportionate to total mortality, which represents a problem in reconstruction of the sex and age structure of the “living” population. However, this “error” in analysis can be fairly well mitigated since it is roughly constant over time. Harvest locations are not necessarily proportionate to local densities either. Mortality data provides a biased estimate of distribution and local densities (comparatively higher mortality closer to humans, in areas with lower density; Jerina *et al*., 2013), but the error is within the range of errors of other data sources (telemetry, non-invasive genetics).

More accurate analysis of sex and age structure and reconstruction of population dynamics requires long data series. Reliability of reconstruction estimates (age-at-harvest method) is poorer (wider confidence interval) towards the end of the time series, when bear cohorts (all cubs born in a year) are not yet completed (high share of bears from last cohorts still alive).

2.3. Brown bear counting at permanent counting sites

In conservation management of protected species, it is crucial to know the population size and its temporal dynamics. There are multiple methods available for monitoring population size. Most are based on field counting, including counting on permanent counting sites (Jerina *et al*., 2019). Aside from providing data on population size, share of 0+ and 1+ cubs, litter size and share of female with cubs, this monitoring method also provides insight into relative bear density in the country (Jerina *et al*., 2019).

2.3.1. Description of monitoring

Bear counting on permanent counting sited has been conducted every year since 2004. The sites are pre-selected and as a rule permanent. Every year bears on 167 separate counting sites are counted; all counting sites are feeding sites frequented by bears, they are at least 3 km apart and at least 2 km from the nearest settlement. Counting is conducted three times a year, in spring (May or June) summer (August or September) and autumn (October or November). Bears are recorded from the afternoon (one hour before dusk) to exactly midnight. Every bear that comes to the counting site is recorded complete with time of arrival and duration of stay. Females with cubs of the year (0+), females with yearlings (1+), cubs of the year (0+), yearlings (1+) and other bears are recorded separately. The direct result of the count is the total number of all present bears, number of females with 0+ and 1+ cubs, and number of other bears.

2.3.2. Utility and scope of the monitoring

At its core the acquired data shows the trend of relative brown bear population size, whereby any omission of counting at an individual counting site must be appropriately accounted for (described in Jerina et al., 2019). Aside from population size and modelling of relative dynamics, the data may be used to monitor relative natality, litter size and relative share of adult females with cubs in a certain reproductive period. It is also possible to monitor the duration of stay and time of arrival at the feeding site by sex and age category, and model local densities at feeding site areas (Jerina et al., 2019).

By considering certain additional environmental factors (e.g. beech masting) and including these factors in analyses as covariates, it is possible to significantly improve the accuracy of the estimate of relative population size (Jerina et al., 2019) and forecast absolute size of the population and its temporal dynamics.

2.3.3. Shortcomings of the method

In individual countings (just like in any counting in nature) errors may occur because of differences between observers. These can be significantly reduced if the same person goes to the same counting site every time; in that case at least the temporal trends are unbiased. Counting is also strongly dependent on weather conditions. For example, the likelihood that a bear notices an observer on an open stand rises sharply in windy weather, whereas the ability to correctly identify sex and age (cubs) categories may be reduced by rain or fog, when overall detectability of bears if low. The impact of weather is particularly important because counting is conducted at the same time and conditions at individual counting sites may be very unfavourable despite good weather overall. Beech masting in autumn has a strong impact on bear presence at feeding sites. In years with strong masting the number of bears at feeding sites in autumn is lower, as nature provides a better, high-quality source of food. Failing to account for the weather and masting may lead to wrong conclusions. It is precisely these limitations, combined with generalised judgements about poor implementation of monitoring (the allegation that managers frequently do not count bears, they just make up the data from experience), that have led to criticism of this method in the past.

In interpreting the sex and age structure identified at counting/feeding sites, it is necessary to consider that representation at feeding sites is not necessarily proportional to representation in nature. In spring, female bears with cubs of the year use feeding sites more rarely when they leave their dens and mating starts, in order to reduce the risk of infanticide. Identified shares of sex and age categories may thus be systematically biased.

2.4. Collection and analysis of non-invasive genetic samples

In ecology and conservation, genetics is used with increasing frequency to estimate population size and viability, genetic variability, degree of inbreeding and other characteristics. An important part of genetic monitoring of brown bear in Slovenia is non-invasive analysis of genetic samples, which is largely based on analysis of collected scat samples.

2.4.1. Description of monitoring

Two brown bear censuses based on non-invasive genetic sampling have been carried out so far in Slovenia, in 2007 and 2015. In both years an extensive collection of scats was undertaken with the help of volunteers (especially hunters) in the brown bear range. In 2015 it was carried out together with Croatia to determine the size of the single population in both countries. All field data was entered in a database (Biotechnical Faculty, Department of Biology; Skrbinšek *et al*., 2017). Population size is reconstructed from non-invasive genetic samples with the capture-mark-recapture method.

2.4.2. Utility and scope of the monitoring

For populations similar to and smaller than ours, size estimates derived from non-invasive genetic sampling produce the best results among the methods in our current toolbox. Using non-invasive genetics, we can also estimate the sex structure of the population; if sampling is repeated several times, it is also possible to track the spatial expansion of the species (share of females in marginal areas, densities in specific areas) and, to a certain extent, survival of individuals and tracing of individuals over time (typically little data about many animals, the opposite of telemetry).

2.4.3. Shortcomings of the method

The way it has been developed in Slovenia, where sampling is done almost exclusively by volunteers (mostly hunters), the method has the following shortcomings: (i) it is expensive compared to other methods, (ii) it requires a lot of preparation and organisation, (iii) it cannot be conducted without volunteers, but it is unlikely the volunteers can be motivated to join every year. Due to these limitations, the method can only be used in multi-year intervals. Another shortcoming is the time it takes to prepare and analyse samples (currently 1-2 years).

In Slovenia, which is small relative to brown bear ranges, the capture-mark-recapture method based on non-invasive sampling is very sensitive to the assumption of spatial closedness. In the first sampling in 2007 the estimate for spatial openness was corrected with migration distance (derived from samples), in the second census in 2015, sampling was conducted simultaneously in Croatia.

2.5. Analysis of invasive genetic samples

2.5.1. Description of monitoring

Invasive samples are various tissues collected from removed bears. Since 2003 samples of all removed individuals have been collected systematically. Skeletal muscles, heart muscles, liver and hair (together with skin or at least follicles) represent the bulk of the tissue bank maintained by the Biotechnical Faculty (departments of biology). Procedures for the analysis of samples and processing of data are similar than for non-invasive samples, as described in chapter 2.4.1.

2.5.2. Utility and scope of the monitoring

Invasive genetic samples are of better quality than non-invasive samples (more loci can be determined), and the probability of contamination is lower (Skrbinšek et al., 2017). Invasive genetic samples can be used for the same analysis as non-invasive samples, but the monitoring has broader scope: it can be used to monitor dynamics of effective population size as well as sex- and age-specific natality (in combination with animal age), and to create genealogy over longer time horizons.

2.5.3. Shortcomings of the method

The biggest downside of invasive genetic samples is the sampling, which depends on removal and projects in which bears are harvested. Moreover, interpretation and analysis should account for the fact that the probability of *capture* (mortality) of individuals within the country and between countries are not constant, or else all findings may be subject to systematic error.

2.6. Work of Intervention Group

2.6.1. Description of monitoring

In Europe's anthropogenic landscape, the potential for human-bear conflict is significant. In Slovenia, conflict situations are resolved by a special intervention team for rapid reaction in the event of threats to humans or property by large carnivores – the Intervention Group. Operating since 2000 under the auspices of the Slovenia Forest Service, the Intervention Group is in charge of nation-wide interventions. The data about its activities is collected in a single database and regional task forces report monthly to the Slovenia Forest Service (Kragelj, 2011).

2.6.2. Utility and scope of the monitoring

The Intervention Group's collected data is presented in annual activity reports, which describe individual conflict interventions and their spatial and temporal (seasonal) distribution. These conflict cases often overlap with recorded damage cases. As part of Life DinAlp Bear preparatory action A1, data on the work of the Intervention Group was collected together with damage cases and traffic accidents involving bears and presented in the form of weighed conflict intensity (chapter 3.1.2; *Jerina et al.*, 2015). Together with data on damages, the data on the work of the Intervention Group may be instrumental in estimating socio-economic carrying capacity; knowing that is in turn essential for the planning of brown bear management in Slovenia.

2.6.3. Shortcomings of the method

The Intervention Group has a specific purpose – resolving conflict situations – and the scope of collected data is accordingly narrow. This data is thus unsuitable for monitoring the majority of population parameters and processes such as population size, natality or distribution. The data partially overlaps with the data of damage monitoring.

2.7. Monitoring of brown bear health

2.7.1. Description of monitoring

Since the start of Life DinAlp Bear in 2014, samples have been routinely collected to analyse brown bear health. Samples for parasitological, microbiological, molecular and histopathological analysis are collected from selected harvested bears. Between 2014 and 2017 samples of 36 bears or just under 10% of the animals harvested in this period were collected. Before that, bears with unknown causes of death suspected to be of pathological origin had been autopsied.

2.7.2. Utility and scope of monitoring

Laboratory analysis of data may be used to monitor the general health of the brown bear population and to determine the presence of any new pathogens that might have a significant impact on mortality or general physical fitness of brown bear.

2.7.3. Shortcomings of the method

Collection of samples is spatially and numerically confined to harvested animals. Even though the sampling as such is routine (harvested animals/killed in accidents) and does not entail high costs, laboratory analyses are expensive and a preventive examination of a large number of animals is probably not feasible within the limited financial frameworks.

3. Overview of additional research

3.1 Analysis of human attitude to brown bear (human dimensions research)

Human dimensions research involves the study of opinions, convictions and values of people in a certain area about the importance of nature, natural resources and conservation. This includes studies on why certain interest groups have formed a certain opinion. Opinions and convictions of the general public and interest groups are probably the best indicator of a society's attitude to a certain issue (Majić Skrbinšek, 2016) and hence a key component of brown bear management.

Human dimension studies are quantitative and qualitative studies of public attitude to bears and bear management. Their chief purpose is to determine: 1) people's tolerance limit to brown bear (socio-economic carrying capacity) and 2) what types of encounters with brown bear (situations) people in a certain area perceive as conflict. At the same time, such studies may provide an estimate of knowledge and interest in bear management. Human dimensions research is conducted by first selecting a target group in which to assess the scope of opinions, attitudes and perceptions in the target population. In the second phase a questionnaire is made based on the findings of the first phase. The key is to get a large enough sample, which may be an obstacle in certain countries and environments, or on certain subjects. Opinions and convictions of the public may change fast with the help of high-profile events well covered by the media, which makes one-off studies irrelevant to long-term population management. The results of human dimensions studies are instrumental to successful resolution of misunderstandings between the public and managers, making management more successful in the long term.

3.1. Brown bear diet

Feeding is a crucial activity for any animal species. Diet affects numerous population parameters of species including habitat choice (presence and movement of species in space), natality, mortality, fitness (size and mass) and health. Anthropogenic food, which may be available deliberately (food at feeding sites specifically designated for one or more species) or accidentally (food waste, organic waste, crops) is widely and easily available in anthropogenic landscapes. For omnivores such as bears, anthropogenic food is a high-quality food source (in terms of macronutrients) and as such a strong attractant that may have a significant impact on ecology and, by extension, management of the species. Even though anthropogenic food is probably still not the main reason why bears venture into human settlements, it may be reasonably concluded that bears are often attracted to the vicinity of settlements by accidental sources of anthropogenic food. Diversionary supplemental feeding (especially with maize) has always been one of the principal management measures, one of whose goals is to reduce wandering of bears close to human settlements and hence the prevalence of damage and conflict cases. Supplemental feeding is highly controversial. Although there is an increasing body of evidence and indications that the type of feeding conducted in Slovenia and many other European countries reduces human-bear conflict, the measure has numerous effects on targeted and non-targeted species, some of which are highly undesired (e.g. pseudo-domestication of species). Knowing to what extent accidental anthropogenic food can affect the development of conflict behaviour in bears, and whether feeding sites as an important management measure have the desired impact on the bear population, is therefore exceptionally important for bear management. To achieve that, it is necessary to know and monitor bear diet and dietary behaviour.

3.1.1. Analysis of scat and stomach content

In the past several studies of bear diet were conducted (Krofel, 2008, Kavčič, 2016, Kraft, 2016, Štraus, 2018). They were all based on analysis of scats or stomach content (harvested individuals). In both methods individual recognised types (groups) of food are separated in the laboratory with a system of sieves, whereupon relative frequency (presence of type relative to sample size) and volume / mass (volume / mass relative to volume / mass of entire content) may be determined. The method is inexpensive and, with some practice, relatively straightforward. On the other hand, detecting and estimating the volume / mass share of an individual type is strongly affected by its digestibility. The results may therefore be biased against certain types of food, which is why the methods are not very well suited to estimating easily digestible food (e.g. meat and most of the anthropogenic food). Nevertheless, for certain major types of food such as beechnut or maize we can get relatively reliable estimates of diet shares that can be used with relative ease for comparison between individuals (analysis of stomach content, rarely analysis of scat content) and seasons.

In harvested bears it is easiest to extract and appropriately store the entire stomach, whose content is subsequently analysed in a laboratory. The advantage is that food in the stomach is less digested, which provides a more relevant estimate of the shares / content of eaten food, including food that is more easily digestible. On the other hand, such research is constrained by accessibility of stomachs. Culling rules, which set a time frame for the cull, render it difficult to compare diet by season and, even more importantly, between conflict (emergency cull) and non-conflict animals: in the summer, samples are restricted almost exclusively to conflict bears, while at other times of the year non-conflict animals represent the majority of the samples. Moreover, the stomach content of culled bears at the time of shooting is not necessarily representative of a longer period, as animals are baited with various feeds, whose share is therefore overestimated.

3.1.2. Stable isotopes

Stable carbon and nitrogen isotopes have become well established in animal ecology as a method to analyse digested food (Javornik *et al*., 2017). The method leverages the fact that the ratio of stable-isotope carbon and nitrogen in an animal's studied tissue is a mixture of the ratio of stable-isotope carbon and nitrogen of food sources in a given time period prior to tissue sampling. By analysing the stable-isotope ratio in animal tissue and its food sources, we can estimate the share of a certain food source in digested food. Other samples may be used as well; the only difference concerning tissues is that they represent digested food at different time periods (e.g. bear livers represent food digested over the last several weeks, while hair may represent food in the last several months).

The advantage of this method compared to the previously mentioned methods for analysis of animal diet is that by default, analysis of stable isotopes produces an estimate of digested food directly available to animals for energy metabolism and biosynthesis of tissue. On the other hand, the method has important limitations and assumptions. A fair synthesis of all limitations and assumptions is that stable isotopes are restricted to the study of dietary shares of food types that are isotopically distinct, such as for example plants with photosynthesis mechanism C4 (e.g. maize) and most other anthropogenic food sources comprising C4 plants. However, the monitoring of these food types in bear diet is of extraordinary importance in brown bear dietary ecology and the future management of the species in Slovenia.

4. Overview of potential indicators of brown bear population status

Wildlife management requires knowledge of indicators of population status and its interactions with the environment (in the case of bears, especially with humans). The indicators may differ depending on managed species and / or systems, and their principal objectives. For the purposes of this report, the indicators were divided to: (i) indicators of bear population parameters and processes, (ii) indicators of human-bear interactions, (iii) other indicators (e.g. indicators of the effect of management measures).

4.1. Indicators of parameters and processes in the bear population

The first major group of indicators covers population parameters and processes, which provide insight into the state and fitness of the population. These indicators may serve as early warnings about unfavourable conservation status of a species. Shown in Table 1, these are mostly population processes such as natality, mortality, size and spatial distribution.

Table 1: Indicators of brown bear population status.

Indicators of processes and population parameters	Description / note
Size	Number of individuals in monitored population
Absolute / relative mortality	Number of dead animals (no. of dead / no. of all animals
Absolute / relative natality	Number of births (no. of births / no. of all animals
Spatial distribution	Surface area of species' permanent presence
Spatial distribution of reproductive females	Surface area of permanent presence of reproductive females
Sex structure	Share of males and females in population
Effective population size	Very simplified description: no. of animals in a population that contribute genes for the next generation
Genetic diversity of population	Diversity of genes in population
Functional integrity of population	Scope of gene flow between parts of population

4.2. Indicators of human-bear interaction

Successful brown bear management requires monitoring people's attitudes to brown bear, which can have a rapid and strong feedback effect on the state of the bear population. People's attitude can shift significantly due to extraordinary, stochastic events (e.g. attack on humans), but it may also be swayed by the bear management system and the types of mitigating measures used to reduce conflict. Conflict situations are an integral part of the attitude and they can be presented through the following indicators: **(i) Number of conflicts per time unit, (ii) Spatial occurrence of conflicts, (iii) Financial scope of conflict / damage** (sum of values of conflicts), **(iv) Type of conflict** (damage, attack, collision with vehicle) and **(v) Conflict index** (weighed value of individual types of conflict).

People's attitude to bears can also be measured directly with surveys and targeted questionnaires in the framework of human dimensions research. Provided they are well formulated and successfully implemented in management, public opinion polls can provide an accurate representation not just of **people's attitude** to bears but also of knowledge about the species and its management, and opinions on the efficacy of individual management measures.

Several measures are being carried out to reduce damage by bears, and by extension the incidence of conflict with bears. One of the longest-running measures is diversionary **feeding**. Bearing in mind adverse side effects, assessment of the effectiveness of this measure requires knowing the **quantity of feed** introduced into the environment to divert bears and other species away from settlements, **how much of the food is consumed by bears** (the share of feed in their diet), and the **effects of feeding**.

In addition to feeding and compensation for damages, a lot of effort has recently been invested in **preventive actions to prevent damage cases and other conflicts**. Electric fences are thus used to protect sheep, goats and beehives, with sheep and goats also protected by sheep dogs. Closer to settlements, damage is prevented by installing bear-proof composts and garbage bins. One of the ways to verify the effectiveness and efficiency of the measure is by **monitoring costs relative to damage**.

4.3. Other indicators

The above-mentioned indicators involve monitoring parameters and process of the brown bear population and human-bear interactions. The latter category in particular also displays the costs of damage by bears and conflicts. Since economic carrying capacity may significantly impact attitude to the species, complete understanding of the economic aspects requires monitoring not just costs but also income generated by bears, which is important in reducing the scope of manipulation regarding the importance of a certain activity. For brown bear, some of the indicators which we can monitor are: (i) **scope of eco-tourism** associated with brown bear (number of guest per day per observatory), (ii) total **income from brown bear-related eco-tourism** (iii) **income generated by hunting** of brown bear.

Additionally, to determine the performance of management it is also necessary to know the impact of environmental factors on brown bear behaviour, especially towards humans. **Extreme weather** may have a potentially large but unknown impact on bears. Another known yet insufficiently studied impact is **beech masting intensity**. Beech being the main masting tree species, its masting intensity affects bear presence at feeding sites (e.g. fewer counted bears and more difficult culling), wandering into settlements (frequency of conflict), frequency of collisions with vehicles, etc. Masting typically varies significantly between years and years of strong masting are often followed by years of poor masting. The importance of local differences in masting intensity is relatively poorly researched, but they probably have an impact on spatial distribution of bears.

5. Selection of indicators

Many of the indicators listed above describe similar population properties. For example, absolute and relative population size describe the detailed dynamics of the number of bears in a population. Absolute size denotes absolute number of animals and relative size relative changes in size over time, most commonly in the form of indices. Often it is not necessary to monitor both parameters, as relative size can be calculated from absolute size. On the other hand, for many species it is difficult to determine absolute size (e.g. because of cost, cryptic nature of species, large population size and distribution). In such cases, it makes more sense to use relative size (provided this meets management / research objectives). Optimisation can thus significantly reduce the cost of data acquisition (measurements, preparation and analyses): given a broad choice of indicators, it makes sense to choose the most useful ones for the specific species, area or management objective.

Within the Life DinAlpBear project, a selection of indicators was prepared in a participatory manner, in several meetings and workshops involving experts on bear management and research. In the first workshop (27 March), which was national and is described in the next chapter, we presented the broad outlines of the monitoring methods used in Slovenia to monitor bears, including their benefits and downsides. Its main purpose was to create a list of all indicators that we need for managing or studying bears, and also to rank individual indicators by importance. The second workshop (23-24 May) was international and representatives of Slovenia as well as Italy, Croatia and Austria took part. We presented: (i) the results of monitoring optimizations with a predetermined preliminary selection of indicators, (ii) all existing national monitoring schemes, and (iii) set minimum indicators for bear management / research at population level.

5.1. National workshop

The workshop for the selection of indicators for bear monitoring and management in Slovenia was conducted on March 27, 2019. It featured 17 experts on bear ecology and management in Slovenia and representatives of the competent ministry and agencies working within the ministry responsible for brown bears. The results are shown in Table 2. The workshop examined 25 indicators, which were divided into three categories (Table 2 and Chapter 4); 17 indicators were recognized at the workshop as key for the quality management of the bear population in Slovenia, and eight as potentially important. The latter are not crucial for the choice of monitoring in the final optimization, but they can be monitored provided there is enough money and time.

Table 2: Indicators for brown bear management in Slovenia and their importance

Indicator	Importance of indicator
Indicators of population processes and parameters	
Absolute/relative size	Key
Absolute/relative mortality	Potentially important
Absolute/relative natality	Key
Spatial distribution of population	Key
Spatial distribution of reproductive females	Key
Sex structure of population	Potentially important
Non-anthropogenic bear mentality	Key
Effective population size	Potentially important
Genetic diversity	Potentially important
Functional integrity of population (especially across motorways)	Potentially important
Indicators of Human-bear interactions	
Spatial occurrence of conflict	Key
Number of conflicts	Key
Value of conflicts	Key
Type of conflict with brown bear	Key
Conflict index (spatially and temporally)	Potentially important
Attitude to brown bear	Key
Investment to prevent material damage (agriculture)	Key
Investment to prevent conflict (garbage bins, compost)	Key
Other indicators	
Feeding intensity (quantity of feed and no. of sites)	Potentially important
Dynamics of importance (share) of deliberate and accidental anthropogenic sources in bear diet (especially maize)	Key
Hunting effort per bear	Potentially important
Scope of eco-tourism (no. guests/day/observation platform)	Key
Eco-tourism (income)	Key
Hunting (income)	Key
Local monitoring of masting	Potentially important

Of the indicators identified as key or potentially important for brown bear management in Slovenia, all but one is described in Chapter 4. We further identified and added the indicator **bear hunting effort**, which indicates the time that a hunter must invest in killing one bear. On the one hand, it evaluates the effort required to cull a single bear, while at the same time it could be used generally as an indicator of population size in the absence of better indicators.

6. Previous monitoring methods and selected indicators

So far, six kinds of monitoring have been regularly carried out in Slovenia, as described in Chapter 2. For a while, health monitoring was also conducted, and many shorter, targeted studies have been undertaken, as described in Chapter 3. Individual monitoring / research may include the same indicators, while some of the key indicators are not included in any existing monitoring scheme. For some indicators, the data are collected, but they are not part of the targeted monitoring.

6.1. Selected indicators in previous monitoring methods

Different monitoring schemes involve different numbers of indicators, as shown in Table 3. The existing monitoring scheme at least partially covers 17 (68%) of the selected indicators, of which one indicator, spatial distribution, is covered only partially. The biggest category of indicators is “population parameters and processes”, where all selected parameters are (at least partially) covered. In the “human-bear interaction” category, six of the eight selected indicators have already been covered by existing monitoring methods (75%). In the "other indicators" category, only one indicator is monitored in the current monitoring scheme (14%). It is important to note that in this category, three key indicators are not covered.

The most indicators are at least partially covered by non-invasive genetics (Table 3). All these indicators are in the category “population parameters and processes”. Furthermore, five of the six indicators in the category “human-bear interactions” which are already being monitored, are covered by two monitoring schemes. Six indicators are covered by only one monitoring, and many methods cover only one indicator.

Table 3: Indicators selected at workshop and coverage by existing monitoring scheme.

Indicator	**Importance of indicator**	**Covered by monitoring**	**Damage monitoring**	**Mortality monitoring**	**Counting at counting sites**	**Non-invasive genetic sampling**	**Invasive genetic sampling**	**Intervention Group**	**Health monitoring**	**Human dimensions research**	**Analysis of diet**
Population parameters and processes											
Absolute/relative size	Key	Yes		Yes	Yes	Yes					
Absolute/relative mortality	Key	Yes		Yes		(Partially*)					
Absolute/relative natality	Key	Yes		Partially*	(Yes)		(Partially *)				
Spatial distribution of population	Key	Partially*	Partially*	Partially*	Partially*	Partially*	Partially*	Partially*			
Spatial distribution of reproductive females	Key	Yes		Partially*	Yes	Partially*	Partially*				
Sex structure of population	Potentially important	Yes		Partially*	Partially*	Yes	Partially*				
Non-anthropogenic bear mentality	Key	Yes		Partially*					Yes		
Effective population size	Potentially important	Yes					Yes				
Genetic diversity	Potentially important	Yes				Yes	Yes				
Functional integrity of population (especially across motorways)	Potentially important	Yes		Partially*	Partially*	Yes	Yes				
Human-bear relations											
Spatial occurrence of conflict	Key	Yes	Yes					Yes			
Number of conflicts	Key	Yes	Yes					Yes			
Value of conflicts	Key	Yes	Yes					Yes			
Type of conflict with brown bear	Key	Yes	Yes					Yes			

Indicator	Importance of indicator	Covered by monitoring	Damage monitoring	Mortality monitoring	Counting at counting sites	Non-invasive genetic sampling	Invasive genetic sampling	Intervention Group	Health monitoring	Human dimensions research	Analysis of diet
Conflict index (spatially and temporally)	Potentially important	Yes	Yes					Yes			
Attitude to brown bear	Key	Yes								Yes	
Investment to prevent material damage (agriculture)	Key	No									
Investment to prevent conflict (garbage bins, compost)	Key	No									
Other indicators											
Feeding intensity (quantity of feed and no. of sites)	Potentially important	No									
Dynamics of importance (share) of deliberate and accidental anthropogenic sources in bear diet (especially maize)	Key	Yes									Yes
Hunting effort per bear	Potentially important	No									
Scope of eco-tourism (no. guests/day/observatory)	Key	No									
Eco-tourism (income)	Key	No									
Hunting (income)	Key	No									
Local monitoring of masting	Potentially important	No									

* Partially – monitoring / study may answer certain but not all aspects of parameter.

6.2. Important indicators not monitored so far

Despite the long-standing surveillance of bears in Slovenia (the first monitoring was introduced in 1994), all important indicators are not included in the monitoring scheme. In the category "population parameters and processes", all indicators are covered, except for one that is only partially covered: "spatial distribution of brown bear", an indicator that was defined in the workshop as key and is partially covered in six different monitoring schemes. Each of the monitoring methods has certain limitations and assumptions that do not produce a complete picture of the spatial distribution of brown bear in Slovenia. With existing monitoring, we can closely monitor the change of local densities in areas where bear density is more significant. However, they cannot be used to monitor marginal distribution of bears. Nevertheless, this information is not so important that we should have a new method. What is more, existing monitoring can be leveraged to closely monitor relative changes in distribution (i.e., population expansion or contraction), which may be sufficient for management.

In the indicator category "human-bear interactions", two key indicators are not covered in the current monitoring scheme. Data on the effort required for the prevention of material damage and a portion of conflicts are collected and already published (Buatista *et al*., 2019), but not in the context of reporting on bear status and management. This data will be collected for the first time in the C2 action report "Conflict mitigation in the hot spot areas - damage cases".

Indicators in the last category (other indicators) were much more poorly covered by existing monitoring as only one indicator was covered. Three non-covered indicators were identified as potentially important. The intensity of feeding, as the first of these three indicators, is partially covered by the indicator "share of maize in diet". Given that a lot of maize at feeding sites is consumed by non-targeted species (Fležar *et al*., 2018), this parameter is a better indicator of the importance of feeding maize than the amount of maize available.

Three key indicators that are not covered by the current monitoring scheme are linked to economic gains from brown bear management. Two describe tourism activity directly associated with bear observation in nature. It should be emphasized that on the basis of these indicators, the effects of eco-tourism (and the impacts of specific use of feed and feeding) on the behaviour of bears can be evaluated as well: there are indications that bears at eco-tourism feeding sites are much more habituated to humans, which is probably good for eco-tourism but not for reducing human-bear conflict. The third indicator (income from hunting; hunting tourism and sale of game meat) is linked to income generated by bear hunting.

7. Selection of monitoring methods and optimisation

“Monitoring of claims” and “Intervention Group” (Chapter 5) cover the largest number of indicators recognised as key – 4 (Table 4). Together they cover four key and one potentially important indicator, which are in fact covered only by these two monitoring methods. Both involve responses to conflict. We recommend that an annual report be published for both monitoring methods together with the number, distribution and extent of damage / conflict cases, complete with a comparison over longer time intervals.

Three monitorings (health, people's attitude, nutrition analysis) cover only one key indicator – and each of these indicators is covered by only one monitoring (Table 4). “Health” and "analysis of diet" (stable isotopes) are conditional on culling and it is reasonable to take samples from culled bears for both monitoring methods along with samples for invasive genetics and teeth for ageing. For the analysis of health, we recommend taking samples from bears whose cause of death cannot be conclusively determined or which show signs of pathology. For the analysis of nutrition (the importance of maize in diet) with the help of stable isotopes, it is advisable to take samples (muscle, liver) of all culled bears during the action plan period, with analyses conducted every two years. Within a few years, the results can be leveraged to optimise monitoring by sampling only a portion of the culled animals (the most indicative category) a part of the year.

Only one study of people's attitude to bears has been conducted so far, but it forms a good basis for subsequent surveillance. We advise that the research is included at the regular within period of validity of action plan (5 years).

Table 4: Overview of monitoring methods implemented in Slovenia and number of indicators they include.

Monitoring / study	Previous/existing activities	Coverage of key indicators	At least partial coverage of important indicators
Monitoring of damage	Monitored regularly every year	4 - 6 (24 – 35 %)	1 (12 %)
Monitoring of mortality	Monitored regularly every year	3 - 4 (12 – 24 %)	1 (12 %)
Counting at permanent counting sites	Monitored 3 times per year every year	3 - 4 (18 – 24 %)	1 (12 %)
Non-invasive genetics	Conducted twice (2008, 2015)	2 - 3 (12 – 13 %)	3 (37 %)
Intervention Group	Monitored regularly every year	4 - 5 (24 – 29 %)	1 (12 %)
Bear diet (emphasis on importance of maize)	Several studies so far, no regular monitoring	1 (6 %)	/
Invasive genetic sampling	Conducted twice (2008, 2015)	0 - 2 (0 - 12 %)	3 (37 %)
Health	Ongoing as part of DinAlp Bear	1 (6 %)	/
People's attitude	Conducted once as part of DinAlp Bear	1 (6 %)	/

Five indicators can be covered by at least two of these monitoring methods (mortality, counting and non-invasive genetics), which are complementary.

Population size as one of the most important bear management indicators can be reconstructed / obtained with all three above-mentioned monitoring methods. The most accurate size estimates are currently produced by non-invasive genetics. Organization and implementation of this monitoring are time-consuming and costly. Moreover, the sampling is done by volunteers (many hunters) whose volunteering services need to be used tactfully. Consequently, this monitoring cannot be carried out very often; so far, it has been executed twice in a span of eight years. Considering the range of complementary methods (calibrated reconstruction on the basis of harvest - Jerina and Polaina, 2018 - and reconstruction based on monitoring at permanent counting sites - Jerina *et al*., 2019), it makes sense to conduct this practices at similar intervals in the future. In the meantime, the other two methods for determining population size, which are both calibrated to genetic estimates, should be used. Recording and collection of mortality data is part of the existing routine and, apart from ageing on the basis teeth analysis, is cost-effective. Provided the results are calibrated with population size data obtained with non-invasive genetic sampling, they are relatively reliable, especially in the years immediately after calibration year (Jerina and Polaina, 2018). In addition, only mortality monitoring can be used to calculate absolute mortality. The more distant the estimate of population size derived from non-invasive genetics is, the less reliable the estimate based on mortality monitoring, since the errors in the model add up. In order to provide the most accurate estimate of brown bear population size, especially in the last period prior to new genetic sampling, it must be improved with the help of counting at permanent counting sites (Jerina *et al*., 2019). The results of this method are more susceptible to various environmental "disturbances" (e.g., masting, bad weather during counting), but its advantage is that the annual estimates are independent. A combination of both methods can provide a sufficiently accurate estimate of the size of the brown bear population in Slovenia over the entire period between the individual monitoring with non-invasive genetics. At the same time, counting is the only monitoring that estimates natality of the species fairly accurately. Natality has been recognized as one of the key indicators for managing the species in Slovenia. We propose that monitoring thereof be implemented on the same scale (the same number of counting sites) in the future. However, it is recommended that only two counts be conducted instead of three in each year, namely the spring count and the first autumn count.

Monitoring of invasive genetic samples is the only way to obtain the potentially interesting indicator "effective population size". Samples for invasive genetics are collected routinely and are not associated with high costs, so it makes sense to continue collecting them. On the other hand, the analysis, like non-invasive genetic sampling, is costly; it therefore makes sense to carry out both analyses at the same time, probably together with Croatia, on a minimal yet large enough sample to reduce costs.

Although the bookkeeping of costs associated with preventive measures to prevent damage is not part of regular monitoring and will be fully collected for the first time in the Life DinAlp Bear C2 action report, it makes sense to issue such a report annually together with damages and conflicts to thus evaluate the performance of individual measures.

Data on the value of individual activities are important for their realistic valuation. Therefore, we recommend that in addition to the various damage indicators, the following **indicators of**

income related to bear management are also collected: (i) extent of eco-tourism (number of guests / day / observatory), (ii) income from eco-tourism (income from visit), (iii) hunting income (trophy and meat). Knowing the extent of eco-tourism by location will also be important for understanding the impact of this activity on bear behaviour bears (habituation).

Table 5: Recommendations for monitoring, implemented indicators and reporting

Monitoring / research	Recommendations	Reporting content	Implemented indicator (partially covered indicator)	Area of implementation
Monitoring od damage	Conducted in current scope, publication of annual report together with Intervention Group	Number, spatial distribution and value of damage cases	Spatial occurrence of conflict, number of conflicts, financial scope of conflict, types of conflict, conflict index(spatial distribution of brown bear)	All countries
Monitoring of mortality	Conducted in current scope, biannual analysis with report	Calculation of size based on reconstruction of population dynamics	Population size, absolute mortality (relative mortality, spatial distribution, distribution of (reproductive) females, sex structure, non-anthropogenic mortality)	All countries
Counting at permanent counting sites	Conducted once in spring and once in autumn at same number of counting sites	Estimate of natality and local densities; used to improve accuracy of estimate derives from mortality monitoring	Population size, relative natality (spatial distribution, distribution of females with cubs)	Dinaric population
Non-invasive genetics	Conducted every 8 years (except in Alps or in extraordinary cases/situations)	Estimate of population size, spatial distribution, densities on each side of the motorways and female expansion	Population size, sex structure, spatial distribution, distribution of females	All countries
Invasive genetics	Conducted every 8 years together with non-invasive genetics	Supplement to non-invasive genetics	Effective population size (relative natality)	All countries
Intervention Group	Conducted in current scope, reporting together with damage events	Number, spatial distribution and prevalence of conflict cases	Spatial occurrence of conflicts, number of conflicts, financial scope of conflicts, types of conflict, conflict index (spatial distribution of brown bear)	All countries
Health	Annual collection of samples and analysis, biannual reporting	Short description of activity and results with emphasis on potentially important pathologies	Causes of non-anthropogenic mortality	Slovenia
People's attitude	Conducted every xy years (perhaps 4)	Analysis of public attitude to brown bear and management of bear population, temporal changes	People's attitude	All countries
Diet	Samples for stable isotopes collected from all harvested bears (muscle and liver), reporting biannual	Estimate of share of consumed anthropogenic food (maize) in bear diet in individual year and comparison with baseline estimate	Share of anthropogenic food in bear diet (in particular importance of maize), temporal dynamics of the importance of anthropogenic sources	Dinaric population
Cost monitoring	Annual report on monitoring of costs associated with measures to prevent damage by bears is compiled together with the report on damage	Number, spatial distribution and value of preventive measures by type	Investment required to prevent material damage (agriculture, …) and other conflicts (garbage bins, compost)	All countries
Revenue monitoring	Creation of protocol and recommendations for acquisition and presentation of revenue from eco-tourism and brown bear hunting	Number of visits/observations of brown bear and revenue by type	Scope of eco-tourism (number of guests/day/observatory), revenue from eco-tourism, revenue from hunting (trophies and meat)	Slovenia

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