CANTABRIAN BEARS.
DEMOGRAPHICS, COEXISTENCE AND CONSERVATION CHALLENGES

GUILLERMO PALOMERO, FERNANDO BALLESTEROS, JUAN CARLOS BLANCO AND JOSÉ VICENTE LÓPEZ-BAO (EDITORS)

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All of the photographs in this book have been taken by the Brown Bear Foundation, except those indicated with the name and copyright of their respective authors. The photographs of bears were taken in the wild in the Cantabrian Mountains using equipment with long focal lenses and at a sufficient distance to avoid disturbing the species.

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Begoña Almeida, Elsa Sánchez, Elías Suárez, Marcos Simón and Luis Fernández form the tireless and passionate field team of the Brown Bear Foundation in the Cantabrian Mountains. Much of the effort behind the pages in this book belong to them, along with authorship of many the photographs as well. Effort and enthusiasm shared by the other members of the Brown Bear Foundation and the friends who have helped us in one way or another to make this book a reality.

CONTENTS

PRESENTATION

The brown bear is a flagship species of the Iberian fauna. As a key species situated at the apex of the food chain, it plays a crucial role in maintaining the functionality and diversity of the ecosystems it inhabits. Together with other flagship species, such as the wolf, Iberian lynx or Spanish ibex, the Cantabrian brown bear is an outstanding representative of the megafauna which has survived until today. They are the last witnesses of the numerous large mammals of the Pleistocene era, which have survived better in Spain than in the remainder of the Western European countries, contributing as part of the cultural heritage of the human societies alongside which they have coexisted for millennia. The Cantabrian brown bear is a large carnivore and as such, invokes respect as well as fear amongst humans. These animals, at the same time as generating a degree of unrest among livestock farmers are also an emblematic species and indicators of the well conserved condition of the Cantabrian forests.

Corresponding to its singularity, ecological value and its rarity, the Cantabrian brown bear is protected under the highest legal protection categories of the different administrations. It is considered a Priority Species in the European Union Habitats Directive, is strictly protected under the Bern Convention for the protection of the European wildlife and is also categorised as "Endangered" in the Spanish Catalogue of Threatened Species. Given these categorisations, the state and regional administrations are confronted with the challenge of conserving the bear at the same time as protecting the numerous uses of the mountains they inhabit.

Over twenty years ago, with this objective in mind, the specialists in this Ministry and in collaboration with those of the autonomous communities of Asturias, Galicia, Castilla y León and Cantabria, formed the Cantabrian brown bear technical working group and produced drafts of the first conservation strategy for the species, which was approved by consensus in 1999 and brought up to date in 2019 by the Spanish Environmental Sectorial Conference.

The growth of the bear populations, reflected in this book, is the fruit of this coordinated effort between the autonomous communities, local administrations, the General State Administration, scientists, NGOs and other social participants. It is the result of continuous work, undertaken via varied and successful lines of conservation, many of which have been supported by European Community funds. Within this complex network, the close coordination between the administrations and all of the sectors involved and in particular the willingness to work towards a common goal, have been essential to meet the objectives.

During the recent history of brown bear conservation in Spain, the extraordinary contribution of the Brown Bear Foundation (FOP) has been highlighted by different sectors, the foundation being one of the pioneer NGOs in our country to involve private initiatives in biodiversity conservation. The FOP is one of the Spanish NGOs with greatest national and international prestige, and it is no surprise that it is one of the organisations to have developed most European Union LIFE projects for the recovery of the brown bear and its habitats. Additionally, the FOP has also demonstrated how fruitful the collaboration between NGOs and public administrations can be. Its innovative spirit within the Spanish conservation movement is a clear indication of this. An example of this are the "bear patrols", which generate local employment and aid in the collaboration with the countryside rangers of their wardening and monitoring tasks. Not forgetting either the agreements with local bodies, hunting federations and livestock associations for their communal collaboration in the management of the natural resources in bear areas, whilst keeping this compatible with local interests and traditional land uses. This pioneering model has been successfully transferred to other species at risk of extinction living on private lands, such as the Iberian lynx or Spanish imperial eagle, and which both needed a nonconventional conservation approach.

This book reflects the advances made in the knowledge of the Cantabrian brown bear and its habitat, and it does so based on science, a means of working which we applaud and value in the administrations given that scientific knowledge continues to be the strongest pillar of support on which to base decisions.

As such, during this time of biodiversity crisis and the acceleration of extinctions, it is comforting to see that the Cantabrian brown bear has changed course from the inertia that seemed destined to condemn it to disappear. But we should also remember that it is still threatened and that a growing population of bears needs extensive areas of productive and tranquil habitat and which guarantee the connectivity between the breeding nuclei. In such a humanised landscape as the Cantabrian Mountains, the fragmentation of habitats and lowering of their quality constitute important threats requiring permanent attention, without forgetting that the recovery of the populations requires the need for new management and conservation scenarios which will have to be tackled in the future.

One of these scenarios is that created by the interactions between bears and livestock rearing and beekeeping interests. In the light of this, urgent advances are needed for the development and application of prevention methods, since if these interactions are not addressed with practical and efficient measures, they may trigger rejection towards bear presence and reduce the positive perceptive of bears currently shown by rural societies in bear areas. Accordingly, the Ministry for Ecological Transition and Demographic Challenge has anticipated answers and made new appropriate and efficient pre-tested methods available to society for the protection of apiaries and livestock. These measures figure in the "Catalogue of measures for the protection of agriculture and livestock: Interactions with wildlife", available on the Ministry's website. Together with this catalogue of measures, the "Protocol for bear interventions in the Cantabrian Mountains", approved in 2019, objectively sets out the steps to be followed in those situations where they cannot be solved or managed by the affected collective.

Another important factor relevant for the recovery of the Cantabrian brown bear is bear-watching tourism, a recreational activity undergoing a rapid increase in popularity in Spain. There are ever-more private observers undertaking the activity and companies offering the service. In order to manage this properly, the Ministry developed a document of best practices for bear (and also wolf and Iberian lynx) watching and made this publicly available as a complete code of conduct aimed at both companies and individuals. This publication provides simple guidelines, recommendations and advice so that the observations are carried out in an adequate manner, by reducing unwanted effects, enriching the observation experience and promoting awareness of the conservation of these species.

The brown bear, together with the wolf and the large raptors, constitutes a reliable indicator of the environment health of our country, which, according to the World Health Organization, is an irreplaceable element for ensuring public health. Consolidating its presence, in harmony with livestock rearing and the rural culture of the Cantabrian Mountains, is a dream which is beginning to come true thanks to the hard work of all of us who love these mountains.

Hugo Alfonso Morán Fernández.
State Secretary for the Environment.
Ministry for Ecological Transition and Demographic Challenge

INTRODUCTION

Even the most hardened deniers accept that unquestionably, the population of Cantabrian brown bears is growing and moving away from its former critical risk of extinction status. Behind this lie important and sustained conservation efforts which have managed to reduce the pressure from illegal hunting, to protect and improve a large part of the bear habitats and have achieved a generalised level of social support for the species which is fundamental in the Cantabrian Mountains with its markedly seasonal human activity patterns.

But behind these conservation successes also lies science. It is very difficult to conserve what is not known and for this reason one of the common objectives in the Strategies for the conservation of the brown bear in the Cantabrian Mountains and Pyrenees consists in "Promoting applied research for the conservation of the bear and its habitat".

30 years have passed since the first doctoral thesis tackling the problems facing the Cantabrian brown bears was defended. Since then, in addition to final degree projects and bachelors and master's theses, more than a dozen doctoral theses, the majority presented in the Universities of Oviedo and León, have studied its populations, fossils and ecology. Several dozen scientific papers published in prestigious international journals in parallel with these studies have helped put more successful conservation actions into practice.

The Brown Bear Foundation is not a scientific institution, rather a conservation organisation, but we have adopted the habit of working with conservation scientists and with different universities and research centres which have been willing to get involved in the demonstration of new, feasible and possible proposals. From the outset we were clear that putting conservation strategies into practice without the backing of scientific research, is to work blind. It may serve to keep the conscience clear, but it offers far less probabilities of success, and failure is not an option.

We have contributed to the efforts made by institutions, NGOs and many citizens in turning the decline of the Cantabrian bear around; the bear has come out of the extinction ICU and having come out of its critical state which threatened its existence, now it's time to provide it with other kinds of care, the treatment for which needs to be different. We are obliged to be realistic about tackling the new situation given that maintaining the old formulas and appealing to the old fears is not going to be sufficient and we risk quickly losing almost everything gained through so much hard work.

And this is what this book talks about. We review the most up to date information on the demographics of the species and debate and propose new formulas for now conservation challenges. We do this guided by a team of recognised researchers from different disciplines, keeping it clear that the tool capable of helping us to discern the future without falling into prejudices, is through employing the scientific method.

The research projects that are presented in this book have been promoted and managed by the Brown Bear Foundation. A large part of this projects, and the book itself have relied on the collaboration and economic support of the Ministry for Ecological Transition and Demographic Challenge and its predecessors, contributing in this way to the scientific knowledge and its dissemination, which is the logical and necessary extension of the research.

Brown Bear Foundation

CHAPTER 1.

FEMALES WITH CUBS AND THE DEMOGRAPHY OF THE BROWN BEAR IN THE CANTABRIAN MOUNTAINS

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SUMMARY

A standardised method has been used to monitor bear families in the Cantabrian Mountains since 1989. The quantity of information gathered over this time has been remarkable, with more than 4,500 observations of females with cubs between 1989 and 2018. This information has not only allowed us to confirm the recovery of the species in the Cantabrian Mountains, but has also been fundamental in increasing our knowledge about different demographic aspects of the Cantabrian brown bear. For example, we have learned that female Cantabrian bears have between one and three cubs, with an average litter of 1.8 ± 0.7 cubs across the whole population, this being slightly higher in the western subpopulation (1.9 ± 0.7 cubs) compared to the eastern one (1.6 ± 0.6 cubs). Overall, the average monthly cub survival rate is high during the first 16 months of life, estimated at 0.839-0.994, with the most critical period being from April to June of their first year. Infanticide appears to be the principal cause of cub mortality. Family break-ups, which occur during April and May of the second year and which coincide with the mating season in the Cantabrian Mountains, mark a new stage in the cubs' lives. Information on the causes of mortality of bears over one year old is limited, since the data are collected opportunistically, but points to human actions as the principal cause for their deaths and requires more information in the context of geographical expansion in the species.

FAMILY GROUP NUMBER CHANGES

From a historical perspective, the brown bear (*Ursus arctos*) population in the Cantabrian Mountains has shown a similar pattern to those of other large carnivores in the rest of Europe, with a contraction in range and population (López-Bao *et al.* 2017), followed by its subsequent expansion (Palomero *et al.* 2011; Chapron *et al*. 2014; González *et al.* 2016; López-Bao *et al.* 2020).

For species such as the brown bear, where non-invasive genetic sampling techniques and the application of capture-recapture tools have only recently started to be employed (e.g., Pérez *et al.* 2014; Karamanlidis *et al*. 2015; Whittington & Sawaya 2015; Moqanaki *et al*. 2018; López-Bao *et al.* 2020), monitoring of the breeding part of the population (family groups comprising a female with cubs) has been considered a valid method for the adequate monitoring of bear populations by the International Union for the Conservation of Nature (IUCN) (Peyton *et al.* 1999; Palomero *et al.* 2007). The monitoring of females with cubs conveys a series of advantages. Firstly, it constitutes a highly important fraction of the overall population from a demographic and conservation viewpoint (e.g., Knight & Eberhardt 1985, Naves *et al.* 1999; Palomero *et al.* 2011). In addition, it is the easiest part of the population to detect, given the lower mobility shown during the breeding season and greater diurnal activity during the first few months of cub life (Palomero *et al.* 2011).

Helpfully, the landscape characteristics of the Cantabrian Mountains facilitate observations of the family groups at certain times of the year (Planella *et al.* 2019). Furthermore, in addition to being of great use as an indicator of demographic change, monitoring of this part of the population enables us to gather valuable demographic and ecological information of the species (e.g. Martinez-Cano *et al.* 2016; Planella *et al.* 2019) and become aware of possible risk factors (Planella *et al.* 2019). Even so, this method suffers from certain limitations in high density populations, with an increased difficulty of detecting fe-

Photos 1 and 2. The use of high-powered optics and the detection of tracks and signs allows to locate females with cubs without interfering in their daily life.

males with cubs and a greater probability of making identification errors by assigning observations of other individuals to a particular family group and vice-versa. It is also necessary to take into account that family group detection is not constant over time and may depend on factors such as the availability of food, habitat use, accessibility and changes in vegetation cover (Tosoni *et al.* 2017; Planella *et al.* 2019), such that the results from this method should in reality be considered as a minimum count.

Monitoring of the brown bear families in the Cantabrian Mountains has been standardised since 1989, via a surveillance network comprised of the wildlife rangers of the different autonomous communities, the Brown Bear Foundation (FOP) field teams and other linked specialists. This monitoring has enabled us to document the positive growth in both Cantabrian subpopulations over recent years (Palomero *et al.* 2011; González *et al.* 2016; Blanco *et al.* 2020). In addition, it has also allowed us to gather information about other biological aspects of the species, such as the strong philopatry shown by the females (González *et al.* 2016). When female brown bears become independent from their mothers, they tend to overlap their home ranges with them, forming matrilineal clusters (Palomero *et al.* 2006). Consequently, even though the number of females with cubs increases, the breeding area increases at a much slower rate than that of the overall bear population.

Monitoring for female bears with cubs is undertaken by observers scanning the countryside with binoculars and telescopes in search of bears, normally during the first few hours of daylight. In many of the Cantabrian landscapes, the scarce tree cover and fidelity shown by breeding females towards their denning sites facilitates the detection of these family groups (Planella *et al.* 2019). Once a female is located, this is followed up with intensive monitoring during the first few months of the cubs' lives, during which time they are easiest to observe and at their most vulnerable. This makes it possible to obtain numerous observations and to evaluate how the cubs are developing. In those areas where vegetation cover makes it more difficult to make direct observations, data is collected primarily by undertaking systematic transects to detect tracks. No observation of a female with cubs is considered as confirmed unless there is an unequivocal observation by one of the monitoring teams and the observations are validated by a monitoring committee of the different autonomous communities, which shares the data and coordinates the interpretation of all the results combined. In addition, with the objective of avoiding duplications, observations of females with cubs which cannot be assigned with certainty to a particular family group are discarded. For each year's data, four criteria were used to separate the different family groups of females with cubs: i) the spatial reoccurrence in the observations, ii) the simultaneous observation of different family groups, iii) the distance between observations and iv) the composition of the family group (initial number of cubs) as well as the individual characteristics of the individuals (Ordiz *et al.* 2007; Palomero *et al.* 2007).

The follow-up monitoring of a family group once it has been discovered, the spatial fidelity of the females (associated with their philopatry) and the simultaneous presence of different observers help to reduce the uncertainty in the individualisation of the family groups. Large differences exist in the general coat colour patterns of Cantabrian brown bears, from uniformly pale to very dark individuals and, in some cases, with recognisable marks. Although these variations and markings are not sufficient to recognise individuals over successive years, they are very useful for identifying family groups in a given year, in combination with litter size and the observation location. These criteria are also being used in other bear populations to separate family groups of females with cubs (Ciucci *et al.* 2009; Latini *et al.* 2017).

More than 4,500 observations of females with cubs were made in the Cantabrian range from 1989 to 2018, with around 4,100 of these attributable with certainty to specific family groups. A total of 522 family groups (439 in the western subpopulation and 83 in the eastern one) were identified from these data. It should be noted that, except on very rare occasions, it is not possible to recognise females with cubs from year to year and in consequence, a female with cubs is treated separately every time that they breed again. The number of females with cubs detected annually varied from 6 to 38, in 1989 and 2018 respectively, a trend reflecting the recovery that the species has experi-

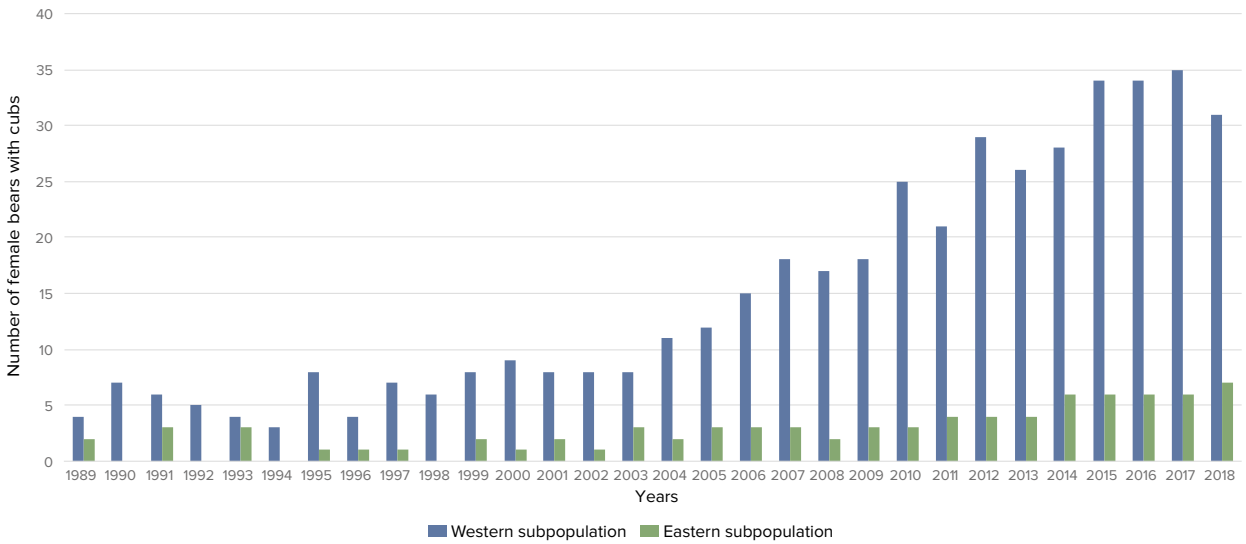

Figure 1. Annual number of females with cubs of the year in the two Cantabrian bear subpopulations between 1989–2018.

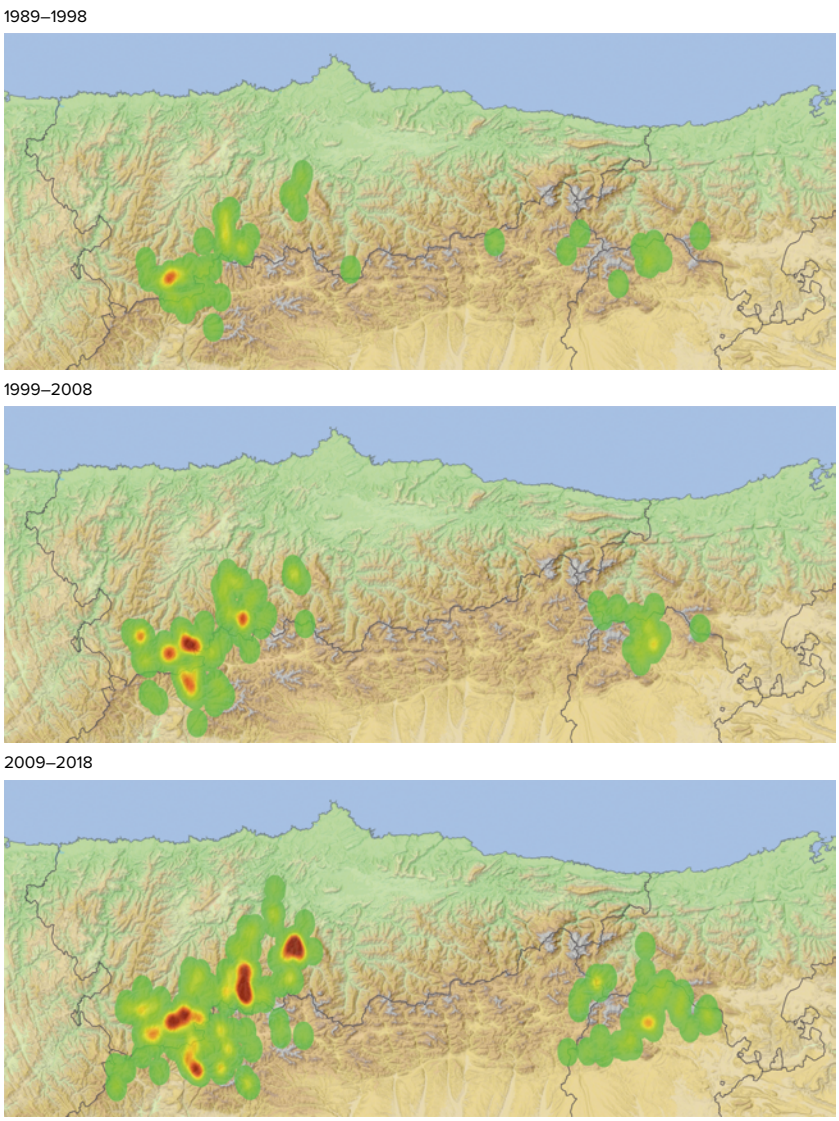

Figure 2. Density map for female bears with cubs of the year for the periods 1989–1998, 1999–2008 and 2009–2018. For each period, the maps are created using the centroids generated from the combined observations of each female with cubs of the year positively identified in this period, establishing a radius of 5 km in order to simulate a home range for each female with cubs in accordance to that of other radio-collared adult female brown bears in similar areas of Eurasia (c. 72 km^2; e.g., Huber & Roth 1993; Mertzanis *et al.* 2005; Ambarli & Bilgin 2012; Gavrilov *et al.* 2015).

enced in the Cantabrian range over recent years (Figure 1) (González *et al.* 2016).

Breeding female bears show intense philopatry, meaning that females tend to overlap home ranges with that of their mother, giving rise to matrilineal clusters. Consequently, even though the number of bears has increased substantially, the area occupied by breeding females is increasing more slowly (Figure 2) (Palomero *et al.* 2011).

Currently, three different principal breeding areas can be distinguished for the western subpopulation, in which the number of breeding females has increased over recent years:

- **Narcea-Alto Sil:** Female bears with cubs have been detected annually in this nucleus since 1989. Indeed, during the first decade of standardised monitoring (1989-1998) this area supported the highest density of females with cubs of the entire Cantabrian Range, with an annual average of three females with cubs of the year. The number of breeding females has risen substantially over time and there is currently an average of 12.4 females with cubs of the year detected annually in this nucleus. This increase has enabled the differentiation of two subnuclei: that in Narcea and the other in the Alto Sil.

- **Somiedo:** Except for 1994, when no females with cubs were confirmed, breeding has been continuous in this nucleus since 1989. A clear increase in the density of females with cubs has been seen over time, from a yearly average of 1.9 families detected in 1989-1998, to an average of 5.4 females with cubs of the year detected during the last decade (1999-2018).

- **Proaza:** Although no breeding was detected between 1996 and 2003, recovery in this area has been observed since 2005 and it now constitutes one of the most important breeding nuclei in the Cantabrian range, with an av-

Photos 3 and 4. Physical characteristics of individuals allow us to identify each family group from another. In the photos, different female bears with their second-year cubs photographed in the same valley in the Fuentes del Narcea, Degaña & Ibias Natural Park (Asturias).

erage of three breeding females detected annually over the last decade.

The breeding nuclei in the eastern subpopulation are less evident, though it can be divided into two main areas:

- **Montaña Palentina:** This is the principal breeding nucleus for this subpopulation. During the first monitoring decade (1989-1998), breeding was irregular and females with cubs of the year were not detected in 1990, 1992, 1994 and 1998. Breeding has been annual since then and although the density of female bears with cubs is clearly inferior to that in the western subpopulation, there has been a progressive increase, with an annual average of 2.3 females with cubs of the year detected during the decade 1999-2008, and 4.8 female bears with cubs of the year detected annually during the past decade (2009-2018) (González *et al.* 2016; Blanco *et al.* 2020).

- **Montañas de Riaño:** Breeding in this area has not been consistent over time. A female with cubs was detected at the beginning of the first decade (1989-1998), but no breeding was confirmed during the second decade (1999-2008). This nucleus now appears to have started recovering over the past decade (2009-2018), and especially over the final three years when a female with cubs of the year has been detected each year.

LITTER SIZE

Female bears in the Cantabrian Mountains have between one and three cubs per litter. These are born in January, during hibernation and remain inside the den with the mother, suckling and growing, for four months. Consequently, the first field observations of females with cubs of the year tend to occur in April and May, although there are occasional records of cubs leaving the den in late March (Planella *et al.* 2019). The earliest records of females with cubs of the year are from 31st March 2015 in the western subpopulation and 9th April 2006 in the eastern one.

From 1989 to 2018, the average litter contained 1.8 ± 0.7 cubs across the entire population in the Cantabrian Mountains. Differentiating between subpopulations, larger litter sizes were seen in the western subpopulation (1.9 ± 0.7) than in the eastern one (1.6 ± 0.6). In the calculations of litter size for the Cantabrian Mountains, the time that the cubs spend in the den is not considered, i.e., from the time they are born in January until emerging in April or May. Similarly, some females with cubs are not

Photo 5. Bear landscape of the Somiedo Natural Park (Asturias).

Photo 6. Bear landscape of the Montaña Palentina Natural Park (Palencia).

seen until months after den emergence, so that their initial litter size may have been higher.

These litter sizes, especially in the eastern nucleus, are among the lowest known for the species (Steyaert *et al.* 2012) and are similar to those of other small and isolated brown bear populations, such as those of the Pyrenees or Trentino region, prior to their respective reintroductions, with values of 1.4 and 1.2 cubs per litter respectively (Camarra 1990; Osti 1991). Similarly, the isolated Apennine population, with an average of 1.9 cubs per litter (Tosoni *et al.* 2017), shows a very similar value to the western Cantabrian nucleus. In larger brown bear populations, the average litter size can be above 2, such as in Croatia (Frkóvik *et al.* 2001) or in Sweden (Steyaert *et al.* 2012).

In our western subpopulation, the majority of litters are comprised of two cubs (55.6%), followed by those with one (29.2%) and, to a lesser degree, those with three cubs (15.3%) (Figure 3).

In contrast, litters of one cub (50.0%) predominate in the eastern subpopulation, followed by those with two (45.1%) (Figure 4). Litters with three cubs were not detected in this subpopulation until 2005, but six family groups with three cubs each were detected between 2008 and 2019 (Blanco *et al.* 2020).

In the western subpopulation, litters of three, and especially one cub are ever more frequent, possibly given the mature age of some of the breeding females and the incorporation of young females into the reproductive population.

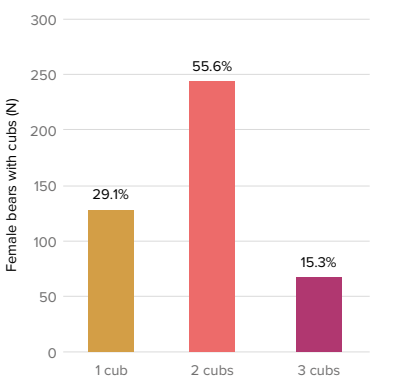

Figure 3. Percentage and number of female bears with one, two or three cubs of the year in the western subpopulation.

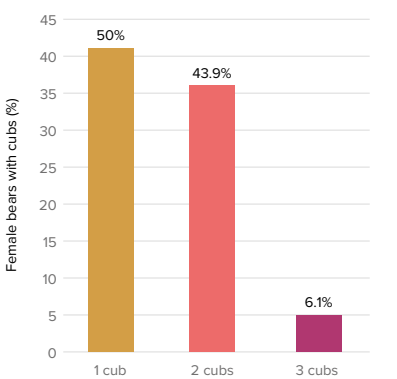

Figure 4. Percentage and number of female bears with one, two or three cubs of the year in the eastern subpopulation.

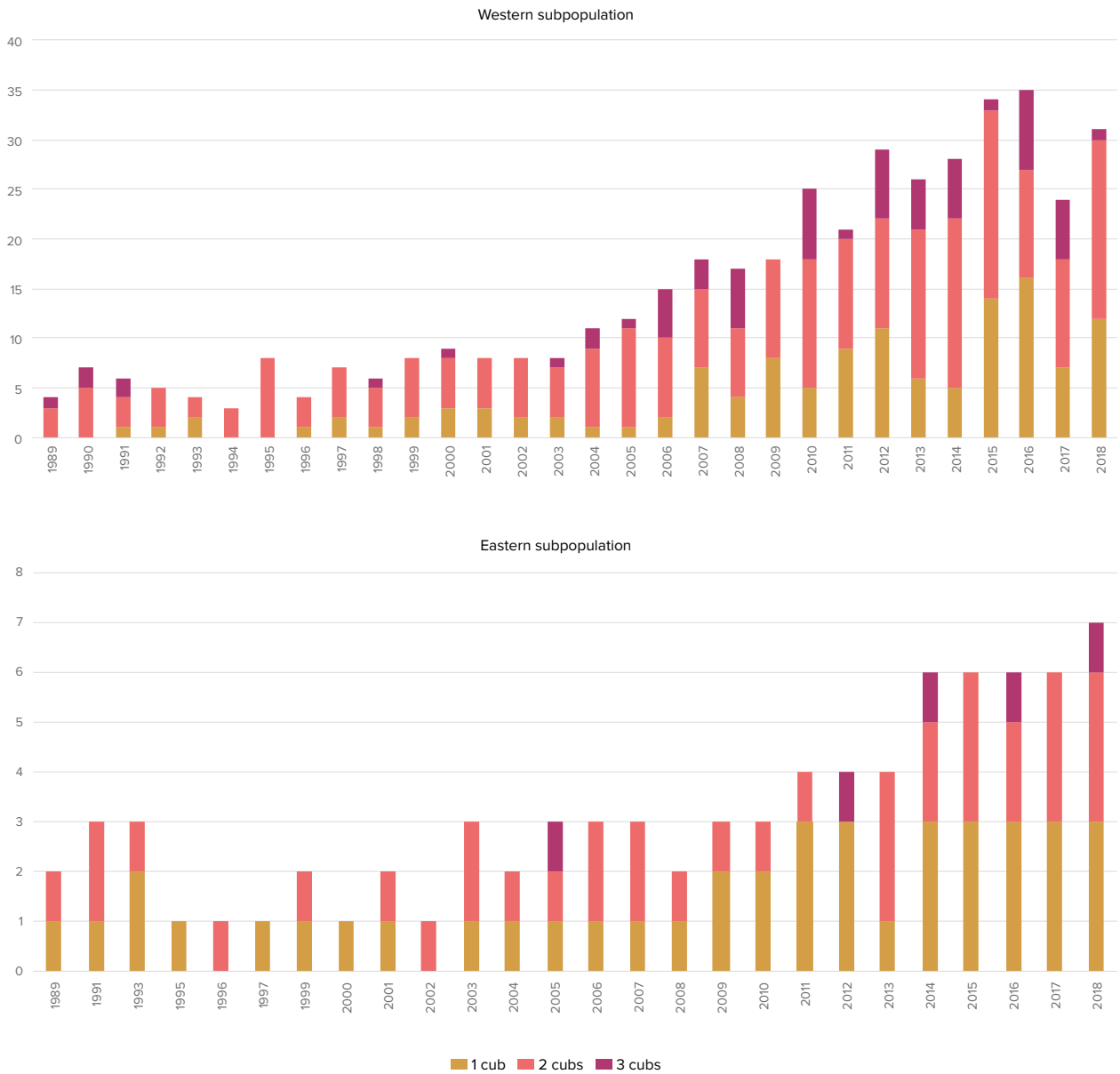

Figure 5. Change in the number of female bears with one, two or three cubs of the year in the western and eastern subpopulations between 1989 and 2018.

CUB SURVIVAL

Among the demographic risk factors for bear populations, which are generally characterised by low breeding performance (Steyaert *et al.* 2012; Shimozuru *et al.* 2017), it is fundamental to understand cub survival during the first stages of life once they have left the den, in order to design conservation policies, e.g., to implement spatio-temporal regulations in sensitive breeding areas. However, this knowledge is lacking for the majority of bear populations.

Fortunately, we have maintained a large database incorporating thousands of observations of females bears with cubs collected continuously over 30 years in the Cantabrian Mountains, providing us with a unique opportunity. Cub monthly survival rates have been estimated from the 3,053 observations of 329 females with cubs, collected between 1989 and 2015 and from the moment when they left the den until their 16th month of life (the cubs are born in winter, mostly in Janu-

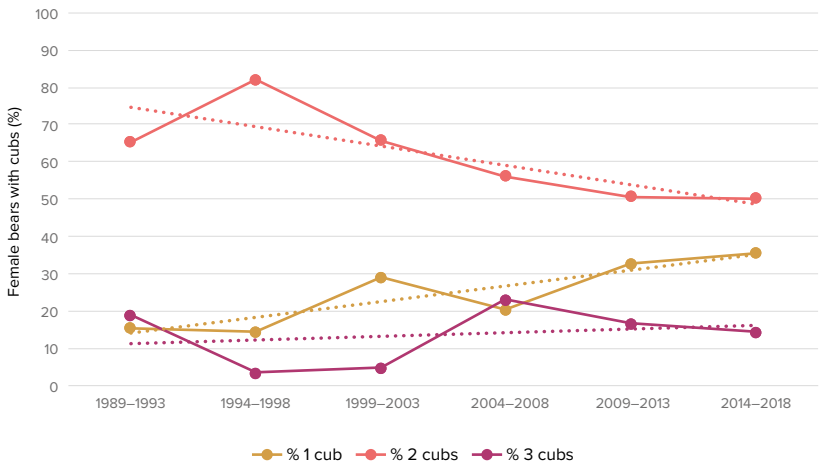

Figure 6. Percentage of female bears with one, two or three cubs of the year in the western subpopulation, by half monthly periods.

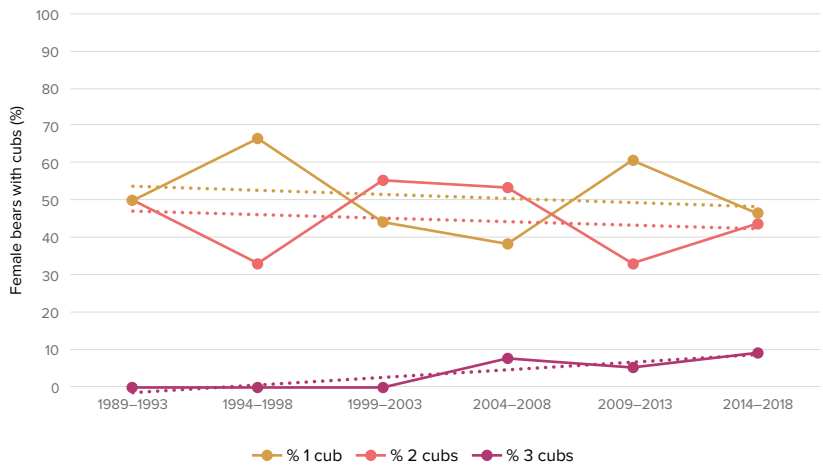

Figure 7. Percentage of female bears with one, two or three cubs of the year in the eastern subpopulation, by half monthly periods.

ary, and remain with the mother for about a year and a half; Palomero *et al.* 2011).

From this total dataset available between 1989 and 2015, set in an annual framework, 2,805 of the observations could be assigned to specific family-year groups (92% of the total data). Given the intrinsic difficulty of identifying the same female bear over the years, except in rare cases (animals with specific markings), each year, once a female bear with cubs had been identified, this was considered as a new breeding bear within the combined dataset. This procedure had no effect on the cub survival estimates. Of the 329 females with cubs in the initial dataset (total number of cubs = 610), 295 family groups were detected (90%) during the first year of cub life. In 178 cases, the family group was observed into the second year and for 88% of these cases, cubs were not detected with their mothers after May that year. Given that knowing the exact number of cubs was a requisite for considering a family-year case as valid for analysis, all cases where the exact number of cubs could not be determined during the first weeks of monitoring were discarded. Neither did we consider those cases where all the observations of females with cubs fell within one particular month, nor in those cases where the family observations were dispersed over long periods of time. Consequently, the final dataset comprised 434 cubs from 227 breeding females.

Mortality due to infanticide, which is principally caused by adult males (Bellemain *et al.* 2006; Palomero *et al.* 2011; Steyaert *et al.* 2013a, 2013b), is important to consider in cub mortality rates (Palomero *et al.* 2011; Planella *et al.* 2019). Estimating the time period during which these events are most likely to occur also enables the establishment of temporary restrictions on human activities. Of the 434 cubs used in the survival rate analysis, we were able to determine the cause of death in 21 cases (5%). Infanticide was the main cause, for 18 cubs of nine females, and for the remaining three cubs, two died from falls suffered on rock outcrops, plus one was abandoned by the mother.

A multi-state capture-recapture model was used to estimate the cub survival rate (see details in Planella *et al.* 2019). The source data for this analysis were the monthly observation and re-observation of each family group for each female, cub(s) and breeding year. The states were defined as the months with-

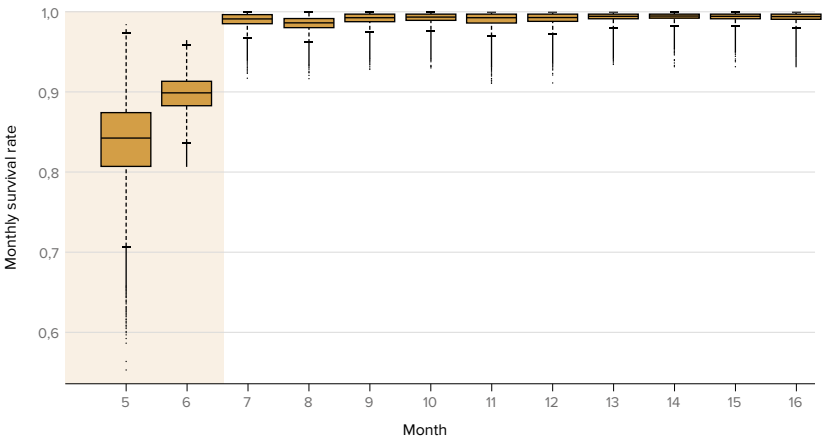

Figure 8. Estimate of the monthly survival rates of brown bear cubs in the Cantabrian Mountains between 1989 and 2015. Adapted from Planella et al. 2019. Drawing courtesy of Marina Torrellas.

in the study period, so allowing us to estimate monthly survival rates. Given that the earliest ever record of a female with cubs in our database was on 31st March, the months considered ranged from the 1st April of their first year, until 30th April of the following year, just before the moment at which natural family break-up normally occurs.

In general, the monthly survival rates for cubs in the Cantabrian range were high, ranging from 0.839 to 0.994. The lowest monthly survival rates were observed during the first two months after abandoning the den. Cub survival rates (average ± sd) for May and June were estimated at 0.839 ± 0.050 and 0.897 ± 0.023, respectively. Survival was markedly higher thereafter, with monthly survival rates always over 0.985 (Figure 8) from July of their first year until April of the following year.

Photo 7. The exit from the winter bear den coincides with the mating season and the females with cubs of the year are especially vigilant in order to avoid infanticidal males.

Infanticide was considered to be the primary cause of cub mortality throughout the study period. When cubs were no longer observed, the probability (average ± sd) that they had died due to an infanticide event was 0.826 ± 0.077 (0.174 ± 0.070 for all other causes combined). Our analysis suggests that litter size has no influence on the probability of suffering an infanticide event (Planella *et al.* 2019). The lowest cub survival rates were correspondingly seen during the bear mating season (April-June) (Palomero *et al.* 2011). Our results on infanticide rates are similar to those observed in other brown bear populations (Swenson *et al.* 1997; Schwartz *et al.* 2006; Gardner *et al.* 2014). In those populations where cub mortality was higher outside the mating season, this was probably associated with food shortage (Shimozuru

et al. 2017), but this does not appear to be a critical factor in the Cantabrian Range given the high monthly survival rates observed during the first months of cub life here.

Apart from the 21 cases of cub death used to calculate the cub survival rate, since 1996 we have registered 20 mortality events resulting in 27 cub deaths in the Cantabrian range, only considering definite cases with direct observations or where cub remains have been collected. Infanticide was the main cause of cub mortality detected, affecting 16 cubs of 10 females (59.3% of dead cubs). Other causes of death have been due to falls from rock-faces (five cubs, 18.5%), disease (two cubs, 7.4%), abandonment (one cub) and being run over by traffic (one cub). Of particular note is that the two cubs which died of disease were diagnosed with canine viral hepatitis caused by Type 1 canine adenovirus (CadV-1) (García-Marín *et al.* 2018) and that both were recovered from the Somiedo area of Asturias two years apart.

FAMILY BREAK-UPS

Female brown bears in Europe spend approximately a year and a half with their cubs; the separation of the mother from her cubs is known as family break-up. Females mate just after separating from their cubs, such that the length of upbringing determines how many times a female can breed during her lifespan (Dahle & Swenson 2003a). In northern Europe, this parenting period varies from 1.5-2.5 years, depending on the number of cubs and the weight they attain, in addition to other factors such as the legal protection afforded to family groups in hunted populations (Van den Walle *et al.* 2020). Family groups usually break up in spring, during the mating season, such that it could be expected that the presence of adult males conditions this separation, or that the female shows interest in abandoning the second

Table 1. Cub mortality events detected in the Cantabrian Mountains between 1996 and 2020. (Sex: M = male, F = Female). * female cub captured on a road on 27.04.12 (after being abandoned or orphaned), brought back to health in a recovery centre and died in transit to the liberation site on 26.10.12. ** cub observed dead, being eaten by a golden eagle, possibly following a cliff fall.

Event	Date	Municipality	Province	Death cause	Number of cubs (Sex)
1	08.06.96	Palacios del Sil	LE	Infanticide	1 (M)
2	24.05.98	Cangas del Narcea	AS	Cliff fall	2 (1 M y 1 F)
3	15.06.00	Degaña	AS	Infanticide	3 (1 M, 1 F y 1 unknown)
4	26.05.01	Somiedo	AS	Infanticide	2 (unknown)
5	02.06.04	Somiedo	AS	Infanticide	2 (unknown)
6	03.06.04	Palacios del Sil	LE	Cliff fall	1 (unknown)
7	01.06.05	Palacios del Sil	LE	Infanticide	1 (M)
8	03.06.05	Degaña	AS	Infanticide	1 (M)
9	24.05.06	Páramo del Sil	LE	Infanticide	3 (unknown)
10	28.04.07	Somiedo	AS	Infanticide	1 (F)
11	08.06.08	La Pernía	P	Infanticide	1 (unknown)
12	20.09.10	Palacios del Sil	LE	Unknown	1 (unknown)
13	26.10.12	Palacios del Sil	LE	Dead during transfer*	1 (F)
14	16.04.14	Cangas del Narcea	AS	Cliff fall**	1 (unknown)
15	23.05.15	Somiedo	AS	Disease (CadV-1)	1 (M)
16	29.05.16	Somiedo	AS	Cliff fall	1 (unknown)
17	02.04.17	Somiedo	AS	Disease (CadV-1)	1 (F)
18	29.04.17	Somiedo	AS	Infanticide	1 (unknown)
19	25.11.19	Santo Adriano	AS	Unknown	1 (M)
20	23.09.20	Huergas de Babia	LE	Run over	1 (F)

Photo 8. A partially devoured dead cub following attack by an infanticidal male in the Somiedo Natural Park (Asturias).

year cubs to go on heat (Dahle & Swenson 2003b).

Family break-up is a very poorly known aspect of bear behaviour. From 2000 until 2016 we registered 10 females with cubs in cases where we made the last observation of the family unit together and the first of it then separated, enabling us to estimate break-up date. In some cases, we have either directly observed family break-up or the periods immediately prior to or following it. All of these cases occurred between 11th April and 20th May, corresponding with the start of the mating season in the Cantabrian Mountains (Palomero *et al.* 2011). In three of these 10 cases, an adult male was seen in the vicinity of the family group at the moment of break-up. In two of these cases, this was clearly the cause of the family break-up; in the third, interaction was observed, but it was not possible to see the cub without the mother until 10 days later. In the remaining seven cases it was not possible to observe the moment of break-up in detail, and so it is unknown if there was an interaction with a male. Four further cases were observed where a male was seen approaching a family group during the mating season, which probably lead to family break-up, but where this could not be confirmed. These cases were observed between 17th April and 29th May. In all cases, the female attempted to repel the male, though the latter persisted and continued to follow the family group.

In those cases with detailed direct observations, a change in the behaviour of the female towards the cubs was noted in the presence of a male during the breeding season, from defending them at the beginning, to losing interest in them but showing increasing interest in the male, and finally driving the cubs away. In studies on Scandinavian brown bears and North American black bears (*Ursus americanus*), family break-ups were also associated with the presence of adult males (Ternent & Garshelis 1995; Dahle & Swenson 2003b; Lee & Vaughan 2004).

Following break-up, sibling cubs tend to remain together for a while. In the Cantabrian Mountains, 35 groups of siblings staying together after separating from their mother were observed between 1989 and 2016, of which 14 could be assigned to a known family group. Of these 14 cases, 12 corresponded to litters of two cubs and two referred to litters of three. Following family break-up, the siblings remained together for an average of 333.6 (±246.7) days. The litter which remained united for the longest spent 747 days together after break-up, an exceptional length of time and unknown to us in the literature. These associations between siblings undoubtedly provides them with greater survival chances, during one of the periods in the brown bear lifecycle with greatest mortality risk.

MORTALITY CAUSES AFTER THE FIRST YEAR

The brown bear is a charismatic species of high conservation interest in Spain and individuals which are found dead, and their mortality causes, do not go unnoticed. We have collected data for all known cases of dead bears in the Cantabrian Range between 1998 and November 2020. This information comes from the regional adminis-

Photo 9. Illegal steel wire snares are usually used to capture wild ungulates but can trap bears and cause them serious injuries or even their death.

trations, Brown Bear Foundation patrols, other biologists and naturalists supplying information, from the press and from specialised literature (Balseiro *et al.* 2020a). For each of the cases presented below, a bear corpse has been confirmed, the remains of which were collected and sent to the relevant regional administration for analysis. We have excluded all cases based on rumours or even where data has been published but for which there was no guarantee of a bear's death. Causes of death were taken from the necropsy and pathology and/or toxicology analyses, published and provided by the different administrations, as well as relying on scientific publications.

In the Cantabrian Mountains, between 1998 and 2020 we have verified 45 cases of death of bears more than one year old (Table 2), where 26 (57.8%) were detected in the western subpopulation and 19 (42.29%) in the eastern one. This list probably includes all, or at least the great majority of the brown bears found dead, but clearly represents only a small proportion of the real population mortality, given that the majority of the corpses go undetected. Based on the available information, 15 cases (33.3%) remain without a specific cause of death. Of the rest, 17 (37.8%) deaths were linked to human action and in 13 cases (28.9%) the causes of death were natural.

Compared to the sizes of the different subpopulations (the western subpopulation is six times larger than the eastern one), a proportionately greater number of dead bears were found in the eastern subpopulation. This could be due to a higher mortality there, or that corpses are more readily found in more accessible areas, or both. However, given that annual growth in both subpopulations over the past few years has been in the order of 10% (González *et al.* 2016; Blanco *et al.* 2020), this doesn't support the idea of greater mortality in the eastern nucleus.

In the western subpopulation there have been the same numbers of deaths due to natural as to human causes, while in the eastern subpopulation, the cause of death could not be determined for the vast majority of bears found dead (Table 3).

Of the 17 individuals determined as having been killed by humans, at least seven (41.2%) were poisoned (three with carbofuran, three with aldicarb and one with strychnine), five were shot (29.4%), three were snared (17.6%), one was run over (5.9%) and one died during capture for a scientific study. This last individual refers to case 1 (Table 2), a 7-year-old male that died from capture myopathy and *Clostridium* sp. infection after being captured in an Aldrich snare for radio-collaring (Naves *et al.* 1999). That over 40% of the bears that died due to human causes were poisoned, is noteworthy. This figure should be considered as the minimum number, given that it is difficult to establish poisoning in the autopsies, since although the analysis covers a wide range of compounds, it is difficult to discard the possibility of non-tested toxins or because the condition of the remains makes detection very difficult (e.g., corpses in an advanced state of decomposition or skeletal remains). Indeed, these figures give an idea of the prevalence of poisoning still persisting in our mountains. At the opposite extreme, the death of only

Case	Date	Municipality	Province	Nucleus	Sex	Age	Death cause
1	07.05.98	Somiedo	AS	W	M	adult	scientific capture
2	10.06.98	Somiedo	AS	W	F	young	natural
3	13.05.00	Cervantes	LU	W	M	young	poisoned
4	10.06.00	Degaña	AS	W	M	adult	poisoned
5	17.06.01	Triollo	P	E	F	adult	poisoned
6	summer.02	Riaño	LE	E	M	adult	indeterminate
7	04.09.05	Cervera de Pisuerga	P	E	?	young	poisoned
8	25.09.05	Polentinos	P	E	M	adult	shot
9	19.11.05	Somiedo	AS	W	?	adult	poisoned
10	13.05.06	Vega de Espinareda	LE	W	M	adult	shot
11	11.08.07	Polentinos	P	E	M	adult	poisoned
12	Sept. 07	Riaño	LE	W	?	adult	indeterminate
13	01.12.07	Cervera de Pisuerga	P	E	?	young	indeterminate
14	28.10.08	Trabadelo	LE	W	M	young	run over
15	20.04.09	Cervera de Pisuerga	P	E	?	young	poisoned
16	08.04.10	Páramo del Sil	LE	E	?	adult	indeterminate
17	31.08.11	Palacios del Sil	LE	E	?	adult	shot
18	26.08.12	Cangas del Narcea	AS	W	M	adult	snared
19*	20.10.12	Vega de Liébana	CA	E	F	adult	natural
20	29.03.13	Teverga	AS	W	?	?	indeterminate
21	10.06.14	Quirós	AS	W	M	young	natural
22	15.06.14	Villablino	LE	W	M	adult	natural
23	13.12.14	Guardo	P	E	M	adult	indeterminate
24	March 15	Boca de Huérgano	LE	E	?	?	indeterminate
25	14.04.15	Belmonte de Miranda	AS	W	F	adult	natural
26	16.10.15	Boca de Huérgano	LE	E	M	adult	natural
27	05.03.16	Quirós	AS	W	M	adult	natural
28	10.03.16	Aguilar de Campoo	P	E	M	young	indeterminate
29	09.09.16	Cangas del Narcea	AS	W	M	young	shot
30	27.11.16	Peranzanes	LE	W	F	adult	snared
31	07.01.17	Cangas del Narcea	AS	W	M	adult	natural
32	21.04.17	Cangas del Narcea	AS	W	M	adult	natural
33	21.04.17	Cangas del Narcea	AS	W	M	adult	natural
34	14.07.18	Cillorigo de Liébana	CA	E	M	old	indeterminate
35	29.09.18	Proaza	AS	W	F	adult	natural
36	05.10.18	Cervera de Pisuerga	P	E	M	adult	indeterminate
37	27.10.18	Burón	LE	E	?	young	indeterminate
38	08.11.18	Cervera de Pisuerga	P	E	M	adult	indeterminate
39	10.12.18	Palacios del Sil	LE	W	?	adult	snared
40**	11.05.19	Palacios del Sil	LE	W	M	adult	natural
41	21.09.19	Somiedo	AS	W	F	?	indeterminate
42	06.04.20	Cervera de Pisuerga	P	E	M	adult	indeterminate
43	31.05.20	Monasterio de Hermo	AS	W	F	adult	natural
44	01.09.20	La Pernía	P	E	?	?	indeterminate
45	29.11.20	Cervera de Pisuerga	P	E	F	adult	shot

Table 2. Mortality detected between 1998 and 2020 in Cantabrian bears over one year old.

Date: This corresponds to the date the remains were either detected and/or removed from the field, or the exact date of death if this was observed or otherwise confirmed.

Province: LU, Lugo; AS, Asturias; CA, Cantabria; LE, León; P, Palencia;

Nucleus: W, western; E, eastern;

*the elderly female bear 19 was captured in bad health on 08.07.11 in Cervera de Pisuerga, brought back to health in captivity and then released, but finally had to be recaptured on 11.12.11 in Vega de Liébana and transferred to the Cabárceno Wildlife Park, where it died on 20.10.12.

**male bear 40 was captured in very bad health on 07.05.19 in Palacios del Sil, and transferred to the Villaescusa Wildlife Rescue Centre (Cantabria), where it died on 11.05.19.

one bear from being run over by a car (in September 2020, a cub of the year was also killed in a car accident; see Table 1, for cubs less than a year old). Although other serious road accidents are known, such as the bear hit by a car in Santiago, Somiedo (Asturias), on 15th August 2020, these have not been included here as death was not proven. In other European countries, deaths from being run over on roads or railway lines are one of the principal causes of bear mortality (e.g. Krofel *et al.* 2012 in Slovenia; Find'o *et al.* 2019 in Slovakia). As the Cantabrian brown bear populations grows and expands in range it is anticipated that deaths caused by vehicles will increase in the future.

Of the 13 bears that died of natural causes, an 18-month-old female died from broken vertebrae, caused either by a fall or from an aggressive interaction with another bear (case 2, Table 2); two females died of old age (cases 19 and 25), one of these with tumours affecting the liver (Balseiro *et al.* 2020b); one adult male showed traumatic injuries resulting from a fall (case 27); two males each weighing 200 kg died together, apparently after falling from a cliff during a fight (cases 32 and 33); another male suffered hindquarter paraplegia due to a fight with another bear and died in a veterinary centre a few days after being rescued (case 40), and an adult female died in a fight with an adult male during a case of attempted infanticide (case 43). The female in case 19 was an aged individual trapped in poor condition in Cervera de Pisuerga (Palencia) in July 2011 and after recovery, was released back into the wild, but finally had to be recaptured in Liébana (Cantabria) in December and was taken back into captivity where it died of old age in October 2012 (when 26 years old). Of the remaining bears, a three-year-old male died from gangrenous myositis, perhaps deriving from a fight with another bear (Balseiro *et al.* 2020a) (case 21), another male weighing 140-160 kg died of acute viral hepatitis (Type I canine adenovirus, García Marín et al. 2018) (case 22), another adult male and a four-year-old female died of traumatic injuries and gangrenous myositis attributed to natural causes (Balseiro *et al.* 2020a) (cases 26 and 35), plus a fourth male died – according to the necropsy – due to hepatic and renal necrosis, without poison being detected (Balseiro *et al.* 2020a) (case 31).

Among the 15 bears for which no cause of death could be assigned, only bones or the skull were found in nine cases (four in the western and five in the eastern subpopulation). However, some cases showed signs of severe injuries of unknown origin, such as case 13, which showed a fronto-nasal impact with internal bleeding (hit by a vehicle? fight with another bear?), or case 23, of a nine-year-old male found still alive in Muñeca de la Peña (Guardo), but with severe lacerations across its body, including rump, perhaps caused either by another bear or possibly by dogs, but which later died.

Clostridium bacterial infections were found in four cases: case 21 concerns a young male which died from gangrenous myositis caused

Table 3. Proportion of dead brown bear cases detected between 1998 and 2020 according to the cause of death.

Death cause	Western subpopulation	Eastern subpopulation
Natural	11 (42,3%)	2 (10.5%)
Human	11 (42,3%)	6 (31.6%)
Unknown	4 (15,4%)	11 (57.9%)

Photo 10. A male bear of around 200 kg which died, together with another male of similar weight, after falling from a rockface. This occurred during the mating season in the Fuentes del Narcea, Degaña & Ibias Natural Park (Asturias).

by *C. sordellii* and *C. septicum*, possibly favoured due to its highly weakened state and diverse injuries of unknown origin, compatible in principal with an attack by another animal; case 35 also had hindleg injuries and gangrenous myositis caused by *C. sordellii* (Balseiro *et al.* 2013); and the presence of *Clostridium* was also detected in case 18, a bear trapped in an illegal snare and which died during the recovery attempt, and finally, years before this in case 1, a bear which died during a capture attempt. These infections appear to have had influence in the deaths of these animals, though their proliferation was associated with pre-existing muscular damage (Balseiro *et al.* 2020a).

The causes of mortality for Cantabrian brown bears over the past 20 years are similar to those found during earlier decades (Braña *et al.* 1979; Naves & Palomero 1989; Clevenger & Purroy 1991), although currently, more deaths from natural causes are detected compared to previously. This is probably due to a greater capacity for detecting dead individuals, plus better techniques for analysis during autopsies, amongst other reasons (Balseiro *et al.* 2020a). Additionally, they coincide in general terms with those described for other European populations (e.g., Mörner *et al.* 2005).

It is difficult to obtain information on the survival of bears more than one year old and the incidence of the different causes of mortality on the species' demographics based on these opportunistically gathered data, given that the search effort, accessibility of the area and other non-quantifiable factors, may affect the results and give little idea of the annual mortality rates of the two subpopulations. Whatever the case, the collection of detailed data for all cases of dead bears found in the Cantabrian Range helps to detect possible population sinks or repeated mortality episodes caused by humans, which require investigation and control. It is worrying to see how there are still cases of bears dying due to being illegally shot, requiring a coordinated approach to confront this conservation problem.

Plenty of diseases are present in the wild which can affect brown bears. Aujezsky's disease which is present in the Cantabrian wild boar (*Sus scrofa*) population (MAPA 2017), could easily enter into a bear which feeds on carrion of this species, leading to its death (Vitásková *et al.* 2019). Much more serious would be the appearance of canine distemper virus (CDV) in bears, one of the most serious diseases and with worst consequences in both dogs as well as wild carnivores, the presence of which has occasionally been diagnosed in brown bears in both America and Europe (Demm *et al.* 2000; Di Francesco *et al.* 2015). Both of the Cantabrian bear nuclei are increasing in number but are still small to guarantee their long-term survival. We do not know if the reduced genetic variability present, amongst the lowest described for a brown bear population (Swenson *et al.* 2011), could result in an immunity deficiency which would make them especially susceptible to a particular disease (Blanchong *et al.* 2016). Consequently, we believe that it is necessary to guarantee an adequate health monitoring system and rapid intervention protocol in the face of the appearance of serious outbreaks in domestic animals, but knowledge of the health situation of our bears and other wild carni-

vores would, without doubt, be a good starting point.

It is probably not feasible to present a program to specifically survey the health of bears, although similar work has already been undertaken in wolves (*Canis lupus*), foxes (*Vulpes vulpes*) and other carnivores (Gortazar *et al.* 2007). However, it would appear to be advisable to standardise the technical and veterinary criteria such that any brown bear sample available in the future (dead or injured animals, orphaned cubs, or any other individual requiring handling), would be the object of a complete set of analyses to determine the presence of infectious diseases or antibodies to different pathogens, to increase our knowledge about the diseases present in Cantabrian bears. In a few years' time, this passive health monitoring could provide highly valuable information, above all if studied in context with other populations of brown bears or other carnivores. Although currently there is no alarm surrounding the state of health of the Cantabrian brown bear population, surveillance, scientific knowledge and the coordination between all those implicated in the conservation of the species are, without doubt, the most important tools to anticipate possible future problems.

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CHAPTER 2.

MONITORING OF THE EXPANDING CANTABRIAN BROWN BEAR POPULATION

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SUMMARY

Monitoring of the brown bear population in the Cantabrian Mountains has been undertaken using annual counts of the number of female bears with cubs of the year. However, the increase in the bear population and its distribution range over the past 25 years make applying this technique ever less reliable, above all in the western subpopulation. Consequently, for the past few years we have been studying the viability of combining non-invasive techniques for the determination of individual genetic profiles made from bear excrement and hair samples together with spatially explicit capture-recapture models (SCR). In 2016 we evaluated the usefulness of a bank of 96 available brown bear single-nucleotide polymorphisms (SNPs) for its application to the Cantabrian brown bear population. In autumn 2017, a total of 128 excrement and 23 hair samples were collected over 148 5x5 km UTM grid squares of the eastern subpopulation to compare two distinct markers: microsatellites and SNPs. We obtained very similar density estimates independently of the marker type employed: 0.96 bears/100 km^2 with microsatellites and 1.05 bears/100 km^2 with SNPs. The eastern subpopulation was estimated at 48.6 individuals (95% BCI: 33.8-67.6 bears) with microsatellites. A study was carried out in 2019 with the aim of determining if it was possible to use this technique in the larger and more densely populated western subpopulation. 507 samples were collected during a total of 1,687 km of transects in 282 5x5 km UTM grid squares, resulting in an estimate of 274.7 bears (95% BCI: 222.5-338.3 bears). The results from both subpopulations are consistent with the number of females with cubs of the year and indicate that sampling along transects 2-5 km in length per 5x5 km UTM grid square between October and December are appropriate for monitoring the bear population in the Cantabrian mountain range, which we propose could be undertaken every five years. Whatever the case, the annual monitoring of females with cubs of the year should continue, at least in the eastern subpopulation.

INTRODUCTION

Currently, approximately 16,000 brown bears (*Ursus arctos*) share the European landscape with over 400 million humans (Linnell & Cretois 2018) (the average density ± sd of the human population in areas of stable bear presence is 19.0 ± 69.9 inhabitants/km^2; Chapron *et al.* 2014). The most recent data available show that of the 10 brown bear populations identified, except for the Scandinavian one, all are stable or increasing (Chapron *et al.* 2014; Linnell & Cretois 2018). The brown bear population of the Cantabrian Mountains separated into the western (5,500 km^2) and eastern (3,100 km^2) subpopulations (with average human population densities in areas of bear presence of 11.0 and 7.1 inhabitants/km^2 respectively; INE 2017), has shown a positive trend over the past few decades (González *et al.* 2016). Compared with the 6 female bears with cubs detected in 1989, the data from 2016 and 2017, for example, show minimum estimates of between 40 and 41 family groups detected per year, respectively (Principado de Asturias *et al.* 2017, 2018).

In Europe, the regular monitoring of populations of species protected under the Habitats Directive 92/43/EEC Annexes is important, both to determine changes in the conservation status of the populations and to comply with the European conservation legislation (Epstein *et al.* 2016). Traditionally, the population of brown bears in the Cantabrian mountain range has been monitored using counts of the females with cubs (Palomero *et al.* 2007, 2011), the most important part of the population from a demographic point of view. From the beginning, the standardisation of field working procedures to undertake the coordinated annual count of female bears with cubs by a large number of specialists from the regional administrations of Galicia, Asturias, Castilla y León and Cantabria, the Brown Bear Foundation and other collaborating organisations, has enabled the collection of an unbroken temporal data series of the minimum annual number of female bears with cubs since 1994. This data series has been crucial for monitoring the growth of the population and generate knowledge applicable for the development of conservation policies (e.g., Palomero *et al.* 2011; Planella *et al.* 2019). This procedure has been complemented over time with new methods for estimating the population, such as the use of molecular tools applied to non-invasive samples (excrement and hair) (Pérez *et al.* 2014; González *et al.* 2016; López-Bao *et al.* 2018), which also enables us to develop species' abundance estimates (e.g., López-Bao *et al.* 2020). In this way, for example, Pérez *et al.* (2014), obtained an estimate of 203 individuals for the western subpopulation (95%CI = 168-260) and 19 in the eastern one (95%CI =

Photo 1. Traditionally, the Cantabrian bear population has been monitored by counting the number of female bears with cubs each year. Standardisation of the field procedures from the beginning has allowed a continuous data series of the minimum confirmed number of females with cubs per year since 1994 until now.

12-14) in 2006, based on a total of 270 non-invasive samples and classic capture-recapture techniques.

Given the continuing population expansion of the brown bear in the Cantabrian mountain range, new methods are required to obtain robust and reliable population estimates. This growth observed over the last few decades translates into an ever-greater effort required to acquire acceptable data on the minimum number of the females with cubs of the year indicator. Associated with the population increase, the annual count of females with cubs runs the risk of offering increasingly lower representative results, not only as a consequence of the increase in family groups, but also of the territorial expansion which accompanies the population recovery. This task is further complicated by overlapping of the bear families due to bear philopatry (Støen *et al.* 2005; Zedrosser *et al.* 2007), which makes the issue of discriminating between individual female bears more difficult and forces the adoption of conservative decisions. The current estimates represent, in consequence, the minimum number of females with cubs, so it is necessary to find new methods of estimating the entire population of brown bears in the Cantabrian mountain range and how this estimate changes over time. Additionally, the information available on the adjustment factor between the number of female bears with cubs one year and the overall bear population that year, remains relatively unexplored (e.g., Servheen 1989; Tosoni *et al.* 2017; Mateo-Tomás *et al.* 2019). For example, Servheen (1989) affirmed that females with cubs represent between 8-12% of the total grizzly bear *(Ursus arctos horribilis)* population. In another case, in the brown bear population inhabiting the Apennines, in very similar environmental conditions to those in the Cantabrian range, an average of 3.9 females with cubs were detected annually between 2006 and 2014 and a total of 51 bears were determined using genetic analyses (Tosoni *et al.* 2017), providing a multiplication factor of 13.1 times the number of females with cubs.

Photo 2. A Brown Bear Foundation staff member collects a hair sample for posterior laboratory analysis.

Concerned with the need to adapt the monitoring system of the Cantabrian brown bears to the increasing population over the last few years, in 2016 we started to work on the viability of using new methods to monitor the entire brown bear population, using a methodology to estimate the population which can be applied periodically and in a standardised manner over the long term. Previous studies on other populations of the brown bear, wolf (*Canis lupus*) and other species, suggested that an ideal monitoring method could be based on non-invasive samples (excrement and hair), with the goal of obtaining individual genetic profiles for each bear, combined with spatially explicit capture-recapture (SCR) techniques (e.g., Royle *et al.* 2014; López-Bao *et al.* 2018b; Mollet *et al.* 2015; Moqanaki *et al.* 2018; López-Bao *et al.* 2020). So, for the past few years we have been working on this in order to test the viability of this proposed methodology in the Cantabrian Range.

The study of non-invasive genetic samples and the spatially explicit capture-recapture models for monitoring the Cantabrian brown bear population has been carried out in various phases. A pilot study, in 2016, first looked at the possibility of using single-nucleotide polymorphisms (SNPs) in non-invasive bear samples. In 2017-2018, using the eastern subpopulation as

a study case, given its lower density and overall population size, the proposed methodology was implemented in addition to evaluating the differences existing when using two different molecular markers (microsatellites and SNPs). It was concluded that in the case of the eastern subpopulation, the final results of the tests undertaken were comparable, independently of the molecular marker used (López-Bao *et al.* 2020). Finally, during the third phase, in order to complete the evaluation of its applicability in the different situations present within the Cantabrian brown bear population, the same methodology proposed was applied to the much denser and more numerous western subpopulation in 2019 and 2020. This phase was carried out using only microsatellites as the molecular markers.

THE USE OF NON-INVASIVE GENETICS

During the 1990s, interest in improving the monitoring of brown bear populations was part of the reason for developing non-invasive monitoring schemes using DNA analyses (Taberlet *et al.* 1997; Woods *et al.* 1999; Mowat & Strobeck 2000; Carrol *et al.* 2018). This methodology has been used to evaluate the status of small brown bear populations in different parts of the world (Bellemain *et al.* 2007; De Barba *et al.* 2010; Proctor *et al.* 2012; Chapron *et al.* 2014; Tumendemberel *et al.* 2015; Moqanaki *et al.* 2018; López-Bao *et al.* 2020).

Traditionally, non-invasive samples (excrement or bear hairs) have been analysed using different microsatellite sets (e.g. Taberlet *et al.* 1997; Andreassen *et al.* 2012; De Barba *et al.* 2017). In addition, important advances have also been made over the past few years using genome sequencing in bear species (e.g., Norman *et al.* 2013, 2017). The entire genome has been sequenced for species such as the giant panda (*Ailuropoda melanoleuca*), polar bear *(Ursus maritimus)* and the brown bear, and different marker SNP panels have also been published, which have been used, amongst other things, to investigate the recent evolutionary history of bear species, or to study the connectivity between brown bear populations (Miller *et al.* 2012; Norman *et al.* 2017).

Faced with designing a brown bear monitoring program based on the use of non-invasive sampling to identify individuals, it is necessary to be able to satisfactorily identify individual genetic profiles with non-invasive samples, including in areas with a small number of individuals. During a first phase, in 2016, we tested the effectivity of a 96 SNPs marker panel developed for the brown bear by Norman *et al.* (2013), to identify the genetic profiles of individuals in the Cantabrian population in non-invasive samples. For this trial we used 35 excrement and 12 hair samples which had been recently collected from the eastern subpopulation. Given that the aim was to test the efficiency of the SNPs to identify individual genetic profiles, despite the known gene flow between both subpopulations (González *et al.* 2016), it was decided to undertake the test on the smaller subpopulation, where, as a result, the differentiation of individuals might be more compromised. Of these initial analyses, 52 polymorphic SNPs were selected for the following phases of the study, where both types of molecular markers were analysed. The DNA was extracted from the excrement and hair in the CIBIO-InBIO laboratory (Portugal), which is dedicated to processing low quality DNA samples. The low quantity and quality of the DNA in the samples increases the risk of contamination, which would render the affected samples useless. In order to avoid this, sterilising ultraviolet light and a positive pressure to avoid the entry of possible contaminants from outside the laboratory are used, so avoiding contamination problems resulting from aerosol transfers.

The methodological details for DNA extraction are given in López-Bao *et al.* (2020). Two problems associated with the use of DNA extracted from non-invasive samples which can affect the final result are: i) inconsistencies in the quantity and quality of the DNA samples obtained in each extraction and ii) the presence of inhibitors in the final solution of DNA obtained associated with components such as microorganisms, digestive tract enzymes, bile salts, etc., which may inhibit the reactions necessary for the posterior use of the DNA. These reasons justify that the quality of the DNA extracted from the non-invasive samples is not directly verified, choosing however to genotype all of the samples collected. The microsatellites were amplified using a double PCR (Taberlet *et al.* 1997; De Barba *et al.* 2017). PCR amplifications were undertaken using the Qiagen

Photo 3. A member of the CiBio-inBio technical team processing the simples in order to extract DNA from the excrement.
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Master Mix kit using four primer multiplex-PCR with between two and six loci markers for each. All of these amplifications included a negative internal control to monitor for possible cross-contamination. Each sample was amplified four times for each multiplex. For each sample, a consensus genotype is generated using analysis of the four repetitions per locus and only those genotypes considered highly reliable were used (> 80%: Miller et al. 2002).

The SNP genotyping was made using a Fluidigm Biomark system. All non-invasive samples were genotyped twice for SNPs. This genotypic duplication procedure allows for the elimination of possible errors which are frequently associated with poor quality DNA samples, which are essentially of two types: i) the non-amplification of one of the alleles and ii) the appearance of false alleles (alleles which don't exist but arise given the poor quality of the mould from where they are copied). The reactions for genotyping are accompanied by negative controls and one positive control, represented by a sample of a known high quality genetic profile for those SNPs in the tested panel used (i.e., a brown bear sample from the same population where the 96 SNPs panel was developed, the Scandinavian brown bear population). The consensus genotypes for the double replicate samples were determined by always accepting the heterozygous genotypes. The amplification rate was used as the quality criteria for the set of autosomal SNPs in each sample, with all samples under the 80% rate being excluded from the analysis.

We identified the sex of each brown bear individual using ZFX/Y and SRY markers (Pagès *et al.* 2009) and the genotyping of SNPs in the sex chromosomes. ZFX/Y and SRY genotyping was performed together with microsatellites in the same multiplex systems. For SNPs, we classified samples as males when genotyping was successful for the Y-linked SNPs and, otherwise, as females. This information was subsequently validated with information of X-linked SNPs, to guarantee that the males only have one allele for each of these markers, while females can have either one or two alleles in the X chromosome.

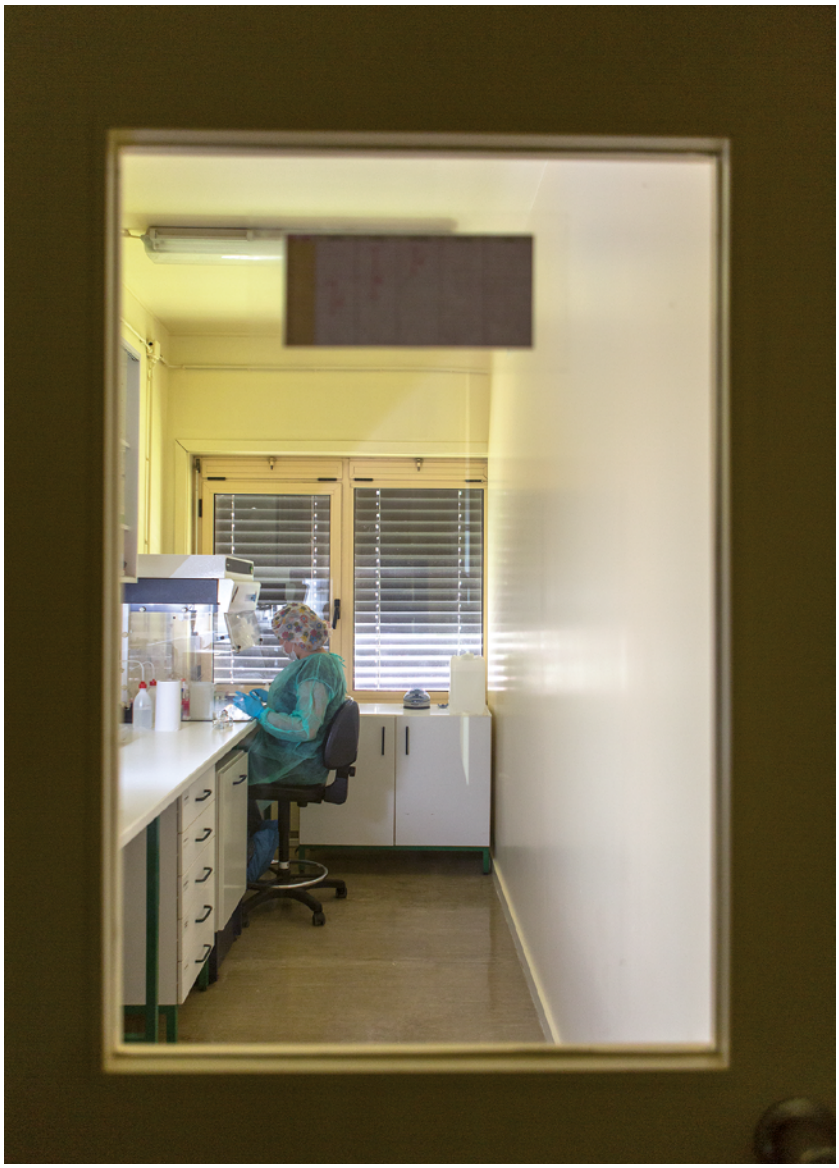


Photo 4. Laboratory dedicated to the extraction of DNA from non-invasive simples. The laboratory contains equipment fundamental for minimising the risk of contamination, such as UV lights to sterilise the air before and after use, and sterile ventilation with positive atmospheric pressure which avoids problems of contamination by transference of aerosols with the exterior. ©João Ferrand

NEW APPROACHES FOR ESTIMATING POPULATION SIZE

Once the individual genetic profiles were obtained, a spatially explicit capture-recapture model (SCR) was applied (Efford 2004; Royle *et al.* 2014) to calculate the estimates of brown bear density and abundance. This type of model takes into consideration movement of the animals by supposing that each individual has an activity centre (which may be equivalent to its home range centroid) and that the probability of capturing an individual is a function of i) the Euclidian distance from the activity centre or the detection location (e.g. hair trap or the centroid in a sampling cell), ii) the scale parameter of the seminormal function, informative regarding animal movements, and iii) the basal detection probability (the probability of detection when the trap or the detector location coincides with the activity centre). SCR models assume that each individual in a population has its own activity centre (and that this is static over the survey period: Royle *et al.* 2016) and that all activity centres are uniformly distributed across the study area. However, during a recent application of SCR combined with non-invasive samples on the wolf, the utility of this technique has also been shown even for social species, or those that form social groups at some point during their annual cycle (López-Bao *et al.* 2018b), as long as the movement of the animals is not synchronous (they do not move simultaneously, so that detectability is not identical between individuals) or that their activity centres coincide exactly.

The latent variable to estimate in SCR is the location and the number of activity centres of the individuals present in the state space S (Royle *et al.* 2018). As in all capture-recapture processes, there is a spatial assignation of capture events. In our brown bear surveys, there is no detection site for individuals, such as a camera trap or a specific hair trap, and so the centroid of each 5x 5 km UTM square cell is considered as a detection location. Consequently, all non-invasive samples collected and genotyped within a sampling cell are assigned to the centre of the

cell for analysis. The selection of the 25 km^2 UTM reference square cells addresses the spatial ecology requirements of the bears. Although specific data for Cantabrian brown bears is not available, this square size selected is equivalent to approximately 1/3 of the average home range of radio-collared adult bears in similar Eurasian regions (c. 72 km^2: Huber & Roth 1993; Mertzanis *et al.* 2005; Ambarli & Bilgin 2012; Gavrilov *et al.* 2015; Moqanaki *et al.* 2018). While for field work sampling it is preferable to use the 5x5 km UTM squares to facilitate the collection of samples by field workers, for data analysis and SCR models it is preferable to use a hexagonal grid overlaying the former, with the same surface area within each grid unit. The use of hexagons in the SCR analysis reduces sampling bias due to edge effects of grid polygons, given the lower edge to perimeter ratio in hexagons, in addition to hexagons being the closest polygons in shape to a circle and which can be used to uniformly space a grid. This approximation of a hexagon to a "circular" pattern allows the representation data pattern curves in a more natural way than with data from squares, adjusting itself to the study of the activity centre point process of the SCR method, given that the distance between neighbouring centroids is always identical. Consequently, the centres of the hexagons are used as "detectors" (Russell *et al.* 2012) and all of the genotyped non-invasive samples from with a grid hexagon are assigned to the same detector (Gardner *et al.* 2009; Russell *et al.* 2012). This size of sample cell also complies with the requisite of the maximum space between detectors needing to be at around twice the sigma scale parameter (σ is the parameter which determines the reduction in frequency of detection of individuals as the distance between their activity centres increases: Sollmann *et al.* 2013; Sun *et al.* 2014). A cell size adjusted to movements consequently avoids an excessive loss in resolution of σ.

Data analysis was undertaken by applying Poisson distributed observation models under a Bayesian framework, which permit effective estimation of the SCR model parameters using multiple detections of the same individual at the same detector with only one sampling occasion (Royle *et al.* 2014; López-Bao *et al.* 2018b). The total number of activity centres (*N*) was estimated by applying the data expansion technique (Royle *et al.* 2014), in which potential individuals are added with zero capture data histories. The space states (*S*) are generated as an area centred in the study area with a buffer added to the cell network surveyed. The buffer distance applied is 2.5σ (Royle *et al.* 2014). The survey cells beyond the 2.5σ buffer will have a marginal chance of detection of individuals and the density estimates will be equal to the estimate of average density in the space states *S* (Royle *et al.* 2014). The SCR analysis methodology requires that at least 4-5 genotyped individuals are captured in at least 2-3 different sampling sites (different detectors), or to put it another way, it needs at least 15 different spatial captures to obtain reliable information on the sigma movement parameter and at least 30 total captures and recaptures overall (including the former, though with an increasing number of captures, the precision of the es-

Photos 5. The new population models allow us to estimate the entire Cantabrian brown bear population, including subadult animals and adult males.

timate increases: Royle *et al.* 2014). Details of how his model is used and its practical use in the case of the brown bear can be found in López-Bao *et al.* (2020).

CONSISTENT ESTIMATES REGARDLESS OF METHOD

The second phase of the work was carried out in 2017-1018, using the eastern subpopulation as a study case and with the methodology proposed, which combined non-invasive genetics with spatially explicit capture-recapture models. Here we evaluated if the molecular marker selected (microsatellites vs SNPs) could influence the total population estimates. A set of 18 microsatellites habitually used in brown bear populations were used for this phase (Andreassen *et al.* 2012; De Barba *et al.* 2017, Taberlet *et al.* 1997).

Between November and December 2017, non-invasive samples were searched for and collected in 148 5x5 km UTM grid squares, within each of which one or more transects between 2 and 5 km in length were prospected on foot to search for bear excrement or hairs. These totalled 624 km and averaged 4.4 km per square (sd = 3.1 km). The best areas for detecting bear excrements within each 5x5 km square were selected taking into account the survey period (autumn) and biological cycle of the species. In total, 128 excrement and 23 hair samples were collected.

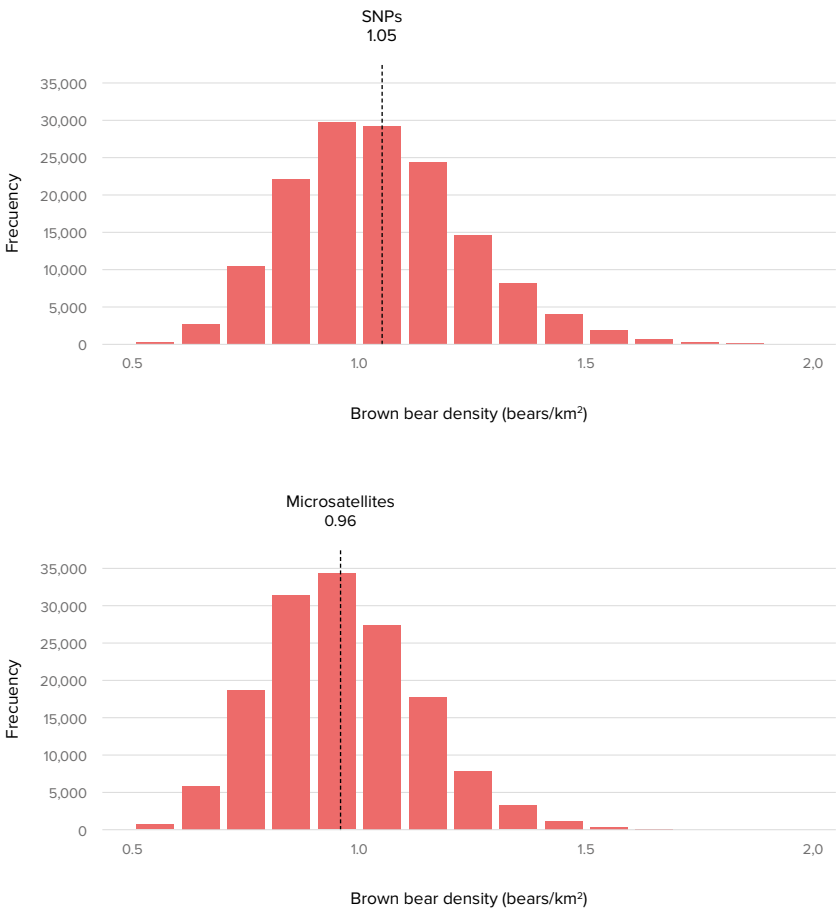


Figure 1. A posteriori distribution of the estimated density of brown bears in the eastern subpopulation of the Cantabrian Mountains, using microsatellites and SNPs. The discontinuous line indicates the average value derived from a total of 150,000 samples from a posteriori distribution of the density estimates (López-Bao et al. 2020).

Based on the number of non-invasive samples collected (n=151) and the genetic profiles obtained (104 microsatellite profiles and 94 SNP profiles: López-Bao *et al.* 2020), applying spatially explicit capture-recapture models (SCR) produced similar results in terms of brown bear density in the eastern Cantabrian subpopulation. The density estimate using microsatellites revealed 0.96 bears/100 km^2 (95% BCI: 0.67-1.34); while that using SNPs was 1.05 bears/100 km^2 (95% BCI: 0.71-1.49: López-Bao *et al.* 2020). The precision of these estimates, measured by the variation coefficient (i.e., the standard deviation divided by the average), was slightly lower when using microsatellites (17.7 compared to 19.0: López-Bao *et al.* 2020). Similarly, the estimates of the sigma scale parameter (the parameter which determines the reduction in frequency detection as the distance between their activity centres increases) were similar for microsatellites (0.23; 95% Bayesian Credibility Interval: 0.20-0.27) and SNPs (0.24; 95% Bayesian Credibility Interval: 0.20-0.28).

In this phase, the effectiveness of using both a set of 52 SNPs (López-Bao et al. 2018a) as well as a set of

18 microsatellites in the identification of individual genetic profiles using non-invasive samples (excrement and hair), was shown. The combination of either of these molecular methods together with the spatially explicit capture-recapture methods provides a robust methodology for estimating the brown bear population.

BROWN BEAR POPULATION SIZE ESTIMATE TRIAL

In combination with the preceding phase, and once the similarity between the estimates of the eastern subpopulation obtained using both SNP as well as microsatellites was confirmed (López-Bao *et al.* 2020), the use of microsatellites in the western subpopulation was chosen in 2019 in order to test the proposed methodology in an area of greater brown bear density and complete a trial to estimate the total brown bear population across both subpopulations over the entire distribution of the brown bear, including areas within the autonomous communities of Asturias, Cantabria, Galicia and Castilla y León. For the field survey work planning, the baseline of 5x5 km UTM grid squares was used to divide up the study area, with 148 squares in the eastern subpopulation and 282 in the western one. For the eastern subpopulation, the sampling period was November-December 2017, while in the western one it was October-December 2019. The autumn was chosen as the preferred sampling period for biological reasons and greater detectability of the bears, as well as to reduce potential risks and disturbance to the species. Winter was excluded, in which a significant part of the population hibernates, and so is indetectable, as well as the spring and summer, in order to avoid disturbance to females with cubs of the year, whose excrement and hair samples are difficult to detect and collect at this time. In addition to the effort already mentioned for the eastern subpopulation, 1,687 km of transects were covered in the western subpopulation (an average of 5.9 km per square). In total, 151 non-invasive samples were collected in the eastern subpopulation and 507 in the western one. This trial showed that it is possible to address sampling within all of the squares within the Cantabrian brown bear's distribution range in a period of 3-4 months given an adequate number of experienced participants (over 10,000 km^2 were surveyed).

As noted before, using microsatellites, the eastern subpopulation density estimate was 0.96 bears/100 km^2 (95% BCI: 0.66-1.34), while in the western one it was of 2.50 bears/100 km^2 (95% BCI: 2.02-3.08). Estimates of the sigma scale parameter were of 0.235 (sd = 0.018) in the eastern subpopulation and 0.249 (sd = 0.020) in the western one. The similarity in this parameter is coherent with a similar spatial ecology across the Cantabrian range.

Using the method proposed, 48.6 bears (95% Bayesian Credibility Interval: 33.8-67.6) were estimated in the 2017 brown bear population in the eastern subpopulation and 274.7 bears in the western subpopulation in 2019 (95% Bayesian Credibility Interval: 222.5-338.3). Taking into account the estimated population size of 19 individuals in the eastern subpopulation in 2006 (95% CI = 12-40: Pérez *et al.* 2014), our results are in accordance with the growth shown by this subpopulation over recent years, reflected in the growth in number of females bears with cubs of the year detected, which rose from 3 in 2006 to 6 in both 2016 and 2017 (Principado de Asturias *et al.* 2018).

The trials undertaken in the two bear nuclei in the Cantabrian range between 2017 and 2019 demonstrate the utility of the evaluated monitoring method. We believe that molecular tools, such as microsatellites, applied to non-invasive samples (excrement and hair) collected during a discrete sampling event, together with the application of spatially explicit capture-recapture methods, can provide a robust methodology for estimating the Cantabrian brown bear population size. In addition, the two tests carried out in 2017 and 2019 show that it is viable to survey the entire distribution area of the species in a relatively short period of time and with an acceptable level of effort. Based on the results obtained, we consider that the spatial scale adopted for the survey (5x5 km UTM grid squares), the effort applied (transects between 2 and 5 km in length in each grid square) and the timing of the sampling (October-December) are appropriate for monitoring the species. The trials undertaken in both subpopulations have allowed us to prove that despite the different abundance and detectability of the bears present, given the survey effort established, the requirements of the SCR meth-

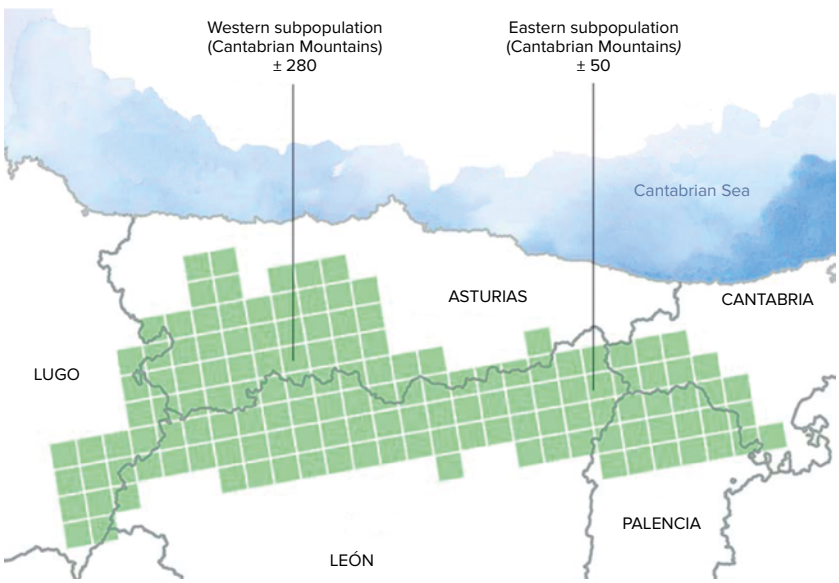
odology have been fulfilled regarding the number of captures and recaptures necessary for analysis.

Taking the eastern subpopulation as an illustrative example (López-Bao *et al.* 2020), the estimates obtained allow us to establish an equivalence between the number of family groups (females with cubs of the year) and the overall population size. If we consider that female brown bears usually breed every second year (Palomero *et al.* 2011), that the proportion of adult female bears in the Cantabrian range population is similar to that in other protected populations (0.274-0.279: Nawaz *et al.* 2008; Tosoni *et al.* 2017; Mateo-Tomás *et al.* 2019), and given an estimate of the proportion of non-breeding adult females compared to total adult females of 0.22 (Tosoni *et al.* 2017), it is possible to estimate a population of 55.1-56.1 bears in the eastern population given the 6 females with cubs of the year detected in both 2016 and 2017. Furthermore, taking into account that according to Servheen (1989), those female bears with cubs (in this case grizzly bears, which usually breed every third year) represent between 12% and 8% of the entire population, it is also possible to estimate 49.9 bears for this subpopulation using the most conservative estimate, and up to 75 bears for the upper limit. This exercise is useful to illustrate the similarity between some of these estimates when using the number of females with cubs as the baseline and the total population estimates obtained.

The monitoring of females with cubs of the year is becoming an ever-greater challenge in the western subpopulation. However, we consider that it is still feasible to use this method in the eastern subpopulation. Aside from its interest for evaluating population change, the monitoring and surveillance of females with cubs continues to play an important role. The collection of data on the number of females with cubs, of the number of cubs per family, of their progress during the first few months of their life and of their spatial location, provides us with highly valuable information for conservation purposes (e.g., Planella *et al.* 2019). Consequently, we propose to continue monitoring of the number of females with cubs in the small eastern subpopulation as well as collected as much information as is possible in the western subpopulation, but without the objective of using this information as an indicator of this population's change.

The final question which can be raised relates to the frequency with which a population estimate for the brown bear in the Cantabrian range should be made. We do not believe that this needs to be annual. Considering that the average generational time for the brown bear in the Cantabrian range is 9.0-9.1 years (Martínez-Cano *et al.* 2016), and that Article 17 of the Habitats Directive 92/43/ECC requires periodic monitoring of those species included in its annexes, and communication of this by member states every six years, we consider it appropriate to produce estimates for the entire Cantabrian range at least every five years. These estimates could be made with greater frequency in specific cases, such as for the eastern Cantabrian subpopulation (González *et al.* 2016).

Figure 2. Situation of the brown bear in the Cantabrian Mountains in 2017–2019.
Source: FOP.



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Photos 6. A brown bear in the Cantabrian western subpopulation.

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CHAPTER 3.

CLAIMS ATTRIBUTABLE TO BEAR DAMAGE

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SUMMARY

New conservation challenges are arising from the current demographic growth and territorial expansion experienced by brown bears in the Cantabrian Mountains, among which is the mitigation of the damage caused to human interests, such as livestock rearing and agriculture. In order to start quantifying the impact bears have in the region, we collated all the official claims files for bear damage registered by the respective administrations in Asturias, Cantabria, Castilla y León and Galicia between 2009 and 2018. An average of 585 claims of bear damage per year were accepted over the period, equating to annual compensation payments of 250,000€. Of the claims, 60.2% corresponded to damage to beehives, 22.7% to fruit trees, 12.9% to livestock and the remainder to other damage types. Attacks on hives constitute the principal damage caused by Cantabrian bears and possibly the majority of these were adequately formally appraised by and paid for by the corresponding administrations. However, the typology and spatial distribution of the claims for livestock damage suggest that they probably do not represent the reality of predation by bears. It is illogical that the damage to livestock occurs above all to cattle and is concentrated almost exclusively to a few municipalities in the western nucleus, when in the eastern sector, bears coexist with extensive livestock grazing, but there are no claims. The difficulty in evaluating these attacks and the regular carrion feeding behaviour of bears may explain this difference between claims made and the real damage suffered. The establishment of a comprehensive protocol for damage inspection, detailed examination of those attacks genuinely made by bears and linked to research into the importance of carrion in bear diet, plus the need to make advances in a compensation mechanism adjusted to the real costs and economic losses incurred, are vital. Finally, and above all else, an increase in the use of and improvements to preventive measures to avoid attacks, plus an evaluation of their use, are urgently required.

INTRODUCTION

The conflicts related with the presence of large carnivores in areas with human activities, such as livestock rearing and agriculture, constitute one of the principal threats to the conservation of these species (Can *et al.* 2014; Ripple *et al.* 2014; López-Bao *et al.* 2017; Bautista *et al.* 2019). For this reason, the conservation of large carnivores should be tackled from a socio-ecological perspective, taking into account not only biological and ecological aspects which impact on their relationship with these human activities, but also the perceptions and values of those people implicated and also the factors which may generate changes over the short and long term (Lozano *et al.* 2019). From a social point of view, the conflicts associated with the damage caused by carnivores to livestock or agricultural interests not only have an economic component derived from the direct and indirect loss from the damage, but also a highly significant emotional component, since it conditions the perceptions existing about the species and the management and conservation policies. A direct relationship between the scale of the conflict and the quantity or importance of the damage caused or claimed does not always exist, although the information of how much damage is caused and how this is temporally and spatially distributed is fundamental to address the conflict and make advances in future coexistence and conservation issues.

The brown bear (*Ursus arctos*), given its omnivorous diet with a strong vegetarian component, does not generally generate such a high level of conflict compared to other predominantly carnivorous species, such as the wolf (*Canis lupus*), although all the European populations of bears include a greater or lesser proportion of anthropogenic food in their diet, such as livestock, beehives, fruit trees and cultivated crops (Bojarska & Selva 2012). European bears produce damage which is compensated for by the respective administrations responsible for the management and conservation of the species via ex-ante aid in favour of preventive measures or ex-post payments to compensate the losses from damage and spread the conservation cost of the species across society (Bautista *et al.* 2019).

The current recovery of large carnivore populations occurring in Europe is commonly associated with the reappearance of ancient conflicts with human interests (Rigg *et al.* 2011). In the Cantabrian Mountains, the brown bear population is undergoing recovery and has shown continuous growth since the end of the last century, leading to reasonable optimism about its long-term conservation (González *et al.* 2016; Blanco *et al.* 2020). This population growth has led to a greater presence of the species and expansion back into territories from where it had disappeared some time ago, and, in parallel, to an extension of the measures put in place to prevent possible damage and to improve knowledge about the species among the principal social agents. This situation generates new conservation challenges, which in a setting of important social changes in the rural environment and of global change, requires detailed knowledge of the problem in order to adopt the precise measures necessary. An increase in or the maintenance of particular damage types and the recurrent broadcasting of some of the most striking stories among these by the media may contribute to worsening the perception of the brown bear and so reducing its social acceptance, multiplying the impact of the sectors with the most negative attitudes (Kaczensky *et al.* 2004).

For these reasons, the characterisation and information about the damage produced by bears is fundamental for maintaining a smooth, just and efficient compensation system, accompanied by a policy of aiding and informing the rural community about preventive measures which reduce the conflict to admissible and manageable levels. In this chapter we aim to estimate the damage caused by the brown bear in the Cantabrian Mountains over the past decade, analyse the current situation and see where action is needed. Finally, we propose recommendations to improve both our knowledge of the situation and the efficiency of the damage compensation payments system, with the objective of contributing to the desired state of peaceful coexistence between bears and people.

THE SCALE OF THE CONFLICT: CANTABRIAN BEAR DAMAGE FIGURES PAID BY THE ADMINISTRATIONS

In order to quantify the magnitude of the conflict, we compiled

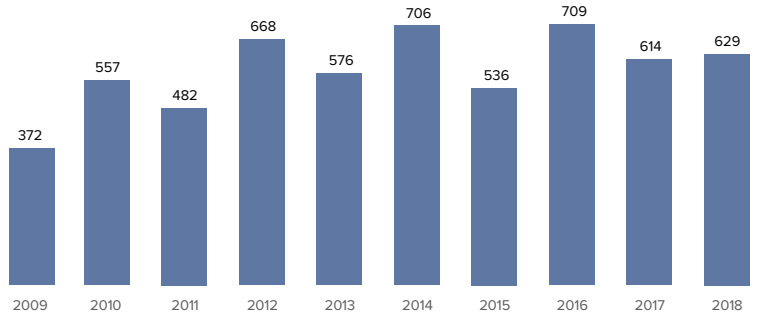


Figure 1. Change in the number of bear damage claims paid by the Cantabrian Mountains administrations between 2009 and 2018. Data for Cantabria are lacking between 2009 and 2014, although their contribution to the total is very small (annual average <30 damage claims in 2015–2018).

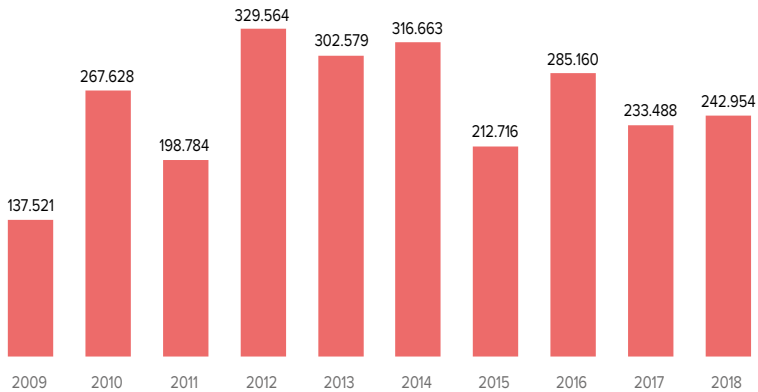


Figure 2. Changes in the economic compensation paid (€) for bear damage by the Cantabrian Mountains administrations between 2009 and 2018.

and integrated the data from the official claims forms of bear damage which had been appraised and registered by the regional governments of Cantabria, Principality of Asturias, Castilla y León and Galicia between 2009 and 2018. The data from Asturias, Castilla y León and Cantabria were provided by the respective administrations within the framework of the collaborative agreements in place with the FOP, while the data for Galicia were compiled and evaluated during the preparation and execution of the LIFE Bear Courel Project, undertaken by FOP and the Galician government. For Cantabria, only the data from 2015-2018 were available in digital format.

During the period analysed, the regional authorities in the Cantabrian Mountains accepted and paid compensation for an average of 585 claims a year (mean ± sd = 584.9 ± 104.8) (Figure 1). These claims equate to an average annual cost of 250,000 euros (mean ± sd = 252,706 ± 59,628 euros) (Figure 2). As the data series for the region of Cantabria is incomplete (2015-2018), we have only analysed the change in damage compensation costs for the western sector of the Cantabrian Mountains, where a positive relationship is seen with time, i.e., the number of claims has increased over time, even though this increase was not statistically significant (binomial negative GLM, p = 0.059). Zarzo-Arias *et al.* (2020), in their analysis of a longer time period also found a significant positive trend for the number of claims in the western part of the Cantabrian Mountains.

It is important to take into account that over the period of the study, the Cantabrian brown bear population experienced continuous growth, which based on the number of females with cubs was estimated at over 10% annually (González *et al.* 2016; Blanco *et al.* 2020). Considering only the western part, given the absence of some of the data for Cantabria, the annual number of claims which received compensation payments was positively and significantly related to the number of females with cubs detected that year (binomial negative GLM, p=0.020). However, the change in the number of damage claims may be affected by other factors, such as the implantation of prevention measures, variation in the availability of natural foods, differences in management of the compensation payment system between the different administrations or the degree of social conflict and predisposition to making damage claims (Bautista *et al.* 2017, 2019; Molinari *et al.* 2016; Zarzo-Arias *et al.* 2020).

In order to evaluate the damage being claimed in relation to the bear population, we estimated the damage ratio, defined by Bautista *et al.* (2017) as the average number of damage claims over a six-

year period, divided by the number of bears estimated for the area covered. We have used the last six years of the study period and a Cantabrian brown bear population size of 323 individuals at the end of this period, given the most recent population estimate deriving from genetic sampling and spatially explicit capture-recapture methods (see Chapter 2). The damage ratio in the Cantabrian Mountains between 2013 and 2018 averaged 1.8 damage events per bear per year. This figure falls within the lower part of the range of values obtained for the different European brown bear populations, which vary between less than 0.5 damage events per bear per year in Estonia and the Polish and Slovakian Carpathian Mountains, to more than 7 in the French Pyrenees and the Scandinavian population in Norway (Bautista *et al.* 2017). The differences in the damage ratios of different regions or countries are related to variations in livestock management and their compensation schemes, and also to the historic presence of bears, social conflict and the intensity of application of adapted livestock handling and other preventive measures in areas well-accustomed to coexisting with bears, compared to those with recent presence following natural expansion or reintroduction. Examples of this can be seen in the Trentino region of the Italian Alps or the Dinaric Alps of Slovenia, with bear damage ratios of 2.7 and 1.2 respectively, while in neighbouring regions such as Véneto (Italy) or Carinthia (Switzerland), still with very few bears of recent appearance, these damage ratios reach values of 4.2 and 6.4 respectively (Molinari *et al.* 2016). Within the Pyrenean population, the damage levels are nine times higher in France than in adjacent Catalonia, reflecting the different management methods and social problems existing between the two flanks of the same mountain range (Bautista *et al.* 2017).

Considering the compensation payments made between 2013 and 2018 for accepted claims and the population size estimated earlier, damage from bears supposes an economic outlay of 823 euros per bear per year. This figure is less than half of that paid across Europe as a whole, which reaches 1,800 euros per bear per year (data from 2005-2012, Bautista *et al.* 2019), although very large differences are seen between different countries and bear populations. Evidently, the global social costs for maintaining this system of bear damage compensation payments are significantly higher than these values, since the expenses of technical and administrative staff and wildlife rangers who carry out the work of checking, evaluating and processing of these claims, as well as the operative costs associated with these processes also need to be taken into account. Whatever the case, the importance of paying for the damage caused by large carnivores is currently accepted by society to balance the biased cost of coexistence with large carnivore species, which basically falls on livestock farmers in rural areas, and as a mechanism to reduce this conflict and to increase tolerance towards carnivore presence (Nyhus *et al.* 2005; López-Bao *et al.* 2017; Ravenelle & Nyhus 2017).

TYPES OF BEAR DAMAGE AND THEIR DISTRIBUTION IN THE CANTABRIAN MOUNTAINS

Cantabrian bears live in a landscape which has been widely modified by human presence and activities, so

Photo 1. A brown bear knocks a beehive to the ground to eat the honey and bee larvae in an apiary in the western Cantabrian Mountains.

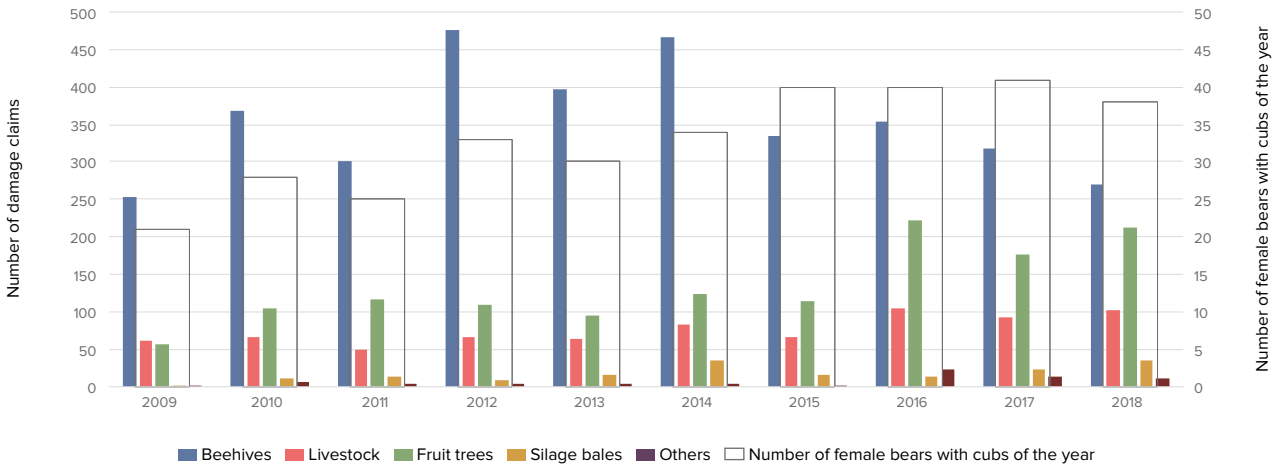


Figure 3. Changes in the number of claims of the different bear damage types paid by the Cantabrian Mountains administrations between 2009 and 2018, in comparison with changes in the number of female bears with cubs of the year (FCY) counted annually.

that the numerous and varied anthropogenic resources of possible trophic interest to bears, above all linked to agricultural and grazing activities, create a potential scenario for conflict. Above all else, Cantabrian bears cause damage to beehives, followed by fruit trees, livestock and other types: 60.2% of the damage claims compensated between 2009 and 2018 in the Cantabrian Mountains corresponded to beehives, 22.7% to fruit trees, 12.9% to livestock and the rest to hay bales and other varied damage types. Of the 2.5M euros paid in compensation over the last 10 years, more than three quarters, 1.9 M euros, corresponded to damage to beehives. The relation of three to one between beehives and livestock in the Cantabrian Mountains is exactly the opposite of that for the whole of Europe's bear areas combined, where damage to livestock, particularly sheep, comprises the majority of the claims and triples the total damage to beehives (Bautista *et al.* 2017).

The trends evolving in the claims of the five different damage types over the period of the study reveal some differing patterns which merit closer attention (Figure 3). Although damage to beehives declined during the latter part of the study period, damage claims to fruit trees and livestock have risen throughout the period of the study. Beehive damage has fallen from 64% of the total compensated claims paid in 2009, to 33% in 2018 and distinct factors may influence the trend over time in the number of attacks (Naves *et al.* 2018; Zarzo-Arias *et al.* 2020). The number of attacks on beehives has fallen, despite an increase in the bear population, probably thanks to the enormous efforts invested in protecting beehives in those areas which traditionally have had bears, while dam-

Table 1. Number of bear damage claims paid, rejected and the percentage rejected for each damage type in the Principality of Asturias between 2009 and 2018 (excluding those claims still being processed or challenged).

	Paid	Rejected	% rejected
Cows	266	107	28.7%
Sheeps	132	7	5.0%
Goats	76	6	7.3%
Equines	88	26	22.8%
TOTAL LIVESTOCK	561	146	20.7%
BEEHIVES	1,575	209	11.7%
FRUIT TREES	1,218	10	0.8%
SILAGE BALLS	145	3	2.0%
OTHERS	53	12	18.5%
TOTAL	3,552	380	9.7%

Table 2. Distribution by population nucleus and province of the number of bear damage claims paid by the Cantabrian Mountains administrations between 2009 and 2018 (incomplete data for Lugo and Cantabria; see text).

	beehives	cattle	sheep	goats	equines	Fruit trees	Silage balls	Others	TOTAL
TOTAL	3,520	351	201	80	122	1,329	172	74	5,849
Asturias	1,587	266	132	76	88	1,235	145	60	3,591
León	1,064	77	69	4	30	92	11	11	1,357
Lugo	220	0	0	0	0	0	14	0	234
Palencia	538	3	0	0	2	1	2	2	548
Cantabria	112	5	0	0	2	1	0	1	121
Western nucleus	2,457	335	195	78	114	1,318	165	70	4,732
Eastern nucleus	924	10	4	0	4	7	2	3	954
Corridor	140	8	4	1	4	4	5	1	167

age has started to appear in areas into which bears are expanding, or which have only sporadic bear presence. Confirming this reduction in damage to hives, we are unable to find a relationship between the number of beehives damaged in the western Cantabrian area and the number of females with cubs detected the same year (binomial negative GLM, p=0.558), nor in the previous year (binomial negative GLM, p=0.068). However, in the same region between 1991 and 2008, Fernández-Gil *et al.* (2016) found a positive relationship between the number of attacks on beehives and the number of females with cubs of the previous year, which they suggested would lead to a greater presence of young bears in the population which may be more likely to cause damage. It is also possible that thanks to the extensive use of preventive measures to protect beehives, this relationship has disappeared.

It was interesting to discover that the percentage of claims rejected following a negative appraisal from the agent or the technical staff undertaking the damage check, after considering that the damage was not caused by a bear, varied markedly between the different damage types. In Asturias, the only region where we have reviewed the details of these reports, a little less than 10% of the total claims for bear damage were denied, excluding those which were still active or being challenged at the time of the analysis (Table 1). However, the percentage of claims of damage to livestock rejected was over 20%, reaching more than 28% when relating to claims of attacks on cattle. Over 11% of the claims of damage to beehives were rejected, while the percentage of rejected claims for damage to fruit trees or hay bales was minimal. The rejection of claims of damage to livestock showed no relationship with the number of livestock head affected, given that the number of livestock head affected was similar for paid and rejected claims (e.g., for cattle: 1.05 head/claim paid and 1.04 head/claim rejected). These differences in rejection percentages reflect differing levels of conflict for each damage type and probably have more to do with the existing social pressure, plus the difficulty of determining the bear as the culprit. It is much easier to determine damage in beehives or fruit trees as having been caused by bears, compared to attacks on livestock, especially of larger animals such as cattle or horses, which may die from other causes unrelated to bears, but then be consumed as carrion. Occasionally, these livestock deaths may be attributed to bear attacks without certain proof.

Comparison of the intensity of the different damage types in distinct areas allows the detection of spatial patterns which may provide information about the factors which influence the occurrence and claims of bear damage. The raw data of the number of different bear damage claim types by province are shown in Table 2. The same data are presented grouped by the two Cantabrian bear subpopulations and the intermediate interpopulation corridor. The division by provinces showed that Asturias is the region with most damage events (63% of all claims), followed by León (23%) and Palencia (9%). In Lugo and Cantabria, although the intensity of damage events was clearly lower, only incomplete data series have been analysed.

Grouping of the data by damage claims in the two Cantabrian bear nuclei was much more interesting, with very different bear population sizes and densities. Logically, damage claims were far more numerous in the western nucleus, though it was noteworthy that practically all of the claims for damage to livestock and agriculture were concentrated in this subpopulation, while damage to beehives was much more widely distributed. The two Cantabrian subpopulations of bears, which are now connected genetically (González *et al.* 2016), still maintain marked differences in both the number and density of bears in each. An estimated 275 bears and a density of 2.50 bears/100 km^2 have been estimated in the western subpopulation, compared to an estimated 48 bears at a density of 0.96 bears/100 km^2 for the eastern one (see Chapter 2). The two nuclei show distinct landscape characteristics: the western bears use areas with a more rugged terrain and greater scrub cover than the eastern ones, which, however, use areas of higher altitude and more extensive forest cover (Lamamy *et al.* 2019). This may generate differences in the spatial and trophic ecology of the two bear nuclei, which in turn influence the frequency and intensity of the different damage types. Table 3 presents the damage ratios calculated for both population nuclei and the results are particularly interesting. Eastern bears generate a greater number of damage incidents, above all in the disproportionate number of attacks on beehives. Each eastern bear commits an average of 2.14 attacks on beehives per year, compared to 0.85 for each western bear, despite there being far fewer bears and a lower number of apiaries in the eastern nucleus. It would be of particular interest to undertake a more detailed analysis to evaluate the factors which may be influencing this difference. In contrast, damage to livestock is concentrated almost exclusively in the western nucleus, where compensation is paid at the rate of 0.29 attacks per bear per year, whereas livestock attacks are practically absent in the eastern subpopulation. A similar pattern is seen in damage to agricultural interests, especially to fruit trees, which are frequent in the west, but very scarce in the eastern Cantabrian Mountains. Table 3 also includes the data obtained by Bautista *et al.* (2017) for the same population nuclei, but covering the period 2005-2010, which revealed very similar results, though a reduction in damage to beekeeping interests can be seen, while damage to livestock and agricultural interests have risen in the western nucleus.

A more detailed spatial analysis can be made grouping the claims of damage by municipality. We have calculated the density of compensated bear damage claims annually per 100 km^2, to produce a comparable rate between very differently sized municipalities, which are shown in Figure 4. This map permits a rapid visual means of appreciating the notable differences in the intensity of damage between municipalities, sometimes even between neighbouring ones with very similar habitats and livestock farms. Municipalities such as Somiedo, Belmonte de Miranda, Proaza, Degaña and Ibias (in Asturias) or Villablino, Palacios del Sil and Vega de Espinareda (in León) stand out for their intensity of damage claims. In the following sections we describe the special characteristics of the different damage types and the distribution by municipality of these and we evaluate the degree of representativity of the real damage caused by bears.

Table 3. Comparison of the bear damage ratio between the western and eastern parts of the Cantabrian Mountains, estimated as the average number of damage claims accepted per bear per year (± sd), between 2013 and 2018. The data corresponding to the period from 2005–2010 estimated using the same procedure by Bautista *et al.* (2017) are included.

		Damage ratio (number of claims per year and per bear) (Mean ± sd)				
Area	**Years**	**Total**	**Apiaries**	**Livestock**	**Agriculture**	**Others**
Western Cantabrian	2013–2018	1.83 ± 0.29	0.85 ± 0.27	0.29 ± 0.06	0.65 ± 0.20	0.04 ± 0.03
Eastern Cantabrian	2013–2018	2.21 ± 0.56	2.14 ± 0.55	0.04 ± 0.02	0.02 ± 0.02	0.01 ± 0.02
Total Cantabrian	2013–2018	1.89 ± 0.21	1.06 ± 0.21	0.26 ± 0.05	0.54 ± 0.17	0.03 ± 0.02
Western Cantabrian	2005–2010	1.70 ± 0.47	1.20 ± 0.37	0.26 ± 0.04	0.30 ± 0.15	0.006 ± 0.014
Eastern Cantabrian	2005–2010	2.80 ± 1.10	2.60 ± 1.10	0.07 ± 0.04	0.16 ± 0.08	0.008 ± 0.021

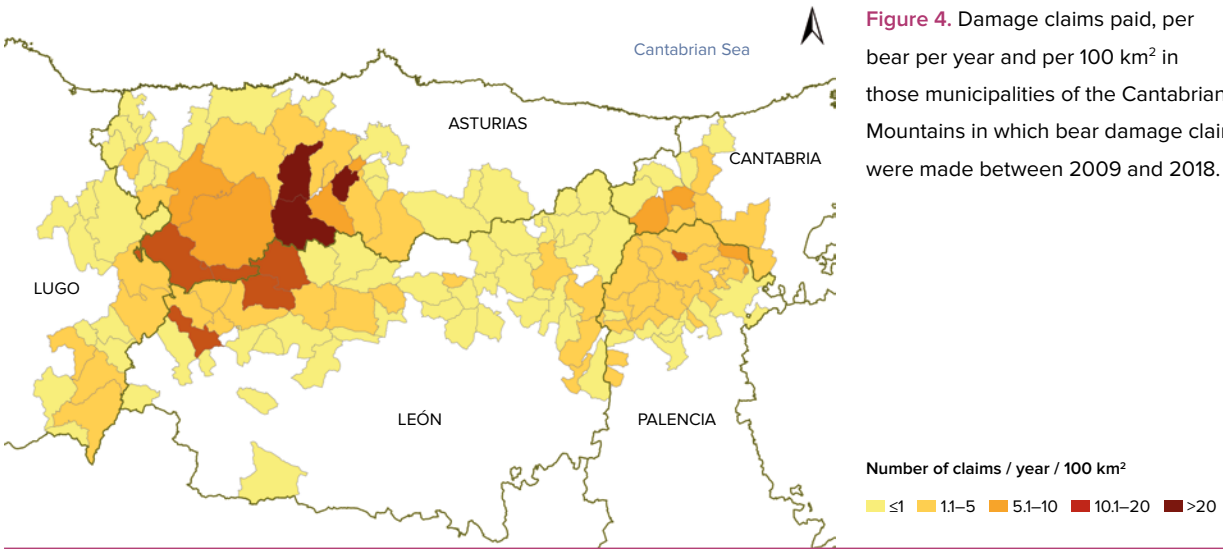


Figure 4. Damage claims paid, per bear per year and per 100 km² in those municipalities of the Cantabrian Mountains in which bear damage claims were made between 2009 and 2018.

DAMAGE TO APICULTURE

The damage caused by bears to apiaries is the principal impact of brown bear presence. This damage constitutes over 60% of all the claims filed and compensated for by the regional administrations. The attraction of bears to honey and the bee larvae being farmed by humans is well known, dating back to ancient times, as have the methods used by beekeepers to protect them from bear attacks. Fruit of this long history of coexistence are hundreds of stone structures, known as *alvares* or *alvarizas* in the Galician mountains and as *cortines* in western Asturias and León. These are circular stone enclosures with vertical walls over 2 m high, built using the drywall technique and generally crowned by a row of loose rocks, which for centuries have guaranteed protection from bears. An example of their enormous past importance has been the detection and cataloguing of 192 *alvares* in five municipalities in the mountains of Lugo during a recent study undertaken as part of the LIFE Bear Courel Project. Currently, very few are still in use, and the majority are abandoned and in ruins, given that bear attack prevention is now normally made using highly efficient electric fence enclosures, compatible with modern farming needs.

In the decade from 2009 to 2018, bear attacks produced an annual average of 352 paid claims (sd = 76.3) and 1,202 damaged beehives (sd = 338.2). Assuming that this figure is relatively representative of the real situation, given that the majority of the damaged beehives are declared in order to receive economic compensation and proving it was due bear attack tends to be straightforward, even though we have evidence of cases where this damage is not reported and declared, above all on apiaries for personal use or those

Photo 2. An ancient beehive enclosure (alvar) in the mountains of Lugo, built to protect the hives from bear attacks.

which are not inscribed in the regional beekeeping registers.

As described previously, in order to analyse the intensity of bear damage to beehives in the Cantabrian bear population, we used the data from the six years, 2013-2018, during which time an average of 3.5 beehives per bear per year were compensated. The Cantabrian population shows the highest rate of attack on beehives of anywhere in Europe (Bautista *et al.* 2017; Naves *et al.* 2018). For example, the rate obtained during the study period is very much higher than the 0.03 hives attacked per bear per year in Croatia (Hipolito *et al.* 2018), although closer to the 3.2 beehives and/or bee colonies destroyed by bears per year in western Greece (Karamanlidis *et al.* 2011). The principal reason for this higher rate of attack on beehives may be related to their higher abundance in bear areas. Within the European Union, Spain has the highest number of censused hives and this is also increasing. According to the Castilla y León beekeeping Census, Galician beekeeping Census and data from the Ministry of Agriculture, Fisheries and Food, a total of 191,543 beehives were present in the five Cantabrian regions in 2018-2019. This means that bears damage 0.63% of all the censused hives annually, a very low rate of occurrence and of little relevance overall for the beekeeping sector. This incidence of damage is higher if we only consider the bear areas themselves and especially in areas of higher bear density, where they may have a significant impact on individual apiaries, even though the global impact on the beekeeping sector is small and inferior to other factor affecting the activity, such as diseases affecting bees, the effects of climate change or the problems deriving from biocide use (Higes *et al.* 2010).

The average number of beehives attacked during this period was 3.51 (sd = 4.06), based on 3,277 claims with specific information on the number of hives damaged during each attack, including entire hives with and without honey supers, brood boxes, as well as 'gum hives' made from bark or tree trunks and other traditional hives (Figure 5). This damage intensity is very similar to that described by Bautista *et al.* (2017) for the whole of Europe from 2005-2012 (3.7 hives destroyed per attack), though below that observed by Naves *et al.* (2018) in a particular area of western Galicia from 2006-2008 (5.1 hives per attack). When bears enter into an apiary, they usually attack one or two hives, knocking them to the ground to extract the frames easily, which they then often carry off to a different quiet spot to eat the honey and larvae. If they do not find enough food to satiate themselves, they may attack more hives, although a proportion of all those cases with the greatest number of damaged hives actually corresponds to repeated attacks over successive days, until the damage is finally discovered by the beekeeper. In a detailed study, Naves *et al.* (2018) showed that damage was greatest in the largest apiaries and also in areas with greater vegetation cover and lower human presence in the surroundings.

Attacks on hives have been recorded in every month of the year, although logically, the greatest number of attacks occur between April and October (92.9% of all attacks), and especially during June and July (46.3% of total damage) (Figure 6). This temporal pattern has as much to do with hive activity and

Photo 3. A Brown Bear Foundation staff member analysing a beehive damaged by a bear.

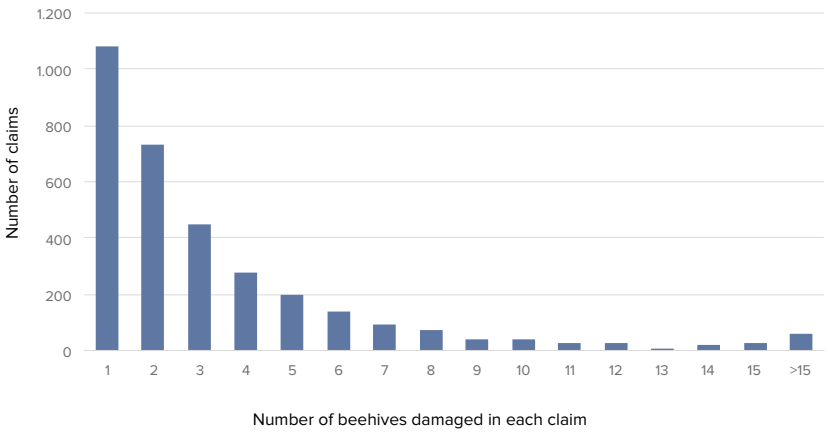


Figure 5. Distribution of the number of bear damage claims paid in the Cantabrian Mountains between 2009 and 2018, in relation to the number of beehives damaged in each attack.

the presence of sufficient honey and larvae for them to constitute an attractive and profitable food resource, as to the bear's own feeding ecology and the availability of other food resources.

Analysing the spatial distribution of damage by municipalities (Figure 7), attacks on hives can been seen as widely spread across the entire range of the Cantabrian brown bear, but concentrations of attacks are clearly visible in particular municipalities with high levels of both beekeeping and bear presence. A degree of continuity is observed across municipalities, with the principal areas incurring damage clustered in SW Asturias and NW León, and in a part of the Montaña Palentina (Palencia), Liébana (Cantabria) and eastern León. Evaluation of the damage to hives rarely presents difficulties and it is very likely that this spatial distribution corresponds quite well with the real pressure bears exert on beekeeping activities.

The application of preventive measures and their adequate maintenance, together with the history of coexistence of humans and bears and the corresponding conservation of the knowledge on how to avoid attacks, are all closely linked to the level of damage produced by bears on hives (Naves *et al.* 2018). Damage to hives is easily avoided by applying preventive measures, normally electric fencing, which are close to being 100% effective if properly installed and adequately maintained (Smith *et al.* 2018). For example, Seijas *et al.* (2016) proved that the use and adequate maintenance of electric fences on those apiaries which suffered most repeated attacks in the province of León, produced a reduction in attacks from 41% down to 16%. Bears tend to repeat their attacks on apiaries from one year to the next but avoid or are unable to access those which are well protected. Naves *et al.* (2018) demonstrated that in the Cantabrian Mountains, the probability that an apiary is attacked is positively related to the intensity of the damage suffered the previous year and negatively related to the number of preventive measures in place.

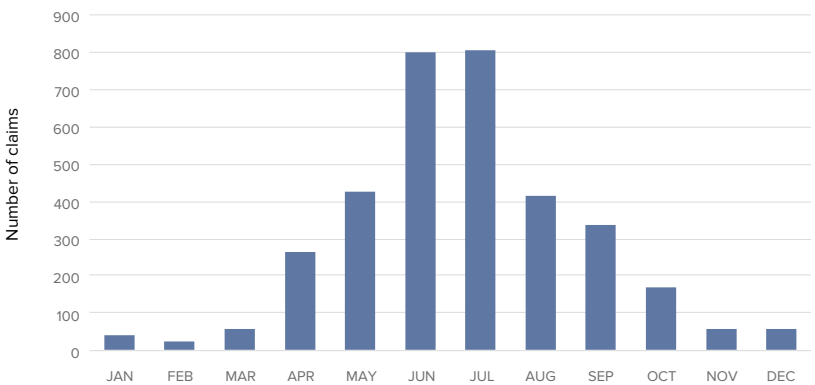


Figure 6. Monthly distribution of the number of beehive bear damage claims paid in the Cantabrian Mountains between 2009 and 2018.

DAMAGE TO FRUIT TREES

The second most important damage type caused by bears in the Cantabrian Mountains is to fruit trees, comprising almost 23% of the accepted and compensated damage claims. Crop growing activities are poorly represented in the bear areas of the Cantabrian Mountains and are basically limited to the production of fruit and vegetables for household consumption and fodder for feeding livestock, which

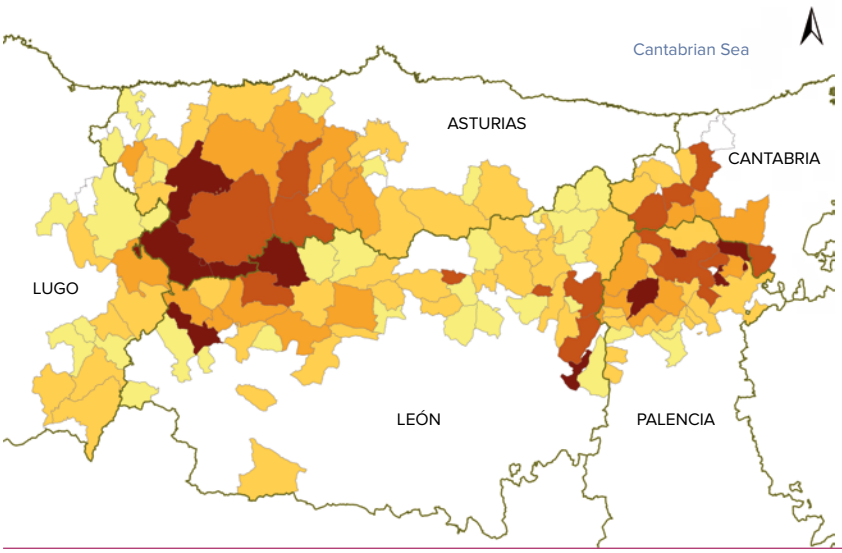
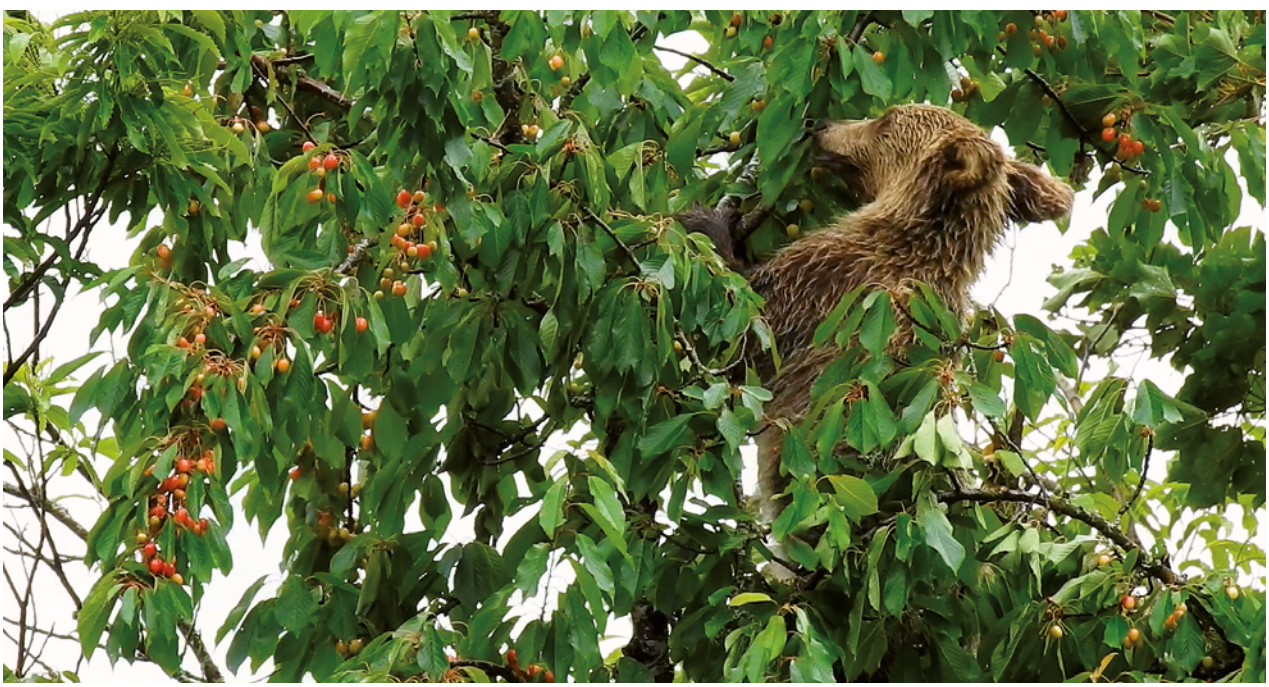


Figure 7. Representation of the number of beehives compensated per bear, per year and per 100 km² in those municipalities of the Cantabrian Mountains with attacks registered between 2009 and 2018.

is the principal economic activity in the majority of these areas. For this reason, the damage caused by bears on agricultural activities is more limited than to beekeeping resources. Between 2009 and 2018, a yearly average of 132.9 (sd = 53.4) fruit tree damage claims were accepted and compensated for, totalling a little more than 13,000€ per year.

Among the different fruit trees damaged by bears, by order of importance, most damage is caused to cherry trees (*Prunus avium*), but also to apples (*Malus domestica*), pears (*Pyrus communis*), plums (*Prunus domestica, P. insititia*), hazelnuts (*Corylus avellana*) and figs (*Ficus carica*), plus exceptionally to sour cherry (*Prunus cerasus*) trees and even oranges (*Citrus sinensis*). Although in a few cases these referred to commercial plantations, practically all damage claims related to fruit consumption or tree damage in small orchards with the fruit trees in the surroundings to rural villages, which are visited by bears at night in summer and autumn. Damage to fruit trees is heavily

Photo 4. A young bear feeds on cherries in the top of a tree.



concentrated between July and October (Figure 8), normally starting with cherries, which mature in the summer, although the highest peak in damage levels occurs in September, coinciding with the ripening of other fruits, principally apples, plums and hazelnuts.

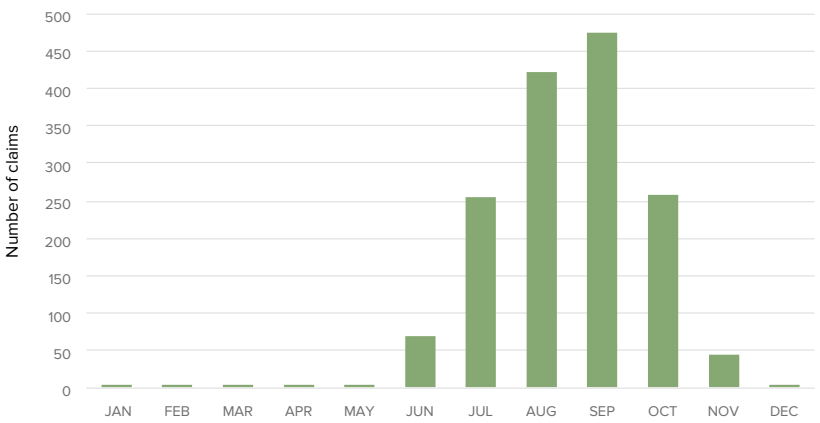


Figure 8. Monthly distribution of the bear damage claims on fruit trees paid in the Cantabrian Mountains between 2009 and 2018.

The relevance of damage to fruit trees in the Cantabrian Mountains is related to the importance of fleshy fruits in the diet of the Cantabrian bears. Cherries, which are the first to ripen, are a very important food resource for Cantabrian bears, which have increased their generally consumption of these, probably as a response to global warming effects (Rodríguez *et al.* 2007). Under the current scenario of rural depopulation and decreasing exploitation by local people of the fruit produced in the surroundings to human settlements, it is easier for the bears, along with other species of fruit-eating birds and mammals, to take advantage of this readily available resource (López-Bao *et al.* 2015). Despite cultivated fruits being less abundant and much more concentrated than wild species, their distribution plus the higher nutritional value of many domestic fruits, converts them into a rich and predictable food resources for bears and also other carnivores (López-Bao & González-Varo 2011).

Photo 5. Cherry tree with branches broken by a bear feeding on its fruits.

In addition to the loss of the fruit crop itself and breakage of trees limbs and even trunks, which do not usually generate too much discontent, these events can give rise to coexistence problems, by contributing to the close approach of some individual bears to rural settlements, which may trigger habituation and social alarm processes (Chapter 4). This kind of damage claim has increased progressively in frequency over the study period analysed (Figure 3), in parallel with the brown bear population, but also given the greater knowledge of affected landowners to the possibility of claiming compensation for this type of damage.

Fruit tree damage by bears occurs mainly in the western part of the Cantabrian Mountains (92.9% in Asturias and 6.9% in León), with just four claims compensated in the eastern sector throughout the entire period analysed. This contrast is logical taking into account

the differences between the areas (Lamamy *et al.* 2019): the eastern bears inhabit areas of higher average altitude, though on the southern slopes, human populations are also located higher up and the number of fruit tree orchards and plantations are much lower than in the valley-bottom villages of western Asturias.

DAMAGE TO LIVESTOCK

Attacks on livestock, especially sheep, constitute the main incident type caused by bears over most of Europe (Bautista *et al.* 2017), though in the Cantabrian Mountains, it is the third most important type after damage caused to beehives and fruit trees. Between 2009 and 2018 the regional administrations in the study area accepted and paid compensation for an annual average of 75.4 livestock damage claims (sd = 18.7) and 94.7 livestock head (sd = 29.6), with an average outlay of a little over 40,000 euros per year. Independently of this number, these are particularly significant damage incidents due to their notoriety, especially from the point of view of their importance in the social perception of the conflict between humans and bears.

Cantabrian bears are basically vegetarian and consume animal proteins through eating carrion or invertebrates (Naves *et al.* 2006), but can behave as opportunistic predators attacking wild ungulates, generally young individuals (Blanco *et al.* 2011), or domestic animals. In this latter case, the smaller livestock, sheep and goats, tend to be more accessible to bears, especially where the flocks graze freely and without protection. Indeed, in the majority of the European bear populations, attacks on livestock are principally aimed at sheep (Bautista *et al.* 2017). As a result, the predominance of attacks on cattle among the claims paid in the Cantabrian Mountains is particularly striking, as was previously highlighted by Clevenger *et al.* (1994) and Pollo (2006). The data for the accepted claims between 2009 and 2018 show that compensation has been paid for a greater annual average number of attacks on cattle (37.0 ± 8.4), than sheep (33.6 ± 17.1), than goats (11.2 ± 6.1), or horses (12.9 ± 4.9).

All livestock species, including cattle and horses, form part of the bear's diet in virtually all of its European populations, albeit in low proportion, as for wild ungulates (Naves *et al.* 2006; Ciucci *et al.* 2014), although the importance of ungulates in the brown bear's diet follows a latitudinal and temperature gradient, being more important in the Nordic countries, with lower average annual temperatures than in the warmer more southerly countries (Niedziałkowska *et al.* 2019). However, what remains extremely difficult to determine is if the domestic and wild vertebrates in the bear's diet were predated or were eaten as carrion. Bears are facultative carrion feeders (Mateo-Tomás *et al.* 2017) and consume a large number of carrion items of natural origin, such as wild ungulates which succumb to inclement weather or are predated by wolves, as well as carrion from anthropic origin, such as wild ungulates which have been hunted or

Photos 6 and 7. A Cantabrian bear feeds on cattle carrion.

Photo 8. A male bear feeds on red deer carrion in the Montaña Palentina Natural Park (Palencia).

livestock which has died from various reasons and is left for scavengers.

This intense scavenging activity by brown bears creates great uncertainty in the evaluation of livestock damage claims, in which it is sometimes not easy to determine if a predation event occurred, or if the animal died from other causes, such as from disease or an accident and was subsequently consumed by the bear as carrion. In some cases, the indications of an attack are evident, but in the majority of cases it is not possible to determine with certainty if an attack or scavenging event occurred. Several times during our bear field monitoring we detected deaths of livestock due to falls from cliffs, illness or other causes, and the subsequent consumption of the corpses by one or more bears, sometimes before the farmer detected the death and made a claim. On several occasions, the subsequent official claim appraisal process attributed the death to bear attack based only on signs of bear presence (paw prints or excrements), or signs of consumption of the corpse. Quite a few of these cases acquired high significance and widespread broadcasting in the local and regional press, with complaints from the affected farmers directed towards bear attacks, even though the subsequent research confirmed the bear's innocence.

For these reasons we consider that the livestock damage claims do not represent the real number of attacks on livestock by bears. This difference between damage claims and real attacks has already been highlighted by other authors (Pollo 2006; Bautista *et al.* 2017; Zarzo-Arias *et al.* 2020). The delay in reporting the damage, the experience of the person responsible for evaluating the situation, the social and mediatic pressures, and other circumstances such as the weather or the presence of scavenging bears, can weigh heavily on the correct evaluation of the potential damage incident. It is also clear, however, that it is important to improve the accreditation procedures to minimise the uncertainty factor and enable consensus and social acceptance of the bear. Currently, aspects indicative of scavenging, such as the absence of signs of fighting, the absence of injuries typical of an attack, or the suspicion of another cause of death, are not always sufficient to reject the damage claim, if bear tracks or excrement are found in the close surroundings. If signs of bear presence are found in the area, the damage may be attributed to the bear for fear of making a mistake and prejudicing the farmers, or even in order to avoid animosity towards the animal. However, the reality is that these false damage claims confer an unjustified negative image of the bear and make debates about the cohabitation between bears and livestock more difficult.

Further evidence supporting the idea that the livestock damage

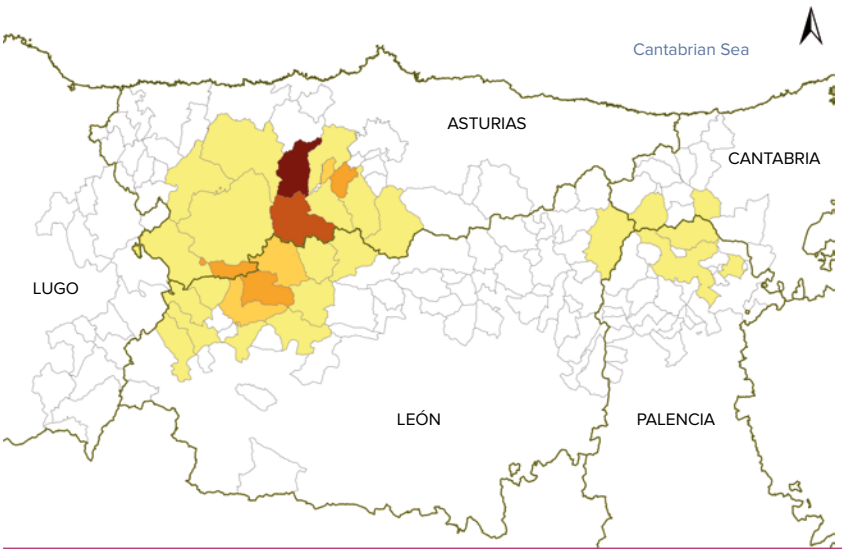


Figure 9. Representation of the number of large livestock head (cattle and horses) compensated per bear, per year and per 100 km2 in those municipalities of the Cantabrian Mountains with attacks registered between 2009 and 2018.

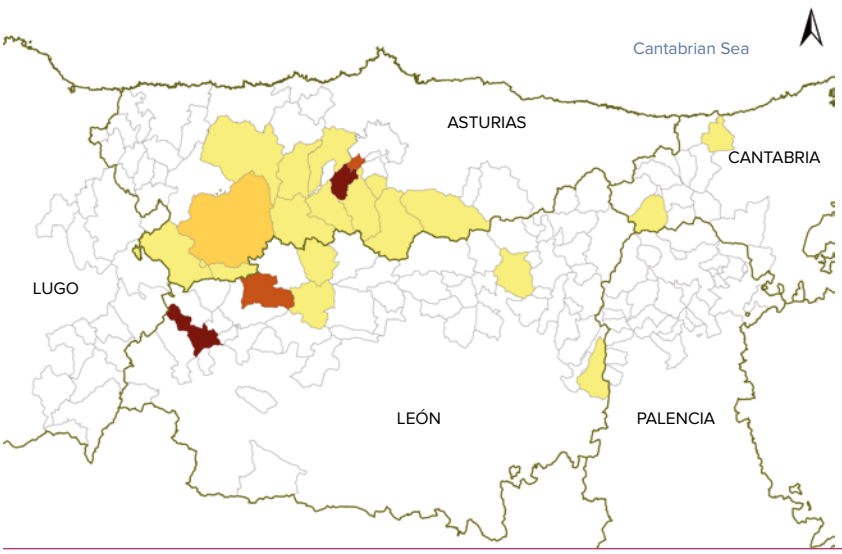


Figure 10. Representation of the number of small livestock head (sheep and goats) compensated per bear, per year and per 100 km2 in those municipalities of the Cantabrian Mountains with attacks registered between 2009 and 2018.

claims do not reflect reality lies in the spatial distribution of these claims. As seen before, livestock damage by bears is heavily concentrated in the western subpopulation and practically absent in the eastern one (Table 3). 95% of the compensation payments of damage claims for cattle and horses is concentrated in the western subpopulation, even though there is also a high density of cattle under an extensive grazing regime sharing the countryside with the bears in the eastern nucleus. In the western nucleus, a very high incidence of claims in a few municipalities also stands out, which doesn't always coincide with those municipalities showing most social conflict with the bear (Figure 9). The case for small livestock is similar, with 97% of the claims from the western sector, which are concentrated in just a few municipalities (Figure 10). Sheep and goats grazing in the mountain grasslands are protected from wolves by the presence of livestock guarding dogs, and, on occasions, by a herder, and are held in enclosures at night, so greatly reducing the possibility of a bear attack. However, in the western part, and especially on the north-facing slopes in Asturias, sheep are frequently left unprotected in small estates adjacent to rural villages, where nocturnal attacks by bears are possible. Considering the damage to large livestock, the spatial concentration in claims and large differences in attack frequency observed between neighbouring areas exhibiting similar bear presence, availability of food resources and environmental variables, support is given to the idea highlighted earlier that damage claims do not reflect the real attacks made on livestock

by bears. In the case of sheep, the majority of the claims made do appear to correspond to bear attacks, but for cattle, many of the damage claims probably correspond to scavenging of carcasses of cattle which had died from other causes and the spatial differences in the damage claim intensity may be related to differences in livestock handling, social conflict or the habitual means of evaluating damage claims in place, more than to the true predation pressure exhibited by bears.

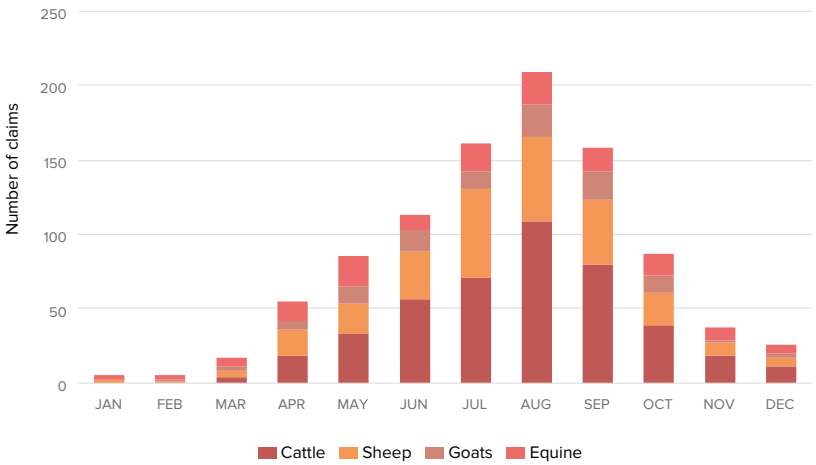


Figure 11. Monthly distribution of the bear damage claims for livestock paid in the Cantabrian Mountains between 2009 and 2018.

The claims for damage to cattle are clearly concentrated in the half year period from June to October (Figure 11). Attacks on cows are claimed, above all, in July to September, coinciding with the months that the cows and their calves graze freely in the mountains. The damage claims for sheep and goats follow a similar seasonal pattern, while attacks on horses are more widely spread throughout the year. This pattern more closely reflects the presence of cattle in the mountains than the trophic needs of bears. Overall, in the European bear diet, ungulate vertebrates are consumed either through predation or scavenging preferentially in spring, and less in summer and autumn (Niedziałkowska *et al.* 2019).

OTHER DAMAGE TYPES

After beehives, fruit trees and livestock, the subsequent damage type in importance is the breaking open of silage bales. Since the 1980s, the technique of conserving fodder as silage in plastic-wrapped round bales has extended throughout the Cantabrian livestock rearing areas, almost completely replacing the natural haymaking process. Currently, round bales or other silage bales constitute a habitual component of the Cantabrian Mountain landscapes from summer onwards. The fermentation process which occurs inside the bales, guaranteeing the quality of the fodder, appears to attract bears, which rip open the plastic with their claws, without consuming the silage, but in doing so, they alter the conservation properties of the silage and ruin it for use as fodder. Between 2009 and 2018, an annual average of 17.3 (sd = 10.8) claims for silage bale damage were appraised and compensated, equating to an annual average of slightly over 3,300 euros. This type of damage was very unusual during the first few years of the period analysed but has increased notably over the last few years (Figure 3).

Among other exceptional agricultural damage claims, we have registered a few cases of damage to vineyards with grape consumption (19 cases), damage to kitchen gardens for the consumption of potatoes, courgettes, lettuces and other vegetables (11), damage to sweetcorn crops (9), the consumption of wheat and rye crops (5) and damage to bean crops (2).

During this period bears have also produced other varied types of damage, sometimes in their attempts to access food resources, such as damage to roofs (9 cases), gates and fencing (8), attacks on Mastiff dogs (5), damage to local barns (*hórreos*) (2) and mountain cabins (2), attacks on chickens (1) and damage to vehicles (1), cattle feeders (1) or pine trees (1). These are very infrequent cases, but are worrying as they normally occur in very humanised environments, which may lead to a degree of social alarm. In the Cantabrian Mountains, however, we haven't detected some damage types which are more or less habitual in other European bear populations, such as those on wildlife or game feeders, captive-reared game species, fishponds,

pig farms, compost heaps or other elements which are unusual in this rural area. Nor have claims been made for damage by bears trying to access rubbish containers and premises, even though this behaviour has been detected on occasions in the Cantabrian Mountains (see Chapter 4).

Even though damage to livestock feeders or the consumption of animal feed are very poorly represented in the claims database, we have collected miscellaneous information about this which reflects an incipient and still rare problem, but which could extend more widely and contribute to the conflict given the possibility of habituation of the bears to very attractive foods, the proximity to human habitations and the risks of sudden encounters between bears and people. Over the past four years we have registered at least eight cases of bears coming to eat commercial feed, as much in calf creep feeders in the pastures, as in kennels or dog hopper feeders, even entering into cabins in the process. In rare cases we have detected up to four different bears feeding simultaneously on pelleted feed for calves during 14 consecutive days. Electric fences or other deterrent measures solved the problem in some cases, although they may not always be possible. The increasing use of these types of devices for supplying feed to cattle and dogs and the strong impact of the damage caused in the social perception of the risks of cohabitation with bears forces us to pay special attention to the issue and to find the most adequate preventive measures.

Photos 9 and 10. A bear feeds on calf fattening fodder in a feed hopper located in high altitude pastures of Laciana (León).

RESEARCH AND MANAGEMENT PROPOSALS

As explained in previous sections, the distribution patterns of compensated damage claims, combined with uncertainties existing in their appraisal and valuation, suggest that the compensation paid by the different regional administrations does not represent the real damage caused to livestock by bears. We wish to make it clear that the enormous workload undertaken by the regional wildlife rangers, specialists and managers responsible for the procedure is extremely important and has undeniably helped towards

the conservation of the brown bear over all these years, not only for the obligatory response to compensate the losses suffered by a sector of society, but also for their continuous efforts in informing, awareness raising and monitoring of the conflicts arising between bears and farming interests made on site. However, it still appears to be necessary to make advances by improving the procedures for revising and valuing the damage, in order to obtain information more closely reflecting the real situation and to help in reducing the social conflict. In this sense, the information about damage claims presented in this chapter, together with changes in the social perception and other aspects of the relationship between bears and humans exposed in other chapters of this book, enable us to make some recommendations for future research and management of bear damage:

A more exhaustive protocol for the inspection of damage needs to be established, especially for livestock attacks, including undertaking an either partial or complete necropsy in situ, to obtain precise information on important aspects such as bruises, haemorrhages and condition of the injuries, the existence of ante-mortem or post-mortem injuries, the presence of corpse fauna, the distance between teeth marks in the bite marks compatible with the animal's death, or other data. Additionally, if there are bite marks with subcutaneous haemorrhaging, compatible with causing the animal's death, it would be very interesting to incorporate taking a saliva sample into the protocol, which could subsequently be used to reliably determine the species causing the death (López-Bao *et al.* 2017). The final objective needs to be the identification of the types and distribution of the lethal wounds, the way the corpse was manipulated and also the way in which it was consumed. Detailed inspection of the surroundings in search of carnivore signs and any indications of struggle, attack, dragging, falls or other actions which help in determining the cause of death, are already undertaken by the wildlife rangers, although the development of detailed protocols or field guides similar to that prepared for the LIFE DinalpBear Project (Černe *et al.* 2019), could be very useful for standardising criteria and giving more confidence to the final assessment for those agents involved.

A detailed study needs to be undertaken to discover the real damage caused by bear attacks, including collecting data on damage cases which are not claimed for different reasons (e.g., absence of remains to confirm the attack, unregistered or illegal farming units, lack of interest or knowledge of the owner). This should be both via detailed monitoring in pilot study areas through interviews with beekeepers and livestock herders, and through the study of bears using techniques such as radiotracking, which would enable the real damage incidence levels on anthropogenic resources to be determined and its relationship with physiological, ecological and social aspects. This type of research, together with detailed study in specific areas and the establishment of the distribution and dynamics in damage hotspots (Gastineau *et al.* 2019; Hipolito *et al.* 2020), would allow an adequate understanding of the predation by bears on livestock and the factors which influence the frequency and intensity of the damage. It would also allow for the identification of individuals which repeat attacks and the possible existence of bears which specialise in particular damage types. This research should also include an analysis of the consumption of carrion by brown bears, to help in determining to what point cases of scavenging are attributed instead to predation and also to determine the general importance of carrion in the bear diet and if there are risks associated with health, poisoning or even habituation. It is also important to gather information on the availability of food resources and their seasonal and interannual variation, given their possible relation with damage events and as a baseline for the improvement of the protection given to those areas of higher trophic value (Zarzo-Arias *et al.* 2020).

Given its relation with some specific damage types and in order to avoid risks and conflicts in a scenario of bear population growth, it would be convenient to monitor bear habituation phenomena and the factors which may favour them, in addition to evaluating the efficiency of the deterrent measures employed. Many habituation processes can derive from situations related to damage events, such as repeated attacks on insufficiently protected beehives, the consumption of fruit in the surroundings of rural villages, or attraction to anthropogenic resources such as livestock or dog feed, sometime inside

barns, compounds or cabins, which can end up being genuine ecological traps for the species (Majic & Krofel 2015; Lamb *et al.* 2017; Lamb *et al.* 2020).

In order to reduce social conflict and increase trust shown by farmers in the compensation system, it is necessary to improve the compensation process to make it more agile and adjusted to the real costs and damage incurred. The payments must include both the emergent costs as the intangible associated costs (e.g., of the search efforts when looking for damage remains or to the changes in livestock management in scenarios of damage events or perceived high risk), as well as the costs corresponding to the profits lost due to the loss of particular animals on the farm and the difficulty of replacing these. Much of the social conflict which can be perceived in the Cantabrian bear areas following high profile events attributed to damage caused by bears, is normally linked to complaints about the loss compensation table, in addition to the delay in the payment, and that on occasions, the intangible costs lead to more bad feeling than the direct costs (Bautista *et al.* 2019). Apparently simple measures, such as updating the compensation payment tables in consensus with farming organisations, so that they are paid within one or two months of the claim being accepted, could help to significantly reduce the scale of the conflict. However, efforts also need to be made to explain and inform about the reality of livestock attacks by bears, clarifying with detail and transparency the reasons why some claims should be rejected, to avoid bad feeling amongst the farmers.

In addition to the need for a good system of compensation payments, it is essential to extend, improve and evaluate the use of preventive measures which manage to keep damage caused by bears at adequate levels for peaceful coexistence (Rigg *et al.* 2011). Aid programs for installing preventive measures established by the different regional administrations should be maintained and increased, taking into account that the European Commission has ruled that it is possible to subsidise up to 100% of the direct and indirect costs deriving from damage caused by large carnivores using European and national funds, including preventive measures, and that these measures are not in conflict with the principals of free competition and international agreements. Advances in the integration of the preventive measures and coexistence with large carnivores in the general agricultural scenario and especially in the Common Agricultural Policy (PAC) of the EU are, however, necessary (Marsden & Hovardas 2020). When aid for prevention measures is not used efficiently, the incidence of damage caused does not diminish and the conflicts become chronic or increase (Bautista *et al.* 2019). That said, with an adequate policy of help towards the use of preventive measures it is possible to establish the obligation for adequate protection against attacks

Photo 11. Protection of an apiary with a solar-powered electric fence donated by the Brown Bear Foundation during the LIFE Project Bear Courel.

as a prerequisite for the payment of damage compensation claims, such as is already in place in Castilla y León for damage to apiaries. On the other hand, it is necessary that the prevention measures and policies are based on scientific evidence (Van Eeden *et al.* 2018). Electric fencing is the most efficient method for preventing bear attacks on beehives and livestock (Khorozyan & Walter 2020), although it is not always effective with some of the extensive grazing handling techniques in the Cantabrian Mountains. To avoid bear attacks on gregarious livestock, such as sheep, goats and even cattle, the traditional prevention systems of keeping flocks together while grazing in open areas, using electric enclosures and livestock guarding dogs can be very effective under certain circumstances. Together with these classic prevention systems (predator-proof fencing, removal of attractive resources, keeping livestock in enclosures overnight, guarding dogs), novel methods could be put into place and tested, which would be of potential interest in particular situations (conditioned chemical aversion, changes in livestock handling, livestock radiotracking systems, bear-proof feed hoppers, pellet feeders and installations, etc.). It is important that prevention is undertaken proactively, before damage events become a more serious problem, in order to avoid both repetition by the bear and positive conditioning when the bear receives a reward (Otto & Rolof 2015; Naves *et al.* 2018).

The reduction in conflicts linked to the brown bear, and in general to all large carnivores, requires measures that will permit coexistence between the growing bear population and a rural environment immersed in a difficult juncture due to the current social and environmental changes. Consequently, it is fundamental that programs of damage prevention and the adaptation of human activities to the presence of bears and wolves are developed by the regional administrations (Bautista *et al.* 2019). The Cantabrian brown bear population is growing and expanding in range, so that preventive measures should be proactive and anticipate possible emerging conflicts, both in those areas which have had continuous bear presence as well as

Photo 12. A Spanish Mastiff protects a herd of cows in the Cantabrian Mountains.

Photo 13. A flock of sheep in the mountains of central León. Informing local livestock farmers, such as this shepherd, who become implicated in the application of preventive measures, is the way forward to successfu coexistence between extensive grazing and large carnivores in the Cantabrian Mountains.

the areas with recent bear expansion, where beekeepers and livestock farmers stopped using these measures to protect their interests against bears many years ago. All of the measures directed towards prevention and the compensation for damage caused by brown bears should be based on scientific monitoring and evidence (López-Bao *et al.* 2017) and be framed within the necessary public participation on the part of the administration in charge (Bautista *et al.* 2019), given that social consensus and governance are fundamental to reach a favourable coexistence able to guarantee the conservation of the brown bear.

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CHAPTER 4.

HABITUATION, FOOD-CONDITIONING AND ATTACKS ON HUMANS

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SUMMARY

This chapter explores three aspects of conflictive brown bear behaviour in the Cantabrian Mountains. Firstly, we argue the reasons of why bears approach humanised areas, what constitutes habituation and what their causes and consequences are. Secondly, we present the problem of bears and human garbage. We revise the worldwide literature of the effect of garbage on bears and present the results of a field study undertaken in 2019 in the municipalities of Somiedo (Asturias) and Villablino (León). These show that bears have easy access to garbage containers, many of which are very close to wild habitat in areas of very low night-time illumination. However, until 2019, we knew of almost no cases of bears coming to visit containers frequently, but over the past two years a few bears with this habit have appeared, reminding us that this is a significant problem affecting the majority of bear populations. We make a few suggestions of how to reduce the presence of bears in towns and villages and go over the importance of the prevention and aversive conditioning in order to dissuade bears conditioned to garbage. Finally, we summarise the characteristics of the brown bear attacks on humans in Spain which have occurred since 1989. A total of seven attacks have occurred (aggressive encounters with physical contact) in the Cantabrian Mountains and one in the Pyrenees, all of which were caused by sudden encounters, produced light to moderate injuries and lasted just a few seconds until the bear fled. All of these attacks in the Cantabrian Mountains have occurred in the eastern subpopulation, which may derive from genetic differences affecting bear behaviour between the two Cantabrian nuclei.

INTRODUCTION

It is generally accepted that the key to coexistence between bears and humans is that their activities do not coincide in space and time (Lamb *et al.* 2020). As many residents of the small mountain villages affirm, "the bears should be in the mountains and the locals in the villages"; and if there are bears that approach humanised areas, they should do it in the dark at night. However, in an environment where the number of bears is increasing and where sporting, free time and wildlife watching activities have exploded in frequency, these conditions are ever harder to fulfil. Currently, many people are present in the countryside and, ever more frequently, bears approach villages. What is more, with rural depopulation and recovery of the natural vegetation cover, it is commonly difficult to determine where the villages end and the countryside starts.

The principal conflicts between bears and humans tend to be related to attacks on livestock and damage to beehives and fruit trees, as covered in Chapter 3. Another aspect of the bear conflict is the creation of fear, and their simple presence sometimes leads to worry in local residents and in those visiting bear areas (Chapter 5). As we will show, it is estimated that on average, one person dies from large carnivore attack in Europe (excluding Russia) per year (Bombieri *et al.* 2019), which usually corresponds to the attacks caused by bears in Rumania. Here, for hunting interests, the population has been artificially boosted over recent decades via the provision of tons of supplementary food and little effort is made to prevent them from roaming around towns and cities. Even so, the figure is clear, the death of one person a year in a continent with more than 400 million inhabitants indicates that the real risk posed by large carnivores is tiny. Indeed, the problem is not the danger that bears represent for humans, but the fear that their figure provokes in some people. The primal fear of being attacked and devoured by predators – a fear which has allowed the human species to survive despite our limited physical characteristics – is disproportionate. In this sense, the simple appearance of bears in the surroundings of villages is a source of concern for many individuals and sometimes even a conflict in itself. Consequently, we tackle various aspects related to human safety in the Cantabrian Mountains, extracted, in part, from more detailed reports published recently by the Brown Bear Foundation (Blanco *et al.* 2019a, 2019b).

This chapter is divided into three main sections. In the first we see why bears approach humanised areas, what habituation means and what its causes and consequences are. In the second, we present the problem of bears with garbage and other food sources that attract them to villages, such as fruit trees, we review the worldwide literature on the effect of garbage on bears and we show the results of a field study undertaken in 2019 in the Cantabrian Mountains. In the third part, we summarise the characteristics of the attacks by bears on humans in the Cantabrian Mountains compiled by ourselves since 1989, and we propose a few tips and advice on how to reduce bear presence in the surroundings to villages and improve people safety.

Photo 1. Excrement left by a bear in a village in Liébana (Cantabria), where it had been eating apples.

HABITUATION TO HUMANS AND INTRASPECIFIC COMPETITION

Photo 2. Fruit trees within or on the edge of villages constitute an important focus of attraction for bears. In the photo, the Laciana Valley (León).

Habituation to humans by bears usually occurs after repeated exposure to humans without experiencing negative repercussions (Hopkins *et al* 2010; Morales-González *et al.* 2020). Similarly, conditioning to a food source of human origin occurs when a bear learns to associate human presence with a food source, usually after repeatedly obtaining recompense from doing so (Honeyman 2007). Frequent and harmless interactions between bears and people can produce habituated bears, even without food as a reinforcement. Bear watching tourism is one of the activities which can lead to habituation (Herrero *et al.* 2005; Wheat & Wilmers 2016; Penteriani *et al.* 2017). Mueller (2001) demonstrated that subadult male and female grizzly bears in North America are particularly prone to interactions with humans, and, as we show here, the same occurs in Europe.

Habituation can cause certain negative consequences. Habituated bears are more likely to die at the hands of man, to be fed by people and convert into bears conditioned by food, and can end up attacking people who act in an unwise way (Herrero *et al.* 2005). In the latter two cases, the bears tend to be captured and confined in captivity or sacrificed to avoid further conflicts. Bears – omnivorous and opportunistic – may also consume food of human origin and become conditioned by associating humans or their houses with the food. Conditioning to food, with or without habituation to people, is the most widely accepted mechanism used to explain the presence of bears close to villages (Elfström *et al.* 2014c).

In the majority of cases, however, the fact that brown bears come to feed in humanised areas has more to do with intraspecific competition with other individuals of the same population than with the abundance or quality of the food available. A series of studies demonstrating this in Europe have been published, the majority headed by Marcus Elfström, biologist of the Norwegian University of Life Sciences: Ås. Elfström *et al.* (2014a) compared problem bears in Sweden (where there is no supplementary feeding) and Slovenia (where large quantities of food are supplied). Firstly, they demonstrated that the problem bears showed no difference in body coefficient from non-problematic bears, i.e. they are neither thinner (as could be imagined for ill bears), nor fatter. Three results from this study suggested that strong competition with adult males is responsible for the subadults visiting humanised areas. Firstly, the majority of the problems occurred during the mating season (April-June) and that the problem bears were younger than the non-problematic bears; additionally, in areas of high human density, young bears predominated (problematic individuals or not) over adults; finally, in Sweden (with no supplementary feeding), the bear's physical condition was inversely proportional to their density. This all appears to be the result of strong intraspecific competition giving rise to a "despotic distribution" of the population: the largest bears live furthest from people, dominating natural food resources, while the younger bears are pushed to humanised areas where they enter into conflict with people. This competition explains the presence of young bears in humanised habitats (Elfström *et al.* 2014a).

Photo 3. A young brown bear uses the roofs of some buildings in the Somiedo Natural Park (Asturias) to feed from fruit trees.

The same authors in Sweden analysed if those bears occurring in the proximity of humans fed on a richer and more varied diet than those in adjacent natural habitats. Using data from radio-collared wild bears, the nutritive quality in the excrement was analysed using infrared spectroscopy and the conclusion was that less than 1.9% of the variation in diet was dependent on the bear's location, and so this hypothesis was rejected at the start. In contrast, evidence was found that the less competitive individuals (females with cubs and young bears) used the surroundings of houses to escape from the large males – which may kill cubs and young individuals (Planella *et al.* 2019; Ballesteros *et al.* in press) – without necessarily being conditioned by food (Elfström *et al* 2014b).

When talking about the management of bears which regularly feed close to humans, Elfström *et al.* (2014c) – along with others before them – recommend removal of the foods that attract brown bears, but to also take into account that less competitive bears are highly likely to return to humanised areas as they are displaced from natural habitats by the big males. Consequently, these bears using areas close to humans as refugia should not be considered "unnatural", but rather as individuals that adapt their behaviour to the despotic distribution. In this sense, it may be useful to take into account the type of bear that approaches to feed close to humans. The presence of large bears in villages suggests that the food that they find there is highly attractive and/or is absent in the wild; in contrast, the presence of immatures or females with cubs usually indicates that they are avoiding the large male bears. Elfström *et al.* (2014c) summarised these conclusions in one sentence: brown bear immatures and females with cubs fear people, but fear the large dominant males more. Whatever the case, these rules have their exceptions, given that variations between individuals frequently cause behaviours which do not fit the general patterns (Steyaert *et al.* 2014).

In the Cantabrian population, which is growing at a faster pace than the distribution area it occupies (increasing in density more than in its distribution), it is likely that intraspecific competition between bears –more than food necessities– will increase the presence of immatures and perhaps females with cubs in humanised areas, where they seek safety away from large males. But if food is available in these humanised areas, the bears are not going to waste the opportunity. Intelligent management of the availability of food close to humans constitutes the best means of reducing conflicts.

These theoretical conclusions gathered in other European countries fit with the results seen in the Cantabrian Mountains. Here, infanticide is the principal cause of cub death during the first year of life (Planella *et al.* 2019; Chapter 1). Those female bears with small cubs run risks to their own lives by defending their cubs during infanticide attacks, such as the female that was killed and eaten by a male in western Asturias in spring 2020 (Ballesteros *et al.* in press). For this reason, in spring they restrict their movements to areas where they can avoid the attentions of potentially infanticidal males. During this season, females with cubs of the

year prioritise safety (Steyaert *et al.* 2013a) and feeding moves to second place. Their diet at this time is of lower quality than of other bear classes and when the breeding period has passed (the infanticide season), diet quality increases again (Steyaert *et al.* 2013b).

Female Cantabrian bears tend to seek safety from potentially infanticidal males in rocky areas, where the cubs can move around much more easily than the heavy adult males. But in other areas, the females seek proximity to man, e.g. in Sweden, 19 families of females with cubs which were successful, kept significantly closer to human habitation during the mating and infanticide period, than 11 families which failed due to infanticide (Steyaert *et al.* 2016). Cases of females with cubs which appear to seek 'human shields' are however known from the Cantabrian Mountains, such as the female with a cub in May 2015 in Fondos de Vega (Asturias) which stayed in plain sight of observers and photographers who watched from a road 150 m away. The female, sheltered on a very steep slope and separated from the observers by an almost inaccessible gorge, stayed two or three weeks at the site before disappearing. During this time the female and cub spent long periods seeing humans and habituating to them. This female was probably using the observers as a human shield and although she could have moved out of sight at any time, elected the stress caused by presence of the public to the danger of losing her cub to an infanticidal male. The female with cubs which wandered around close to a few settlements of Proaza (Asturias) in spring 2020 and other females with cubs which have been seen at this season close to roads and villages, were probably using human presence to protect themselves from potentially infanticidal males.

It is foreseeable that the greater the density of bears, the more cases of

Photo 4. Young brown bears (as in the photo) and females with cubs are more likely to use humanised habitats than adult males.

immatures coming to feed in the surroundings of settlements and more females with cubs in spring coming to find human shields in inhabited areas will be seen. This appears to be inevitable in such a humanised range as the Cantabrian Mountains, where the villages and bear-inhabited mountains are intimately interlinked.

GARBAGE IN BEAR AREAS: A SOURCE OF CONFLICT

General information about bears and garbage

Garbage constitutes an extremely attractive resource for bears

Leaving the damage caused to beehives and livestock to one side, the majority of bear conflicts occur around food sources provided by humans, such as garbage, dog food, fruit trees and even bird feeders (Lackey *et al.* 2017). Bears change their behaviour to exploit these resources and in this process approach villages, destroy personal belongings – such as stable, garage or even house doors – and threaten people's safety. In areas with abundant bears – and even in some areas where they are threatened – the corresponding administrations are frequently obliged to concentrate their efforts on resolving the immediate problems of conflictive individuals, employing aversion methods or even taking individuals out of the wild, though the most practical solution is to resolve the ultimate cause of this conflict. As long as there is garbage, urban fruit trees and other food resources available, the bears will try to make use of them.

While conflicts related to garbage occur with the majority of bears on the planet, this has been most studied in the black bear (*Ursus americanus*) in the USA. The brown/grizzly bear (*Ursus arctos*) is not as abundant as the American black bear and tends to live in less humanised areas (McLlelan *et al.* 2018), but is also attracted to garbage, generating the same problem as the black bear and has been the objective of studies in both North America and Europe (Majic & Krofel 2014).

Garbage constitutes a highly profitable food source for bears. It is available all year round and under all environmental conditions, it is predictable in location and time, it is highly concentrated, and moving from one container to the next requires minimal effort. For a bear, it is very difficult to resist this temptation (Beckmann & Berger 2003a).

Photo 5. The proximity between high quality forests and villages in many places in the Cantabrian Mountains can make it easier for bears to search for trophic resources of human origin. Bear landscape in the Natural Park of Fuentes del Narcea, Degaña and Ibias (Asturias).

Garbage modifies the biological parameters of the bear

Garbage can determine the size, behaviour, physiology, ecology and the demographics of bears, at least in the case of American black bears, where these aspects have been studied in depth. For example, in a now classic study carried out in the Smoky Mountains (Tennessee and North Carolina) between 1968 and 1988, based on 1,210 American black bears captured in the wild in areas with little human influence and 492 individuals captured in humanised environments, more males were seen in humanised areas (60%) compared to wild areas (52%), wild males were significantly older (average age 3.9 years old) than those in humanised areas (2.9 years old) and the same was seen for females (4.9 in wild areas and 3.7 in humanised ones). Males and females in humanised areas were significantly larger and developed faster than those in the wild areas and the percentage of lactating females was higher in humanised areas (56%) than in wild ones (33%) (Peter *et al.* 1990). That there were more males in humanised areas indicates that, in the case of black bears, the areas with more garbage (more food) are defended by larger individuals, as is seen in European brown bears in wild areas (Elfström *et al.* 2014a). This difference may have arisen since black bears are less aggressive and probably more tolerant of human presence than brown bears, allowing a close coexistence of black bears with people which is not possible with brown bears. In North America and Europe brown bears are rarely allowed to roam around humanised areas with garbage, perhaps with the exception of Rumania. If this familiarity between brown bears and humans was allowed (which is not recommended, since a dramatic increase in attacks on humans would occur), the brown bear would probably end up behaving like black bears, and the largest males would end up dominating the best areas of anthropic feeding resources.

In a later study, Beckmann & Berger (2003a), using data from between 12 to 15 years, compared the demographic parameters, lifespan and reproduction in two populations of the black bear in the Lake Tahoe (Nevada and California) catchment. Bears with access to garbage reached densities three times higher than the historic values for those same areas and the proportion of males was 4.25 times higher than that of females. In the humanised areas, the males increased their average body size by 20%, and females by 50%, compared to those in the wild areas, and some even increased their weight over the winter, rather than losing it, as occurs in wild bears. The area covered by each bear in areas with access to garbage decreased by 90% in males and 70% in females, and the animals commenced hibernation significantly later than those in wild areas. Over their lifespans, females in these humanised areas give birth to three times the number of offspring as those in the wild.

The presence of garbage also decreases the average daily activity period in American brown bears (8.5 h compared to 13.3 h in bears in the wild: Beckmann & Berger 2003b). Additionally, the bears feeding on garbage were more nocturnal (to avoid the presence of humans) and hibernation started later and lasted less. The authors concluded that the alterations to the ecology and physiology of bears with garbage available to them can be very much faster than had previously been supposed.

Studies have demonstrated that the highest mortality rates due to the grizzly bear occur in areas where food and garbage are not well handled (Benn 1988; Benn & Herrero 2002). For example, in the emblematic Banff National Park (Canada), even though the number of incidents related to non-natural foods is relatively low, in the few incidences occurring, the bears are either killed or translocated (Honeyman 2007).

In one area of British Columbia (Canada), the average survival rate of grizzly bears that approach humanised areas, attracted by the greater quantity of food available (in this case, a specific type of berry), is 17% lower than of those individuals which do not use humanised habitats. The area attracts dispersers which occupy the spaces left by the dead or translocated individuals, creating an "ecological trap", with negative repercussions on the dynamics of the population over a much more extensive area (Lamb *et al.* 2017, 2020).

Garbage feeding bears can cause much wider conflicts

As highlighted by Majic & Krofel (2014) in their revision of problem bears in Europe, access to anthropic food sources is the principal cause of conflicts with bears and of the

appearance of problem bears, in agreement with numerous studies undertaken in North America (Jope 1985; Creachbaum *et al.* 1998; Herrero 2002; Herrero *et al.* 2005), Asia (Sato *et al.* 2005) and Europe (Serban-Parau 1999; Swenson *et al.* 2000; Huber 2010; Bereczky *et al.* 2011; but see Elfström *et al.* 2014b, 2014c for Scandinavia).

The relationship between garbage and conflicts has been studied in special depth in the Yellowstone National Park and its surroundings (Gunther *et al.* 2004). The highest proportion of the conflicts caused by grizzly bears are related to anthropic food sources (447 cases of 995). As also occurs with the black bear, the number of incidents in which brown bears caused damage to houses, garages, cars, etc. in order to access foods of anthropic origin was inversely correlated with the abundance of natural foods. In other words, when natural food availability falls, those bears habituated to food of anthropic origin search for it with special vigour and end up causing important conflicts.

Following strict garbage control measures, the Glacier and Yellowstone National Parks (USA), have experienced a spectacular drop in the number of people injured by both grizzly and black bears. At the same time, they have had to kill, or translocate many fewer bears than before. Though the levels have never been as high as in the parks in the USA, the number of people injured in the national parks in the Canadian Rocky Mountains have also fallen as a result of improved management of foods and garbage (Herrero & Higgins 1999).

Various authors underline the fact that the dense vegetation surrounding villages, humanised areas, pastures with livestock and cultivated areas, increases the risk of incidents with brown bears, both in North America and in Europe (Kaczensky 1999; Gibeau *et al.* 2002, Sato *et al.* 2005; Bereczky *et al.* 2011). In this sense, in the Cantabrian Mountains we should expect to see the highest probability of conflicts with garbage occurring in those villages situated in the areas of highest bear density, surrounded by forests and close to rivers and streams (where the vegetation tends to be denser). We also suppose that the location of the garbage containers (which would be more accessible for bears the further they are from the village and closer to dense vegetation, in poorly lit areas) and the characteristics of the village (the smaller and quieter the better), will also influence the probability of conflict.

Cultural transmission of the conflict

The habit of eating from garbage appears to have a large cultural component, which is transmitted from mothers to cubs, as has been suggested by Gilbert (1989) and Aumiller & Matt (1994) and observed by Madison (2008). The tendency for brown bears to develop conflictive behaviours may be due to social learning between mothers and cubs, by genetic inheritance, or by both factors. Over recent years the information collected on the tendency of the cubs of conflictive bears to be conflictive themselves, has been contradictory. Recently, the article by Morehouse *et al.* (2016) has thrown significant light on this problem. Between 2011 and 2014 the authors collected and undertook genetic analysis of grizzly bear hairs in southwest Alberta, Canada. A total of 213 unique grizzly bear genotypes were identified (118 males and 95 females), which were analysed for parent-offspring relationships. 76 mother-offspring relationships (which stay together for 2 and a half years) and 119 father-offspring relationships (where there is no male presence for cubs to learn from). The results support the hypothesis of social learning, but not that of genetic inheritance. The cubs of problematic females have more chance of being involved in conflicts, but not of being more conflictive when their fathers were problem bears. If problem bears had inherited behaviour, there would be a significant relationship between conflictive fathers and conflictive behaviour in their offspring. In consequence, it now appears clear that social learning may perpetuate conflicts in brown bears (Morehouse *et al.* 2016). This conclusion highlights the importance of avoiding the onset of the conflict from the very beginning.

Field study on garbage in the Cantabrian mountains

With these conclusions in mind, above all gained from North American literature, we planned a field study in the Cantabrian Mountains, the general objective of which was to test if a real or potential problem with bears and garbage exists on the ground, and to find appropriate solutions or prevention measures. For this, we characterised and quantified the

most important variables which might explain conflicts between bears and garbage by studying a series of variables related to the location and other characteristics of dozens of containers located in bear areas. At the same time, the Brown Bear Foundation rangers spread across the entire bear range were all interviewed and were requested to undertake the same interviews with their contacts among the rangers from the different administrations, naturalists and local residents to collect data on the bears visiting containers over the past few years. The field work was undertaken in two neighbouring municipalities with high bear densities. One is Somiedo (Asturias), legally protected as a Natural Park; the other is the Villablino municipality (León), which borders Somiedo to the southwest, has a population density 10 times higher than Somiedo and has no protection beyond forming part of the Natura 2000 network.

Both municipalities have high bear densities. According to the Brown Bear Foundation database, between 6 and 8 females with cubs of the year are present annually in Somiedo, equivalent to 50-65 bears in total (multiplying the breeding females by 8), while in Villablino, between one and three females with cubs of the year are usually detected, representing approximately between 10 and 25 individuals. Teams of Brown Bear Foundation wardens have been permanently based in each for at least the past 20 years, aiding the collection and interpretation of the data. The bulk of the fieldwork was carried out in February and March 2019.

In Somiedo, we visited 21 localities in 10 of the 15 parishes present, i.e. two thirds of the hamlets and villages that exist, and collected data on 43 containers or groups of containers, in addition to a recycling point and a garbage transfer centre. In Villablino, we visited the 13 villages forming its municipality, in addition to the Leitariegos ski station, which at weekends receives around 1000 skiers and probably other non-skiing visitors.

The following variables were considered:

1. Garbage management in both municipalities, deduced from the visits to the villages and interviews with their mayors.

2. Village size and structure, plus the distribution of the groups of containers in the villages, with special attention paid to those on the edge of or outside the village, i.e. those most accessible to bears.

3. Location and any protection measures of the containers, quantifying the proportion of containers with protective lids (with a roof covering or not) and their condition status.

4. Quantity and attractiveness of the garbage for bears.

5. Distance from the containers to inhabited houses and street lamps.

6. Distance of the containers to vegetation corridors and forest cover.

Given the criteria above and our impression during the fieldwork, each container or group of containers was assigned a category relating to its exposure or vulnerability to bears (Low, Medium, High, Maximum), accepting that this is higher in those in worse condition or least protected, those furthest from street lamps, houses and asphalted streets and closest to uninhabited areas and those with natural vegetation.

Field study results

The garbage in both Somiedo and Villablino towns is well managed. No garbage was seen dumped in the countryside nor outside the containers. These are well distributed in the villages, in good condition and, in general, without overflowing garbage. In summary, we perceived no important problems with garbage management in the municipalities, although we did not visit them in summer, when the human population in the mountains multiplies.

However, numerous opportunities for bears to access garbage exist in the containers located in small, almost uninhabited villages, at picnic sites and other areas with containers outside the villages.

In Somiedo, of the 34 container groups analysed, 3 (9%) presented the maximum risk category, 5 (15%) were considered high, 16 (47%) moderate and 10 (29%) of low risk. Of the 48 container groups in Villablino, one (2%) was considered maximum risk, 4 (8%) high, 12 (25%) medium and 31 (65%) low. However, bears either do not visit the containers, or do so only truly exceptionally. The data from the FOP wardens and the interviews with our network of con-

tacts only collected a few cases of bears only sporadically visiting garbage containers in a few locations in the Cantabrian Mountains, but not habitually so. One of the most significant cases occurred in September 2019 in Villablino, when a young bear came to eat food at a garbage container for a few nights. The bear was captured on camera and the video went viral in the social networks. After the containers were emptied and the Bear Patrol of the Castilla y León government intervened, the bear did not return.

Other cases of bears visiting garbage containers have occurred in 2020. In the hamlet of Sograndio (Proaza, Asturias), a female with cubs of the year came to eat dog and cattle feed in an unoccupied house. The bear family was subsequently seen visiting garbage containers, until they were surprised at a container one night by the Bear Patrol of Asturias, who frightened them off with shouts and vehicle horn blowing, after which they were not seen in the settlement again. Similarly, in Sisterna (Ibias, Asturias), a young bear was feeding on cherries inside the village during the day. Frightened off by shouts and firecrackers used by the Bear Patrol of Asturias and Brown Bear Foundation patrol, it abandoned the fruit trees. However, it reappeared at the end of September and beginning of October, feeding secretively in the garbage containers at night. Dissuasion measures by the same rangers, this time including rubber bullets and shouts – and perhaps as well the availability of sweet chestnuts and other natural autumn food sources – have meant that the animal has abandoned the containers, at least temporarily.

So, although a few bears have been observed visiting garbage containers, we don't believe that there are any bears conditioned to garbage in the Cantabrian Mountains, which visit them regularly and depend to a large degree on this source of food. But given the increase in the bear population and the constant temptation present in the form of village fruit trees and garbage containers, we can predict that the problem is far from being resolved.

Conclusions from the field study

At this time, there does not appear to be an evident problem of bears habituated to garbage in the Cantabrian Mountains, although a few worrying cases have appeared during the past year. Given that black, polar and brown/grizzly bears, both in North American and in Eurasia are attracted to garbage (Elfström *et al.* 2014c), the question arises as to why this hasn't happened in Spain. Of course, this is not through a lack of opportunities. As we have seen, both in Somiedo and in Villablino, – and we suppose in many other locations in the Cantabrian Mountains – there are containers and other sources of garbage which are easily accessible to bears and which could attract individuals in to feed from them at night with very few risks involved. The container in Villablino from which the bear fed in September 2019, was inside the town (5,780 inhabitants), in a well-lit, asphalted area and with occupied houses, which would have given it a low risk category. The majority of containers that we analysed during the study were much more vulnerable than that used by the bear in question.

As mentioned before, the appearance of bears dependent on garbage constitutes a process which includes habituation to people, the learning

Photo 6. Bears rarely come to garbage containers in the Cantabrian Mountains. This container, however, has been knocked over and opened by a young bear in the Fuentes del Narcea, Degaña & Ibias Natural Park (Asturias).

process of where to find garbage and the best means of exploiting it, all of which require some time. That this process is not completed and that there is no subsequent cultural transmission between bears, must presumably be the cause for bears not being conditioned to garbage in the Cantabrian Mountains. If this process takes time to consolidate, options occur to try and interrupt cases as soon as they are detected. Most importantly, it is vital to remove the garbage or other source of attraction once bears are detected feeding from it and secondly dissuade those bears which begin to frequent garbage containers.

Why do the bears in the Cantabrian Mountains rarely come to garbage there, in contrast to those in North American and elsewhere in Europe? Perhaps the environment in the Cantabrian Mountains provides sufficient food for the bears, so that they don't need to come to garbage. However, it is very likely that there are specific seasons with food scarcity, which could lead the bears to exploit garbage, which energetically is a highly profitable food source. In order to exploit garbage, at least a few individuals need to have a significant tolerance level towards humans (habituation). It is also possible that bears have not turned to garbage as they have not yet learned to do so, and there is no bear culture for exploiting it. We have seen that the tendency towards creating conflicts (and many other bear behaviours) are transmitted from mothers to their offspring (Morehouse *et al.* 2016). It is possible that the culture to exploit garbage in the Cantabrian Mountains has not commenced, and that bears do not do it because their mothers have not taught them. However, if this culture started to become established, it could spread very rapidly.

This indifference of Cantabrian brown bears towards garbage is very unusual if we review the situation in other populations. In Abruzzo (Italy) with a population numbering around 50 individuals, there is one bear that comes habitually to garbage and two more that come irregularly (Paolo Ciucci, pers. comm.). In Rumania, the bears which came to garbage containers in the city of Brasov ended up becoming very popular and constituted a local tourist attraction, until the local authorities closed the containers. However, many Rumanian bears currently habitually come to garbage, a custom which the authorities are trying to eliminate in the majority of the country. Whatever the case, the indifference of Cantabrian bears towards garbage containers in villages and the absence of individuals raiding containers could change at any time. We need to be prepared to face the appearance of garbage conditioned individuals, since it is a common behaviour among brown bears over the majority of their distribution range.

Finding solutions to the conflict: prevention and adversive conditioning

In order to prevent conflicts with bears it is necessary to prevent habituation by individuals, thorough studying the causes which lead some individuals the frequent humanised areas. However, it is also important to accept that the appearance of subadult and female bears with cubs close to humans, due to competition with adult males and above all during the mating season (spring), is to some degree inevitable. It is also essential to avoid the appearance of bears conditioned to food, and especially those feeding on garbage. Consequently, once bears are detected starting to come to containers, swift action needs to be taken, firstly by removing the garbage and reducing accessibility to the containers, and, if necessary, carrying out aversive condition on those individuals which start to become conditioned. The appearance of bears in fruit trees close to human habitations is a more complex issue, needing to be approached on an individual case basis.

Prevention of access to garbage and other food sources

Field studies have corroborated that stopping access to anthropic food sources is the best means of avoiding conflicts. The incidents caused by bears in the Denali National Park (Alaska) fell by 96% when bear-proof food storage containers were supplied to hikers (Schirokauer & Boyd 1998). The long-term data set collected in Minnesota indicates that the reduction in American black bear conflicts there is associated with changes in garbage management and not with an increase in the number of bears shot. Of all the measures implemented to try and reduce conflicts between bears and humans, those blocking access to garbage and other attractive substances have been the most successful to date (Colorado Parks and Wildlife 2017). For this

to be achieved, the first measure is to send a clear message to society that allowing bears to become accustomed to feeding on garbage or other food sources of human origin is harmful to people and especially to the bears themselves. As signs in the American National Parks warn, "a fed bear is a dead bear".

Bear-proof garbage containers are sometimes presented as the panacea to solve this problem, but field studies in the USA on black bears have demonstrated that these are useless if they are not accompanied by information campaigns and by the application of laws obliging correct garbage management (Colorado Parks and Wildlife 2017).

Bear-proof garbage containers have never been tried in Spain, but many brands and models covering a variety of applications are available in the USA, covering residential, commercial and camp site uses. Their price depends on the projected use, but the residential containers, which can vary from a plastic can with screw-on lid to a metallic box designed to house two containers for household garbage, vary from $50 to $1200 US each.

The following questions need considering before deciding to use these containers (Lackey et al. 2017):

- Container design.
- Practical implementation. Economic aspects need to be resolved and be accepted by the town halls.
- Informing residents and an adequate legislation to guarantee that these containers are used and garbage is not deposited in other devices.
- Maintenance of these containers and the contracts with garbage collection companies, which regularly refuse to collect the garbage in bear-proof containers.

Bear-proof garbage containers are presented as the solution to the garbage problem, but in the Cantabrian Mountains at least, this proposal might be too simplistic. In Spain, containers are designed and standardised so that they can be collected and emptied automatically by public garbage collection companies. The appearance of new containers not conforming to these standards creates a garbage collection problem which is difficult to resolve. In those areas where bears are conditioned to garbage, it is insufficient to have just one or a few bear-proof containers; all of the containers in the area need to be bear-proof, otherwise the bears will simply go to those remaining unprotected containers. Apart from their high cost, the main problem is garbage collection. Currently, it appears highly improbable that the garbage collection system in the mountain villages can be changed to adapt it to the technical demands of the bear-proof containers. However, although their general use appears to be a difficult alternative, it is possible that they may be successfully used in specific instances, such as at isolated houses with regularly visiting bears or during specific periods of crisis in certain areas.

The most important factor to remember, however, is that conditioning to garbage is a behaviour which extends through the bear

Photo 7. Numerous garbage containers are present around the edges of almost uninhabited hamlets and villages in the Cantabrian Mountains and are easily accessible for bears at night.

population via imitation (Morehouse *et al.* 2016), so it is crucial to prevent this behaviour before it extends and becomes consolidated within the bear population.

Additionally, in the case of bears roaming around villages, garbage may act in synergy with other attractions, such as fruit trees (above all cherries and apples), dog and cattle feed and others. Bears may visit villages to plunder fruit trees and then go on to visit garbage, or vice versa. In this sense, it would be useful to develop a broad-spectrum plan to avoid different possible routes of habituation to humans and conditioning to anthropic food sources by bears. This plan should include those aspects related to garbage, but not be restricted to them.

Aversive conditioning

When bears start to frequent garbage or the proximities to towns and villages for other reasons, aversive conditioning may be necessary, which uses a negative stimulus to cause pain, discomfort, or irritation in an animal exhibiting an unwanted behaviour. However, aversive conditioning is not an effective tool if the foods attracting the bears have not been removed first (Beckmann *et al.* 2004; Lackey *et al.* 2017). Consequently, the garbage and other attractants need to be eliminated prior to the aversive conditioning. Whatever the case, aversive conditioning can be difficult to undertake, expensive and is not always effective in the long term. Bears which are seriously conditioned tend to revert to the unwanted behaviours after a few months (Gillin *et al.* 1994; Shivick *et al.* 2006; Leigh *et al.* 2008), so that it is fundamental to act quickly to stop these behaviours from consolidating.

Between 2002 and 2005, a study in the Sequoia National Park (California) evaluated the efficiency of various aversive conditioning methods in 150 American black bears: projectiles of varying intensity, pepper spray and the direct harassment of the individuals (Mazur 2010). These methods were successful in stopping conditioning to the food. Regarding those bears which were already conditioned, in 17 of 29 individuals subjected to treatment had their undesired behaviours corrected, 6 needed constant treatments and 6 had to be sacrificed or relocated. In those bears conditioned to food, the success rate increased when the aversive techniques were applied shortly after when the bears had had access to anthropic food. Aversive conditioning was less successful on young bears (of one to two years old) than for adults. Rubber bullets were slightly more effective then lower impact projectiles.

In Spain, we have the experience of a young bear which habituated to feeding on fruit trees in the hamlet of Castro, Somiedo (Asturias), over a number of days during August 2014. The bear was frightened during several consecutive days by expert personnel shouting, throwing firecrackers and using dogs. This process was sufficient to drive it away, and it did not return. Speed in undertaking the action was key, but it was also important that the fruit on the trees (in this case, figs) disappeared over a few days, eliminating positive reinforcement for the bear over time. With bears conditioned to garbage, which is a more constant and predictable food source, this dissuasion will probably be more difficult if it is not carried out during the early stages of the conditioning process.

BEAR ATTACKS ON HUMANS

Attacks by bears on humans constitute the most dramatic example of the conflict between both species. This theme has been the subject of numerous studies, among which we highlight the worldwide review undertaken by Bombieri *et al.* (2019); we ourselves have also made a thorough review, available online in Spanish (Blanco *et al.* 2019b). Abundant literature references on the issue can be found in both. Bombieri *et al.* (2019) highlighted that in Europe, bear attacks on humans produce an average of one death a year, almost always in Rumania, where various circumstances converge to take the conflict to its climax, as detailed in Blanco *et al.* (2019b). Considering such a low figure, it is easy to see that attacks by bears (and other large carnivores) on humans are much more a psychological problem than a true threat to people safety. But the fear that bears and other large carnivores generate play an essential role in their perception and reflects in the conservation policies of these species in different countries.

Following the international literature (Smith *et al.* 2005; Smith & Herrero 2018), we consider an attack as an incident in which a bear voluntarily makes physical contact

Photo 8. Bears rarely attack humans, but many of these incidents are caused by females with cubs.

with a person. Other incidents, such as charges, threats, etc., are not considered as attacks and are not considered within this study. In this manner we follow international standards and avoid the enormous subjectivity that the concept of an "attack" carries in the absence of physical contact. The incidents we studied occurred between 1989 and half way through 2020; we have talked directly to the people involved in six of all seven cases occurring the Cantabrian Mountains, and in the other case, with a close family member to whom the attacked individual recounted the event two days later. For the case in the Pyrenees, we reviewed the news articles in the media. Other details on methodology can be consulted in Blanco *et al.* (2019b, in press).

The attacks in the Cantabrian Mountains and Pyrenees

Over the past 30 years we have documented eight incidents with physical contact in Spain, seven in the Cantabrian Mountains and one in the Pyrenees, none of which resulted in death. Indeed, we know of no proven case of a death caused by bears in Spain ever. Perhaps, even the chronicle of King Favila is closer to fiction than to truth, given that it was written around 990, a century and a half after his death. The incidents have been described in detail in Blanco et al. (2019b) and a summary can be consulted in Table 1.

Among the eight people involved in incidents, 4 suffered minimal or no injuries, another was treated in an outpatient clinic and sent home after receiving several stitches, while the other three were hospitalised after the attack. Among the latter, one was a 75 year-old man, whose principal (mild) injuries were caused by his fall; the other two received important bite wounds, one in the upper part of the thigh and the other in an arm. Of the eight cases, only one (number 1, Table 1) suffered a wound which was potentially life-threatening, due to the bleeding.

Of those affected, two suffered serious bites requiring surgery, another two received mild bites requiring two and seven stitches, respectively, and another two were also bitten (one on the shoulder and another on the calf), but in both these cases, the bears hardly used any force, did not break the skin and did not draw blood, revealing the degree to which they controlled their aggression. One of those attacked also suffered a cut on the arm which required seven stitches. In another case, the victim suffered a mild scratch, perhaps caused as the bear went over the top of him as it fled. In another case, a 77 year-old man suffered a cracked rib and a blow to the thigh. In contrast to grizzly and Asiatic bears, our brown bears never direct their attacks to the head, face or torso (Blanco *et al.* 2019b). All of the wounds were inflicted on the arms or legs.

Regarding the type of attack, all occurred in situations of sudden encounters and none were predation attacks. Indeed, in two of the cases, overconfidence by the humans may have played a role: in the first (number 1), the individual followed bear tracks through the snow until surprising it from its den; in the second (number 3), the game warden knew that the bear went to feed at a feeding station located in the cave. In the remaining cases, those attacked did not detect bear presence nor foresee the attack.

The game warden in incident number 3 stressed that he hadn't been attacked by the bear, but that the bear had simply "pushed him aside". It is also true to say that in various of these cases, it would be more correct to say that the people were knocked down, barged or pushed out of the way by a fleeing bear, than being attacked by them. It appears clear that several of the bears disturbed suddenly from their bedding sites did not want more than to move the person aside who was standing in their escape route.

Table 1. Bear attacks on people (incidents with physical contact) in the Cantabrian Mountains and Pyrenees from 1988 until 2020. Provinces: P, Palencia; Le, León; C, Cantabria.

Nº	Date	Location (Province)	Attacked person (age)	Attacking bear	Cause	Injuries
1	30.12.1999	Casavegas (P)	Male (35)	Adult male	Sudden encounter in resting den	Severe bite that affected the femoral artery and vein. Required surgery and healing took several weeks
2	15.5.2004	Lebanza (P)	Male (75)	Solitary bear	Sudden encounter	Minor injuries. After falling to the ground the bear did not hurt him. Discharged from the hospital in one week.
3	26.4.2007	Casasuertes (Le)	Male (50)	Adult male	Sudden encounter in ungulate feeder, presence of a dog	No injuries caused by the bear. Light scratches to the face when falling into bushes
4	14.4.2010	Rebanal de las Llantas (P)	Male (56)	Female with cubs	Sudden encounter	No wounds. Soft bite in the calf muscle.
5	27.9.2012	Dehesa de Montejo (P)	Male (48)	Solitary bear	Probably close to a carrion	Minimal wounds. Two stitches in a foot.
6	3.6.2015	Villaescusa del Bardal (C)	Male (35)	Adult male	Sudden encounter	Radial displacement and fracture of the ulna, tears in the arm. Surgery, healing took weeks
7	6.3.2018	Polentinos (P)	Male (77)	Solitary bear	Sudden encounter and presence of a dog	Minor injuries. A fissured rib and a bruise on the thigh.
8	23.10.2008	Les (Lleida)	Male (72)	Solitary female	Sudden encounter and screams in a hunting action	Scratch on the arm (7 stitches) and bite on the leg (7 stitches). No hospitalization.

All of the attacks were brief; the majority lasted a few seconds and probably, none of them more than a minute. In all cases the bear fled after the attack (in one of them, the shaken victim saw how the bear defecated as it ran), indicating that the bears were frightened.

It is notable that in two of the cases (numbers 1 and 4), where the victims defended themselves to some degree, it was when they stopped their defence that the bear stopped its attack and fled. The first struck the bear with a pair of binoculars whilst the bear was biting his leg; when he stopped his resistance, the bear left. The second struggled with the female that was on top of him and had trapped one of his legs in its mouth, but when he went still and 'played dead', the bear fled. These data support the current rules in the American parks which recommend not fighting back and to play dead if attacked by a grizzly or black bear.

Of the eight attacks, one was caused by a female with cubs and the rest by solitary bears. Of the latter, one was caused by an adult female in the Pyrenees (which was radio-collared), another three by adult males (deduced by the size of the tracks left in the snow) and the rest by individuals of unknown sex. In one of the latter cases, the victim considered the bear to have been of medium size (number 5). The predominance of females with cubs observed in American grizzly bears has not been mirrored in our small sample size in Spain. Here, the females with cubs (1/8 cases) participated in the attacks at a very similar proportion to that at which they occur in the wild (a female bear with cubs / 8-12 bears: Servheen 1989). Nor was the attack by the female with cubs more violent than the others; indeed the victim suffered no injuries at all.

Photo 9. Sudden encounters constitute the principal cause of attacks. Here a female is present with cubs in dense vegetation, a combination of factors to avoid.

It is not clear in how many of the cases carrion or another food source was present. Attack number 3 occurred at a cereal feeding station, which the bear visited regularly, although maybe it did not attack for being disturbed while feeding, but rather for being cornered in a cave. In case 5, vultures were seen circling in the area shortly before the attack, suggesting that the bear was feeding at or was close to carrion, or – more probably, considering the time of day – denned for the day. In the case 6, food had been put out as a lure for photography, but it is unknown if the bear was associated with this.

In two of the attacks (numbers 3 and 7), a dog was involved. In the first case it is not clear if it had any role to play. The dog entered into the cave where the bear was present and fled immediately, but the game warden attacked was just outside inadvertently blocking the bear's escape route. Without a dog, the result may have been the same. However, in the second case the dog detected the bear and started barking repeatedly; when the owner went to see what was happening, he encountered the bear just 1 m away, which triggered the attack. In both cases involving dogs however, the person involved escaped almost practically unharmed.

In two incidents, two of the people shouted at the bears at short distance. In the first (case 8), the female, already disturbed during a hunt, had passed the hunter with-

out detecting them; when the hunter shouted, the bear attacked. In incident 5, the bear slightly changed course and jumped at the individual when they shouted to their colleagues to warn of the bear's presence, although it is difficult to know if the shout caused the attack to be directed at the victim.

All those attacked were men, and in seven of the eight cases were alone. In case 5, a group of three people were present and the bear only briefly attacked one of them. The people attacked were walkers (3), rangers of the regional administrations (2), two local people from the nearby villages and one hunter. The age of those attacked varied between 35 and 77 years old. In very general terms they represent a sample of the people typically present in bear areas and there was no bias towards age class or more vulnerable groups (women or children), which is normally observed in predation attacks. All of those attacked were off the forest paths tracks and paths. It is quite likely that bears shun areas close to these, at least to bed down for the day, perhaps conferring greater security for people walking them.

The geographic distribution of the attacks is biased, with many more in the Cantabrian Mountains (7) than in the Pyrenees (1), which is to be expected considering the number of bears in each (330/50 respectively in 2019 = 6.6:1) and that the Pyrenean one has been reintroduced. There is however, one result which is highly surprising: the concentration of attacks in the eastern subpopulation of the Cantabrian Mountains. This fact requires special attention to be paid to it.

The concentration of attacks in the eastern Cantabrian nucleus

As Blanco *et al.* (in press), highlighted, it is very significant that all of the attacks with physical contact have been in eastern nucleus of the Cantabrian Mountains (Figure 1), which is all the more surprising given that the number of bears there is 6 times lower than in the western subpopulation. The geographical pattern of attacks is significantly different from that expected at random (Chi-squared test, df = 1, with Yate's correction: 35.29; $p < 0.0001$), and the probability that these differences are random is minuscule.

It is important to note that the people attacked and the circumstances around these attacks are similar to those described in other studies undertaken in North America and Europe (Herrero 2002; Herrero & Higgins 1999, 2003; Quigley & Herrero 2005; Stoen *et al.* 2018, Smith & Herrero 2018; Bombieri *et al.* 2019), and we have been unable to detect a single characteristic that explains the concentration of attacks in the eastern nucleus. The same types of people undertaking the same activities (rangers, villagers, tourists and photographers walking through the forests) are found equally in the western nucleus, where no attacks have been registered over the same study period.

The accessibility and habitat characters may play a part in the bear attacks. Lamamy *et al.* (2019) compared the landscape characteristics of the two nuclei and their results are useful for our analysis. On one hand, the eastern subpopulation has a lower availability of rocky areas and cliffs, which may make it easier for human-bear encounters. In contrast, the human density (7.1 inhabitants/km^2) in the eastern nucleus is slightly lower than in the western one (11.0 inhabitants /km^2), and in the eastern nucleus there is a lower density of roads and paths, it is located at higher altitude and has more forest than the western one (Lamamy *et al.* 2019), which would reduce the possibility of encounters with bears. Taking these partly conflicting results into account, and that the differences in landscapes between the two subpopulations are very subtle, it seems very unlikely that this reason alone is responsible for the disproportionate difference in the attacks.

Among the attacking bears in the eastern subpopulation, there was a very big male (case 1), a medium sized individual (case 5) and a female with cubs (case 4), so eliminating the possibility of a single particularly aggressive individual. If we also reject the options of particular activities which provoke attacks, a higher human population and a greater proximity of bears to humans in the eastern nucleus, one plausible explanation is that this subpopulation harbours more aggressive individuals than the western one. Recently, Benazzo *et al.* (2017), taking into account popular belief and some observations on the peaceful behaviour of the bears in the Apennines (where no attacks on humans have been registered in the last century), studied the pattern of genetic divergence between the

Photo 10. All of the bear attacks in the Cantabrian Mountains have occurred when people were off paths and trails. In areas with a high bear density, it is important to keep out of the scrub.

Apennine bears and those in other areas of Europe in 22 genes associated with aggression. Interestingly, they found a significant enrichment for fixed differences in these genes, suggesting that genetic drift or the hunting of the most aggressive individuals may have produced a genetic change in the Apennine bears, reflected in their less aggressive behaviour.

As is well known, the Cantabrian brown bear population was divided into two at the beginning of the 20th century (Nores & Naves 1993), and the two nuclei remained genetically separate for almost a century (Gonzalez *et al.* 2016), with posterior persecution reducing the number of bears even further (Wiegand *et al.* 1998). In 2006, the population was still divided into two nuclei (eastern and western), with no genetic flow between them (Pérez *et al.* 2009), but this has now started to re-establish thanks to dispersing males (Gonzalez *et al.* 2016; Blanco *et al.* 2020). In consequence, a process similar to that described by Benazzo *et al.* (2017) in the Apennines may have caused genetic differences which affect bear behaviour in both Cantabrian bear subpopula-

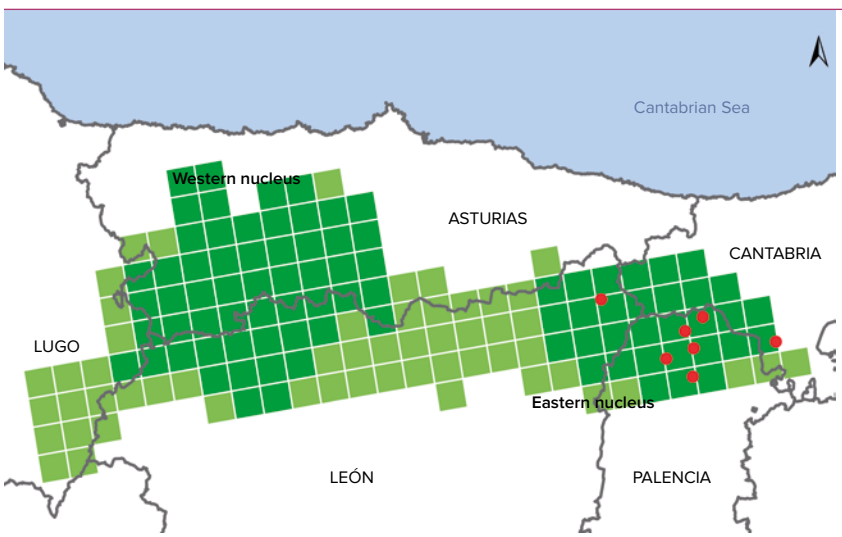

Figure 1. Location of the attacks on people (incidents with physical contact) in the Cantabrian Mountains between 1988 and 2020.

tions. The inbreeding which has characterised the two nuclei in the Cantabrian Mountains until very recently (Pérez *et al.* 2009; Gonzalez *et al.* 2016) may have modified some characters which were selected by chance, simply because the more aggressive individuals in the western nucleus were eliminated, but survived in the eastern one, with this characteristic later spreading throughout the nucleus. That selection deriving from hunting and human persecution can affect inheritable behavioural characteristics has been demonstrated in brown bears (Leclerc *et al.* 2019) and in other large mammals (Reimers *et al.* 2009; Ciuti *et al.* 2012; Lone *et al.* 2015), but in the absence of genetic analyses comparing the two Cantabrian subpopulations, this explanation continues to be speculative.

The simple fact is that the attacks on people in the Cantabrian Mountains have been disproportionately concentrated in the eastern subpopulation and this fact needs to be taken into account in the regulations governing protected areas and in the policies covering brown bear conservation in the Cantabrian Mountains.

Avoiding bear attacks

Summarising, the probability of suffering a bear attack in Spain is extremely small and to date there have been no deaths that we have been able to verify. As noted above, all of the attacks registered occurred in wild locations, well separated from humanised areas and were made by bears surprised at close quarters and which were probably bedded down for the day. Many of the incidents which we see as attacks were due to the reaction of frightened individuals which were simply trying to flee, following sudden encounters with man. Even in the most serious cases, the bears only bit or clawed their victims in the legs or arms, avoiding the terrible face or head injuries which characterise the bear attacks in Asia and North America (Smith & Herrero 2018). Whatever the case, that a really serious attack hasn't happened over the past few decades doesn't mean to say that it couldn't happen in the future. The population growth shown by Cantabrian bears and the ever-increasing use of the mountains for recreational, sporting and wildlife activities increases the probabilities of contact between bears and humans and, in consequence, the risk of attacks.

The best means of avoiding attacks is by avoiding risky situations, such as approaching bears to photograph them, or harassing them or letting our dogs do it, and much more so in the case of females with cubs or where they are feeding on carrion or other food. If walking in bear areas with fresh bear signs, it is sensible to avoid walking cross-country through dense vegetation where a bear may be bedded down. If this is unavoidable, it is convenient to talk or make noise at regular intervals to let any bears hear us and move away before a sudden encounter situation could arise. As we have said, in Spain there has never been an attack on someone walking on a forest track or path. Care needs to be taken in proximity to carrion, given that there could be a bear bedded down close by. If your dog finds and harasses a bear, it may end up being chased, and if it runs to seek safety with you, could bring the bear in pursuit. In all bear areas it is convenient (and a legal obligation in most protected reserves) to keep your dog on a lead. Otherwise, the steps to take to avoid attacks and how to behave during bear encounters have been explained in detail on numerous occasions (Blanco *et al.* 2019b).

Once again, it is important to remember that attacks by bears are extremely rare and that large carnivores constitute much more of a threat to our peace of mind than to the safety of those people that live in and use areas occupied by bears.

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CHAPTER 5.

THE PERCEPTION OF THE BEAR IN RURAL SOCIETY AND ITS PRESENCE IN THE PRESS

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SUMMARY

Under the scenario of population growth and range increase of the Cantabrian brown bear, the possibility of bear-human coexistence in the same territory, the compatibility of bears with certain activities, such as livestock farming, or the direct risk that bears pose to humans, are recurring questions in debates relating to its conservation and future. The population of brown bears in the Cantabrian Mountains, currently estimated at 330 individuals, persists in a landscape dominated by human activities. However, at the current time and in general terms, the Cantabrian brown bear is a positively valued species within its distribution range and despite such a close coexistence and the population increase noted over recent years, the fears or worries related to its presence are notably low amongst the rural human population. Indeed, the majority of the inhabitants of the Cantabrian Mountains consider that the presence of the brown bear is compatible with rural life (86.7% of 730 people surveyed). In a scenario where the number of interactions between bears and humans is predicted to increase in the future, working to maintain optimal acceptance towards the increasing presence of the species, in addition to monitoring changes in this acceptance level on the local scale, is key to consolidating its recovery and conservation.

THE CHALLENGE OF COEXISTENCE WITH AN INCREASING SPECIES

The brown bear population of the Cantabrian Mountains, currently estimated at around 330 individuals (see Chapter 2), persists in a landscape dominated by human activities. In areas with stable presence of the species, our bears share the territory with an average human population density of 11.0 and 7.1 inhabitants/km^2, in the western and eastern subpopulations, respectively (INE 2017). Although at first sight the Cantabrian bear population may seem like an exception, given its capacity to survive in humanised environments, in comparison to other European brown bear populations, we can see however, that it is not (Chapron *et al.* 2014). This is due to the brown bear's capacity for adaptation. In other regions of Europe with permanent presence of the species, the average human population density has been estimated at 19.0 inhabitants/km^2 (Chapron *et al.* 2014). Consequently, right across Europe we can find situations similar to those existing in the Cantabrian Mountains, or even regions where there are even higher densities of both bears and humans, such as in Rumania, Greece or Italy, to give a few examples (Bombieri *et al.* 2019).

The positive growth seen in the brown bear population in the Cantabrian Mountains (González et al. 2016), is undoubtedly excellent news, but raises new conservation challenges which are necessary to address to ensure consolidation of its recovery. This growth can be expected to lead to an increase in the number of interactions with people and their crop growing, livestock farming, touristic and other interests (see Chapter 3, and e.g., Fernández-Gil *et al.* 2016; Bautista *et al.* 2017; Planella *et al.* 2019). In fact, damage caused by bears to livestock, fruit trees and beehives were amongst the commonest themes of debate during the 18 talks of the "Living with Bears" program organised in 2017 by the Principality of Asturias in collaboration with the Brown Bear Foundation, held in different Asturian municipalities with bear presence. In addition to bear damage, the more than 400 people participating in these talks also highlighted other concerns such as the restrictions on public use deriving from the presence of the species in the region, their role

Photo 1. The brown bear persists in a humanized landscape in the Cantabrian Mountains, like this one in the Somiedo Natural Park (Asturias), where people undertake different activities such as livestock breeding, hunting or ecotourism.

in tourism development and the threat of poaching.

These debates with local inhabitants of the rural areas started by presenting both negative and positive aspects of coexistence with the species, quickly leading to more general questions such as the problems of rural life, or viability of livestock farming in the mountains, showing both the convergence and also confusion existing over the different social, economic and environmental factors which converge on rural environments. It is also important to emphasise the cases of bears approaching villages, occasionally generating worry amongst the residents, which is rapidly reflected in the press (e.g., Araujo 2016 *Diario de León*; Cuesta-Cifuentes 2018 *El Diario Montañés*), though fears over people safety, given bear presence close to villages, hardly arose during the aforementioned debates. Indeed, in other European regions, the suggestion has been made that fear of the brown bear is principally linked to what one imagines could happen during an encounter (Lescureux & Linnell 2010; Johansson *et al*. 2012a). People showing fear towards large carnivores also tend to be those showing greatest opposition towards their conservation and recovery (Johansson *et al.* 2012b).

In a scenario of population growth and range increase, such as that currently experienced by the brown bear in the Cantabrian Mountains (González *et al.* 2016), maintaining an acceptance level towards the increasing presence of the species is key to their conservation (Treves & Bruskotter 2014; Carter & Linnell 2016; López-Bao *et al.* 2017). This is particularly relevant in those areas where such charismatic species have been absent or at a very low density during the past few decades, leading to the abandonment by the local human population of those habits more favourable towards enabling coexistence with these species (López-Bao *et al.* 2017). This does not necessarily refer only to those large areas where the species disappeared decades ago, since the capacity of adaptation by humans to coexist with bears can change, even over very small spatial scales, e.g., between adjacent valleys. It is sometimes surprising to see the lack of knowledge existing in some areas of the Cantabrian Mountains with very recent bear presence, after years of absence, compared to the close level of coexistence and use of preventive measures to avoid damage which are applied to other areas with historic and continued presence of the species, just a few tens of kilometres away.

The possibility that bears and people coexist in the same territory, that the species is compatible with certain activities such as livestock farming, or the idea that the bear is a dangerous animal, are recurring questions that appear in the discussions provoked by the species' presence among multiple sectors of society with different values, perceptions and interests. Living with bears is not exempt from conflicts, and when sharing a territory with large carnivores, a degree of conflict is expected (Chapron & López-Bao 2016; López-Bao *et al.* 2017), either from the negative impacts associated from its presence (e.g., damage to apiculture) or from different opinions on how we should conserve and share the territory with them. Coexistence and conflict are consequently two very tightly interlinked terms (Chapron & López-Bao 2016; López-Bao *et al.* 2017), to the extent that, in many instances, an increase in the former depends on the reduction of the second. The adoption of preventive measures which minimise economic losses caused by the species, for example, is consequently a fundamental line of action to encourage the coexistence between bears and humans (e.g., Eklund et al. 2017). It is also necessary to understand other dimensions of this relationship, however, especially in respect to the degree of acceptance of the species by different sectors of society. This aspect is crucial to achieve optimal coexistence which will allow the bear to persist in the future (Chapron & López-Bao 2016).

Different values, perceptions, symbolisms or fears related to large carnivores can influence our attitude towards these species and their conservation. Even though the perception and attitude towards the brown bear tends to be better in Europe than towards other large carnivores, (Dressel *et al.* 2015), variations in the level of conflict associated with the possible costs deriving from coexistence can end up having influences on different human aspects of vital importance for the future of the brown bear in our territory. One of these aspects is the tolerance, not only to the presence of the species, but also to the increase in its population or the correct implementation of conservation and management measures, such as the response protocols to problem bears, or restrictions on land use (Planella *et al.* 2019). All of this combined will determine our predisposition to live with bears, which may manifest itself in different ways in favour of or in opposition to the presence of the species in the territory. Prioritising this coexistence is fundamental if we take into account that the appearance of conflicts between wild species and humans can lead to an increase in negative attitudes towards the former and, potentially, to an increase in negative behaviours for their conservation, such as poaching (e.g., Carter *et al.* 2017; Hazzah *et al.* 2017; Broekhius *et al.* 2018).

Photo 2. The brown bear is positively valued in the Cantabrian Mountains and its presence is considered compatible with rural life and development.

A CONSERVATION EMBLEM

Although the history of mankind offers a multitude of examples of how large carnivores symbolise socially prized qualities such as nobility, bravery or strength (e.g., Rockwell 1991; Berres *et al.* 2004), the relation between these species and humans has fundamentally been based on the persecution of the former by the latter, craving their eradication (López-Bao *et al.* 2017). According to the *Libro de la Montería* by Alphonso XI (1582), the brown bear was widely distributed across the Iberian Peninsula in the 14th and 15th centuries. Subsequently, and a result of the intense human persecution experienced, the species suffered a strong decline down to its historical minima in the middle of the 20th century (Nores & Naves 1993). From this moment onwards, the brown bear conservation efforts, centred on the fight against illegal persecution, habitat improvements and an increase in social acceptance, backed by the development of specific conservation legislation, has led us to the current scenario, where the brown bear has changed to become an emblem of conservation in the Cantabrian Mountains and an identity badge for the region.

Indeed, currently and in general terms, the Cantabrian brown bear is seen as a positively valued species throughout its Cantabrian distribution. This is reflected by the information obtained in different opinion polls carried out among local inhabitants over the last few years (since 2017) about the perception of the species in the rural environments occupied by the species in the Cantabrian Mountains. In response to the question, "Do you like the bear?", the majority (74.5%) of the 797 people interviewed since 2017 who replied to the question, indicated "a lot" or "very much", with an average value of 4 points out of 5, based on a Likert scale from 1 =

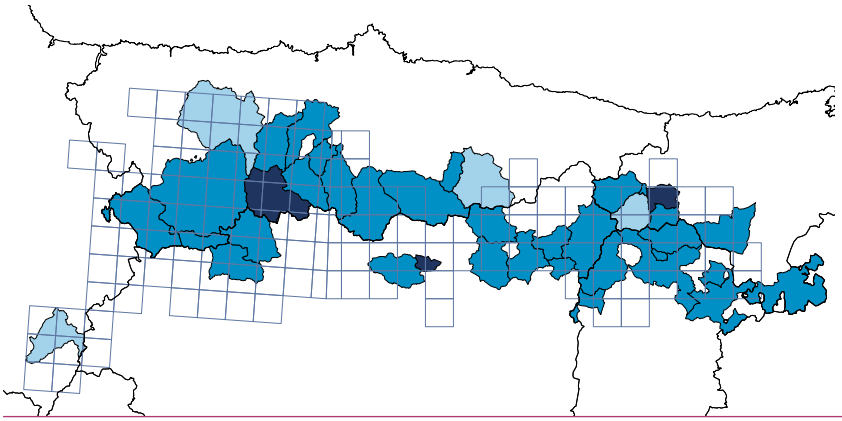


Figure 1. The brown bear is a valued species in the majority of the municipalities with more than five interviewees in the Cantabrian Mountains.

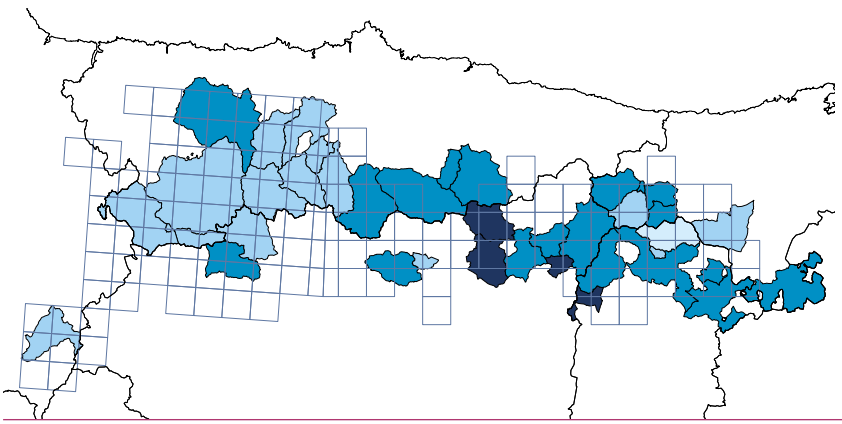


Figure 2. The fear of encountering a brown bear is low in the majority of the municipalities with more than five interviewees in the Cantabrian Mountains.

not at all to 5 = very much (Figure 1). Even in a subgroup of 91 people who had suffered some sort of bear damage to their farming or livestock rearing activities, the average value was 3.6 out of 5.0.

Despite such a tight coexistence scenario as that which exists in the Cantabrian Mountains, and of the increase in bear population over recent years, the levels of fear or worry related to bear presence are notably low amongst the rural population. In response to the question "The thought of encountering a bear frightens or worries you?" 39.6% of the 800 people responding to the question expressed either no, or very little fear of a bear encounter (Figure 2). The average value obtained was 3.0, based on a Likert scale from 1 = absolutely not, to 5 = very much, coinciding with the commonest response: "a bit" of fear of encountering a bear, this being slightly higher in value in those municipalities either in the eastern subpopulation or on the boundaries of the species' distribution (Figure 2). Indeed, for this group of interviewees, the fear of an encounter with a bear was considerably lower amongst those who had seen bears more times, in other words, those with greater experience of the species (negative significant correlation, $r_s = -0.33; P<0.001$) (Johansson *et al.* 2019).

In consonance with these principally positive perceptions towards the species, the majority of those inhabitants in rural areas in the Cantabrian Mountains considered that the presence of the brown bear is compatible with rural life. 86.7% of the 730 people answering the question *"Do you think that the presence of the brown bear is compatible with rural life?"*, replied positively, in other words, that they agreed that the presence of the brown bear is compatible with rural life. This perception was maintained even amongst those who had suffered some sort of bear-related damage, with 82% of these considering that the species is compatible with rural life. It should be emphasised that this acceptance varied between municipalities across the Cantabrian Mountains (Figure 3), indicating that it is necessary to study these general opinions in greater depth, beyond the possible differences between different social sectors (Dressel *et al.* 2015), also taking into account that the perceptions over a

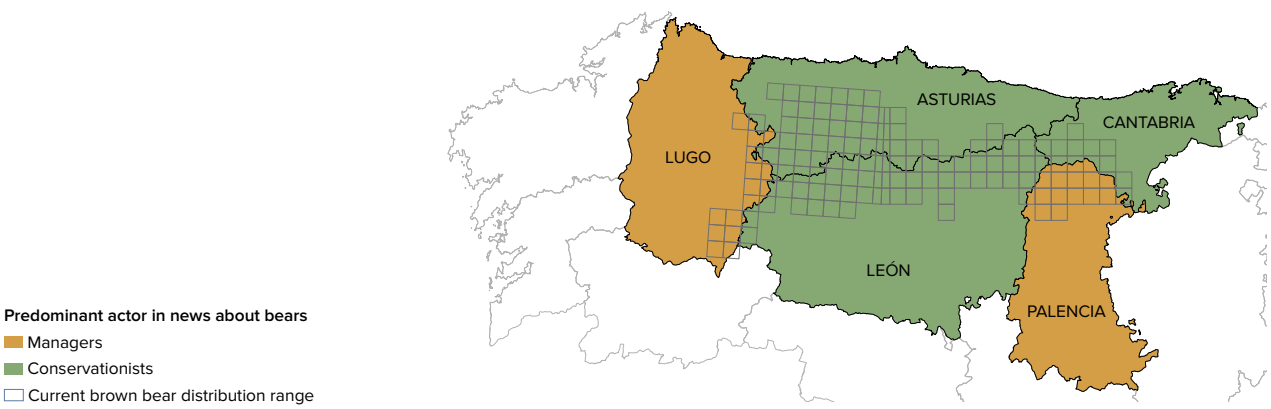
Photo 3. Female bears with cubs of the year have recieved a huge monitoring effort over the past three decades, and have attracted the attention of general public, probably becoming one of the most popular emblems representative of the brown bear conservation in the Cantabrian Mountains.

wide area can vary at the local scale within it (Piédallu *et al.* 2016).

However, this symbolism is not without its controversies and negative aspects, since the same species can represent diametrically opposed viewpoints for different sectors of society (López-Bao *et al.* 2017). See, for example, the symbolism associated with the wolf in the conservation sector (considered as an emblem of pristine nature on occasions) and the livestock rearing sector (where it is perceived as one of the principal threats for the viability of the business). Large carnivores are frequently used as symbols of division between different states of our society (e.g., rural versus urban worlds; between different sectors of society) (Wilson 1997, Skogen & Krange 2003, Figari & Skogen 2011), and it is possible to run the risk that these species are exploited both politically and in the press (Chapron & López-Bao 2014).

THE POPULATION GROWTH AS REFLECTED IN THE PRESS

Among the multiple factors that influence the perceptions that society holds on a particular species (e.g., social norms, knowledge, experience, information), the mass media stands out for its particular capacity to determine the frequency and content of environmental information that reaches the public (Stamm *et al.* 2000). To date however, it has not sufficiently captured the attention of the public in the areas of wildlife management and conservation, such as with large carnivores (Jacobson *et al.* 2011; Sakurai *et al.* 2013). The media has a huge capacity for influencing the public's perception of the environment and, in consequence, on how it should be managed (Siemer *et al.* 2007). Media coverage of wild species in general and of large carnivores in particular, is frequently biased towards the conflicts (Jacobson *et al.* 2011).



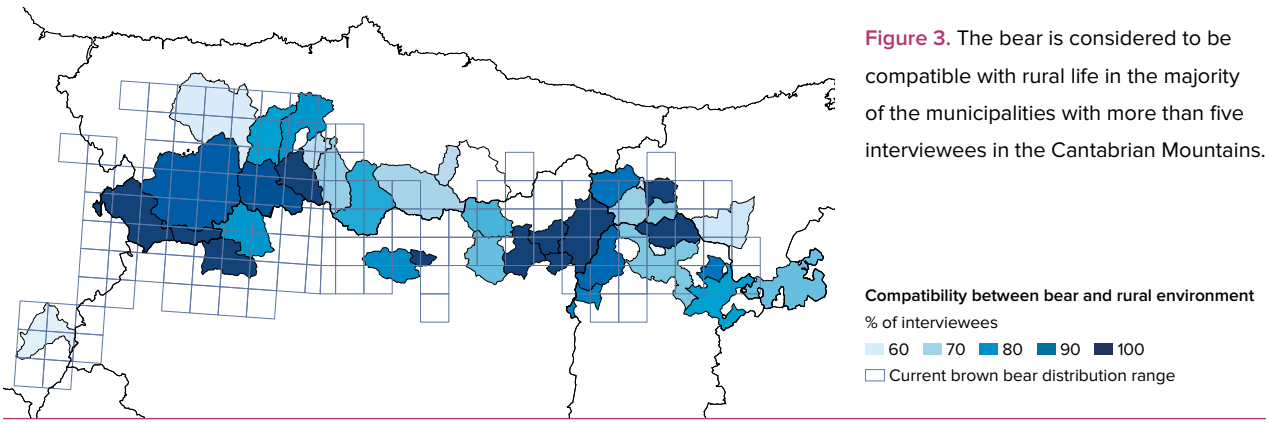


Figure 3. The bear is considered to be compatible with rural life in the majority of the municipalities with more than five interviewees in the Cantabrian Mountains.

This, in addition to contributing to exaggeration of the perception of the risk (Gore *et al.* 2005; Jacobson *et al.* 2011; Sakurai *et al.* 2013), may have multiple focal points, which influence or reflect the opinion of particular social groups with very specific interests, of the public in general or even specific political agendas (Price *et al.* 1997). The focus selected by the media, acting on perception, will consequently affect the comprehension and interpretation of a problem on behalf of the public and will influence it in its attitudes, perceptions and, potentially, its behaviour. Knowing how the media portrays a particular species is consequently very useful for knowing how to approach its conservation.

As such a charismatic species, it is no surprise that the conservation of the brown bear has not gone unnoticed by the media in the Cantabrian Mountains. Consequently, between 2007 and 2016, we collected data on how the main regional newspapers present in the brown bear distribution area have represented it within their pages. *La Nueva España*, *El Diario de León*, *La Voz de Galicia*, *El Diario Montañés* and *El Diario Palentino* have echoed news items related to the brown bear. The species was the principal focus in 78% of the 978 news items which mentioned the brown bear in the regional press. However, the interest generated by the species is not the same across its Cantabrian distribution area, with news items in Asturias predominating with an average of 75 bear-related stories a year. In contrast, *La Voz de Galicia* only included five news pieces a year about brown bears within its pages, which is logical if we take into account the very recent recolonisation by the species there.

In line with its delicate conservation status, which requires specific management and conservation activities, it is precisely these two sectors (conservationists and managers) which appear most frequently in those articles analysed in the Cantabrian Mountains press (Figure 4).

In Asturias, for example, conservationists are the most mentioned agents, appearing in 72.9% of the

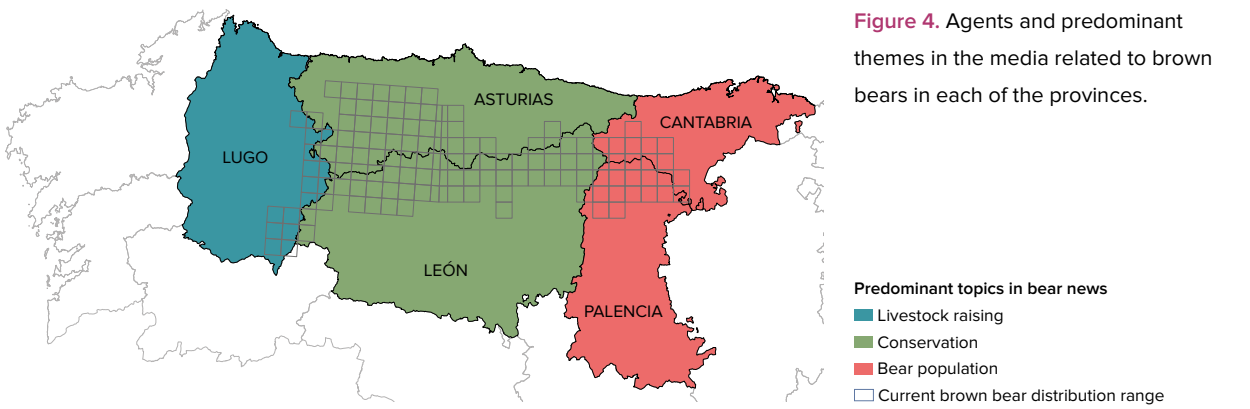


Figure 4. Agents and predominant themes in the media related to brown bears in each of the provinces.

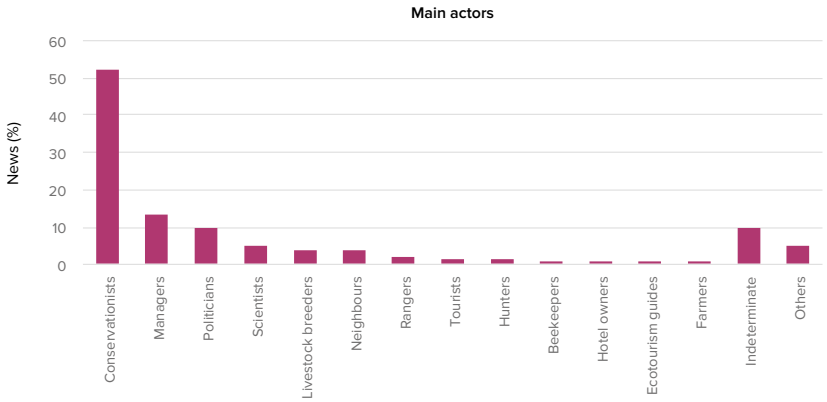


Figure 5. Percentage of news in *La Nueva España* in which each interest group is a principal actor in Asturias between 2007 and 2016.

news items analysed in *La Nueva España* between 2007 and 2016 (of 748 articles mentioning the brown bear, the species was the principal theme in 589), making declarations in 58.2% of the 317 news items in which they appeared. In addition, they were the principal focus of the article in 390 items (52.1%), far higher than the remaining agents, all of which were under 15% each (Figure 5). Conservation was the most frequently mentioned theme in Asturias in the news items of *La Nueva España*, followed by the bear population and management of the species (Figure 6).

Our studies reveal how the regional press reflects the necessity to conserve the brown bear in the Cantabrian Mountains. Consequently, news on the "conservation" and status of the "bear population" predominate in all provinces, except in Lugo. Here, the news items relating to beekeeping interests dominate the press's attention towards the brown bear. This difference may be due to Lugo being an area with a strong beekeeping tradition and of recent recolonisation by the species, and the presence of the bear in the region after a long period of absence is related more directly to the damage caused to beekeeping interests and towards the protection of beehives. There are practically no articles mentioning fear of bears nor of attacks on people.

Galicia is a good example of the change in media interest in the species in line with its growing presence in the region and the development of conservation projects which in turn make it into the news. The European LIFE Project Bear Courel coordinated by the Brown Bear Foundation, was initiated in 2016 to increase awareness and knowledge of local residents and stakeholders about the expansion of the bear population and increase support for bear conservation, immediately stimulating interest in the local and regional media of the bear's presence. In consequence, the best-selling newspaper in the

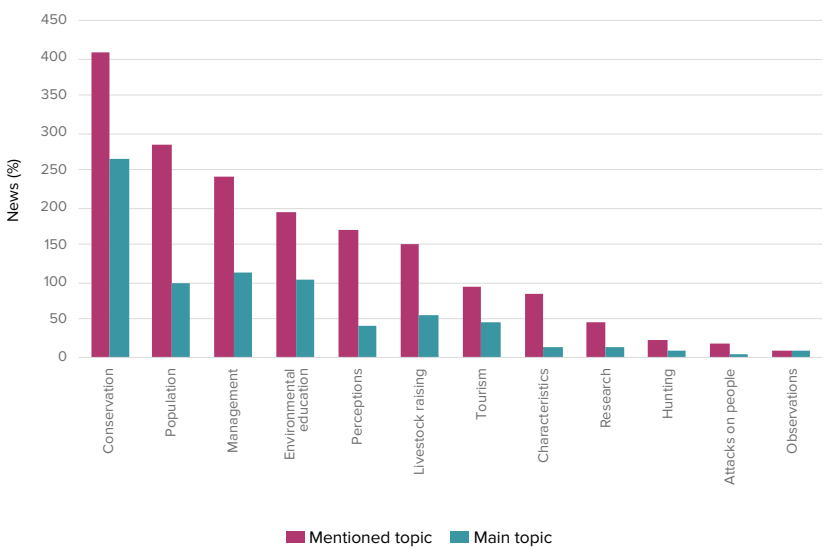


Figure 6. The number of news items in which different bear issues are mentioned and the number of news articles in which they were the main theme in Asturias between 2007 and 2016.

Photo 4. Brown bear conservation and the coexistence between bears and humans attracts media attention in the different provinces of the Cantabrian Mountains.

region (*La Voz de Galicia*) has gone from an average of five news items a year before 2016, to 50 news pieces either specifically about or with direct references to brown bears, between 2017 and October 2020, i.e., an average of 12.5 news items a year. 42% of these news pieces were generated directly either by actions made by or results from the LIFE Project, but more interesting is that 86% had a clearly positive focus, informing about the presence and conservation of the species, coexistence with human activities, or their role as a touristic resource. Only seven were about the damage done to beekeeping interests, even though the number of attacks in this period in the region were much more numerous. Many articles contained educational content, to explain methods of damage prevention or recommendations for good coexistence practices with the species. This interest has extended to other communication channels in Galicia, which have multiplied and spread news of the advances of the project across the entire region, making a marked contribution towards raising awareness and helping configure a positive social perception, which is so important in these situations of expansion into new territories.

INFORMATION AND DIALOGUE TO MAINTAIN PEACEFUL COEXISTENCE

The population increase of the brown bear in the Cantabrian Mountains supposes a change in the conservation challenges posed by the species in the future. The increase in interactions of a diverse nature between humans and bears could lead to impacting on the generally favourable scenario of coexistence currently enjoyed in the Cantabrian Mountains, where, as shown before, 86.7% of those

Photo 5. Giving information talks and leading discussions contribute towards maintaining good coexistence.

interviewed indicated that brown bear presence is compatible with rural life. In comparison, preliminary information obtained in the regions of Huesca and Navarra in the Pyrenees from 2018, shows a very different scene. Here, despite there being only around five bears in this area, the preliminary results from 74 people interviewed showed a more unfavourable coexistence scenario, where the percentage of those interviewed being in favour of compatibility between bear presence and rural life is 25 points lower, at 61.0%. Very locally, a spike of negative perceptions and attitudes can lead to unwanted situations. For example, the discovery in 2016 of a bear which had been shot dead in southwest Asturias (Ordóñez 2016, *La Nueva España*), is important to remember.

Many conflicts arise or grow due to a lack of information, as much about the status of the species and reasons for its presence, as of how to favour a coexistence scenario, or how bear presence can influence the development of human activities. In many cases this is accompanied by a setting of mistrust between the different actors implicated. Sometimes, the sectors most affected by damage caused by or from conflicts with large carnivores raise their voice through the media to seek communication and information, which frequently, is scarce or missing. A greater level of knowledge generally implies a more positive attitude (e.g., Glickman *et al.* 2011), which in addition may benefit from an adequate communication strategy. For example, giving informative talks has been proven as a means of reducing the perception of fear towards large carnivores (Johansson *et al.* 2017). With this in mind, it seems reasonable to undertake an information campaign similar to that made in Asturias in 2017, targeting the inhabitants of bear areas, but also to specific sectors implied in the coexistence with bears (farmers, beekeepers, hunters, tourism businessmen, sports and tourists or visitors to the countryside, etc.). A demand for information exists in these sectors and, in fact, from the talks made in Asturias in 2017, 93% of those surveyed responded that they would like to receive more information about bears. Some of the activities undertaken by the Brown Bear Foundation within the LIFE projects framework and based on visits by social actors in areas of bear conflict or with recent presence of bears to other areas with a higher degree of coexistence between humans and bears (e.g., Somiedo Natural Park, Asturias), where meetings to enable debate between the visiting and local sectors were made, have been very highly valued by the participants.

A society which is more informed about and involved in the prevention and resolution of conflicts will contribute to facilitate the hoped-for leadership needed in order to guarantee nature conservation and sustainable development in the 21st century.

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CHAPTER 6.

CONSERVATION OF THE BROWN BEAR AS AN ECONOMIC RESOURCE

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SUMMARY

This chapter describes the methodological bases used and presents novel economic information we have gathered in order to quantify the direct contribution that brown bears have on local economies and also to measure the current economic and occupational dependence of this resource on different activities and businesses. In contrast to previous studies, we have covered both the majority of the distribution range of the Cantabrian brown bear and considered that the influence of its presence goes beyond that exclusively linked to bear watching tourism. The survey covered 198 professionals (businesses) located in 32 municipalities of Asturias, León, Lugo, Palencia and Cantabria, all falling within the species' distribution and covering areas with different presence levels of the species (as measured by the number of females with cubs). The study reveals that the regular presence of the species (specifically, females with cubs) in a municipality and consequently its fame as a bear area is not, in itself, the only condition necessary for developing a local economy significantly dependent on brown bear presence. Among the results, of particular note is that 40% of the sampled businesses perceived that their clients and income are dependent to a varying degree on brown bear presence; specifically, businesses dedicated to "Services related to wildlife tourism and ecotourism" and "Facilities, environmental education and consultancy management services" are those with a higher probability of economic and workforce dependence on brown bear presence. Likewise, the brown bear is a productive resource contributing to generate or maintain job positions in those cases where more than 30% of the business's income is associated with its presence. In consequence, we estimate that for each one million euros invoiced by companies dependent on bear presence, 17 equivalent jobs have been directly created or maintained in the rural environment. Extrapolation of the sample results covering all of the activities objective of the study in the 26 bear municipalities analysed, shows that even under the most conservative scenario, brown bear presence generated 20 million euros in the rural economy, and in the direct creation or maintenance of the equivalent of 350 full-time equivalent jobs, the majority of these residents in the same locations as their businesses. For the future it will be crucial to establish a monitoring system, based on indicators, to follow the economic contribution of brown bears to the socioeconomic structure of their distribution area, in addition to broaden, determine in more detail and progressively refine this estimate of the Cantabrian brown bear's Total Economic Value (TEV).

INTRODUCTION

"Life itself as well as the entire human economy depends on goods and services provided by earth's natural systems" Gretchen Daily, *Nature's Services: Societal Dependence On Natural Ecosystems* (1997)

Even quite recently, the Cantabrian brown bear was hovering almost on the brink of extinction. Today, thanks to favourable policies and public and private conservation efforts, the situation is changing towards a much more encouraging panorama (Gonzalez *et al.* 2016). This recovery process has been mirrored by a change in social perception, towards one where it is considered to be a species capable of dynamizing the local economy in the mountainous areas it inhabits. This new perception is tightly linked to the development of a distinct tourism model, based on the promotion of a well conserved area and where wildlife observation tourism has consolidated as a complement to other more traditional activities.

The Cantabrian brown bear has been considered as a "flagship species" (Palomero 2011), being emblematic for its scarcity, its symbolic value and it attractiveness to the media, in addition to being an "umbrella species", with demanding requirements regarding the extent and quality of the habitats it requires to survive, such that its conservation directly contributes to that of other organisms and habitats (Barua 2011). Thanks to the brown bear, people acquire a greater general interest and engagement with the environment and its species. In this sense the brown bear has been proposed as the symbol – of considerable publicity value – to represent the brand quality of environmentally friendly products and services (Tattoni *et al.* 2016), without forgetting its ability to attract external resources which are locally invested in activities for the recovery and conservation of the species and its habitats. All of these factors consequently represent an opportunity for economic and social development of those mountain areas where the species is present and they may help to fight against rural depopulation.

Estimating the economic value of natural resources and ecosystem services enables us to obtain a measure of the social preferences and levels of well-being (benefits) which are reached while satisfying said preferences for the conservation of our natural heritage. Furthermore, precise assessment of the socioeconomic effect in the rural environment deriving from brown bear presence, considering it as a natural resource with an allowable degree of sustainable use, plus monitoring of this effect over time, constitute aspects of great interest, not only regarding management of the species and the activities that affect it, but also in gaining support from society in its conservation. Given the conservation challenges that large carnivores such as the brown bears in humanized environments present and the existence of conflicts between bears and human activities, it is necessary to add the positive aspects that the species affords to society and development into the balance.

This chapter presents the work methodology and the principal results obtained during a research project undertaken jointly by the Brown Bear Foundation and the Institute of Natural Resource and Land Planning (INDUROT, Oviedo University), with the objective of determining the socioeconomic influence of the Cantabrian brown bear on rural areas via the application of a methodology and territorial-sectorial approach which are novel in our field.

THE ECONOMIC VALUE OF PROTECTED FAUNA

Both the natural resources as well as their diversity have an economic value; this value may reside in the satisfaction that as individuals we obtain through the direct or indirect use of these resources, now, or in the future, or may come from a sense of social responsibility or awareness that all species have the right to live, or even simply from the satisfaction of considering them as a common asset that all generations have the right to know and enjoy.

The economic valuation of biodiversity, particularly of protected species, is a tool which enables us to put a value on a resource which, under the usual market mechanisms, would not figure (as result of the allocation of prices and quantities) (Pearce 2001). This type of analysis frequently demonstrates that the sustainable use of biodiversity produces a positive economic value and that this value may be higher than other alternative uses which threaten our biological resources (Cunningham *et al.* 2012; Honey

Table 1. Total economic value of the protected animal species and their habitats.

ECONOMIC VALUE TYPOLOGIES FOR PROTECTED SPECIES OF FAUNA				
USE VALUE			NON-USE VALUE	
DIRECT	INDIRECT	OPTION	BEQUEST	EXISTENCE
Non-extractive use and direct consumption	Functional benefits (ecosystemic)	Direct or indirect use in the future	Bequest for descendants and future generations	Ethical and moral values
Ecotourism and wildlife tourism	Self-preservation and species evolution	Species continuity	Habitat protection	Knowledge of the existence and continuity of the species
Exhibits in zoological parks and reserves	Knowledge and scientific research	Semen banks	Avoid irreversible changes	Habitat protection
Cultural activities	Gene bank	Emergency resource		Avoid irreversible changes
Audio-visual and bibliographic production	Indicator elements of the ecosystem state	New knowledge and scientific discoveries	Natural inheritance for future generations	Cultural, aesthetic, and ethnographic values associated with the species
	Control of the natural balance between species			Territorial symbolism and natural heritage

et al. 2016; Topelko & Dearden 2005; Wakamatsu *et al.* 2018).

Over the past few decades, with the objective of determining the economic value of resources such as protected species of wildlife, environmental economists have applied the concept of Total Economic Value (TEV) (Freeman et al. 2014). According to this framework, the goods and services supplied to humans by these resources are measured in economic terms during a fixed period of time, which allow us to improve our well-being. This well-being may be obtained by different usage (*Use values*) or from non-use or "*passive use*" (*Non-use values)* (Loomis & White 1996) (Table 1).

TEV = UsE value + NoN-Use value

Since the 1980s, studies oriented towards quantifying the non-use value of rare, threatened and endangered species have predominated, under the premise that this constitutes a large part, or even their complete, total economic value. In other words, without any form of extractive or consumptive use by humans, the satisfaction experienced by part of society knowing that the mere existence and preservation of the species is its principal source of economic value. However, this situation is neither applicable to all species nor remains stable over time. Empirical evidence shows that once a certain density or population size

Photo 1. A Cantabrian bear feeds on Alpine buckthorn (*Rhamnus alpina*) fruits.

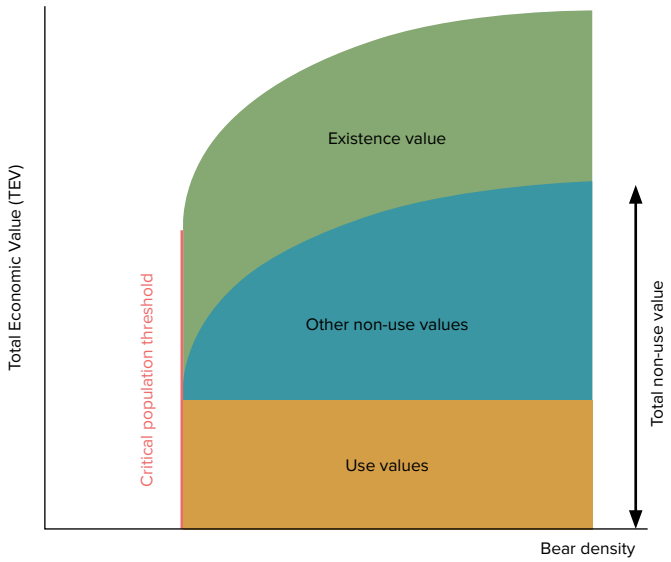

Figure 1. Schematic representation of the total economic value of a protected species such as the Cantabrian brown bear (Adapted from Fredman 1995).

threshold is reached, even in critical situations (risk of extinction), conservation and recovery efforts of protected species can start to generate use values (Fredman 1995) (Figure 1). Currently, the typical examples are the benefits generated in the sectors and activities related to ecotourism and wildlife tourism, through the exhibition of individuals in captivity or semi-captivity, via the provision of cultural services such as environmental education or the production of audio-visual and bibliographic materials. In this situation, as is currently the case for the Cantabrian brown bear, the species' TEV is the combination of its use and non-use values.

Economic evaluation examples

Different examples of economic valuation can be found in the scientific literature, mainly focused on use and non-use values of wild flora and fauna. In these studies, the most commonly technique employed is the so-called Contingent Valuation Method (CVM) (Carson *et al.* 1992; Kotchen & Reiling 2000; Kriström 1990). Using this method, estimates of the effects of specific actions on the well-being of the human population are made, based on the construction of a hypothetical market in which these individuals express their maximum willingness to pay or be compensated for undertaking a specific policy or action which has an impact on the natural resource.

For the Cantabrian brown bear, the most recent economic valuation study was carried out in 2010 using CVM (García de la Fuente *et al.* 2010). Amongst other results from that study, the finding that the non-use economic value of the Cantabrian brown bear in Asturias was higher than the greatest economic penalty considered within the legislation of the time stood out. In other words, that this latter quantity would not be sufficient to compensate the damage caused to Asturian society in the event of the bear's loss.

Other examples of economic valuation, although referring to other areas and with a different focus (away from estimates and types of public policies involved) can be found in studies on the Tibetan brown bear (South Korea) (Han & Lee 2008) and the American black bear (Honey *et al.* 2016). In the second case, a study of the different companies providing hunting services and tourism combined with interviews to the operators involved, concluded that bear-watching tourism had a greater economic impact than hunting.

Another research project in Japan (Kubo & Shoji 2016) used information resulting from different specific questionnaires to estimate the willingness of wildlife watchers and tourist to pay for services, finding evidence that brown bear watching could lead to a "win-win" situation between tourists and and local communities, i.e. it could lead to a mutually beneficial situation amongst all actors involved. Finally, an interesting approximation of the publicity value of the brown bear in terms of its economic contribution has recently been made in the Italian Alps (Tattoni *et al.* 2016), given that the species has suffered a drastic decline in acceptance by locals over the past few years following its increasing presence.

Previous studies of the direct use value of the brown bear in the cantabrian mountains

Recently, the Spanish government's Ministry of Agriculture and Fisheries, Food and Environment published a report entitled "Wildlife tourism in Spain" (MAPAMA 2017). This gathered together the results from a series of different projects promoted by the Ministry undertaken with the objective of characterizing wildlife or eco-tourism and in particular, the observation of large mammals such as the brown bear, grey wolf and Iberian lynx, estimating the benefits and socioeconomic impact of these activities in those areas where they occur. Among the principal results, a demand for brown bear observations by watchers was confirmed, which included both those contracting specialized services as well as those going independently. This totalled some 7200 people in 2016, with a direct economic impact of 0.63 M euros, which was mainly split between hotels, bars, restaurants and other activities. Furthermore, it was estimated that 12 jobs – 7 directly and 5 indirectly – were generated by these bear watching activities in the local labour market.

Photo 2. The observation of wild Cantabrian bears is a growing ecotourism phenomenon. Somiedo Natural Park (Asturias).

A new line of research

While the Ministry study represents a valuable precedent and an interesting reference of the direct use value of the brown bear, economic analyses should not be limited to "wildlife watching tourism" as the only source of income and jobs linked to species threatened with extinction (Catlin *et al.* 2013).

With the objective of quantifying a new reality, in which the brown bear has turned into an element capable of generating income (economic benefits) and direct jobs in those areas of presence, it is necessary to establish a methodology which can be applied both to the collection of socioeconomic data and its subsequent analysis, in addition to a monitoring mechanism using reliable indicators to permit calculations of trends in the economic contribution deriving from bear presence over time. Given this framework, the INDUROT, in collaboration with the Brown Bear Foundation, undertook a research in 2019 to answer a series of questions which had not been tackled to date: What role is the brown bear currently playing in the economic dynamization of the rural areas where it is present? What are the businesses and activities most favoured by the presence of the species? What methodologies, based on economic science and foundations, can be applied to quantify this reality? What indicators and monitoring protocols would be necessary to measure the capacity of brown bears to boost rural economies and how does this change over time?

In contrast to previous studies, this research project covered the entire distribution range of the Cantabrian brown bear and considered, in addition to wildlife watching tourism, its capacity to also attract other types of consumers and visitors that dynamize local businesses and that don't necessarily undertake "observation tourism", such as rural tourism, hiking and walking, outdoor sports and adventure activities, research and education activities, etc. The results can be considered as closely representing two of the non-extractive, direct use

Table 2. The economic activities and categories (strata) objective of this study.

ACTIVITIES	ACTIVITY STRATA	
Services linked to wildlife tourism and ecotourism	A	Services linked to wildlife tourism and ecotourism
VRIC management services	B	Facilities, environmental education and consultancy management services
Environmental consultancy and education services		
Services linked to adventure and sports tourism	C	Active tourism and accommodation
Traditional accommodation services		
Rural accommodation services		
Retail trade	D	Retail trade, food and beverage
Food and beverage		
Manufacture of artisanal and food products	E	Manufacturing companies and transport services
Transport services		

value typologies in Table 1: those associated with *Eco- and wildlife tourism* and also the *Exhibits in semi-captivity* (linked to the Valles del Oso and the bear enclosure in Proaza).

Note however, that these figures detailed in the following sections, only form part of the brown bear's TEV, as they do not include non-use values, nor other use benefits at the regional scale (e.g. those arising from audio-visual and bibliographic material production, the contribution of bears in making nature and landscape a quality brand of Asturias to support touristic services, and exports of food products outside the region, etc.).

HOW CAN WE ESTIMATE THE BEAR-RELATED VALUE GENERATED IN THE RURAL ECONOMIES OF THE CANTABRIAN MOUNTAINS?

Measuring the impact that the Cantabrian brown bear may be having in the economy of the rural areas where they are present requires paying special attention to those economic activities which at the local level are most closely linked to the presence of the species (Penteriani et al. 2017). Consequently, the objective population of this study was comprised of those economic agents present in the bear areas and susceptible to develop activities influenced positively and directly (to a greater or lesser degree) by brown bear presence. These activities were clustered into 5 main categories named *strata* (Table 2).

The data necessary to reach this estimate came from a specific survey carried out in the species' distribu-

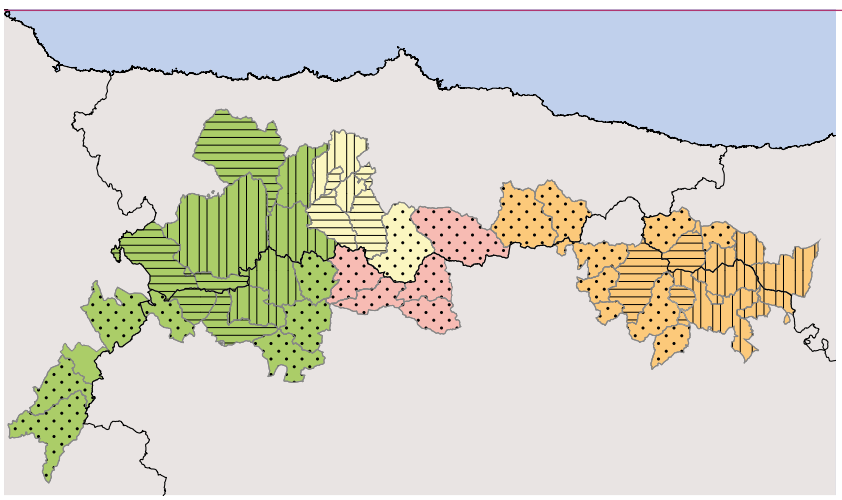

Figure 2. Municipalities studied in function of their sector and presence of female bears with cubs of the year.

tion area. Given that the Cantabrian brown bear has been separated in two isolated subpopulations for a considerable length of time, affecting the social perception of the species in each, combined with a central contact zone recently occupied by bears dispersing from both nuclei, (Gonzalez et al. 2016)1758 population of the Cantabrian Mountains (northwestern Spain, the study was divided into four large sectors (western, central, corridor and eastern), distributed across municipalities strung across the Autonomous Communities (Spanish regions) of Asturias, Galicia (Lugo), Castilla y León (León and Palencia) and Cantabria (Figure 2).

Given that this is a huge area with important variations in the presence and abundance of the species, the municipalities were classified according to their sector and the presence of females with cubs of the year in 2016. The index of bear presence was measured using the minimum number of different females with cubs in 2016 in each municipality. This defined two supra-sectors, Sector 1 (Central-Western Sector) and Sector 2 (Eastern Sector) – the municipalities in the Corridor were consequently excluded from the analysis – with three categories of municipalities identified depending on the level of presence of the species in each (Type 1: Municipalities with more than one female with cubs in 2016; Type 2: Municipalities with one female with cubs in 2016; Type 3: Municipalities within the area covered but without breeding females; for strategic reasons, various municipalities in Galicia and also Potes, in Cantabria, were included) (Figure 2).

Photo 3. The commercialisation of local products with a brown bear image as a symbol and quality brand.

Data collection

The data collection process needed to allow for the results to be representative of both the sectorial and territorial facets, such that errors in the estimations could be quantified and to achieve a balance between the effort involved (available resources) and the quality and quantity of information gathered. Two basic design criteria for data collection were consequently established:

1. *Territorial representativeness*: the survey was targeted at prioritising the 26 municipalities categorised as Types 1 and 2, given their consolidated brown bear presence.

2. *Sectorial representativeness*: the survey was as exhaustive as possible across all the activities dependent on bear presence.

In order to plan the data collection, to calculate the final survey effort and its distribution across the strata and bear distribution areas, official information on the number of businesses and establishments with dedicated activities objective of the study in municipalities with bears was compiled from regional statistical sources in 2018. In parallel, a pilot study was carried out in 15 municipalities with consolidated presence of the species and of females with cubs. This preliminary sample enabled us to estimate a series of statistics and create guidelines for the design of the final survey: the need to undertake exhaustive sampling (covering the entire population) covering all those businesses belonging to strata A and B (Table 2) located in bear municipalities classified as Types 1 and 2 (Services related to wildlife and ecotourism, VRIC management services, Consultancy and environmental education services) was determined. Similarly, the need to apply Bootstrap re-sampling techniques (Efron & Tibshirani 1998) was confirmed, in order to calculate the sample sizes necessary in the remaining strata

Photo 4. Local guides undertaking ecotourism activities in the Fuentes del Narcea, Degaña & Ibias Natural Park (Asturias). ©Quei Vitorino Experiencias Medioambientales

(C, D and E), given that the distribution of the principal economic parameter analysed (percentage of economic dependence on bear presence) showed a non-normal distribution. Thanks to these techniques, the definitive sample size in Types 1 and 2 bear municipalities was fixed at 190 questionnaires. In addition, it was considered of interest to gain results from a few extra questionnaires in some of the 24 municipalities catalogued as Type 3, above all in Galicia and Cantabria (Potes), raising the overall planned sampling effort to 200 questionnaires.

Questionnaire design

The mechanism for data collection was based on a carefully designed questionnaire. This anonymous and voluntary questionnaire recorded no personal data nor allowed for the identification of the business, focussing on, but not sticking exclusively, to the following topics:

1. General information about the business or activity: location (municipality), legal status, date of establishment, etc.

2. Link between income and customers of the activities undertaken and brown bear presence: here the respondent indicated the activity, turnover and/or number of clients in 2017 and the proportion of these which depend on brown bears.

3. Link between jobs generated by the activities undertaken and brown bear presence.

The percentage of dependence on brown bear presence aims to measure the economic influence of the species on the turnover and business's workforce, considering that this situation occurs when:

1. 1. The main objective pf the client is to observe brown bear during their visit.

2. The client hopes to see brown bears during their visit.

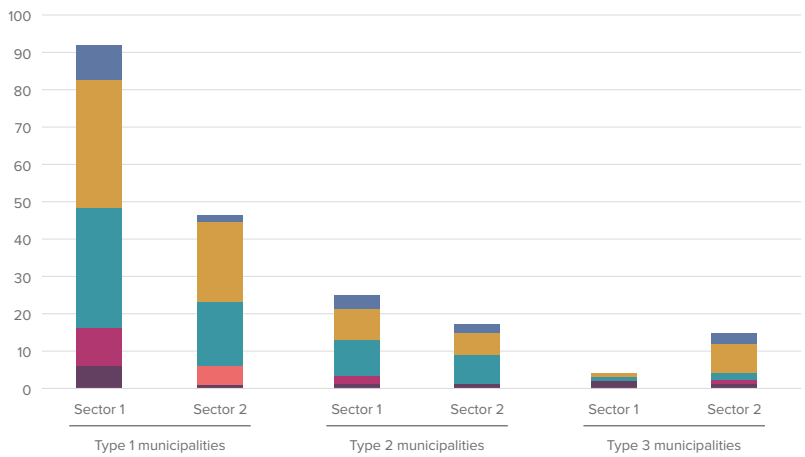

Figure 3. Number of valid questionnaires and their sectorial and territorial distribution. Sector 1 (Central-Western), Sector 2 (Eastern).

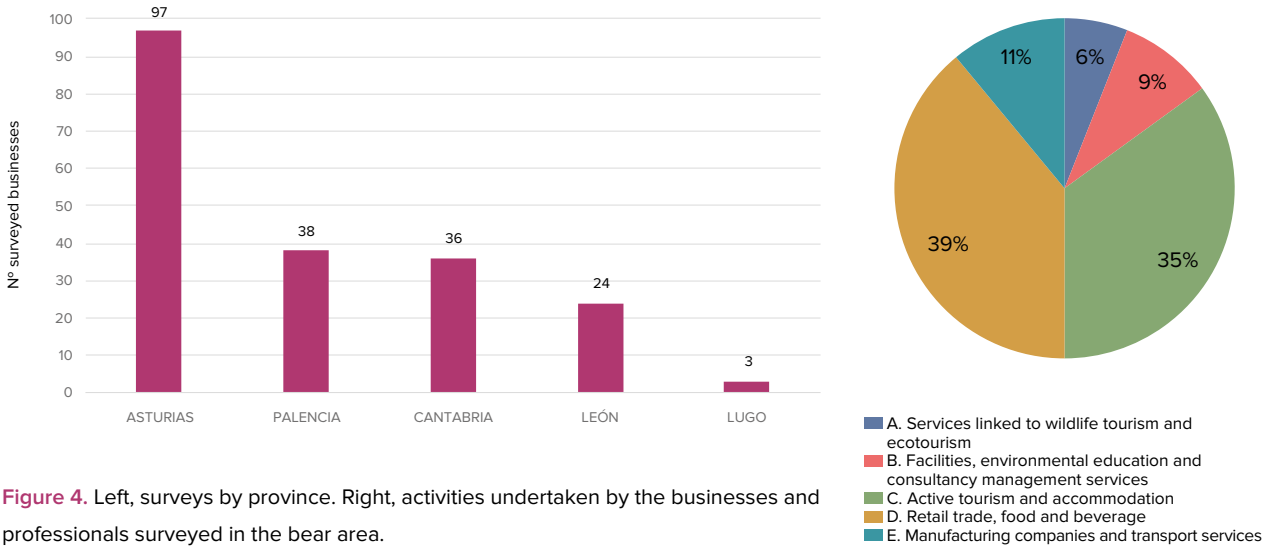

Figure 4. Left, surveys by province. Right, activities undertaken by the businesses and professionals surveyed in the bear area.

3. The choice of visiting the destination by the client was influenced by the way in which the business uses the brown bear in their name, brand or publicity.

4. The client chose the destination from amongst other options as they considered that the presence of bears awarded it a special attractiveness and natural value.

Data coverage and analysis techniques

Given the relative complexity and length of the questionnaires, plus the need to guarantee the reliability of the answers, the survey was undertaken via direct personal interviews with the owner, workers and other professionals of the businesses in the bear areas. These were made in random order by the interviewer within the selected localities, except in the case of certain rare activities undertaken by very few businesses, where the person in charge was contacted in advance by telephone.

A total of 198 valid interviews were undertaken in a total of 32 municipalities in Asturias, León, Lugo, Palencia and Cantabria, with the following sectorial and territorial division (Figure 3). In all cases, the businesses interviewed provided the proportion (percentage) of their income they estimated derived from brown bear presence, whereas only 56% revealed information relating to their annual turnover (112 businesses). Accommodation, food and beverage services (hotels, bars, restaurants, etc.) were the activities most represented in the sample (Figure 4).

Sample values concerning the business's dependence on brown bears indicated high variability and dispersion, in addition to a strong asymmetrical distribution. In part this can be attributed to the predominance of zeros, in other words, businesses that did not perceive any economic dependence on bear presence. In order to obtain representative and statistically robust results, techniques such as *bootstrap* (Efron & Tibshirani, 1998) and *score* were applied, which under these circumstances allow hypotheses and inference tests to be drawn about the parameters of interest.

ECONOMIC DEPENDENCE ON THE BROWN BEAR

The economic dependence of each business was given as a percentage value, as perceived by the respondent. In global terms, 40% of the businesses surveyed perceived that to some degree their income and customers were due to brown bear presence; within this group, 18% of these considered that they were highly dependent on it (with over 40% of their revenues related to the species), in other words, they considered that almost half of their income depended, at the time, on the brown bear. In contrast, the remainder of those surveyed (60%) considered that the impact of the brown bear on their activities was

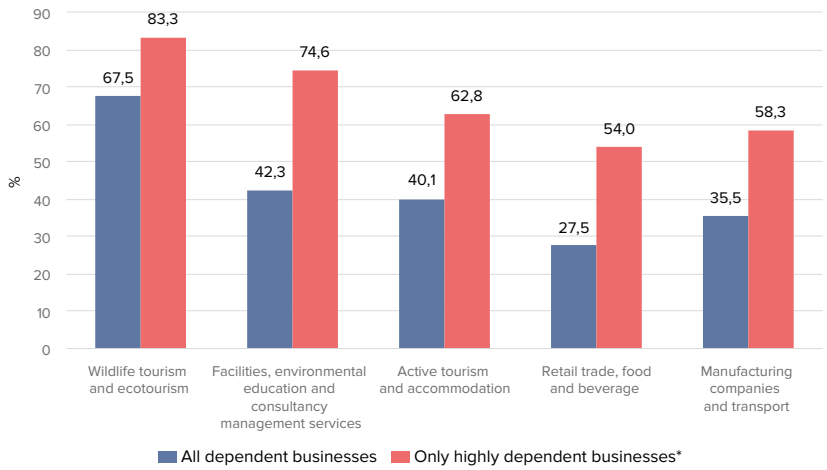

Figure 5. Economic dependence (%) on brown bears of those businesses dependent on its presence to some degree, by activity type; (*those businesses where over 40% of their income and clients are dependent on brown bear presence).

either zero, or practically zero (dependence values of 5% or less).

With regard to the activities undertaken, as could be expected, services related to wildlife tourism and ecotourism are the most heavily dependent on the presence of the species, with an average dependence of 68% of their turnover. In the case of retail trade and food and beverage services, a significantly lower dependence index is observed, with an average of 28% of their income (Figure 5).

Photos 5 and 6. Local revitalisation linked to the bear. “The bear houses” in Proaza and Somiedo (Asturias).

Results by regions

During the analysis of the probability of a business or activity being economically dependent on bears or not, certain differences were observed in relation to the sector in which the business was located, at the global scale. Whilst almost half of the businesses in the Central-Western sector showed a certain economic dependence, this reduced to 27% in the Eastern sector. Similarly, the probability of finding businesses with an activity heavily dependent on bears fell by 10 percent in the Eastern sector compared to the Central-Western sector.

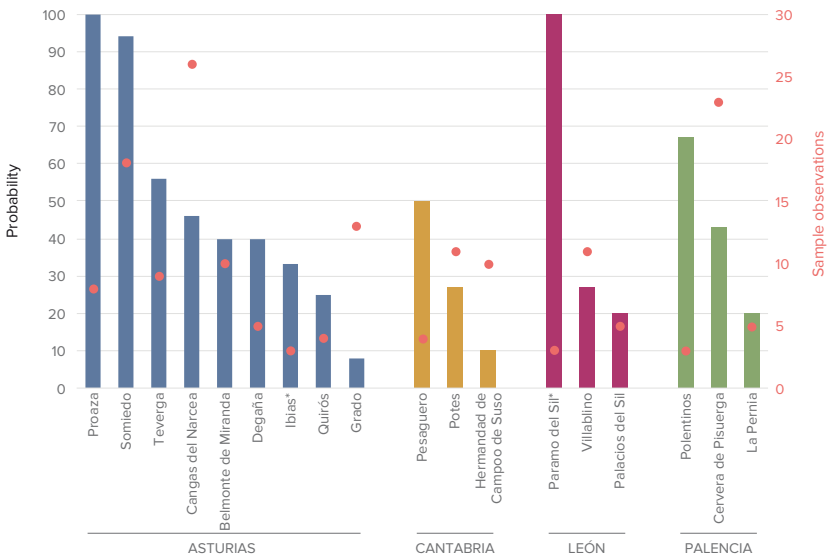

Figure 6. Probability that the businesses analysed, by municipality, are economically dependent on brown bears and their sample sizes (* insufficient sample size).

One aspect which appears to exert greater importance in whether a business has a higher probability of being dependent to some degree on brown bears is the existence of a consolidated bear population (presence of females with cubs). Consequently, a greater percentage of bear-dependent businesses were found in municipalities defined as Type 1, compared to Types 2 and 3, although this lower frequency of dependent businesses could also be influenced by the fact that Type 2, and especially Type 3 municipalities were less represented in the final sample (61 cases) than those in Type 1 (137 cases).

At the provincial level, as we noted before, the brown bear distribution range covered municipalities located in five different provinces. Asturias is the region with the highest probability of finding bear-dependent businesses, followed by Palencia, León and Cantabria; given an insufficient sample size, it was not possible to obtain consistent estimates for Lugo.

In general terms we can conclude that considering both bear-dependent and non-dependent businesses, the proportion of businesses whose income depends to some degree on bears is higher in the Central-Western sector, in municipalities with more than one female with cubs and in Asturias (53% of dependent businesses); the municipalities of Proaza and Somiedo stand out as those whose economies in 2017 showed the highest proportion of brown bear dependent businesses within the species' entire distribution range (Figure 6).

Within these differences of economic dependence among local entities, the adoption of the brown bear as a strategic resource is extremely important. This becomes evident when comparing the situation of municipalities such us Proaza or Somiedo, where the use of a bear logo has become the brand to differentiate their territories and businesses, compared to others such as Cangas del Narcea or Cervera de Pisuerga. All of them are excellent bear areas, but the local business network has opted for a different "use" of the brown bear as natural capital.

However, it is difficult to completely isolate the effect of the bear from the more general strategy of some territories which have made important efforts in steering their economic development towards their natural wealth. This is the case of Somiedo, one of the most emblematic natural areas in Asturias and where the Brown Bear Foundation maintains an information centre open for the public. Here it is extremely difficult to separate the local effect of it having been the first Natural Park declared in Asturias, from the growing impact that bears have had there over recent years.

Bear-watching viewpoints in the Fuentes del Narcea, Degaña & Ibias Natural Park (Asturias).

Bear-watching viewpoints in the Fuentes del Narcea, Degaña & Ibias Natural Park (Asturias).

Ultra-trail and marathon "desafiOSOmiedo" in the Somiedo Natural Park (Asturias).
©Edp desafiOSOmiedo.

The "Bear Trail" Green Route, in the bear valleys (Asturias).
©Asturias Bear Foundation.

PRC–P5 "Bear Trail" in the Montaña Palentina Natural Park (Palencia).

Photo 7. Examples of the use of the bear "brand" on trails, viewpoints and mountain roads.

In Proaza, where in 1996 a "Bear's House" (the headquarters of the Bear Foundation of Asturias, FOA) was inaugurated, the existence of a famous Bear Trail and the enclosure created to house the emblematic bears *Paca* y *Tola,* individuals which were impossible to reintroduce into the wild, are a clear reflection of the close and direct association between the species and local businesses.

Bear-related turnover

Once the percentages of dependence had been determined and using the data of the total turnover supplied by 112 of the businesses surveyed, it was possible to determine the total income attributable to bear presence according to the respondents. The final figure for the sample of businesses analysed in 2017 totalled 1,402,890 euros attributable to brown bear presence, representing 14% of the overall turnover (9,923,197 euros) of those businesses that provided this information.

In addition, given that we knew the approximate number of each type of business across the entire species' range (from statistical and administrative sources), the sample results of economic dependence and average turnover per activity stratum have been calculated to obtain an estimate for the entire bear distribution range studied, once again using *bootstrap* techniques. Thus, under the most conservative scenario for 2017 (based on the lowest confidence interval value of the percentage dependence per stratum), it was estimated that the brown bear contributed by generating 20.5 M

Table 3. Equivalence used to transform the different employment types into full-time equivalent employment.

	1 Year-round full-time work	1 Year-round part time work	1 Short-term (<1 year) full time work	1 Short-term (<1 year) part time work
FTE jobs	1	1/2	1/3	1/6

euros in income (between 10.6 and 30.5 M euros within the 95% confidence limits) in local businesses in the 26 bear municipalities analysed, thanks to the benefits derived from the positive image and capacity of attraction of the brown bear.

SOCIAL DEPENDENCE: CONTRIBUTION TO RURAL EMPLOYMENT

One indicator of the social impact that the protection of the species has within the species' distribution area is without doubt its contribution to local job creation. In order to determine this more precisely, it was necessary to exclude all those jobs, which although located within the species' distribution area and belonging to activities linked in some way to bears, are not dependent on it. Secondly, given the complexity of the local job market, all professional situations (salaried or self-employed, full-time or part-time jobs, annual or short-term contracts, etc.), had to be taken into account and standardised to a common measurement, the employment full-time equivalent (FTE), via the transformation figure in Table 3.

Combining all the businesses sampled (198) produced a total of 732 jobs in 2017, equivalent to 583 FTE jobs, with a clear predominance of year-round full time jobs (Figure 7).

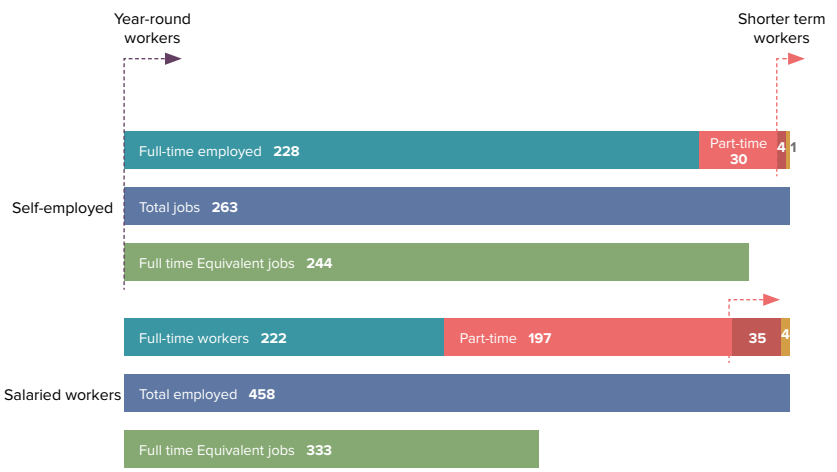

Figure 7. Jobs generated in the bear area, by type.

In order to determine the influence of bears on the creation of rural jobs it is necessary to link two factors noted before, the economic dependence (declared) and the workforce dependence (FTEs). This process showed that when the influence of the brown bear is moderate or low in the turnover (less than 30% of the turnover depends on the bear), the resource is insufficient to create jobs in itself, in other words, the businesses would maintain the same number of workers with or without presence of the species (Figure 8). In those cases where more than 30% of the income depends on the brown bear, jobs directly linked to the species started to be created, above all, and in a more direct manner in those businesses which offer "Services linked to wildlife tourism and ecotourism".

Jobs linked to bear presence

Analysing in detail the information provided by the businesses regarding the part of their workforce dependent on bears it was possible to conclude that in relative terms, 7% of the total employment existing in the activities and municipalities surveyed was due to bear presence, a figure in accordance with that shown by the MAPAMA (2017) study. In those businesses which indicated they showed at least some

Photo 8. The brown bear is a productive resource that contributes to the creation and maintenance of local employment in the Cantabrian Mountains.

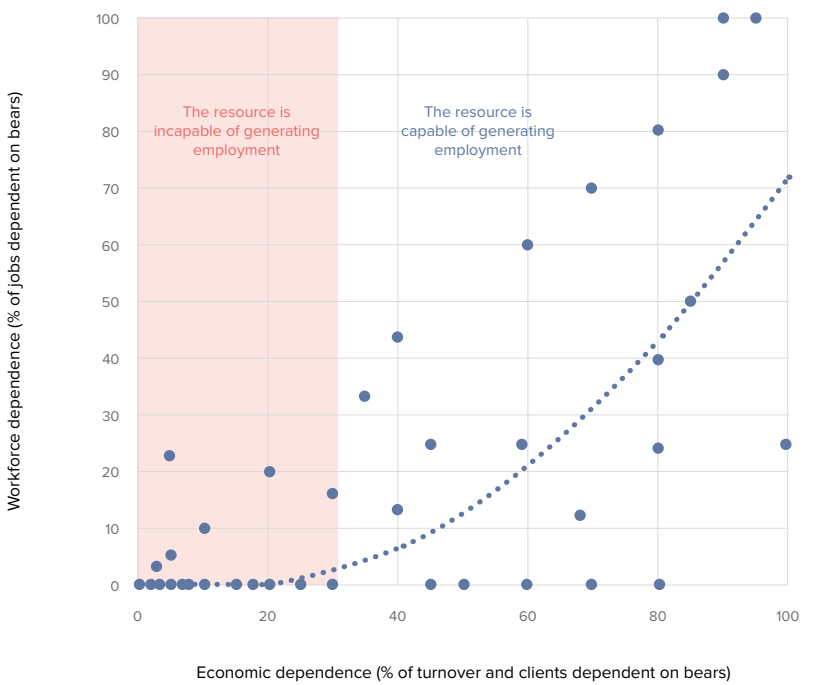

Figure 8. Relation between economic dependence and workforce dependence on the brown bear in the businesses sampled in the survey area.

economic and workforce dependence on the brown bear, an average of 48% of the jobs were explained by bear presence. Specifically, 41 FTE jobs were estimated as directly dependent on the brown bear in the study area (Figure 9), though with a different distribution among each of the activity strata, given that the greatest degree of workforce dependence is found among the activities in stratum A (in comparison with food and beverage services and retail trade, stratum D, where only 4% of the jobs depend on bear presence).

The analysis also revealed that the work linked to bears constitutes a source of employment for the local inhabitants in these rural areas; 62% of the net jobs created thanks

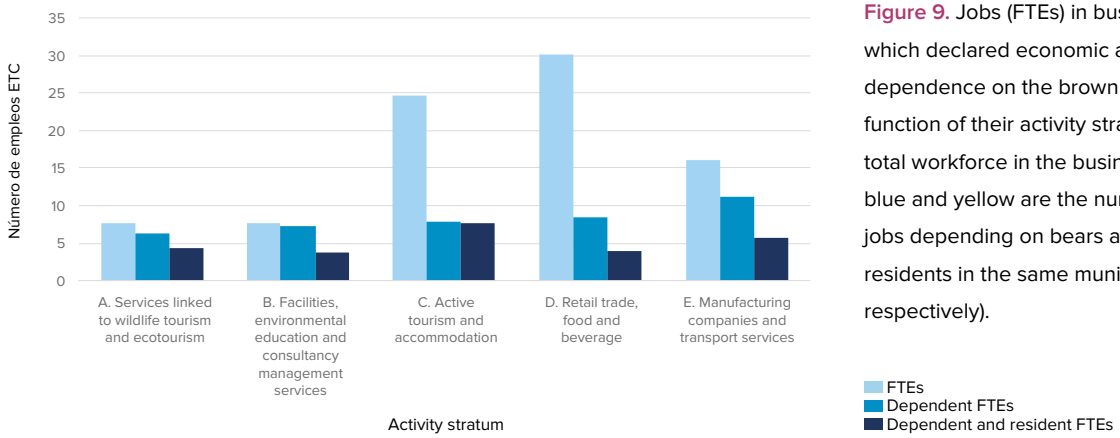

Figure 9. Jobs (FTEs) in businesses which declared economic and workforce dependence on the brown bear in function of their activity stratum (in green, total workforce in the businesses; in blue and yellow are the number of these jobs depending on bears and affecting residents in the same municipality, respectively).

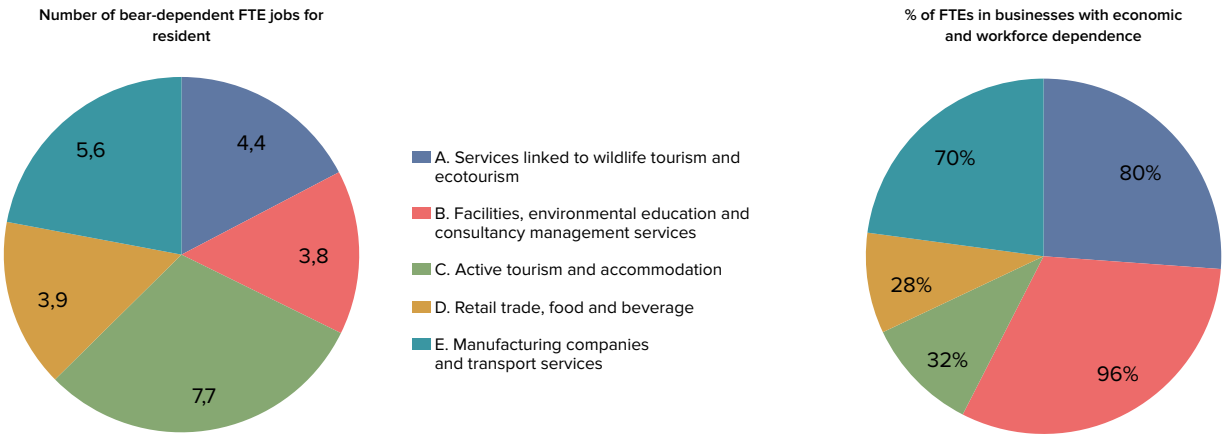

Figure 10. Capacity of the brown bear to create and sustain employment in the businesses sampled in the survey area, per activity strata.

to bears (25 of the 41 jobs) were occupied by people living in the same municipality as the business location, consequently having a positive social impact and helping to revert rural depopulation in these areas (Figure 10).

In the private sector (excluding the activity stratum B, which contains a high presence of public entities), the greatest capacity for bear presence to create employment is associated with "Wildlife tourism and ecotourism services". That said, although its capacity to create employment in retail trade and food and beverage services is far lower, the gross contribution in terms of total FTEs is highly significant, given the large number of establishments and volume of local employment concentrated in these activities.

On the basis of the results from economic and workforce dependence linked to bears in 2017 arising from the sample of businesses surveyed, it was concluded that in the case of businesses economically dependent on the species, for each million euros of turnover, 17 full-time jobs were created in the bear's distribution area. This ratio of FTEs/M euros is higher than that published by the Ministry in 2017 (11.1 FTEs/M euros of direct impact in 2016). Among the reasons for this difference are the consideration of what is understood by the "direct impact" of the bear in the economy (which in the present study has gone beyond that exclusively linked to observation

tourism) and also the greater coverage in both area and sample size in the present study. In addition, our multiplier refers to income or gross turnover of the businesses, which includes taxes and other concepts which should be deducted to reach a figure completely comparable to the Ministry study.

Finally, an estimate of the contribution given by bears to the total number of jobs created across the entire study area was made, by extrapolating the sample values to the universal study ambit. Consequently, again under the most conservative scenario, it was estimated that in the 26 bear municipalities analysed brown bears contributed to directly generate or support 350 FTE jobs (between 180 and 519 jobs with a 95% confidence interval) for the local economy.

Photo 9. The brown bear is an emblem in the Cantabrian Mountains. In the picture, fountain with a bear footprint in Cervera de Pisuerga, the villa that constitutes one of the main entrances to the Montaña Palentina Natural Park (Palencia).

FUTURE CHALLENGES

Over the past few years, changes in the perception of the presence of the brown bear in the rural world, the development of a tourism model based around the promotion of well-conserved territories, the use of the brown bear as a brand to represent the environmental quality of products and services, and public and private investment in natural protected areas motivated in large part by the presence of the species, have provided an opportunity for economic and social development in the mountainous areas within the species' distribution range.

The results presented in this chapter constitute a first step in the estimation of the use value of the brown bear, both within the framework of the biodiversity and protected species Total Economic Value (TEV), as well as a necessary advance in the capacity to monitor how the temporal economic contribution of the species evolves over time (in parallel with the species' much-needed demographic increase and the maintenance of efforts to conserve it). However, the results shown here do not include the indirect or induced effects of the brown bear on the local economies and in any case only gather part of the brown bear TEV, as they does not include non-use values or other use benefits which need to be quantified at the regional scale (deriving from audio-visual and bibliographic production, the contribution of bears to make nature and landscape a quality brand of Asturias that supports touristic services and exports of food products outside the region, etc.).

The need to establish monitoring indicators

The results show the economic and biological situation at a particular time (2017), but both the productive, as well as the sources of local economic development and the status and distribution of the species are dynamic over time, in addition to the interaction between all these dimensions, fruit of the coexistence between humans and bears. With the aim of following the temporal evolution of the economic contribution of the brown bear to the socioeconomic system and so making it easier to undertake adaptive management, both of the species itself as well as its relation with the productive sectors, it is necessary to establish a protocol for the systematic collection of data on a regular basis, allowing for the visualization of possible variations in the different parameters analysed and to antici-

pate social and economic dynamics linked to the species.

This monitoring could be based on three criteria:

- A data collection system which is uniform and consistent over time and across territories.
- Monitoring and analysis which allows for the detection of socioeconomic changes relating to Cantabrian brown bears over time.
- Monitoring and analysis which allows for the detection of inter-territorial differences associated with the "marginal benefit" or "positive effect of bears" of some bear areas compared to others within, or outside, their distribution area, but with similar territorial and socioeconomic characteristics.

From now on, the repetition of the socioeconomic survey, but paying more attention to covering the Type 3 municipalities and those in the bear corridor, at 4- to 5-year intervals, using the same established questionnaire and sample design, would provide a socioeconomic 'barometer' which would regularly quantify the impact of the brown bear in the rural areas of the Cantabrian mountains.

ACKNOWLEDGEMENTS

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CHAPTER 7.

CLIMATE CHANGE AND BROWN BEAR CONSERVATION

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SUMMARY

The current climate change scenario may produce different impacts on species, ranging from on their genes to their physiology and behaviour, and for all possible interactions between all these. As a result of global warming, the scientific literature suggests that the brown bear will be more active during the winter (spending less time hibernating) and that it will forage in more humanised areas. To what point these changes may influence its reproductive success, despite its phenotypic plasticity, is a question which needs to be addressed. Similarly, areas protected for the species may see a decline in their effectiveness, as the extent and quality of habitats adequate for the species reduce. Climate change is only considered as a threat in 11 of the 49 management or conservation documents covering the brown bear in the world. Of these, only two suggest management measures and neither of these provide indicators for these measures. Alterations in the bear's feeding pattern in the Cantabrian Mountains, related to climate change, have been observed over the past decades. Recent projections predict a drastic population reduction, caused by the loss of large areas of the distribution of various plant species key for their feeding and cover. However, the limitations of such models, the capacity of adaptation of the species, non-linear effects of climate change and the great uncertainty about these predicted effects should all be taken into account. Additionally, the brown bear was widely distributed across the Iberian Peninsula until a few centuries ago, even as far south as Huelva and Murcia. Beyond the important necessity of favouring the conservation and restoration of habitats, the ecological connectivity between them and their bear populations, management of the human factor as the principal threat to the conservation of the Cantabrian bear in a climate change context, is essential.

POSSIBLE IMPACTS OF CLIMATE CHANGE ON THE BROWN BEAR: A GLOBAL VIEW

Although numerous taxa and ecological processes will be affected by the current climate change process (Scheffers *et al.* 2016), some species have greater adaptive capacities. Those with greater mobility or higher reproductive rates and which survive on a wider range of resources, a priori, present a higher resilience to change (Foden *et al.* 2013). Accordingly, the brown bear, a species with a high dispersal capability and wide trophic niche (Garshelis 2009; Bojarska & Selva 2011; Martin *et al.* 2012), may have an advantage over other species in dealing with the impacts deriving from the current anthropogenic climate change. However, despite this phenotypic plasticity, within its distribution range it depends on some areas of certain species and habitats of high ecological value which are themselves threatened, not only by climate change, but by human activity as well. In some bear populations, the best feeding or hibernation sites are limited, or declining, or are even at risk of disappearing completely, such as in the Himalaya or Gobi Desert, given ongoing changes in the ranges of its habitats and the distribution and frequency of rains (Mukherjee *et al.* 2020; Qin et *al.* 2020).

The scientific literature relating to the possible impacts of climate change on different bear species is limited (Navarro & López-Bao, unpublished). Despite the low number of studies, it is known that changes in the climate have direct or indirect impacts on these species, both in the past and currently, and foreseeably, in the future. These studies are mainly related to the polar bear (*Ursus maritimus*) (e.g., Towns *et al.* 2009; Atwood *et al.* 2016; Boonstra *et al.* 2020), but also panda bear (*Ailuropoda melanoleuca*) (e.g., Li *et al.* 2015), American black bear (*U. americanus*) (Johnson *et al.* 2017) and the brown bear (*U. arctos*), both in the past (Albrecht *et al.* 2017), and at the current time (Evans *et al.* 2016). Few specific studies have looked at climate change effects on the brown bear to date (15 publications between 2007 and 2020), with three of these being specific to the Cantabrian Mountains (Rodríguez *et al.* 2007; Penteriani *et al.* 2019; González-Bernardo *et al.* 2020a). However, the possible impact of climate change on the brown bear has attracted the attention of academia across the wide geographic range of the species. These studies evaluate the possible relation of climate change with changes in hibernation patterns (Evans *et al.* 2016; Pigeon *et al.* 2016; Delgado *et al.* 2018; Bojarska *et al.* 2019; González-Bernardo *et al.* 2020a), changes in food resource availability (Rodríguez *et al.* 2007; Deacy *et al.* 2017; Hertel *et al.* 2017) and the indirect effects deriving from human activities, such as hunting (Bischof *et al.* 2017). Likewise, a group of studies makes projections using different models and climate change scenarios, centred on the future distribution ranges of the species and its habitats (Roberts *et al.* 2014; Su *et al.* 2018; Dai *et al.* 2019; Penteriani *et al.* 2019; Mukherjee *et al.* 2020; Qin *et al.* 2020).

Effects on hibernation and feeding

The phenomenon of hibernation extensively studied over the past few decades (e.g., Hellgren 1998), affects different species of bears unequally, and some indeed do not hibernate at all (e.g., *Tremarctos ornatus*, *Helarctos malayanus* and *Ailuropoda melanoleuca*). The brown bear hibernates facultatively, in other words, it only hibernates if not doing so supposes a greater adaptative cost. Not all brown bears will be obliged to hibernate, and non-hibernation has been described in the literature in various populations, including in historic times (Nores *et al.* 2010; van Gils *et al.* 2014; Krofel *et al.* 2017). For example, in the 14th century, Alfonso XI of Castilla described how female bears with cubs did not hibernate, in the book *Libro de la Montería* (Casariego 1976). In the Cantabrian Mountains several centuries later, we have estimated that the probability that a cub does not hibernate in its first year is higher than that it will (0.42 vs. 0.29; Planella *et al.* 2019), indicating that female bears with cubs of the year tend not to hibernate.

Brown bear hibernation appears to be conditioned primarily as much by biotic (availability of food resources) as by abiotic factors (meteorological conditions), and while the response varies between individuals (Krofel *et al.* 2017; González-Bernardo *et al.* 2020b), temperature appears to have a greater effect on hibernation than food availability (Pigeon *et al.* 2016; Johnson *et al.* 2017). Years with warmer winters are associated with bears both enter-

ing later into their dens and exiting them earlier (Evans *et al.* 2016). In Alberta, Canada, an increase in the average maximum monthly spring temperature resulted in an earlier exit from dens, while an increase in precipitation in the form of snow delayed it (Pigeon *et al.* 2016). Similarly, the thickness of the snow cover is negatively correlated with the probability of observing brown bears in winter in the eastern Polish Carpathians (Bojarska *et al.* 2019). The meteorological conditions closest to the den entry and exit dates are what appear to have greatest importance for hibernation duration (Delgado *et al.* 2018). Therefore, global warming will tend to push bears towards shorter hibernation periods, or to not hibernating at all (Pigeon *et al.* 2016; Evans *et al.* 2016; Johnson *et al.* 2017).

Food availability also affects entry into the den, with greater availability leading to a later start of hibernation. In Canada, the availability of blueberries (*Vaccinium* spp.) in autumn explained a large degree of the variation observed in the den entry date, with a higher availability of blueberries associated with a later entry (Pigeon *et al.* 2016). In a similar manner, supplementary feeding is related to an increase in the probability of seeing bears in winter in Poland. However, this effect could not be separated from the overall increase in bear numbers in the study area (Bojarska *et al.* 2019). A study carried out in Sweden showed that the natural bilberry (*V. myrtillus*) crop was shown to be conditioned by the weather, and that bilberries directly and positively affected the body mass and reproductive success of bears. Bilberry production was negatively affected by exceptionally cold winters, freezing conditions during the flowering period and by short and wet summers. When bilberries were scarcer, even with lingonberries (*V. vitis-idaea*) available as an alternative, the latter were not a substitute. However, when food resources in general were abundant, that is, above average in presence, the critical effect of bilberries disappeared (Hertel *et al.* 2017).

This mismatch between ecological processes due to climate change and

Photo 1. It is not uncommon to see female bears with cubs of the year active during the winter months in the Cantabrian Mountains.

its associated effects has frequently been documented via alterations in the phenology of species (Samplonius *et al.* 2020). However, the demographic consequences of trophic asynchrony are still poorly studied (Samplonius *et al.* 2020). The opposite phenomenon, in other words trophic synchrony resulting from climate change, has not been actively studied in practice. The response to the concurrence of two of its principal food sources in years with abnormally high spring temperatures has been studied in the Kodiak bear (*U. a. middendorffi*) (Deacy *et al.* 2017). These bears stopped eating sockeye salmon (*Oncorhynchus nerka*), if red-berried elder (*Sambucus racemosa*) fruits were available several weeks earlier than normal, coinciding with salmon spawning. The authors documented how the changes in food resource phenology induced by the climate can alter trophic networks via a mechanism different from trophic mismatch.

The influence of the climate and other local factors on brown bear feeding habits was analysed for a study spanning three decades in the Cantabrian Mountains (Rodríguez *et al.* 2007). The authors discovered a positive association between the temperature, which increased locally throughout the period of the study, and the consumption of cherries (*Prunus* spp.), with the higher the temperature, the greater the consumption of cherries. Additionally, they detected that the bears appeared to feed at lower altitudes. Consequently, these studies suggest that global warming generates changes in brown bear feeding behaviour via the modification of the distribution and phenology of the trophic resources. That said, the consequences on the bears' productivity are unknown.

Projections on bear habitat and distribution

Over the past few years, species distribution models have started to be used with the objective of predicting the possible spatial changes in habitats and species under different climate change scenarios. For the brown bear, this has been carried out in North America (Roberts *et al.* 2014), Europe (Penteriani *et al.* 2019) and especially in Asia (Su *et al.* 2018; Dai *et al.* 2019; Mukherjee *et al.* 2019; Quin *et al.* 2020). Although these had different focusses, modelling tools, emissions scenarios and time frames, in general these models indicated a negative tendency in relation to net habitat change and distribution of the brown bear. The main exception is a study undertaken in the southern Rocky Mountains in Canada (Roberts *et al.* 2014). This study evaluated the vulnerability resulting from climate change in the grizzly bear (*U. a. horribilis*), using the changes projected for the end of this century in 17 of its main vegetative food sources. While the great majority of the species were projected to maintain between 94% and 100% of their actual habitat, some would considerably reduce in range. These included Alpine sweetvetch (*Hedysarum alpinum*), a perennial plant with rhizomes which is a fundamental food source in spring and autumn when there is little else available. The potential habitat loss in three fruiting species of lower importance for bears was also identified. Additionally, all plant species showed altitudinal changes, generally showing a move to higher elevations. Apart from the apparent benefits indicated in the study (an increase in distribution range and species richness at high altitudes), the authors highlighted the limitations of the models which made the conclusions unreliable.

The principal limitations for species distribution models come determined by their assumptions and by those relevant aspects which are not included. For example, they suppose that the species is in balance with its surroundings and that they conserve their ecological niche over time. They also lack mechanisms for biotic interactions, and they do not include barriers to, nor limitations of, species' migration and colonisation processes (Roberts *et al.* 2014). In addition, input data suffers from location errors, sampling bias and the incorrect identification of species, which may reduce the usefulness of these studies in research and their subsequent use in conservation (Tang *et al.* 2020). In relation to the influence of climate change on the evolution of different habitats, it would be necessary to add in the progressive adaptation response of plant species under the new scenarios. Accordingly, some authors make the case for an adaptive response by the brown bear to climate change (Moritz & Agudo 2013), with the consequent alteration to its distribution niche (Madani *et al.* 2018), or to its occupation of new ecological niches under new environmental conditions (Dubuis *et al.* 2013), while others support an insufficient adaptation response to climate change over the past 30 years (Huang *et al.* 2019).

Whatever the case, the utility of these models is that they point towards aspects which need to be taken into account for biodiversity management and conservation. For example, in the study by Roberts *et al*. (2014), the possible significant reduction of an important food species in the brown bear diet during critical periods for the species (following den exit and during autumn fattening), and during periods of scarcity of other trophic resources.

The projections made in Asia predict reductions, from relatively moderate, to severe, in the available habitat and distribution of the brown bear by the middle of this century. Su *et al.* (2018) showed that in central Asia and in the Asian uplands, the habitat adequate for the brown bear (3 ssp: *Ursus arctos isabellinus*, *U. a. pruinosus* and *U. a. gobiensis*) may reduce by 11% compared with what is currently available. The changes in temperature and rainfall explained over 90% of this habitat reduction. The average annual temperature of brown bear habitats, spatially averaged for the region, is currently -1.2°C and it is predicted that it will increase to +1.6°C in 2050. Similarly, the average annual rainfall is predicted to increase by 13% (from 406 to 459 mm) around the middle of the century. Although a reduction of 11% in available brown bear habitat may not seem large, at the scale of this study it represents the loss of 375,000 km^2. With specific reference to protected areas, Dai *et al.* (2019) evaluated the suitability of the current and future habitat in the Sanjiangyuan National Park in China and identified potential climate refugia for Tibetan brown bears (*U. a. pruinosus*). The results indicated that 91% of the current potentially adequate habitat under the current climate scenario would be unsuitable by the 2050s decade. Looking at all of the protected areas in the Himalaya Range, Mukherjee *et al.* (2020) assessed the connectivity to predict the actual and future distributions and movements of the Himalayan brown bear (*U. a. isabellinus*) under different climate change scenarios for 2050, and their results pointed towards a massive reduction of approximately 73% compared to the current distribution.

An extremely small population of less than 50 brown bears (*U. a. gobiensis*) exists in the middle of the Gobi Desert in southwest Mongolia, within and surrounding the Great Gobi A Strictly Protected Area (Chadwick 2017). These bears persist in one of the driest and most inhospitable areas of the world, with temperature oscillations ranging from -40°C in winter to +45°C in summer. Qin *et al.* (2020) modelled how the distribution of the principal plant species in its diet would change under scenarios for 2050 and 2070, confirming that the variables associated with rainfall would have the strongest effect on the distribution of the selected plants. The results showed reductions and expansions among the different plant species over time and the general tendency was for a displacement of the habitat adequate for bears towards the southeast.

For the Cantabrian Mountains, Penteriani *et al.* (2019) modelled the effects of climate change on the brown bear based on the direct effects on seven plant species fundamental for its food and shelter: bilberry (*V. myrtillus*), European beech (*Fagus sylvatica*), sweet chestnut (*Castanea sativa*), pedunculate oak (*Quercus robur*), Pyrenean oak (*Q. pyrenaica*), sessile oak (*Q. petraea*) and Scots pine (*Pinus sylvestris*). The moderate and pessimistic emissions scenarios, RCP 4.5 and RCP 8.5 respectively, were used in the analyses, both for 2050 and for 2070. Considering the species contemplated above, the authors concluded that the Cantabrian bear would lose a considerable part of its current geographic distribution, which would be reduced to approximately a half in the moderate scenario, both in 2050 and 2070.

Effects on human activites which impact on the brown bear

The lower tendency for brown bears to hibernate as a consequence of climate change, or the fact that the hibernation periods are shorter, may lead to, amongst other effects, a higher risk of negative interactions and conflicts between bears and humans during the winter period. In countries where bears are hunted and where the long-term effects of hunting have been studied, it is expected that milder winters will expose bears for longer during the hunting season, as they will foreseeably hibernate less, or not at all. This may suppose an increase in the vulnerability of the species during this period of the year. In Sweden, climatic conditions affect the probability that a bear survives the au-

tumn hunting season (Bischof *et al.* 2017), such that males have a lower mortality risk during harder winters, which is attributed to their earlier entry into the hibernation den. In fact, in the den entry date study, male entry was correlated with the timing of the first snowfall and ambient temperature. Consequently, ever-shorter and warmer winters may extend the period during which bears are vulnerable to activities such as hunting.

With reference to the greater presence of active bears in winter, it is worth underlining the expected increase in recreational activities as a result of the socioeconomic changes in society, leading to greater levels of leisure activities and tourism and of the forecasts for a warmer climate, especially in winter (Scott 2006). Activities related to wildlife tourism and ecotourism have grown continuously over the past decades, being one of the tourist sectors with greatest growth and it is not free of impacts (Balmford *et al.* 2009; Balmford *et al.* 2015; Blumstein *et al.* 2017). More people during longer periods in forest and mountain areas and growing large carnivore populations, as in Europe (Chapron *et al.* 2014), imply an increased risk of negative interactions between humans and these species (Fortin *et al.* 2016; Penteriani *et al.* 2016a, 2016b; Bischof *et al.* 2017; Bombieri *et al.* 2019).

In accordance with the available evidence, global warming will favour that, in general, brown bears are more active in winter and given the impact of this phenomenon on certain food sources (it has been postulated that in some protected areas, the quantity and quality of habitats available for the species could reduce), they will feed in more humanised areas on occasions. All of this suggests that the vulnerability of the species to humans during the winter will be modified, combined with a possible increase in conflictive situations. To what point all these changes will have an important impact on the bear breeding success and survival, despite its phenotypic plasticity, is a question that needs to be answered.

THE INFLUENCE OF CLIMATE CHANGE ON THE CANTABRIAN BEAR'S MAIN FOOD RESOURCES

Given the increase in emissions of greenhouse gases (IPCC, 2007), the climate is considered as one of the principal external forces or drivers that pushes changes in ecosystems (Millennium Ecosystem Assessment 2005) and in the future it is expected to become the main driver for these changes (Bellard *et al.* 2012; Urban 2015; Willeit *et al.* 2019). The changes expected due to climate change seriously threaten several populations of plant species in the Iberian Peninsula, since the areas most vulnerable to climate change in Europe, after the Arctic, are the Mediterranean region and mountain areas. Temperature increases exceeding that in other areas are expected in both, with a rise of over 1.5°C, along with a reduction in average rainfall, which in accordance with the most pessimistic scenarios, could approach 30% in various Spanish regions (Amblar *et al*, 2017). These trends, matching observations made over the past few decades, would suppose a general increase in both evapotranspiration rates and the surface area considered arid.

Photo 2. The warmer temperatures will facilitate the access of tourists and visitors to the mountain in the fall and winter. Riaño and Mampodre Mountain Regional Park (León). ©Wildwatching Spain

The analysis of changes in rainfall over longer-term series collected in the Cantabrian Mountains shows changes in the magnitudes and frequencies registered in the different meteorological stations in the region (Amblar *et al.* 2017). The trends observed are unequal, but in some areas important declines have been registered since 1990 and there has been an apparent general change in the rainfall pattern. Thus, over the past few decades, the average annual rainfall peak has tended to come forward, now occurring more frequently in the autumn, with particular rainfall increases in September and October and to such a degree that over 200 mm may fall in some weather stations in the latter month alone. In parallel, a reduction in the maximum monthly and daily rainfalls in autumn and winter have been seen (Ortega & Morales 2015). An increase in the number of days with moderate rain in winter and the number of consecutive dry days in spring during 1986-2005, have also been highlighted, associated with greater persistence of anticyclonic systems (Bartolomeu *et al.* 2016). Regarding snowfall, a general decrease in the number of days with snowfall and the length of time this persists on the ground has been observed since 1990. The reduction in snowfall across all weather stations over the past two decades is over 20%. Additionally, a slight change in pattern can be seen during the past few decades with an increase in the number of days with snowfall in the spring. In addition, its presence in the summer season is increasingly scarce, with a drastic reduction seen in June and September (Ortega & Morales 2015).

According to a model of the *Hadley Centre for Climate Prediction and Research*, the predicted changes for the end of this century, compared to the current situation and using the scenarios of greenhouse gas emissions produced by the Intergovernmental Panel on Climate Change, will include a 15% drop in rainfall and an increase in temperatures of up to 4°C in the Cantabrian Mountains. Similarly, the scenarios of climate change in the high mountain regions of Spain predict that by 2040, the maximum winter temperatures will have increased by around 2°C and that this increase will be particularly important during November and March (Ortega & Morales 2015), such that, in all probability, this will contribute towards even lower snowfall.

Meteorological conditions and their irregularity have been associated with the interannual variation and synchronisation in the production of dry fruits of various tree species, fundamental food sources for brown bears during their pre-hibernation fattening phase or for passing the winter for those bears that either do not hibernate or only do so for a shorter time and with more interruptions. Local conditions, such as the substrate, microclimate, the availability of pollen or conditions favourable for pollination are related with the fruit crop of these species. Less evident and studied are the climatic effects at greater geographic and time scales. However, the interannual variation in fruiting of various species has been significantly linked to the indices of the North Atlantic Oscillation (NAO), which largely controls the climate of the Iberian Peninsula (Fernández-González *et al.* 2010). As a result, during negative phases of the NAO, which tend to coincide with warmer and drier springs, among other species, lower variation in the fruiting of European silver fir (*Abies alba*), European beech (*F. sylvatica*), sessile oak (*Q. petraea*), and pedunculate oak (*Q. robur*) was seen in 76 forests in Central Europe (Fernández-Martínez *et al.* 2016), several of these being important in the bear's diet (Naves *et al.* 2006; Bojarska & Selva 2011). Independently, more recent studies such as that by Dyderski *et al.* (2017) claim that under the scenarios predicted by the IPCC (2013), a drastic reduction in optimal areas of oak and beech dominated forests in the Cantabrian Mountains can be expected, which will lead to changes in bear diet.

Unlike other brown bear populations further north, which are dependent on fleshy fruits during the fattening phase, when bears lay down fat reserves for hibernation and in preparation for breeding (Bojarska & Selva 2011; Hertel *et al.* 2017), the bears in the Cantabrian Mountains depend principally on dry fruits (acorns, beech mast, sweet chestnuts, etc.) during the autumn and winter (Naves *et al.* 2006; Rodríguez *et al.* 2007). Additionally, the fruits of cherry trees form an important part of their diet, including an increase in importance of this food source observed over the past few decades and coinciding with the increase in temperatures in the Cantabrian Mountains, showing a trend towards a more Mediterranean diet, from a cooler and more boreal one (Rodríguez *et al.* 2007).

Chestnut

In general terms, the sweet chestnut (*C. sativa*) is favoured by summer rainfall exceeding 100 mm and annual rainfall of over 1,000 mm in the Atlantic-Cantabrian region (average of 1,200 mm, with some areas of the northern Cantabrian Mountain slopes reaching 2,000 mm). The minimum annual rainfall for survival varies between 600 and 800 mm, depending on its distribution and interaction with temperatures (Carneiro-Carvalho *et al.* 2020). The average annual temperature in optimal areas usually lies between 10 and 14ºC, with winter minima of between 0 and 5ºC and summer maxima between 18 and 31ºC (Cuenca Varela & Majada Guijo 2013). A few scientific papers have been published to date regarding the dependence of the sweet chestnut on climatic conditions (Pereira *et al.* 2011; Gomes-Laranjo *et al.* 2018 Pérez-Girón *et al.* 2020). In any case, the fruiting productivity of sweet chestnuts depends on several abiotic factors, in addition to their location, such as the variety, their age, height, substrate and exposure to the sun (Pereira *et al.* 2011), and is also conditioned by biotic factors such as pest infestations and diseases.

The onset of the chestnut harvesting season may vary by more than 20 days in response to cold or warm springs, and indeed, fruiting dates have advanced by more than a week over the past few decades (Gordo & Sanz 2009). For this reason, as a consequence of climate change, an increased crop is to be expected associated with a longer and warmer growing season and milder winters. Moreover, Pérez-Girón *et al.* (2019) tested the climatic influence on the Gross Primary Production (GPP), the Net Primary Production (NPP) and the Carbon Use Efficiency (CUE), in the sweet chestnut stands to determine the risk of loss of these ecosystems. The authors claim that under the most probable climate change scenario (RCP 2.6), with a predicted increase of up to 1.7°C in the annual mean temperature, the sweet chestnut forests in the NW of the peninsula will not only not see a threat to their viability (although long, very dry summers may lead to a declines or compromises in the sweet chestnut crop), but some sweet chestnut stands in the mountains with sufficient rainfall (especially in April and May) and soil humidity, could even see increases in their crop production, which typically requires an average annual temperature above 10°C for at least six months a year (Berrocal *et al.* 1997). Similar conclusions also derive from the studies of Roces-Díaz *et al.* (2018) and Krebs *et al.* (2019), in which they analyse the distribution of the sweet chestnut in Europe since the last ice age (approximately 21,000 years ago), and in particular during the specially warm period of the mid Holocene (6,000 years ago), confirming that if the current climate continues to warm to levels similar to this period, the sweet chestnut in the Cantabrian Mountains should be able to adapt with relative ease.

Sweet chestnuts are also attacked by a series of insects and pathogens which diminish its productivity, and in some cases can even compromise its survival. Among the more problematic pathogens affecting sweet chestnut groves in the Cantabrian Mountains at present are the "chestnut blight" fungus *Cryphonectria parasitica* and the "ink rot" fungus *Phytophthora cinnamomi*. Among the insects, the non-native chestnut gall wasp *Dryocosmus kuriphilus* attacks buds, so affecting both growth and flowering of the tree, via the formation of galls. Some of these problems, such as ink rot or gall wasp presence, may become worse in the future under a climate change context. For example, it is known that the distribution of *P. cinnamoni* is determined by the temperature, as its survival is limited in ranges with temperatures below 0ºC, and it needs optimal high temperatures for growth (Marçais 2018). In the long-term study (1982-2006) undertaken in N Portugal, Pereira *et al.* (2011) attributed the continuous decline in fruit production was due to ink rot and chestnut blight. Indeed, researchers from the Forest Research Centre in Lourizán (Pontevedra), expect problems of adaptation to drought conditions and an increase in ink rot, while sweet chestnut producers attending the International Meeting "Challenges in Plant Health in light of the future: European Legal Framework and Climate Change" celebrated in Valencia in 2018, affirmed that they expected an increase in incidence of ink rot and that it will increasingly occur at higher altitude. This puts the stands of native sweet chestnut at risk, given that they normally occur at higher altitudes than those in plantations. From the study published by Gil-Tapetado *et al.* (2020), it is possible to deduce that being an ectothermic insect, under a climate change scenario, *D. kuriphilus* will

Photo 3. Sweet chestnuts are a food resource during the autumn fattening period and over the winter months, and may increase in importance over the coming years.

increase its activity, favouring its propagation and overall density of individuals, which will undoubtedly impact on the production of fruits.

Furthermore, within the current distribution range of the Cantabrian bear, *D. kuriphilus* has been present in Asturias since 2014/2015. It was detected in spring 2017 in the area comprising the El Bierzo region of León, the eastern part of the province of Lugo and the northern part of León Province, even though it is very likely that it had been present since 2016. Being already present and widely distributed in these areas, efforts need to move directly to controlling the population to an acceptable damage threshold and given that other alternatives of control (chemicals, chromatic traps, etc.) are either not efficient or present environmental limitations, a chalcid wasp, *Torymus sinensis* is being used around the world, including in Spain, as a biological control agent. This parasitoid, also originating in China, shows close synchronisation with the *D. kuriphilus* lifecycle, parasitising its galls at an early stage in their development, resulting in a more efficient control than that produced by native parasitoids (e.g., Borowiec *et al.* 2018). For the moment, *T. sinensis* is still inefficient in controlling the gall wasp in NW Spain (Nieves-Aldrey *et al.* 2019), although it is expected that its populations will establish and start to grow in the short term, reducing the gall wasp populations in the medium term. As examples of similar cases, the number of buds with *D. kuriphilus* galls in France began to fall four years after parasitoid release (Borowiec *et al.* 2018), while in Italy it occurred after eight years (Quacchia *et al.* 2008). Additionally, the successful establishment of *T. sinensis* in the Basque Country and Navarra, where it has not been released, is probably the result of natural dispersion from the established populations in France (Nieves-Aldrey *et al.* 2019) and suggests that it may soon arrive naturally to the distribution area of the Cantabrian brown bear. An increase in temperatures would also favour the activity of this parasitoid (Gil-Tapetado *et al.* 2021).

Other plant health issues present and which may occasionally affect

the annual sweet chestnut crop are the ascomycete fungus *Mycosphaerella maculiformis* and the pear blight beetle *Xyleborus dispar*. The former causes the disease called "fersa" or "fog", which in the case of an early and intensive attack can cause the premature fall of the spiny fruits (MAPA 2018). The latter preferentially attacks young sweet chestnuts trees under stress (from drought, frost, poor soils, transplants, previous disease, having suffered mechanical damage, etc.), and can kill them. Consequently, this can be a problem in young plantations, especially during a process of climate change (Díez Casero 2015). We believe that special attention needs to be paid over the coming years to the impact of the endophytic fungus *Gnomoniopsis castanea,* which causes the so-called "nut rot" in the chestnuts (Lione *et al.* 2019). This fungus was only described for the first time in 2012 but is already categorised as the principal cause of nut rot in Europe, Asia and Oceania. If its role as an emerging pathogen is confirmed, it could end up eliminating a highly significant part of the annual sweet chestnut crop.

Deciduous, marcescent and evergreen oaks

In Spanish, the deciduous pedunculate (*Quercus robur*) and sessile oaks (*Q. petraea*) are known as 'genuine' or 'Atlantic' oaks, in contrast to the other species of marcescent and evergreen 'Mediterranean' oaks, such as the Pyrenean oak (*Q. pyrenaica)*, cork oak (*Q. suber*) or western holm oak (*Q. ilex rotundifolia).* In general, the Atlantic oaks reach their southwestern range limits in the Cantabrian Mountains and Atlantic coast, and in the case of the pedunculate oak, it reaches as far south as the Sierra de Sintra in Portugal (Fernández-Lopez *et al.* 2013). The Atlantic oaks need a climate with Atlantic tendencies with moderate soil humidity, and have the capacity to tolerate low winter temperatures, while in contrast, those species considered sub-Mediterranean or Mediterranean are characterised by a greater tolerance to water stress and summer drought (Sánchez de Dios *et al.* 2009; García & Jiménez 2009).

The evolutionary history throughout the Quaternary has determined that, in the face of drastic environmental changes, oaks have been able to develop adaptative mechanisms (Kramer 2010). In the middle Holocene, some 6,000 years ago and with temperatures some 0.5-2ºC warmer than now, the distribution area of the pedunculate oak was similar, or even greater than it is today, and has also remained quite stable since then (Vila-Viçosa *et al.* 2020). Recently, it was noted that both pedunculate and sessile oaks may be favoured by climate change in Europe, gaining, in conjunction, in their distribution range. However, in the south of Europe it is possible that a net loss in distribution range occurs (Dyderski *et al.* 2017), with habitat fragmentation maybe contributing to this factor (Kramer 2010). In the Cantabrian Mountains, where diverse niches occupied by different oak species with different evolutionary strategies converge and overlap, it is expected that the opportunities for hybridisation and introgression between species may increase (Kramer 2010). Regarding the Atlantic oaks, these may be benefitted by an increase in temperatures, in detriment to European beech cover, fundamentally due to their better adaptation and competitive capacity (Rubio-Cuadrado *et al.* 2018), and the marcescent and evergreen oaks will also be benefitted, enabling the establishment of these species in new areas, albeit taking into account the preferences that the Mediterranean oaks show for different substrate types (Villar-Salvador *et al.* 2013; Fernández-López *et al.* 2013, Lucas-Villar *et al.* 2013). Some areas are known, such as in Liébana (Cantabria), the Montaña Palentina (Palencia) or the Trubia and Somiedo Valleys (Asturias), where the acorns from western holm oaks currently form an important part of the diet of Cantabrian bears. Consequently, an increase in the presence of marcescent and evergreen oaks would constitute an increase in feeding opportunities for them. For both pedunculate and sessile oaks, the the predictions are that they will maintain their current distribution ranges, indeed with a 1% increase by the end of the century (Benito Garzón *et al.* 2008).

Temperature increases and variations in the rainfall patterns may reduce fruit production, expose these forests to greater and more intense forest fires, or to an increase in infestations or diseases. Oak forests can also suffer phytosanitary problems deriving from insects or fungi. Attacks by the chrysomelid beetle *Altica quercetorum* are frequent and responsible for important attacks on oak leaves, especially pedunculate and sessile oaks, leaving the trees with a much-reduced leaf cover, so inhibiting photosynthesis

and the production of reserves. This weakening may also predispose the trees to attacks by other pathogens (Fernández de Ana *et al.* 1996). Being a thermophilous insect, climate change may lead to an increase in occurrence in oak forests, both due to increased temperature as well as through a reduction in factors which are unfavourable for survival, such as rainfall or winter cold. Other insects which may also significantly affect oaks include three lepidoptera: winter moth *Operophtera brumata*, mottled umber *Erannis defoliaria* (Lombardero 1994) and scarce umber *Agriopis aurantiaria* (Pérez Otero *et al.* 2008). Drought periods, associated with climate change may increase the concentration of nitrogen in the leaves, making them more attractive to defoliators (White 1984). The buprestid beetle *Coroebus florentinus* is present in Atlantic and Mediterranean oak forests (Lombardero *et al.* 1996; Cárdenas *et al.* 2018) and can provoke a decrease in or complete failure of the acorn crop (Van Halder *et al.* 2002). Warmer conditions resulting from climate change processes may increase its populations and favour its expansion into areas where it is currently unusual or absent (Cárdenas & Gallardo 2013; Buse *et al.* 2013). Additionally, increases in the damage caused by species such as the green oak tortrix *Tortrix viridana* may be seen if climate change conditions lead to greater synchronisation between bud break and egg hatching, increasing the damage caused and impairing acorn production (Soria & Notario 1990). Finally, the chestnut weevil *Curculio elephas*, may also reduce the overall crop and quality of the acorns (Mansilla *et al.* 2003; Arias-LeClaire 2018). Pathogenic fungi are also present, such as the very common oak leaf powdery mildew *Erysiphe alphitoides* (=*Microsphaera alphitoides*) of Atlantic oaks. This pathogen, favoured by higher air humidity, repeated fine rain and temperatures from 10-20°C (Mansilla 1997; Mansilla *et al.* 1999), may find less favourable conditions due to the longer drier and warmer periods deriving from climate change, unlike the situation for most of the insects noted above.

European beech

The European beech (*Fagus sylvatica*) is a species which may be gravely threatened by climate change.

Photo 4. Western holm oak woodlands in Liébana (Cantabria), one of the areas in the Cantabrian Mountains in which holm oak acorns have been observed to be an important food source for the brown bear.

Photo 5. A brown bear feeding on oak acorns.

A long term study in Switzerland showed that extreme heat and droughts in summer led to the early failure in mast production, with average summer temperatures over 1.5°C and average rainfall 45% lower than normal observed in those forests with early abortion of mast production (Nussbaumer *et al.* 2020). This suggests that the average temperature, plus decrease in rainfall and increase in the frequency of extreme climatic phenomena in the Iberian Peninsula will greatly reduce beech mast production. At the same time, it has been observed that among saplings distributed over an altitudinal gradient, those at lower altitudes show greater phenotypic plasticity (Vitasse *et al.* 2013). This indicates that the saplings of lower altitudes may be more interesting as candidates for undertaking assisted migrations or for use in plantations for adaptation to climate change.

Forests of European beech will be severely harmed according to the predictions, with an up to 97% loss compared to the current distribution range. In the Iberian Peninsula it is predicted that they will only maintain some 4% of their current area and only gain an extra 4% in new areas as we approach 2080 (Benito-Garzón *et al.* 2008). Other studies consider that there will be similar range losses (c. 90%) due to increasing aridity and that the Pyrenees will be an important refuge area for the species given climate change. The greatest losses will be in the lowest areas and in the Cantabrian Mountains, while it will remain stable in the majority of the Pyrenees, except in westernmost parts, where greatest losses will occur (Serra-Díaz *et al.* 2012). A recent study modelling its future distribution in the Cantabrian Mountains based on two emissions scenarios predicts that it will reduce drastically by 2070, with losses of 40 to 90% based on moderate and pessimistic scenarios, respectively. However, these projections do not imply the elimination of the current population, but probably should be interpreted as producing less favourable conditions for the establishment of new saplings, plus invoking higher mortality rates and local reductions in population density (Castaño-Santamaría *et al.* 2019). In this sense, a study of the competitive relation between European beech and sessile oak in the Picos de Europa suggests that the competitive advantage of the former over the latter will decrease as the temperature gradually increases over the course of this century, due to climate change, as has already been observed since the 1960s. This interaction will develop in a progressive and discontinuous way, given the slow development and long life-spans of both species and the heterogeneity of the territory (Rubio-Cuadrado *et al.* 2018). In general, a reduction in growth rate of the European beech is expected (Jump *et al.* 2006), and that it will be both displaced in altitude, as has already been seen in the northeast of the peninsula (Peñuelas & Boada 2003), and towards the north.

Fleshy-fruited species

The diet of Cantabrian bears is characterised by the importance of dry fruits, especially during autumn fattening and winter, although the fleshy fruits of various other plant species are highly relevant, especially in summer and autumn. Little information is generally available on the likely effects of climate change on these fleshy-fruited species, however.

Wild cherry (*Prunus avium*) is of great importance in the summer

diet of Cantabrian bears. It is a species of mild climates and in which aspects such as bud burst, flowering, seed germination and dormancy are controlled by the temperature (Ducci *et al.* 2013). Its flowering period has come forward significantly over the last few decades, especially in C Europe. While a longer period of activity may increase overall growth in the trees (Hemery *et al.* 2009), the lack of temperatures low enough that are necessary in winter may reduce the size of its flowers. The majority of species in the genus *Prunus* exhibit a double mechanism for the control of induction of the dormancy period, ensuring the correct onset of dormancy in the autumn, facilitating their adaptation to avoid the negative effects of global warming on the development of buds in winter. Wild cherry is an exception to this, however, which maintains growth during the shorter winter days with intermediate temperatures, only stopping when low temperatures are experienced. This behaviour could affect the normal development of buds in winter and produce delays or erratic opening of these in spring (Hemery *et al.* 2009). The wild cherry is also unable to support frequent or severe drought, which may induce water stress or even mortality, and increase susceptibility to pathogens, though this is not expected in general in the north of the Iberian Peninsula. This said, some studies consider that wild cherry is highly appropriate for planting in dry or very dry areas (Grundmann & Roloff 2009). The species requires cold temperatures for germination, but significant exposure to high temperatures can induce secondary dormancy which cancels out the previous effects of and cold treatment. Therefore, warmer winters can influence the sexual reproduction of the wild cherry, although studies have shown that it can en-

Photo 6. Bears in the Cantabrian Mountains use beech and oak forests for cover as they forage for beech mast and acorns during the autumn fattening period.

sure development even at high temperatures, permitting a greater capacity to respond to environmental changes (Hemery *et al.* 2009).

The distribution range of the wild cherry may shift from north to northeast, as is predicted in general for flat-leaved trees. It is quite likely that the competition with other species will increase and it will probably have fewer favourable areas available for development. However, it is a pioneer species capable of rapidly colonizing clearings by seed or shoots suckering from its roots and it possesses a high genetic variability, such that it is probably able to migrate satisfactorily in the face of different climate change scenarios (Hemery *et al.* 2009).

Other fruiting trees include the whitebeam (*Sorbus aria*), highly prized by the brown bear, and the rowan (*Sorbus aucuparia*), of much lower trophic interest for the Cantabrian bear. These species are going to be affected by climate change, although they exhibit photoperiod dormancy regulation, an advantage for the opportunistic synchronisation of plant development under seasonal changes in the environment. Studies in Norway have demonstrated that the rowan may enter into dormancy even during climatic anomalies of 5-8°C above normal (Heide 1993). The greatest risk lies in that with a prolongation of the growing period, the chances of suffering damage from late spring frosts increases. In both whitebeam and rowan, an increase in growing season is noted given the increase in temperature, given that it stimulates earlier bud burst (Vitasse *et al.* 2013).

Bilberry (*V. myrtillus*) has been an important species in the diet of the bears in the Cantabrian Mountains, but its contribution appears to have declined over the past few years (Rodríguez *et al.* 2007). The formerly regular observations of bears feeding in extensive bilberry stands above the treeline in late summer have declined considerably and indeed, are currently infrequent given the scarcity and irregularity of crops of this fruit, which are affected by late spring frosts as a consequence

Photo 7. The extensive bilberry stands above the treeline in the Cantabrian Mountains will be negatively affected by climate change and consequently will decline in importance as a food source for the brown bear.

of their earlier growth activity and the lack of protective snow cover. Long term studies (>40 years) in N Europe, in natural or almost unaltered habitats, indicate the absence of an inherent annual cycle in the production of flowers and fruits and show a complex response of fruiting success which is related to environmental stresses, climate, pollinizer activity and predation (Boulanger-Lapointe *et al.* 2017). In these studies, warmer winters showed little influence on fruiting success and the abundance of fruits was strongly correlated with pollinator activity. The results of the studies also indicate that the impacts of climate change depend on the location and that the populations located in the warmest parts of the species' distribution area could be more negatively affected by the higher temperatures (Boulanger-Lapointe *et al.* 2017). The predictions for the Cantabrian Mountains indicate that the bilberry will experiment a considerable reduction in distribution range (c. 50%, 2050-2070) (Penteriani *et al.* 2019), such that its importance as a food source for bears will continue to decline.

Other species are also going to see an increase in growth period induced by climate change, but will also suffer a negative effect on the production of fruits, as they need a minimum number of cold days to fruit successfully. In the case of *Rubus* species, apart from other phenological changes, the risk of damage from late frosts occurs, as noted for bilberries and whitebeam. For example, in wild raspberry (*R. idaeus*) and blackberries (*Rubus* spp.), the lack of the necessary minimum number of sufficiently cold winter days has been seen to affect leaf bud break, causing delay and an erratic and unequal opening, and the same has been observed for flower bud opening in raspberries (Atkinson *et al.* 2013).

On the other hand, some typically Mediterranean species may increase in importance as food sources. This is the case, for example, of the strawberry tree (*Arbutus unedo*), which already forms part of the diet for those Cantabrian bears living at lower altitudes, but which may increase in importance in the future. In addition to being a plant adapted to Mediterranean habitats, it is not particularly affected by drought, suggesting that it is a species with greater competitive advantage in a climate change scenario (Retuerto & Carballeira 2004; Santiso & Retuerto 2016).

Almost no information exists for some species of high relevance to the bears in the Cantabrian Mountains, such as European crab apple (*Malus sylvestris*), Alpine buckthorn (*Rhamnus alpina*) or alder buckthorn (*Frangula alnus*), and it is unknown how they may be affected by climate change in the region. For this reason, and despite the information providing a degree of optimism for plant species such as sweet chestnut, wild cherry or strawberry tree, caution needs to be exercised and a watchful eye needs to be kept on the changes in population and other species in the bear diet, given the limitations in knowledge, in general uncertainty and that the effects of a warming climate may accumulate and are foreseeably non-linear.

HOW TO INTEGRATE THE THREAT OF CLIMATE CHANGE IN THE CONSERVATION AND MANAGEMENT OF BROWN BEAR POPULATIONS

As presented above, brown bear populations are not exempt from possible climate change impacts, raising a challenge for conservation and the management of its populations. However, even though we have seen an increase in interest of the threat that climate change poses for bears, the degree to which climate change has been incorporated into the plans for management and conservation of the species has been insufficient to date. In order to understand how the threat of climate change has been integrated into plans, we reviewed a total of 49 management and conservation documents (e.g., conservation strategies, action plans, recovery plans, management plans, etc.) from around the world, compiled between August and November 2020. Climate change has only been considered as a threat in 11 of these documents (22%), pertaining to five countries: Canada, United States, France, Italy and Greece (Table 1).

In the management plan for Nunavut, Canada (NDOE 2017), for example, although climate change is considered to be affecting terrestrial and marine habitats, this is followed with the statement that the impacts on the grizzly bear are not clear. Likewise, it adds that

the effects of climate change on the habitat are a challenge to predict and mitigate. The possible effects of climate change highlighted include changes in the primary productivity, which may affect the plants and animals that serve as food sources for the bear, as well as changes to the hibernation periods of these. In the conservation plan for the grizzly bear in the Yukon, Canada (YGBC-MPW 2019), climate change is also considered as a potential threat to bear populations and which needs to be approached through greater knowledge. In the framework of the recovery plan for the grizzly bear in the USA (USFWS 1993), a supplement was added subsequently with recovery criteria based on habitats for the Northern Continental Divide (USFWS 2018). Climate change is viewed in this document as a factor with the potential to impact directly and indirectly on bear populations, both positively and negatively. This apparently contradictory and ambiguous view is due to the fact that majority of brown bear biologists in the USA and Canada do not believe that the changes in habitat predicted under a climate change scenario directly threaten the species (Servheen & Cross 2010). Additionally, they consider that these changes may even improve the habitat and lead to more abundant food sources. At the same time, however, these ecological changes may also affect the movement and the frequency of interactions and conflicts between bears and humans (Servheen & Cross 2010), a reasoning which is incorporated into the management plan for southwest Montana (MFWP 2013). In the conservation strategy for the Great Yellowstone ecosystem (USFWS 2016), climate change is considered an unpredictable factor with the potential for affecting the availability and distribution of trophic resources. Finally, the plan for Wyoming (WGFD 2016) recognises that the climate changes may affect the vegetation at the regional scale, the hydrology, patterns of fire and the prevalence of pathogens, which in turn may influence the abundance, the scope and the altitudinal distribution of the foods consumed by grizzly bears.

On the opposite side of the Atlantic, in the recent action plan for Greece (Mertzanis *et al.* 2020), climate change is seen as a moderate threat, cited as the last of 13 threats listed for the species. It is contemplated as a desynchronisation of the biological and ecological processes due to climate change. For its part, in the action plan for the French Pyrenees (DREAL 2018), climate change is considered as a threat for the conservation of the species, in general. However, it does not provide deal specifically with the brown bear. Finally, in the action plan for the Apennines (AAVV 2010), climate change is considered as a risk factor given the reduced number of individuals in the population at that time (<12 individuals in 2011).

It is striking that the only documents that contemplate any formal measures focussed on mitigating the effects of climate change are the new action plan for Greece and the management plan for southwest Montana, 4% of the total number of documents. The Greek plan proposes the use of large-scale telemetry monitoring for studying the spatial behaviour (above all in winter), habitat use and the interaction with humans. In other words, the measure is based on scientific research, with the aim of discovering how climate change affects the brown bear in order to evaluate how to approach its management in the context of climate change. For its part, the Montana plan establishes that monitoring needs to detect the changes in habitat or in bear behaviour which are suspected to be related to climate change and mitigate these where possible. They indicate, for example, that education campaigns could be put into place to warn hunters that hibernation dates will be later due to warmer autumns, which means that bears will be active for longer than during the past. Additionally, and very interestingly, this plan notes that the best manner to mitigate the possible negative impacts of climate change is through well-connected populations of brown bears, given that it increases resistance to environmental variability. However, no measure is formally established in this sense in the plan. In fact, this measure is recurrent in the bibliography about conservation of biodiversity in the face of climate change (e.g., Dai *et al.* 2019).

Sadly, none of the documents that include measures establish indicators for these. By way of contrast and given the scarce number of measures and the absence of indicators in the brown bear management or conservation documents, we have also reviewed the conservation and management documents referring to the polar bear (*U. maritimus*). The polar bear is considered as an emblematic species in relation to

Table 1. Inclusion of climate change in the management or conservation documents across the world concerning the brown bear (*Ursus arctos*) and polar bear (*U. maritimus*). The "climate change" column refers to if climate change is considered a threat factor in the particular document. If the document contemplates lethal control of the species, this is termed "Management", otherwise, if lethal control is not contemplated, it is considered "Conservation".

Country	Area	Document type	Climate change	Measures	Indicators	Reference
Brown bear						
-	Global	Action Plan	No	-	-	Servheen *et al.* 1999
Canada	Alberta	Recovery Plan	No	-	-	Alberta Government, 2016
Canada	Nunavut	Management Plan	Yes	No	No	NDOE, 2017
Canada	Yukon	Conservation Plan	Yes	No	No	YGBCMPW, 2019
Canada	Prairie Population	Recovery Strategy	Yes	No	No	Environment Canada, 2009
USA	Federal	Recovery Plan	No	-	-	USFWS, 1993
USA	Bitterroot	Recovery Plan	No	-	-	USFWS, 1996
USA	North Cascades	Recovery Plan	No	-	-	USFWS, 1997
USA	Yellowstone	Recovery Plan	No	-	-	USFWS, 2007
USA	Yellowstone	Recovery criterio reviYesón	No	-	-	USFWS, 2017
USA	Northern Continental Divide Ecosystem	Habitat recovery criterio	Yes	No	No	USFWS, 2018
USA	Yellowstone	Conservation Strategy	Yes	No	No	USFWS, 2016
USA	Idaho	Management Plan	No	-	-	IYGBDAT, 2002
USA	Southwest Montana	Management Plan	Yes	Yes	No	MFWP, 2013
USA	Wyoming	Management Plan	Yes	No	No	WGFD, 2016
USA	Wind River Reservation	Management Plan	Yes	No	No	ESNAT & SATFGD, 2009
USA	West Montana	Management Plan	No	-	-	Dood *et al.* 2006
-	Europe	Management Plan	No	-	-	Swenson *et al.* 2000
-	Europe	Key Actions	No	-	-	Boitani *et al.* 2015
Spain	Cantabrian Mountains	Conservation Strategy	No	-	-	MITECO, 2019
Spain	Spanish Pyrenees	Conservation Strategy	No	-	-	GTOPP, 2006
Spain	Galicia	Recovery Plan	No	-	-	Decreto 149/1992
Spain	Asturias	Recovery Plan	No	-	-	Decreto 9/2002
Spain	Castilla y León	Recovery Plan	No	-	-	Decreto 108/1990
Spain	Cantabria	Recovery Plan	No	-	-	Decreto 34/1989
Spain	Navarra	Recovery Plan	No	-	-	Decreto Foral 268/1996
France	French Pyrenees	Action Plan	Yes	No	No	DREAL, 2018
Italy	Apenines	Action Plan	Yes	No	No	AAVV, 2010
Italy	Alps	Action Plan	No	-	-	AAVV, 2011
Germany	Baviera	Management Plan	No	-	-	StMUGV, 2007
Austria	National	Management Plan	No	-	-	LKB, 2005
Switzerland	National	Management Plan	No	-	-	BAFU, 2009
Slovenia	National	Management Strategy	No	-	-	MZOP, 2020
Slovenia	National	Action Plan	No	-	-	MZOP, 2020b
Croatia	National	Management Plan	No	-	-	Huber *et al.* 2019
Albania	National	Action Plan	No	-	-	Bego *et al.* 2007
-	Prespa Lakes Basin	Action Plan	No	-	-	Stojanov *et al.* 2012
Greece	National	Action Plan	Yes	Yes	-	Mertzanis *et al.* 2020

Country	Area	Document type	Climate change	Measures	Indicators	Reference
Bulgaria	National	Action Plan	No	-	-	Voeten *et al.* 2007
Romania	National	Action Plan	No	-	-	NIRDF, 2018
Poland	National	Management Plan	No	-	-	Selva *et al.* 2012
Sslovakia	National	Conservation Plan	No	-	-	AAVV, 2016
Latvia	National	Action Plan	No	-	-	Ozoliņš *et al.* 2018
Estonia	National	Action Plan	No	-	-	Männil & Kont, 2012
Sweden	National	Management Plan	No	-	-	Naturvårdsverket, 2016
Norway	National	Management Plan	No	-	-	DKM, 2003
Finland	National	Management Plan	No	-	-	MMM, 2017
Iran	National	Action Plan	No	-	-	Yusefi *et al.* 2015
Japan	Hokkaido	Management Plan	No	-	-	Hokkaido Government, 2017
Polar bear						
-	Circumpolar	Conservation Strategy	Yes	Yes	Yes	Polar Bear Range States, 2015
USA	Alaska	Management Plan	Yes	Yes	No	U.S. Fish and Wildlife, 2016
Canada	Federal	Conservation Strategy	Yes	No	No	GOC, 2011
Canada	Inuvialuit (NW Territories & Yukon)	Management Plan	Yes	Yes	Yes	Joint Secretariat, 2017
Canada	Terranova and Labrador	Management Plan	Yes	No	No	Joe & Goudie, 2006
Canada	Nunavut	Management Plan	Yes	Yes	No	GON, 2019
Canada	Ontairo	Recovery Strategy	Yes	Yes	No	Tonge & Pulfer, 2011
Canada	Quebec	Management Plan	Yes	No	No	AAVV, 2017
Denmark	Greenland	Management Plan	Yes	No	No	DFFL, 2019
Norway	Svalbard	Action Plan	Yes	Yes	No	Miljødirektoratet, 2013
Russia	Federal	Conservation Strategy	Yes	Yes	No	MNR, 2010

climate change effects and in 2009 it was accepted, in the framework of the 1973 Agreement on the Conservation of Polar Bears, that climate change is the principal threat to its conservation. From an evolutionary viewpoint, the polar bear descended from the brown bear, separating from this latter species between 150 and 800 thousand years ago, and probably less than 500 thousand years ago (Kurtén 1964; Rinker *et al.* 2019), in the geological context of the most recent major glaciations (<2 mya). Numerous cases of hybridisation are known in the overlap zones between both species and in a climate change context (Edwards *et al.* 2011; Cahill *et al.* 2013). The number of management and conservation documents for the polar bear (11 in total, Table 1), that present measures (7.63%) and indicators (2.18%) for the species, is greater than for the brown bear.

Given its importance, it is interesting to keep in mind some of the actions of the Climate Change Work Program (CMS 2017) of the Bonn Convention or the Convention on the Conservation of Migratory Species of Wild Animals, given that they could be implemented for the conservation of large carnivores such as the brown bear (Trouwborst & Blackmore 2020). Amongst the more interesting measures, the following can be highlighted: identification and prioritization of the areas currently experiencing rapid climate impacts which are important for brown bears; ensuring that physical and ecological connectivity exists between areas, aiding the dispersion and colonization of species when their ranges change; considering restrictions in the use of areas where the species are present during critical phases of their lifecycle; undertaking management specific to eliminate, counteract or compensate the adverse effects of climate change and other potential threats which may interact with climate change or exacerbate it; integrating protected areas in wider landscapes

and ensure the use of management measures appropriate in the territorial matrix and undertake the restauration of degraded habitats; or cooperating in respect to cross-border protected areas and populations, ensuring that migration barriers are eliminated or mitigated to the maximum degree possible (Trouwborst & Blackmore 2020).

Photo 8. Rangers from the Brown Bear Foundation collecting information during the winter. Long-term monitoring is a necessary measure to know the effects of climate change on Cantabrian bears and adapt their conservation actions.

CANTABRIAN BEARS AND CLIMATE CHANGE

Recent projections for the Cantabrian Mountains predict a drastic reduction in the brown bear population due to the impact of climate change and the principal reason for this tendency is attributed to the loss in distribution area of some plant species which form part of the brown bear diet (Penteriani *et al.* 2019). However, it needs to be taken into account that models have limitations (see below) and are heavily dependent on the information incorporated into them, so the projections should not be taken as definite predictions adjusted to the real situation, given, for example, the complexity and non-linear effects of climate change on ecosystems, or the aforementioned trophic plasticity of species such as the brown bear. Penteriani *et al.* (2019) indicated that by 2050, Cantabrian bear distribution will have reduced to half its current level under a moderate scenario, or to a quarter under a pessimistic one. A model based on the predicted changes in some of the species of importance as food and cover sources for bears may be useful to analyse the behaviour of these species and define possible adaptation strategies. However, it is difficult to predict the changes in the bear population in such a complex scenario, in which Atlantic and Mediterranean plant species converge, but for which the effects of climate change may be opposing and in which the high altitudinal and ecological variability existing in the region will undoubtedly aid in the resilience and adaptability of the bear population. Many uncertainties derive from those highly important species in the bear diet, but which are absent from the models due to the lack of precise data on their distribution or of the effects of climate change on them (e.g., wild cherry, European crab apple, Alpine buckthorn, alder buckthorn, etc.), or of species which may be favoured or increase in importance as food sources for bears (e.g., western holm oak, strawberry tree, etc).

The importance of Mediterranean oaks, such as Pyrenean and western holm oaks, is expected to increase during the autumn fattening phase and will play a highly important role in the future of the species, as is also predicted for the sweet chestnut. Western holm oaks are already present in many areas of the Cantabrian Mountains and bears feed on their acorns in some parts of their current distribution range, as noted before, nor should it be forgotten that the western holm oak was a key species for the brown bear in Mediterranean Spain. After studying the hunting treatises of King Alphonso XI (14th century) and Miguel Lucas de Iranzo (15th century), José Antonio Valverde recreated the distribution and biology of the brown bear in the Iberian Peninsula at the end of the Middle Ages (Valverde 2005; p. 50-62). In fact, in the author's own words, these documents treat the "very important ecological population of western holm oak forests". During this period, the brown bear was present

from Galicia to Murcia and from the limit between the provinces of Cantabria and Biscay south to Huelva, except on the plains, which were already devoid of bears (Valverde 2005). Amongst other things, these Mediterranean bears fed on strawberry tree fruits and acorns (of Mediterranean oaks), hibernated barely five weeks a year and the females with cubs did not hibernate in dens (Valverde 2005). Additionally, it should not be forgotten that the species is currently distributed across other Mediterranean regions (e.g., Turkey) and has existed in locations such as Jordan, Israel or N Africa (Atlas Range). The sweet chestnut, for its part, may be favoured by climate change in some Cantabrian environments, both in distribution and fruiting terms, although the effects will be complex and interrelated with other variables.

Therefore, the adaptability of the generalist species such as the brown bear, in conjunction with historical data from Mediterranean Spain, allows us to think that the bioclimatic 'Mediterranisation' caused by the increase in temperature and the decrease in rainfall in the northern Iberian Peninsula, should not imply a grave threat for the brown bear. That said, and as a consequence of the high degree of uncertainty that exists when analysing particular scenarios such as the Cantabrian Mountains case, it is crucial to understand and monitor the situation, as well as evaluating the final consequences of these changes on the reproductive success of the species, which requires the establishment of long term monitoring programs of Cantabrian bear productivity and survival, so continuing as well as filling in the gaps in the work which has been carried out until now.

What we firmly believe may convert into an important threat for Cantabrian bears is the interaction between the climate change effects and human activities, both directly and indirectly. Shorter hibernation periods, or no hibernation at all, will increase the level of interactions between bears and humans, so increasing their vulnerability. Indeed, a greater interaction between hunting activities and bear presence in winter can be expected, for example, meaning that it is important to work with this sector in order to minimise possible future risks for the species. Additionally, warmer temperatures facilitate access into the mountains during longer periods in autumn and winter, which may lead to disturbance to bears. Similarly, greater access to humanised areas by bears in search of food may occur during years when food supplies are scarce during critical seasons, such as during the autumn fattening or winter periods.

The number of large forest fires has increased during those days of higher temperatures over the past few decades in Spain (Cardil *et al.* 2014). Predictions point towards increases in the number of days with high temperatures and the length of drought periods, plus a decline in rainfall (Ortega & Morales 2015; Bartolomeu *et al.* 2016), considerably increasing the risk of forest fires and their scale, although in the areas in NW Spain occupied by bears, the great majority of the fires are provoked and do not respond strictly to climatic causality (Carracedo 2016). NW Spain has already seen an increase in winter fires (e.g., Vanesa-Moreno *et al.* 2013; Cardil *et al.* 2014; Silva *et al.* 2018; Urbieta *et al.* 2019; Rodrigues *et al.* 2020; Jiménez-Ruano *et al.* 2020), and it is expected that this will be recurring during the autumn and winter (Jiménez-Ruano *et al.* 2020). The majority of fires are provoked, such that an effective policy of the elimination and extinction of fires, added to the abandonment of rural areas, in large part explains the general reduction in number observed over most of Spain (Vanesa-Moreno et al. 2013; Silva *et al.* 2018; Urbieta *et al.* 2019). However, although the overall number of fires has diminished, they are ever-more intense and extensive (Cardil *et al.* 2014; Royé *et al.* 2019) and natural protected areas are being affected ever more (San-Miguel Ayanz *et al.* 2018, 2020). The so-called "fire paradox", predicting larger fires as a consequence of the total extinction of fires and longer gaps between them, then comes in to play, as the accumulation of combustible material increases, which together with climatic conditions prone to facilitating fires, may result in subsequent fires exceeding the capacity for control and extinction (Cardil *et al.* 2014; Royé *et al.* 2019; Rodrigues *et al.* 2020; Jiménez-Ruano et al. 2020). All of this increases the risk to areas of special interest for the Cantabrian bear, such as their feeding areas and, above all, critical areas for reproduction. We believe that it is key that this is taken into account in the plans for forest management and protected natural areas, fostering a management culture orientated more towards prevention.

Photo 9. An increased risk of forest fires and their intensity is predicted for the Cantabrian Mountains.

Summarising, we consider that the synergic interaction between climate change and human activity in the autumn and winter periods will result in an increase in the number of interactions between bears and humans and situations of potential conflict, which we need to get ahead of as much as is possible, in order to mitigate their impacts. Beyond the important necessity of favouring the conservation and restauration of habitats, plus the ecological and functional connectivity of these and their bear populations, management of the human factor, as the principal threat to Cantabrian bears, is fundamental. Consequently, the regulation and planning of the land use activities, such as hunting, mountain sports or ecotourism, are necessary in order to adequately manage the growing and expanding population of brown bears within the climate change context in the Cantabrian Mountains.

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Photo 10. Beyond the necessary importance of favouring the conservation and restoration of habitats and their ecological connectivity for the brown bear population, it is crucial to manage the human factor to guarantee tranquillity for the bears in refuge areas within a climate change context.

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CHAPTER 8.

FROM CRITICALLY ENDANGERED TO VULNERABLE: CURRENT CONSERVATION CHALLENGES FOR THE CANTABRIAN BEAR

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SUMMARY

This chapter addresses how the population recovery of the brown bear in the Cantabrian Mountains affects the consideration of its current state of conservation and its legal protection. In accordance with the criteria of the IUCN Red List of Threatened Species, the population has gone from "Critically Endangered" to "Endangered", and it will presumably move to the category of "Vulnerable" during the course of this decade. The population viability analysis of the Cantabrian bear population suggests that it will continue to grow, provided that a high survival rate of adult females is guaranteed, which is the most relevant factor in population dynamics. However, it is still far from being considered a non-threatened population and the periodic evaluations carried out in compliance with the Habitats Directive (92/43/EEC) consider that it is still in an unfavourable state of conservation. From a legal point of view, the Cantabrian bear is considered "Endangered", although the criteria for including species in the current Spanish Catalogue for Threatened Species contain inconsistencies which may affect the legal coverage of the brown bear and other species undergoing recovery processes, but whose populations are still low in number. The increase in the bear population poses new challenges that make it necessary to update the Recovery Plans, which are the specific legal instruments for the conservation of the bear and its habitat, as well as the expansion of the Natura 2000 Network, considering the expansion of the distribution area of the Cantabrian population. These processes must be carried out with adequate environmental governance and social participation.

THE RECOVERY OF THE BROWN BEAR

The Cantabrian brown bear (*Ursus arctos*) is in a very different situation in 2020 to what it was 30 years ago. The demographic increase in the bear population, reflected in the growth of the minimum number of females with cubs of the year censused since 1989, is evident in Chapters 1 and 2. As the minimum number of breeding female bears in the population is the sum of those detected in two consecutive years, the following figures give us an idea of the magnitude of this recovery. In the 1993-94 biennium, when the Cantabrian bear population probably reached its all-time low, seven females with cubs were detected in the western population and three in the eastern one, while during the last available counts (2017-18), these figures had increased to 66 (in the west) and 13 (in the east). Over this period, annual increases of 10% in the number of females with cubs of the year have been observed in both subpopulations (González *et al.* 2016; Blanco *et al.* 2020).

In addition to this demographic increase, and in part as a consequence of it, genetic flow has been re-established between the two subpopulations –which had remained separated for the majority of the 20th century– thanks to the movements of males. This was first detected in 2008, when the scats from two individuals with genetic markers of western fathers and eastern mothers were found (Pérez *et al.* 2010). 54% of the genotypes detected in another study undertaken in 2013 and 2014 turned out to be hybrid individuals and another 27% were from migrants coming from the western nucleus (González *et al.* 2016). Subsequently, the bidirectional movement of males undertaking apparently habitual movements between the two nuclei has been demonstrated (Gregorio *et al.* 2020), producing a recovery in its genetic variability (Blanco *et al.* 2020). To date however, there are no data of females moving between the nuclei, in agreement with their philopatric behaviour (Kojola *et al.* 2003; Støen *et al.* 2005, 2006). In the interpopulation corridor –the space between the two nuclei with breeding females–, males are currently present permanently, but no resident or passing females have been detected. Even so, over the past few years a few breeding females have been found on the periphery of the reproductive nuclei. Of particular note is the expansion of the distribution area of the brown bear in the northwest of the peninsula, with the continuous presence of males during the past few years to the south of the A6 motorway in the provinces of León and Zamora (Castilla y León) and in Lugo and Orense (Galicia).

Photo 1. The support of the European Commission via different LIFE Projects has been determinant for recovery of the Cantabrian brown bears.

THE CANTABRIAN BROWN BEAR IN THE IUCN RED LIST OF THREATENED SPECIES

In order to determine the conservation status of the Cantabrian bear, it is useful to turn to the Red List of Threatened Species of the International Union for the Conservation of Nature (IUCN), the entity of world reference composed of governmental organisations and civil society. This list uses a series of criteria to objectively and comparably evaluate the conservation status of species or populations, which are generally used in all conservation programs with a scientific basis

Photo 2. The presence of extensive oak and sweet chestnut forests in the Serra do Courel (Lugo) has enabled expansion of the brown bear population in the Cantabrian Mountains. ©Carlos Cortizo

(IUCN 2012, 2019). Cataloguing a species in the different Red List categories, despite lacking in normative character, is a very useful instrument for establishing the conservation strategies which public bodies and private organisations intend to develop. The same occurs with the Red Data Books or lists published by other institutions which use IUCN criteria (e.g., the Atlas and Red Data Book for the terrestrial mammals of Spain: Palomo *et al.* 2007).

The analysis of the situation of the Cantabrian bear requires delimiting the population that we wish to evaluate, deciding which criteria of the IUCN Red List are most appropriate in accordance with the existing information and determining the data we have available in order to make the evaluation.

Red Lists evaluate the conservation status of populations. The Cantabrian bear population split into two at the start of the 20th century with the disappearance of the individuals in the centre of the mountain range (Nores & Naves 1993), giving rise to two genetically and demographically isolated populations from that moment (González *et al.* 2016). For this reason, when the Red List criteria began to be employed, each of these subpopulations was evaluated separately (Blanco & González 1992; Swenson *et al.* 2000; Palomero 2007). Currently however, clear demographic and genetic interchange exists between the western and eastern bears, even though the reunification is still incomplete and genetic structuring still exists in the two subpopulations, which is likely to continue in place even when the population ends up being continuous (Hagen *et al.* 2015; Xenikoudakis *et al.* 2015; Silva *et al.* 2018). Currently, therefore, a single Cantabrian population exists, and it should be evaluated as one unit.

The IUCN Red List criteria have changed since they were first established in 1963 and indeed, since 2001, version 3.1 of the criteria and categories of the Red List (IUCN 2012) has been in place, within which there are nine categories, of which three include threatened species. These are: Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). Additionally,

there are five types of non-exclusive quantitative criteria for making the evaluation (from A to E; IUCN 2012), which refer to population decrease (criteria A and C), geographic distribution (B), population size (D) and to the analysis of extinction probability (E). Given that the Cantabrian population is increasing, which precludes criteria A, B and C, the applicable criteria are D, which refers to the population size as measured by the number of mature individuals (i.e., those capable of reproduction: IUCN 2012, p. 10), and E, based on an analysis of population viability.

According to the criterion D, a population of under 50 adult individuals would be in the category CR, under 250 it would be EN and with under 1,000, VU. In order to leave the threat categories, a population needs, amongst other conditions, at least 1,000 mature individuals. We can estimate the number of adult Cantabrian bears using two information sources: the annual census of females with cubs of the year carried out since 1989 (see Chapter 1), and the estimate of the population size using genetic methods undertaken between 2017 and 2019 (see Chapter 2). For the calculations, we accept that in European (including our) populations, the cubs and immatures represent 50% of the total bear population (Swenson *et al.* 2004).

The number of mature individuals in the Cantabrian population can be estimated from the data on females with cubs of the year, by multiplying the sum of females with cubs of the last two years by two. So, in 2017 and 2018, a total of 79 (41+38) females with cubs of the year were detected in the Cantabrian Mountains, representing the minimum number of adult females (as every year there is a small proportion of adult females that do not reproduce: e.g., Tosoni *et al.* 2017). If we accept that there are as many males as females (Swenson *et al.* 2004; Pérez *et al.* 2014), the total number of adult individuals is double this, i.e., 158. This method provides minimum figures, given that the counts of females with cubs of the year in the Cantabrian Mountains only include those families which can be detected unequivocally (minimum count) and the average time between consecutive birthing by females is a little over 2 years (2.2 years according to Penteriani *et al.* 2018). Another means of calculating the total number of female bears with cubs is to apply

Photo 3. A female Cantabrian brown bear with three cubs in the Fuentes del Narcea, Degaña and Ibias Natural Park (Asturias).

the corrections described in Chapter 2 of this book, although these should be treated with caution, as the calculations apply parameters taken from other populations.

The number of mature bears can also be calculated by dividing the total number of individuals in a population between two (remembering that, according to Swenson *et al.* 2004, only half of the population comprises mature individuals). The latest estimate obtained in Spain for the Cantabrian population, some 323 individuals, derives from the application of genetic techniques carried out in 2017 in the eastern subpopulation and 2019 on the western one (Chapter 2). The number of mature bears would therefore be 162 (very similar to the 158 estimated above based on the number of females with cubs of the year).

Considering these data, the Cantabrian bear has far exceeded the 50 individuals which would place it in the Critically Endangered category, and it currently fits into the Endangered bracket, given that it has less than 250 mature individuals. Indeed, the IUCN has recently taken these advances in knowledge into account and has catalogued the Cantabrian brown bear population as Endangered (EN; Huber 2018).

POPULATION CHANGE PREDICTED IN THE NEAR FUTURE

Assuming that the population continues to grow at a rate of 10% per year and considering that in 2019 we estimated that there were some 158 mature bears, just five years would be needed for the population to reach 250 mature bears, which the IUCN considers constitutes a population as being Vulnerable. However, if as expected, the population growth declines as the overall population increases, this threshold figure of 250 mature bears would be reached later (e.g., if the population behaves as in the *optimistic* scenario projection described in the following section, a population totalling 500 bears, in other words 250 mature individuals, would be reached in ten years' time). As these figures need to be maintained, or exceeded, during five consecutive years for the IUCN to approve the reduction in threat category, the Cantabrian bear population could pass into the Vulnerable category in the 2030 decade. If these predictions are finally confirmed, a powerful recovery process will have occurred, with the Cantabrian bear passing from Critically Endangered to Vulnerable in just a few decades.

For the population to exit the Vulnerable category and leave the IUCN Red Data List entirely, it needs to have at least 1,000 mature individuals, or in other words, at least 250 females with cubs of the year each year, meaning a more than six-fold increase of the current population (currently, around 40 females with cubs of the year are detected annually, giving an estimate of 158 mature bears overall). However, it needs to be taken into account that the more the population increases, so the growth rate will tend to decrease, since intraspecific competition increases the closer to the carrying capacity for the species it reaches (Støen *et al.* 2006; Zedrosser *et al.* 2006; Steyaert *et al.* 2012). Also, despite the notable geographic expansion of the species, the tolerance and appreciation shown by society may decrease as the number of bears and associated conflicts increases, such as has occurred in the Trentino region of Italy, where the proportion of people appreciating bear presence fell from 70% in 1997, to 30% in 2011 (Tosi *et al.* 2015). Taking all of this into account, we do not foresee that the Cantabrian bear population will leave the threat categories of the IUCN Red List in the medium term.

A lowering in the Red List threat category for the population of a species represents an objective milestone in its recovery process but does not necessarily also mean a change in its legal conservation status. In Spain, the brown bear continues to be protected under the 1979 Bern Convention (included in Appendix II) and the Habitats Directive (Council Directive 92/43/CEE, of 21 May 1992; included in Annex IV), in addition to under the actual regional and also national Spanish laws (Natural Heritage and Biodiversity Law 42, of 13th December 2007). It is important to remember that the brown bear is not the only emblematic species of the Spanish fauna which has recovered over the last few decades. Fortunately, other species which were also on the brink of extinction, also currently show favourable population figures. Such is the case of the Spanish imperial eagle (*Aquila adalberti*), which increased from around 50 breeding pairs in 1966 to 612 in Spain in 2019 (629 including Portugal),

Photo 4. The Iberian lynx has experienced increases in both its population and distribution area over the last few years thanks to the enormous conservation efforts applied to the species. ©Fundación CBD-Habitat

showing an annual growth rate of 9.6% and is currently catalogued as Vulnerable (BirdLife International 2019). The bearded vulture (*Gypaetus barbatus*) has increased from 17 breeding pairs in 1979 in the Spanish Pyrenees (Heredia 1991) up to 1,026 individuals in 2016 across the whole of the Pyrenees, of which 748 are adults (Margarida et al. 2020). The same has been seen with the Iberian lynx (*Lynx pardinus*), which has shown an increase from less than 100 individuals in 2002 (Guzmán *et al*. 2004) to 855 in 2019, of which 188 are breeding females, and which also changed category from CR to EN in 2015 (Rodríguez & Calzada 2015). All of these successes in the recovery of species are worth considering when determining the *Green Status* (GS) of the species, a new evaluation system developed by the IUCN and which is currently being promoted together with the Red List evaluations (Akçakaya *et al.* 2018). GS will be implanted over the coming years and it aims to quantitively explore, as far as is possible, the recovery potential of a species, complementing the Red List and providing a tool for evaluating the recovery of populations and measuring the conservation successes (The IUCN Green Status of Species 2020).

Population viability analysis: the importance of breeding females

The change in brown bear population can be measured using a Population Viability Analysis (PVA), which is essentially an exercise in demographic projection of a population. This analysis can constitute a useful tool, not so much for its capacity to make precise predictions, which depends on the available information, but above all for the possibility to evaluate different scenarios or management proposals and reveal the importance of some demographic parameters in the population change (Beissinger & Westphal 1998).

We lack essential demographic data to be able to undertake a PVA of the Cantabrian bear population, above all of the information relating to mortality of different adult age-classes. However, following the IUCN (2019) recommendations, we have addressed the uncertainties in the demographic parameters by

Table 1. Demographic parameters and principal results of the different projection model scenarios for the Cantabrian Mountains brown bear population analysed with the VORTEX 10 program.

	Optimistic Scenario	Pessimistic Scenario	References
Nº iterations	1000	1000	-
Nº simulated years	40	40	-
Carrying capacity K	1000	1000	-
Initial population	323	323	Chapter 2
Type of reproductive system	Polygyny	Polygyny	Bellemain *et al.* 2006
Age at first reproduction	4 years F/M	4 years F/M	Wiegand *et al.* 1998; Gervasi & Ciucci 2018
Reproductive senescence	27 years	27 years	Schwartz *et al.* 2003; Zedrosser *et al*. 2007
Litter size	29.2% 1 cub 55.6% 2 cubs 15.2% 3 cubs	29.2% 1 cub 55.6% 2 cubs 15.2% 3 cubs	Chapter 1
Sex ratio at birth	50:50	50:50	Gervasi & Ciucci 2018
Proportion of reproduction females	0.25	0.25	Tosoni *et al.* 2017; Gervasi & Ciucci 2018
Mortality of cubs 0 to 1 year	0.30	0.40	Gervasi & Ciucci 2018; Planella *et al.* 2019
Mortality 1 to 2 years	0.15	0.15	Bischof *et al.* 2009
Mortality females > 2 years	0.05	0.15	Bischof *et al.* 2009; Gervasi & Ciucci 2018
Mortality males > 2 years	0.05	0.20	Bischof *et al.* 2009: Gervasi & Ciucci 2018
Mean final N for extant populations	960.46 (2.39 SE)	18.45 (0.41 SE)	
Mean growth rate (r) prior to K truncation	0.0419 (0.0004 SE)	-0.0805 (0.0006 SE)	
P extinction	0.0000 (0.0000 SE)	0.0950 (0.0093 SE)	

collecting the most adequate information available and establishing two scenarios, one *optimistic* and the other *pessimistic*, by using the extreme values of the ranges of the parameters for which we have least information available for the Cantabrian bear population. For this we have constructed the scenarios in a stochastic population simulation model using VORTEX 10 (Lacy et al. 2020). We have basically followed the same approaches as Gervasi & Ciucci (2018) in their PVA of the Italian Apennine bear population, mixing the demographic information available for the Cantabrian Mountains with data collected from other European populations (Table 1). This means that the exercise that we develop on this theoretical population lacks validity for predicting future changes in the Cantabrian population, although we consider that it reveals interesting information about its demography.

The most difficult parameters to estimate and for which greatest uncertainties exist in populations of wild animals are those related to the mortalities of the different age and sex classes. No information is available on the death rates for the Cantabrian Mountains, with the exception of that relating to cubs between them leaving their dens and family break-up (i.e., during their first 16 months of life; Planella *et al.* 2019). For this reason, the mortality has been the only parameter which we have varied between the different scenarios, employing the ranges defined in the other European populations (Bischof *et al.* 2009; Gervasi & Ciucci 2018; Wiegand *et al.* 1998). We execute each of the simulation scenarios

described for a 40-year period, corresponding to approximately four bear generations (9.0-9.1 years; Martínez-Cano *et al.* 2016), with 1,000 iterations for each scenario and starting with a population baseline of 323 bears, in accordance with the latest estimate available for Cantabrian bears (Chapter 2). Additionally, we have included the effect of environmental variability and inbreeding depression following the figures recommended by Lacy *et al.* (2020). Considering the current situation of the species, the expansion into new territories over recent years (e.g., the eastern Galician mountains), and the lack of knowledge of the true carrying capacity of the Cantabrian Mountains, in both its ecological and social senses, we have incorporated an orientative carrying capacity of 1,000 individuals into the model, beyond which the program truncates population growth via an increase in mortality.

This simulation exercise on a theoretical population obtained an annual growth rate of 4.2% under the *optimistic* scenario (Table 1), a very much lower figure than the 10% annual growth observed in bears with cubs of the year in the Cantabrian Mountains (González *et al.* 2016; Blanco *et al.* 2020). This allows us to conclude that the mortality rates for the adult cohorts in the Cantabrian bear population have been notably lower than those of the theoretical population. Although we only know the cub mortality rates in the Cantabrian bear population (Planella *et al.* 2019), the results of the simulation suggest that the low mortality rate of adult females is one of the key parameters which has determined its positive growth to date and in all probability will determine its future trajectory. Under the *pessimistic* scenario, in which we used the extremes of the mortality rates (15% and 20% annual mortality in females and males, respectively; Gervasi & Ciucci 2018), the theoretical population declines by 8% annually, and the simulations reflect a probability of extinction in 40 years of 9.5%. The pessimistic scenario of the theoretical population is a long way from the actual situation of the Cantabrian bear population, which shows constant growth, and represents an extreme negative situation which could only be reached with increased bear mortality, especially of adult females.

Photo 5. Members of Seprona (Environmental Protection Service of the Civil Guard) and Castilla and León Environment Rangers investigate and take away the remains of a breeding female brown bear found shot dead in the Montaña Palentina Natural Park (Palencia). The work of both protection services is fundamental for the recovery of the Cantabrian brown bear.

Analysis of the sensitivity of the demographic parameters enables us to see the determinant role of adult female bears on population projections and their importance in conservation. We analysed the mortality sensitivity from 0-1 years, 1-2 years, of females >2 years old, of males >2 years old and the percentage of females breeding annually, developing a total of 1,000 scenarios of 1,000 iterations each in VORTEX, randomly selecting the values of these five parameters in each scenario based on some determined ranges, while keeping the rest of the parameters fixed. Adult female mortality is the parameter which most explains the population growth rate variability in each of the scenarios, followed by the proportion of females reproducing each year (Table 2). In agreement with these simula-

Table 2. Demographic parameters evaluated and the range of values considered in the sensitivity analysis developed in VORTEX using a total of 1000 scenarios of 1000 iterations for each. A regression model has been fitted to each parameter, where the variable response has been the population growth estimate value and the predictor the value selected randomly from the parameter in question of each simulation. The parameters are shown in decreasing order in which they explain the variability of the population growth rate, in accordance with Akaike Information Criteria (AIC) (a measure of the degree of fit of each model, with the lower the figure the greater its closeness of fit; Burnham & Anderson 2010), the relative weight of evidence associated with each model (AIC wi) and the $R^2_{adjusted}$ (degree of variance of the response variable which can be explained by the predictor).

Evaluated parameter	Simulation interval	ΔAIC	AIC w_i	$R^2_{adjusted}$
Mortality of adult females (>2 years)	5-15%	0.0	1	0.68
Percentage of reproducting females	15-30%	865.8	<0.001	0.25
Mortality of young (1 to 2 years)	10-20%	1137.2	<0.001	0.02
Mortality of cubs (0 to 1 year)	30-40%	1138.3	<0.001	0.02
Mortality of adult males (>2 years)	5-20%	1160.1	<0.001	0.01

Photo 6. A male Cantabrian brown bear.

tions, a population decline is seen in 94% of the simulated scenarios with adult female annual mortality rates of over 10%, while only 8% of simulation scenarios showed a decline with adult female mortality rates of 5-6%. This exercise serves to stress the necessity of maintaining a low annual mortality rate of adult females. Wiegand *et al.* (1998) already highlighted the demographic importance of adult females, which need to continue to be a priority objective in the Cantabrian bear population.

UNFAVOURABLE CONSERVATION STATUS

The IUCN Red List is an international reference and of scientific consensus in determining the conservation status of species and populations, but it is the European and national legislations that establish effective protection for these, plus the obligatory management and conservation requirements. One of the priority objectives of the European conservation policies is that the species of community interest (included in the Annexes IV and V of the Habitats Directive 92/43/CEE) reach and maintain a Favourable Conservation Status (FCS), an obligation which directly affects the Member States. The definition of the FCS is laid down in the Habitats Directive, one of the most robust legal tools for conservation in the world (Born *et al.* 2015) and its correct interpretation is important, given that the FCS is a legal concept, and as such, needs to be applied by managers, researchers, conservationists (López-Bao 2017), and ultimately, by the law courts. The term 'favourable' suggests that reaching the FCS goes beyond the simple goal of escaping from extinction. In this sense, the interpretation of the concept employed by the Directive implies that the three aspects related with the FCS need to be considered: demographic viability, evolutionary viability and ecological viability (Epstein *et al.* 2016).

Interpretation of the FCS of large carnivore species is the object of numerous debates and approaches (Mehtälä & Vuorisalo 2007; Laikre *et al.* 2013; Epstein 2016; Trowborst *et al.* 2017; Eriksen *et al.* 2020). However, a series of guidelines have been developed for the preparation of population management plans (Linnell *et al.* 2008), the use of which as a reference by Member States has been recommended by the European Commission, especially when considering cross-border populations. These guidelines define a series of conditions to consider when a population has reached FCS, which has also been the subject of debate (e.g., at what level should cross-border populations reach a FCS; Trouwborst 2014; Epstein *et al.* 2016). Following the scheme proposed by Linnell *et al.* (2018), the Cantabrian bear population fulfils the conditions regarding increases in population size and geographic distribution, of the restoration of the connectivity between subpopulations and of the application of adequate conservation systems and robust monitoring methods, although it does not fulfil the conditions regarding favourable reference population nor the favourable reference range. As with other species (Evans & Arvela 2011; Nilsson *et al.* 2013; Bijlsma *et al.* 2019), no detailed analysis nor established concensus exists of what constitutes a favourable reference population for the Cantabrian bear, nor the favourable reference range. Both aspects should be the objective of evaluation, not only in relation to the quality of habitat available, or the carrying capacity of the habitat, but the social carrying capacity should also been taken into account, understood as the reasonable tolerance limit of the human population towards the brown bear. In theory, the brown bear has plenty of suitable habitat for expansion, but studies undertaken at the European scale (Scharf & Fernández 2018) should be confirmed at the local scale, with careful analyses of aspects related to connectivity and of course, habitat characteristics in relation to potential conflicts. In relation to the favourable reference population, Linnell *et al.* (2008) proposed that this should be higher, and preferably significantly greater than the minimum viable population size to comply with the IUCN criterion E, of an extinction risk of <10% in 100 years, or alternatively, that the reference population is greater than that which allows it to leave the IUCN threat categories (i.e., more than 1,000 mature individuals).

Although there is no clear consensus on the criteria or thresholds to define the FCS, the Cantabrian brown bear population is currently still considered to have an unfavourable conservation status. Article 17 of the Habitats Directive establishes that the Member States must each draw up a report on the application

of the Directive's measures, including up-to-date information on the conservation state of the types of natural habitats and species of community interest, and that this has to be presented to the European Commission every 6 years. These periodic reports need to contain the conservation state of each species in each biogeographic region, using four categories (favourable, unfavourable-inadequate, unfavourable-bad, or unknown), based on the state's evaluation of various parameters (range, population, habitat and future perspectives), as well as providing information of the monitoring, pressures and threats, plus conservation measures (DG Environment 2017). In the latest evaluation report submitted by Spain, corresponding to the period 2013-2018 (MITECO 2019), a tendency towards an improvement in its conservation status was confirmed, but it was clearly established that the Cantabrian brown bear population was still in an unfavourable-inadequate conservation status, both in the Atlantic as well as Mediterranean biogeographic regions.

THE CANTABRIAN BROWN BEAR IN THE SPANISH CATALOGUE OF THREATENED SPECIES

In Spain, the Natural Heritage and Biodiversity Law 42/2007, of 13th December 2007, created the List of Wild Species in Special Protection Regimes (LESRPE), and at its core, the Catalogue of Threatened Species in Spain (CEEA). The latter includes those species requiring greater protection in two categories: Vulnerable and Endangered. For the species included in the LERSPE, the need to periodically undertake an evaluation of their conservation state is established, as a baseline to make an assessment of their current situation and determine if their conservation state is favourable. Additionally, the inclusion of a species, subspecies or population in the LESRPE directly implies a series of prohibitions —listed in Article 57 of the Law 42/2007— and the application of a number of penalties. In addition, the Penal Code typifies a number of actions committed against the protected species as criminal offences, as well as establishing an aggravated typification for those species catalogued as Endangered, hence the importance of these being kept up to date.

The Royal Decree 139/2011, of 4th February, defines the LERSPE and CEEA legislations, plus now incorporates various subsequently approved complementary legal regulations and modifications which change the category of different taxa either in function of their state of conservation, or for scientific questions. The state of those species included in the CEEA should be the objective of periodic evaluation: Vulnerable species every six years and the Endangered species every three. The Agreement of the Council of Ministers of 24th February 2017 approved the criteria for the inclusion of taxa and populations in the Spanish Catalogue of Threatened Species.

The brown bear is included in the CEEA in the Endangered category, which covers those "taxa or populations whose survival is unlikely if the causal factors of their current situation continue to act". However, it is noteworthy that application of the indicative criteria do not adequately justify its inclusion in this category, since criterion A, of a decline in the population over the past 10 years or three generations, is not fulfilled (González *et al.* 2016; Blanco *et al.* 2020; see Chapter 1), nor criterion B, of a reduction in distribution area over the past 30 years (Chapron *et al.* 2014; González *et al.* 2016; Zarzo-Arias *et al.* 2019), nor criterion C, of the probability of extinction of at least 35% during the next four generations (see PVA of the previous section), nor even due to a lack of information about the population, which would recommend applying the expert criterion D, which is exceptional in character. Strictly speaking, the CEEA criteria do not even sustain considering the species as Vulnerable, which is clearly in contrast with the conservation needs of the population.

The Official State Gazette which approved the indicative criteria indicates that "*an adaptation of the criteria of the same theme, agreed by the international scientific community and reflected in the adapted version of the IUCN Criteria, has been used as the reference document*". However, this adaptation was incomplete. The CEEA criteria allude to A) the decline in the population size, B) the reduction in distribution area, C) a population viability analysis, and D) a criterion of experts (of exceptional application). They did not consider criteria C and D of the IUCN Red List (UICN 2012,

Photo 7. Over the coming decades it is essential that the inhabitants of the Cantabrian Mountains maintain a sense of pride about sharing the mountains with bears and are able to see the link between the local economies and bear conservation.

2019), which refers to the small size of the populations. For this reason, those species on the brink of extinction but undergoing a recovery phase, the populations of which are neither declining nor reducing in distribution area, but which still contain very few individuals, do not comply with the requisites for being maintained in the CEEA threat categories. In this way, those species noted before, whose populations have shown recent recovery, including the brown bear, Iberian lynx, Spanish imperial eagle and bearded vulture, would all be excluded from the CEEA.

It is evident that the Cantabrian brown bear has made important advances in its conservation status over the past few decades, and as we mentioned before, its move to the category of Vulnerable, according to the IUCN Red List criteria, could be considered not long from now. But it currently continues to be a threatened species and the irregularity highlighted in the CEEA criteria seriously compromise the efficiency of this legal tool for adequately categorising and giving official cover to the brown bear and other threatened Spanish species. In the next revisions of the conservation state of the brown bear in the CEEA framework, the real advances shown by the species should be taken into account, but also the convenience of completing the indicative criteria to be able to contemplate the small population size and legally back the conservation needs of species undergoing recovery, but still having small populations.

ADVANCING IN THE RECOVERY PROCESS: FUTURE CONSERVATION CHALLENGES

Once the brown bear appeared to escape extinction, since the population in the decade of the 1990s was considered inviable (Wiegand *et al.* 1998), and now that its population has expanded and the number of bears has increased, initiating the reestablishment of the connection between the two subpopulations, it is convenient to ask, "What are the most urgent conservation challenges, in order to strengthen and maintain the recovery path of the Cantabrian bear population?".

Throughout the course of this book we have identified the challenges resulting from an expanding bear population under a climate change scenario. An increase in the bear population may be accompanied by a greater number of negative interactions between bears and humans, and their associated conflicts, if measures to reduce the probability of this occurring are not taken. Locally, an increase in damage to beehives, to fruit trees and to livestock can be expected and to counter this, damage inspection protocols need establishing, detailed investigations are needed to confirm that the reported livestock damages cor-

Photo 8. Environmental agents of the Asturias Bear Patrol with tranquilizer rifles. These professional and specialised teams are essential when intervening with bears suffering problems or which are problematic.

respond with animals truly killed by bears and not to bears feeding on the carcasses of livestock dying from other causes, as well as the fine honing to and acceleration of the compensation methods to adjust them to the real costs and damage caused, and, above all, evaluate, improve and spread the installation, use and maintenance processes of effective preventative measures.

Another foreseeable consequence of the increase in bear numbers and associated with a loss in their perception of humans being a threat, would be the appearance of a greater number of bears more or less habituated to human presence and even individuals that become conditioned to anthropogenic food sources, such as rubbish. It is also probable that more bears will approach villages to feed in fruit trees, as many of these are abandoned. Although the economic consequences are limited –the substitution of a few damaged rubbish containers or payment for damaged trees– the presence of bears in the proximity of villages may not only generate unease in the local population and reduce their tolerance towards bears, but also increase the number of potentially dangerous situations, as much for bears as for humans. The application by the autonomous administrations of the Cantabrian Mountains of the Bear Intervention Protocol (approved by the State Commission for Natural Heritage and Biodiversity of 24th January 2019) is fundamental, and the availability of experienced personnel, capable of undertaking prevention and dissuasion tasks, will be ever more important.

The rising tide of visitors to the countryside and a decreasing tendency for bears to hibernate as a consequence of climate change, may favour an increase in encounters between brown bears and those people practising open air activities, such as mountain sports, fungi collecting or hunting. The zoning of protected natural areas, education of the public in bear areas and the presence of law enforcement officials at the most sensitive sites and times –e.g., at bear-watching sites– to avoid inadequate visitor behaviours, should gain in importance in the future to minimise the possible negative interactions. Accordingly, in order to reach favourable conservation status for the habitats of importance to bears and of the brown bear itself, the complete implementation of the Natura 2000 Network –the European network of protected natural areas established in the Habitats Directive 92/43/CEE–, together with the operational management plans for those areas incorporated within it, is fundamental. Fortunately, the majority of the current distribution area of the Cantabrian bear lies within the current Natura 2000 Network, but there are now reproductive events outside of the network sites and the bear's expansive movements predict the establishment of new territories with permanent bear presence, suggest-

ing that the Natura 2000 Network should be broadened in the near future.

Facilitating and consolidating the population expansion of the Cantabrian bear currently underway is also a crucial challenge to enable its population to reach a favourable conservation status. For that purpose, the conservation of the habitat quality in those areas of recent bear presence should be guaranteed and efforts should concentrate on education and raising awareness about the coexistence between bears and human activities and the application of preventive measures in social scenarios where the bear is still a recent arrival.

The recovery of the species requires updating the legal instruments governing its conservation. The Law 42/2007, cited previously, includes the obligation to produce recovery plans for the taxa or populations included in the Endangered category, including the most adequate conservation measures and the designation of critical areas, the drawing-up and approval of which correspond to the autonomous communities. The four autonomous communities of the Cantabrian Mountains have active recovery plans (Cantabria: Decree 34/1989; Castilla y León: Decree 108/1990; Asturias: Decree 9/2002, which revises the Decree 13/1991; Galicia: Decree 149/1992), but these plans are now obsolete and need revision to incorporate novel conservation measures to provide appropriate answers to the new scenarios and conservation challenges. As required by Article 60 of the Law 42/2007, updating of the Recovery Plans should be undertaken following the orientative framework of the recently renewed Strategy for the Conservation of the Brown Bear in the Cantabrian Mountains, approved by the Environment Sectorial Conference, of 30th September 2019. The approval of this strategy requires the immediate updating of the brown bear recovery plans by the respective autonomous communities, given that not only do the plans need to adapt to the new population situation,

Photo 9. The exchange of information and experiences between social actors from different bear areas facilitates the social acceptance of bears and environmental governance. In the photo, local leaders and representatives from different sectors of Liébana (Cantabria) and Somiedo (Asturias) debate the pros and cons of living with bears.

but also to the new operational objectives and to the new basic lines of action of the national strategy. The revision process for the plans and their posterior implementation also needs to rely on sufficient participation of the rural population. The rural community needs to be conscious of the added value of living with bears and the need to properly address the challenges that may derive from it.

A closer cohabitation between bears and humans poses the necessity of anticipating possible conflict situations. Future challenges should be expected in advance to outline the best strategies in time and mitigate the problems before they undermine the current recovery of the Cantabrian brown bear population.

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The Cantabrian brown bear is moving away from critical extinction risk, providing us with one of the most encouraging joys in nature conservation. Its population hasn't stopped growing over the last few years, enabling a hopeful expansion into the peninsular NW. In addition, this rebirth of a species once deemed to be heading to extinction has occurred in a rural territory undergoing profound transformation, a world of human depopulation, where important traditional land-uses are still carried out at the same time while hosting ever-more tourists looking spend their leisure time in the countryside. This is a scenario that creates new challenges: How can we arrive at the objective of a viable bear population coexisting peacefully with people and their activities? This book looks in depth at these challenges using scientific knowledge so that the reader can find the answers based on the best information available to date.