



FOP Reports 2025 - 2026

Scientific and technical research activities to advance towards a Favourable Conservation Status for the brown bear by assessing the influence of poaching and communication approaches on the species' recovery, and by improving information on plant species of dietary importance to the brown bear under climate change scenarios, in matters of international and national competence

Abstracts



The project "Scientific and technical research activities to advance towards a Favourable Conservation Status for the brown bear by assessing the influence of poaching and communication approaches on the species' recovery, and by improving information on plant species of dietary importance to the brown bear under climate change scenarios, in matters of international and national competence" has received funding from the Ministry for the Ecological Transition and the Demographic Challenge through a grant awarded under the 2025 Call for Proposals, published pursuant to the Order of 23 July 2025 (Official State Gazette (BOE) No. 183 of 31 July 2025). The grant was awarded under Line A of the competitive funding scheme for the implementation of activities of general interest deemed to be of social interest in the fields of scientific and technical research and environmental protection, in matters falling within the competence of the State.



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1. BACKGROUND

Beyond traditional forest management: forests hosting brown bear populations as a source of biodiversity credits

Biodiversity is experiencing a continuous and sustained decline over time (Díaz et al., 2019; Leung et al., 2020), driven by the combined action of powerful demographic and socioeconomic forces that fuel environmental degradation processes. The main drivers of this crisis include the overexploitation of natural resources, climate change, pollution, the introduction and spread of invasive species and, particularly significantly, habitat loss and fragmentation (Jaureguiberry et al., 2022). These factors act synergistically, intensifying their negative impacts and creating a vicious cycle that undermines both ecosystem resilience and the essential services they provide to human societies.

Against this backdrop, the resources currently allocated to halting biodiversity loss remain clearly insufficient. It is estimated that there is an annual global biodiversity financing gap ranging between USD 700 and 900 billion per year (M\$/year), representing a considerable shortfall compared with actual conservation needs (Deutz et al., 2020). The inability of the public sector to address this financial gap has renewed calls to diversify and expand funding sources, particularly through the mobilisation of private capital.

In this regard, the Kunming-Montreal Global Biodiversity Framework (CBD-COP15) has established highly relevant international commitments. Among these, the obligation for high-income countries to increase their public financial support for low-income countries stands out, with the aim of reaching USD 30 billion per year by 2030, as well as the collective commitment to “mobilise” at least an additional USD 200 billion per year. This effort must be achieved primarily through leveraging private finance, promoting public–private blended finance schemes and encouraging innovative financial mechanisms such as green bonds, compensation schemes and biodiversity credits (Target 19; CBD, 2022).

Despite their potential, many of these instruments remain poorly understood or are still in the early stages of development, which hinders both their practical implementation and the assessment of their actual conservation benefits. However, their effective implementation could represent a decisive opportunity to bridge the existing financing gap, create economic incentives aligned with nature protection and promote greater private-sector responsibility in the management of natural capital.

Within this context, the present call for proposals included the objective of advancing the analysis of these emerging mechanisms, with particular attention to biodiversity credits. To this end, it proposed the development of a practical case study to illustrate how these mechanisms operate, assess their feasibility within the current legal and economic framework and, ultimately, develop a set of specific recommendations to guide their potential implementation in Spain.

Actions to further promote strategies that contribute to human–bear coexistence

The expansion and growth of the Cantabrian brown bear population entails several challenges, including an expected increase in damage caused by certain individuals and a greater frequency of bears entering urbanised areas. These circumstances could lead to reduced tolerance towards the species among rural communities and, consequently, to increased public concern and the potential for illegal persecution. Although, in the European context, perceptions of and attitudes towards the brown bear tend to be more favourable than those towards other large carnivores, such as the wolf, increasing levels of conflict associated with the potential costs of coexistence may affect several key human dimensions that are crucial to the conservation and future of the species.

Bear attacks on beehives, orchards and, to a lesser extent, livestock are not a recent phenomenon; rather, they are an inherent aspect of coexistence with the species. However, a growing concern relates to damage to human property within or around villages, including damage to roofs, doors and fences as bears attempt to access food resources such as pet or livestock feed, attacks on chicken coops, and even damage to vehicles in search of food. These incidents are of particular concern because they occur in inhabited rural settlements. The habituation of some bears to human environments may be contributing to increased public concern and declining tolerance towards the species, with potentially significant negative consequences.

To investigate this hypothesis from a scientific perspective, the study *Assessment of social perception towards the brown bear in the Cantabrian Mountains in a context of population growth and expansion, and identification of potential areas where social perception has worsened in recent years* was carried out under the 2024 call of this same funding programme, implemented between 1 July 2024 and 30 June 2025. More than 1,800 interviews were conducted throughout the distribution range of the Cantabrian brown bear. The results confirmed that, overall, the species continues to be viewed positively. However, evidence also suggests that these favourable perceptions may have declined in recent years. Respondents showed a significant decrease in their affinity towards the brown bear and in their perception of the compatibility between the species and rural livelihoods. In addition, fear of or concern about encountering bears has increased, and around half of respondents indicated that they would prefer the population to remain at its current size, among other findings.

Over the past six years, nearly one hundred incidents involving bears entering or approaching villages have generated public alarm in the western Cantabrian Mountains, specifically in the municipalities of Belmonte de Miranda, Somiedo, Proaza, Cangas del Narcea, Degaña and Ibias (Asturias), and Villablino, Páramo del Sil and Palacios del Sil (León), where the highest density of brown bears on the Iberian Peninsula is found. These areas have experienced a marked increase in such incidents and therefore require particular attention. Indeed, under the 2023 call, implemented between 1 January 2023 and 30 June 2024, the study *Monitoring Intervention Measures Applied to Habituated Bears and Capture, Handling, and GPS Tagging of Habituated or Potentially Conflictive Individuals* was undertaken. In addition to monitoring these bears, the project aimed to identify

individuals habituated to anthropogenic food resources through genetic analysis of bear samples collected in and around villages, and to develop a proposal for revising the Protocol for Intervention with Brown Bears in the Cantabrian Mountains. More recently, under the 2024 call, work continued between 1 July 2024 and 30 June 2025 on the capture, handling and GPS-collaring of bears frequenting villages and preying on livestock. The objective was to improve understanding of the processes underlying advanced habituation and to assess bear responses to aversive conditioning measures, particularly the effectiveness of light- and sound-based deterrent devices.

Within the framework of the present call for proposals, the work initiated in previous years was further strengthened, recognising its key role in managing a steadily growing brown bear population in the context of changes in land use and human activities rural mountain areas. The emerging dynamics of coexistence between wildlife and local communities require timely responses based on the best available scientific evidence in order to prevent and mitigate human–wildlife conflicts.

To this end, the project continued with the capture, handling and GPS-collaring of bears showing a high degree of habituation to human presence or with the potential to cause incidents in urban and peri-urban environments. Particular attention was also paid to their role as sentinels against wildlife crime, a threat that has shown a worrying resurgence in recent years.

An example of such an anti-poaching sentinel network is the one established by the Regional Government of the Principality of Asturias in collaboration with Dr López-Bao and Dr Mateo-Tomás. This initiative relies on GPS-collared wildlife, including wolves (*Canis lupus*) and griffon vultures (*Gyps fulvus*), to provide information on threats affecting wild fauna. The bears captured under this project were incorporated into this sentinel network. In the event of a poaching incident, the available spatial data were shared with SEPRONA (the Nature Protection Service of the Spanish Civil Guard) to support its investigations. Notably, this collaborative approach with SEPRONA led, in 2024, to the arrest of an individual linked to the death of a GPS-collared bear monitored by this research team after the animal became trapped in an illegal snare.

This is not an isolated case. The brown bear has historically been subjected to various forms of illegal persecution, including shooting, poisoning and trapping, which drove the species to the brink of extinction during the 1990s. After several decades in which such incidents had become relatively rare, illegal persecution has once again become a matter of concern, with a recent resurgence that could seriously threaten bear populations, even when bears are not the intended targets of these activities.

Illegal hunting, regarded as one of the greatest threats to biodiversity worldwide—second only to habitat loss and degradation—remains a major conservation challenge. Between 1992 and 2017, the European Union allocated more than €70 million to 40 LIFE projects aimed at combating wildlife crime, understood as the illegal capture or killing of wildlife using methods such as firearms, snares, traps or toxic substances. Large carnivores, including wolves, eagles and bears, are among the species most severely affected. In addition to being deliberately targeted because of the damage they may cause to livestock or game species, they are also frequent unintended victims of indiscriminate methods deployed against other animals, such as wild boar, foxes and mustelids.

Given its importance, this action was complemented by conducting transects to search for illegal snares in areas with the highest incidence of this threat, as well as by updating the database on brown bear mortality in the Cantabrian Mountains. The populations of this species have shown a recovery pattern similar to that observed in other European large carnivores, highlighting the need for rigorous monitoring. In the context of its range expansion, it is essential to integrate multiple sources of information to accurately assess population status and trends, enabling a better understanding of growth processes and ensuring that conservation actions and management plans are effectively adapted to the new conditions faced by the species. Mortality data, both for cubs (individuals under one year of age) and adult bears, represent a critical component of this monitoring framework. To this end, all available data since 2023 were compiled, including necropsy reports, in coordination with the competent authorities.

Similarly, it is essential to assess how the media portray the brown bear and the phenomenon of coexistence with the species. An increase in negative news coverage in recent years may be negatively influencing local communities' perceptions of the species and creating a context conducive to an increase in illegal actions against bears. In this regard, it should be noted that both the FOP and some of its scientific advisors already have previous analyses on this topic, which were published in 2021 in the book *Cantabrian Brown Bears: Demography, Coexistence and Conservation Challenges*, published with funding from the Spanish Ministry for the Ecological Transition and the Demographic Challenge. The book explores the challenges facing brown bear conservation from a scientific perspective. Specifically, Chapter 5 examines social perceptions of the brown bear among rural communities and the species' presence in the media, as media coverage of wildlife species—and particularly large carnivores—often tends to focus on conflict situations. This approach not only tends to exaggerate perceptions of risk, but may also reflect or shape the views of different social groups with specific interests, the general public, and even certain political agendas. The way information is presented influences how people understand and interpret an issue, affecting their attitudes, perceptions and even behaviours. Therefore, analysing how the media portray a species is essential for designing effective conservation strategies.

Finally, beyond its intrinsic value, biodiversity conservation is fundamental to ensuring human well-being at multiple levels, as healthy ecosystems provide essential services that sustain human life and environmental balance. These services include climate regulation through carbon sequestration, protection against flooding, soil fertilisation, water purification and crop pollination, which underpins agricultural production and food security. Biodiversity also contributes to maintaining resilient landscapes capable of adapting to natural and human-induced disturbances, as well as preserving genetic diversity, which is crucial for the evolution and adaptation of species in response to environmental changes. However, traditional conservation approaches face significant limitations that may compromise their effectiveness. Planning based solely on conventional methods, such as periodic population surveys or isolated field observations, is often constrained by issues of scalability, limited human and financial resources, and a lack of accurate and up-to-date data. These limitations also reduce the ability to respond rapidly to environmental changes, fluctuations in species populations, or emerging threats such as diseases, wildfires and invasive alien species.

The integration of new technologies offers opportunities to overcome these barriers and optimise conservation efforts. In particular, recent advances in artificial intelligence (AI) have transformative potential for biodiversity management, enabling complex challenges to be addressed with levels of precision and efficiency that were previously unattainable. AI-based tools, including machine learning, big data analysis, computer vision and predictive modelling, can improve species identification, automate habitat monitoring and detect emerging threats with far greater detail and speed than conventional approaches. Examples include individual identification from camera-trap photographs, monitoring migratory movements using satellite data, and predicting areas of potential human–wildlife conflict. Furthermore, AI enables the integration of large volumes of ecological, socioeconomic and climatic information, facilitating more robust strategic decision-making, the prioritisation of critical conservation areas and the implementation of adaptive policies capable of proactively responding to environmental changes. Consequently, the adoption of AI-based technologies not only complements traditional methods but also opens new opportunities for efficient, accurate and sustainable biodiversity conservation.

For this reason, the present call for proposals focused for the first time on analysing the state of the art of AI applications in biodiversity conservation, using the brown bear as a model species. In particular, the aim was to explore how these technologies can support population management, reduce human–wildlife conflicts and promote sustainable coexistence strategies that combine species protection with human activities in rural areas.

It should be highlighted that, given the need to address these and other challenges from a broad perspective and with the involvement of key local stakeholders, the FOP is coordinating the LIFE Human Bear Coex project since July 2023 until December 2027. The project is co-funded by the European Commission and includes as partners the nine municipalities hosting the highest brown bear densities in Spain (Somiedo, Belmonte de Miranda, Proaza, Cangas del Narcea, Degaña and Ibias in Asturias, and Villablino, Páramo del Sil and Palacios del Sil in León).

The project includes among its main actions the training of technical teams and local leaders; the maintenance and clearing of safety perimeters around villages and nearby trails; the planting of fruit trees away from villages as a deterrent measure; the protection of facilities close to homes used for domestic animals or identified as critical attractant points; pilot testing of bear-proof waste container covers and containers; GPS-collaring of particularly conflict-prone individuals; and the replication of results in other bear populations facing similar contexts. Some of the activities developed under this call (O2.1, O3.1 and O4.1) are integrated within this LIFE project.

Reducing uncertainties to further support brown bear adaptation to climate change projections

Between 2021 and 2025, FOP coordinated the LIFE Bears with Future project, co-funded by the European Commission. Its main objective was to improve the adaptability of the brown bear to climate change in the Cantabrian Mountains, contributing to achieving a “Favourable Conservation Status” for the species in the medium and long term through an Ecosystem-based Adaptation

approach. The project promoted best practices and solutions aimed at enhancing the availability of bear food resources and preventing human–bear conflicts.

Within this framework, the project became an outstanding source of knowledge on how key species in the brown bear's diet are expected to respond to global warming, allowing conservation strategies to focus on those species showing greater resilience. A total of 148,883 fruit-producing trees and shrubs were planted following scientifically established criteria based on climate change scenarios, covering more than 150 hectares across brown bear areas in the western Cantabrian Mountains. The project received scientific advice from expert researchers at the Joint Research Unit in Biodiversity (University of Oviedo, CSIC and Principality of Asturias), the University of Cantabria, the University of León, the University of Santiago de Compostela, the University of Vigo, the University of Valladolid and the University of Extremadura. Several of these researchers were also involved in the work carried out by FOP under these calls for proposals. Key studies were conducted, including the *Study of identification and characterization of high suitability areas for fleshy fruit trees and chestnut planting under climate change scenarios*, a *Climate Change Vulnerability Analysis (CCVA) of bear critical areas* and an *Analysis of the sensitivity of cherry tree to climate change*, among others.

Furthermore, under previous funding calls financed by the Spanish Ministry for the Ecological Transition and the Demographic Challenge, FOP carried out studies aimed at improving knowledge and research on climate change and the mechanisms available to mitigate and adapt to its impacts. Specifically, in 2018, FOP conducted a *Review of the Expected Effects of Climate Change on the Brown Bear and Key Trophic Vegetation Species, and Potential Adaptation Strategies*. This work represented the first review undertaken by FOP's technical team of the available scientific information on the impacts of climate change scenarios on brown bear populations, including both direct effects on bear ecology and physiology and indirect effects through changes in fruit production by tree and shrub species that are highly important in the current diet of the species, as well as impacts on critical conservation areas. In 2020, this work was further developed through an *Analysis of Climate Change Adaptation Proposals in Brown Bear Conservation Plans Worldwide and Their Applicability to Iberian Populations*. Together with researchers from the University of Cantabria and other specialists, the study compiled and reviewed in detail the different climate change adaptation strategies, plans and proposals developed and/or implemented in brown bear populations worldwide, particularly in Europe. Their objectives, implementation and outcomes were analysed, as well as their potential applicability and relevance for Iberian populations.

Subsequently, with a specific focus on the effects of climate change on food availability and brown bear resilience, in 2021 the report *Combatting the Effects of Climate Change on the Cantabrian Brown Bear by Preparing Actions to Improve Trophic Availability and Adaptation in Critical Areas* was developed jointly by FOP and researchers from the Universities of Extremadura, Cantabria and Oviedo. In this case, a set of native fruit-producing tree species of interest for brown bears was selected (wild cherry, European buckthorn, strawberry tree, whitebeam, apple tree and chestnut tree) to analyse climate change impacts through data on species presence, characterisation and distribution modelling. Based on the results, areas with the highest suitability and potential

windows of opportunity were identified for their establishment in locations where their survival and fruit production could be favoured.

Under the 2023 call for proposals, these aspects were further investigated, focusing on the response of nut-producing species (acorns, beechnuts, hazelnuts and chestnuts), which represent key nutritional resources for brown bears during hyperphagia. The results anticipated diverse climate change effects on these species in the Cantabrian Mountains. While habitat suitability for beech and Atlantic oak may decrease, Mediterranean oak species and chestnut trees are expected to expand or perform better under future conditions. These changes in species composition are expected to result in adaptive changes in brown bear diet during hyperphagia.

The study also identified vulnerable habitats and suitable areas for less climate-sensitive species, such as chestnut trees, which could become an essential autumn and winter food resource for Cantabrian brown bears in some areas of the mountain range.

Finally, under the previous 2024 call, this research approach was extended to the Pyrenees with several objectives: (i) assessing the impact of climate change on nut-producing species relevant to the diet of the brown bear (*Ursus arctos*) during the hyperphagia period; (ii) analysing functional complementarity between species through species richness; and (iii) identifying vulnerable areas in order to better understand the challenges faced by the species when adapting to changing environmental conditions. Conservation strategies were also proposed to safeguard key food resources essential for brown bear survival and welfare. Overall, this work provided an integrated understanding of the interactions between climate change, food resource availability and the ecological requirements of brown bears during hyperphagia, with the aim of contributing to their long-term conservation under increasing environmental pressures.

Under the present call for proposals, efforts focused on evaluating, based on the available information, the impact of climate change on the phenology and productivity of key nut-producing species in the diet of brown bears in the Cantabrian Mountains, particularly during the hyperphagia period, through the use of vegetation indices and predictive modelling.

Climate change is substantially altering these parameters, with direct implications for agroforestry production and the availability of trophic resources for wildlife. Changes in phenology may disrupt the synchrony between fruiting peaks and the energetic requirements of bears, generating trophic mismatches that could affect body condition and reproductive success. Furthermore, these changes influence forest biodiversity, ecosystem services and rural economies, affecting sectors such as chestnut production, hazelnut and acorn harvesting, and associated forest management systems. Previous studies (Pérez-Girón et al., 2025) showed that, under severe climate scenarios, Atlantic species such as *Fagus sylvatica* and *Quercus petraea* could experience significant reductions in habitat extent, whereas more thermophilic Mediterranean species, such as *Quercus ilex* and *Quercus suber*, could expand their distribution by 2100. This ecological niche shift implies changes in species composition, phenology and fruit availability for wildlife, particularly affecting more Atlantic species.

On the other hand, it is already known that one of the reasons why brown bears (*Ursus arctos*) approach human settlements is the search for food, including cultivated apples in orchards and gardens. However, it was unclear whether bears consume all apple varieties equally or whether they show preferences for certain types or ripening stages. Under this call, we analysed the apple varieties consumed by brown bears in the Cantabrian Mountains, assessing parameters such as fruit sugar content and acidity, and comparing consumed and non-consumed varieties to identify dietary preferences.

Understanding these preferences has direct implications for coexistence management. Since apple varieties ripen at different times, the results allow periods of increased risk of incursions into orchards and inhabited areas to be anticipated. This information supports management strategies, such as planting less attractive varieties near human settlements and promoting preferred varieties in remote areas, thereby reducing conflict risks.

Moreover, it enables the planned management of trophic resources and the design of preventive measures adapted to the distribution and seasonal behaviour of the species, contributing both to its conservation and to sustainable coexistence.

Improving water management in brown bear areas to enhance ecosystem services and address depopulation

In the previous call for proposals, FOP, in collaboration with legal advisors, developed the study *Review of the evolution of the different Integrated Watershed Management (IWM) solutions and their application in designing a pilot program for the subwatersheds in bear habitat areas*. This work resulted in a series of recommendations and proposals that highlighted the need to continue progressing towards more efficient and participatory water management.

The preamble to Order TED/898/2023 states that “it is essential to promote and strengthen the development of studies, analyses, actions and awareness-raising activities, training programmes, campaigns and research that respect natural, geological or climatic boundaries associated with natural structures or systems, such as rivers, river basins, maritime-terrestrial and hydraulic public domains, mountain systems, the Iberian Peninsula, island groups and straits between continents, which transcend political boundaries such as those of Autonomous Communities, provinces or municipalities”. Brown bear areas in Spain are mainly located in mountain systems where several river basins converge, in some cases dividing not only provinces but also municipal boundaries. For this reason, integrated water management should provide solutions to improve the coordination of national water policies in these bear areas, not only because of the intrinsic and direct benefits for the management of the Hydraulic Public Domain (HPD) and water security, but also because it can strengthen efforts to address depopulation in territories where efficient and sustainable water management is essential for maintaining economic activities in key sectors, such as livestock farming (which requires irrigated pastures) and forestry (which depends on water resources that are becoming increasingly scarce due to climate change).

In this regard, as recalled in the preamble of the same Order, the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) is responsible for proposing and implementing the Government's policies on climate, energy and the environment aimed at transitioning towards a more ecological productive and social model. It is also responsible for developing and implementing Government policies addressing the demographic challenge and territorial depopulation. Likewise, this Ministry is responsible for proposing and implementing water policy as an essential public resource, as well as policies to combat depopulation and the development of the National Strategy on the Demographic Challenge.

Therefore, research into how improved integrated water management in brown bear areas can contribute to addressing depopulation is of significant social interest, particularly in municipalities that already have very low population densities. Such research would also support the development of coordination mechanisms between different administrative bodies, including water authorities (river basin organisations), territorial administrations, the General State Administration, Autonomous Communities (competent authorities in protected natural areas, livestock farming and forest management) and local administrations.

2. OBJECTIVES

General objective:

To further advance the conservation of the brown bear and its habitat by integrating the study of innovative financial instruments, strengthening mechanisms to address threats, applying new technologies to support human–bear coexistence, analysing the species' media exposure, assessing the impacts of climate change on trophic resources, and improving water management linked to bear habitats, thereby contributing to the development of replicable models for brown bear conservation and coexistence with rural communities.

Specific objectives:

- O1.1. To gain an understanding of the functioning and current status of biodiversity credits in the international context, assess their potential as a financial instrument for conservation, and develop proposals for their incorporation into the Spanish legal framework.
- O2.1. To contribute to anti-poaching sentinel networks through the capture and tagging of brown bears, remove illegal trapping devices from bear habitats, and update the database on the causes of mortality of the Cantabrian brown bear.
- O3.1. To review the state of the art in the application of artificial intelligence to biodiversity conservation and the facilitation of human–brown bear coexistence.
- O4.1. To analyse media coverage of the brown bear and its influence on rural communities'

perceptions of the species.

- O5.1. To assess the impact of climate change on the phenology and productivity of key nut-producing species that are essential components of the brown bear's diet in the Cantabrian Mountains.
- O5.2. To determine the degree of selectivity shown by brown bears towards different cultivated apple varieties in the Cantabrian Mountains.
- O6.1 To use Biosphere Reserves as living laboratories to improve integrated water management and develop solutions.

3. SUMMARY OF RESULTS

Objective 1.1

A1.1. Biodiversity credits as a financial mechanism for nature and brown bear conservation within the Global Biodiversity Framework - Kunming-Montreal

Actions for the conservation and restoration of nature suffer from a chronic lack of financial resources. Globally, it has been estimated that more than \$940 billion is needed annually, while in Europe the estimate is around €65 billion per year. In Spain, based on the State Strategic Plan for Natural Heritage and Biodiversity to 2030, at least €4,173.2 million is required. These amounts are difficult to achieve through public funds alone, which is why the latest Global Biodiversity Framework, adopted in 2022, emphasizes the need to promote financing mechanisms. Specifically, it highlights the need to encourage instruments such as payments for ecosystem services, green bonds, biodiversity offsets and credits, and benefit-sharing mechanisms (Target 19d).

This study explores the potential of biodiversity credits as a financial tool to support conservation, applying them to forests jointly owned by the Brown Bear Foundation in the Fuentes del Narcea, Degaña e Ibias Natural Park in Asturias, Spain. To this end, a literature review was first conducted, encompassing both academic and grey literature (non-peer-reviewed), with the aim of studying biodiversity credits for their subsequent application. The search yielded a total of 43 scientific papers and 20 technical documents published since 2005.

For the case study, a detailed map of the Habitats of Community Interest under Directive 92/43/EEC present in the work area was created, and a baseline was established using the variables proposed by Vallecillo et al. (2022). The review of data sources showed that the physicochemical metrics available at European scale have resolutions that are too broad or point values that do not reflect the internal heterogeneity of the territory, while the structural and functional variables derived from Sentinel and LiDAR offer adequate resolution and periodicity to characterize relevant ecological

changes.

The proposed model also incorporates landscape metrics—fragmentation and connectivity—essential for interpreting ecological indicators associated with the brown bear (*Ursus arctos*), such as food availability and disturbance levels. Composition variables were integrated using forest mapping, field validations, and six-year reports based on Articles 12 and 17 of the Birds and Habitats Directives, respectively, which provide periodic information on the richness and conservation status of species and habitats of interest. Based on this, a simple and transparent biodiversity credit is proposed, calculated as the initial conservation value multiplied by the effective area and adjusted using a 20% uncertainty factor.

This approach dispenses with the common concept of additionality, which is difficult to apply in relatively well-preserved ecosystems, and relies on the logic of risk as a counterfactual: without active conservation, processes such as erosion, loss of soil fertility, peatland degradation, or biodiversity loss would be plausible. This aims to correct the usual asymmetry of biodiversity markets, which tend to reward restoration after degradation, and explicitly recognizes the value of conserving healthy ecosystems.

To monitor the credit, a set of metrics is proposed that combines structural indicators (NDVI, FCC, connectivity, fragmentation, vegetation height, and vertical structure irregularity) and non-structural indicators (composition, richness, vulnerability). In the absence of reference sites, a relative ranking system based on the initial state is adopted. This allows for verification of changes in the state over time.

The outcome is an operational model that recognizes the value of conserving healthy ecosystems, integrates verifiable metrics for monitoring them, and offers a way to incorporate brown bear conservation into financial mechanisms based on biodiversity credits. Furthermore, this model connects EU conservation policies with the demands of the private sector and is applicable to other elements of Europe's natural heritage. This work is particularly relevant given the current interest within the EU in regulating and developing biodiversity credits.

Objective 2.1

A2.1. Inclusion of Brown Bear Capture, Handling, and GPS Transmitter Tagging in Anti-Poaching Sentinel Networks, Removal of Illegal Snares, and Updating Knowledge on the Causes of Brown Bear Mortality in the Cantabrian Mountains

Since 1 July 2025, in order to contribute to strengthening sentinel surveillance networks and to improve the detection of illegal activities, 25 brown bear capture campaigns have been carried out in Asturias. These operations resulted in the tagging and monitoring of four adult bears, fitted with GPS-Iridium collars. In addition, one cub was captured and equipped with a GPS-GSM fur-mounted transmitter. Monitoring these individuals provides spatial and temporal information that is highly

valuable for the conservation of the species and for identifying risk factors associated with non-natural mortality.

In parallel, and complementing the ongoing surveillance, monitoring, and control activities carried out by the Brown Bear Foundation's teams, several specific operations were launched from 1 July 2025 in natural areas of central and western Asturias. These operations were aimed at detecting and removing illegal capture devices—particularly snares and other non-selective devices—located within the brown bear's range. Their objective was to reinforce surveillance in areas of special interest and to facilitate the early detection of threats affecting this and other wildlife species.

Accordingly, in collaboration with the Environmental Rangers of the Principality of Asturias, the Nature Protection Service of the Spanish Civil Guard (SEPRONA), staff from the Fundación Oso de Asturias (FOA), and gamekeepers from different hunting estates, nine field operations were conducted to search for and remove illegal snares and other potential illegal trapping devices. During these operations, 48 transects were surveyed and 8 snares were removed, leading to the initiation of the corresponding investigations by law enforcement agencies.

The results obtained reveal that the use of illegal snares persists, although in localized areas of the territory, highlighting the need to maintain continuous surveillance and to strengthen efforts to detect, eradicate, and investigate these illegal practices. At the same time, the absence of incidents across most of the surveyed areas constitutes a positive result and reflects the effectiveness of the preventive measures implemented in recent years.

Although the relative importance of anthropogenic mortality appears to have declined compared with previous decades, threats arising from human activities remain present and continue to represent a significant risk to the conservation of the species. The findings of this study highlight the need to maintain long-term monitoring programmes to improve understanding of the causes of mortality, enable the early detection of emerging risk factors, and provide scientific evidence to support and guide management, surveillance and conservation actions for the brown bear.

Objective 3.1

A3.1. Application of Artificial Intelligence to Ease Human–Brown Bear Coexistence Scenarios

Artificial “intelligence” (AI) consists of computational systems capable of performing tasks that typically require human intelligence, such as natural language understanding. Although AI has been under development since the 1950s, it has recently gained considerable relevance due to its commercial availability through large language models. These models are capable of autonomously performing multi-step tasks to achieve a specific goal and are only beginning to be used in the fields of ecology and conservation. In these disciplines, AI applications have primarily focused on the study and monitoring of species.

In this study, the potential of AI applications for brown bear conservation and for facilitating coexistence scenarios with the species was evaluated, based on a literature review addressing this topic in ursids, as well as on a search for experiences applying AI to facilitate coexistence scenarios with these species. A total of 18 studies related to ursids and the use of AI were selected.

To date, the application of AI to coexistence with wildlife species has focused primarily on the identification of individuals, driven by the substantial development of computer vision technologies. Building on these advances, AI has naturally begun to be applied to wildlife monitoring. Furthermore, its applications are extending to the prevention of conflicts between wildlife and human activities through the prediction of high-risk areas and the use of deterrence systems. Overall, however, the application of AI in this context is still at the pilot and/or development stage.

From a deterrence perspective, systems that apply AI show an improvement in relation to the context of habituation. Unlike passive methods, AI-driven deterrence systems trigger a response to an actual threat precisely when it occurs, which promotes the establishment of a negative association in animals, with great potential to increase the likelihood of inducing conditioned aversion in wildlife.

As a future research direction, it will be necessary to expand medium- and long-term trials using already developed systems as well as new AI-based solutions, in order to objectively determine their effectiveness in preventing conflicts and facilitating coexistence scenarios between wildlife and human activities.

Objective 4.1

A4.1. Analysis of media representation of the coexistence with brown bears and potential changes in the types of messages conveyed over time

In a scenario of population expansion and recovery, such as the one currently experienced by brown bears in the Cantabrian Mountains and the Pyrenees, maintaining public acceptance of the increasing presence of the species is essential for its long-term conservation. This is particularly relevant in areas where brown bears have been absent or present at very low densities over recent decades, as well as in areas where, for instance, bears are observed in the surroundings of or even within villages. Among the multiple factors influencing societal perceptions of a given species (e.g., social norms, knowledge, experience, and information), the media stand out due to their considerable capacity to determine the frequency and content of environmental information reaching the public. Indeed, the media can contribute to exaggerating perceptions of the risks associated with living alongside these species, which may also be strongly influenced by emotions. Given the role of the media in shaping public narratives and opinions on any given issue, understanding how media coverage is framed and how it changes over time is essential to mitigating existing conflicts, identifying potential conflict hotspots, and reducing the likelihood of

new conflicts emerging or certain narratives becoming polarized.

In this study, we evaluated the hypothesis that, in association with the recovery of the species and the increase in bear–human interactions, negative news coverage of the species may have increased in recent years. This could be negatively influencing perceptions of the species among the local population. We analysed brown bear-related news articles published in regional newspapers within the species’ distribution range in the Cantabrian Mountains and the Pyrenees between 2019 and 2025. The newspapers considered were: Diario de León, Diario de Navarra, El Diario Montañés, El Heraldo de Aragón, El Norte de Castilla, La Nueva España, La Vanguardia, and La Voz de Galicia.

The proportion of news articles with a negative valence regarding the perception of the brown bear was 19.3%, whereas the proportion of articles showing a negative impact of the activities or attitudes described in the news item on species conservation was 23.7%. Overall, during the study period, 22% of news articles were related to bear–human conflicts, for example, reports on bear damage to beehives, livestock, or crops, or expressions of fear or concern regarding the presence of bears near villages. This contrasted with 45% of articles whose main topic was related to species conservation.

The probability that a news article presented a negative valence regarding the representation of brown bears differed among the media outlets analysed, with the highest probabilities observed in newspapers from the Pyrenean region. The probability that a news article presented a negative representation of brown bears increased over the study period. However, the probability that a news article presented a negative valence regarding the impact of the activities or attitudes described on species conservation decreased over time.

Overall, these results highlight the importance of continuously monitoring the representation of brown bears in the media to identify changes in narratives that may influence social perceptions of the species and to guide communication strategies that promote both conservation and coexistence.

Objective 5.1

A5.1. Environmental impact of climate change on the phenology of fruit-producing species of importance for the brown bear using vegetation indices

This study analysed the phenology of five forest tree species producing dry fruits that are of major importance for the diet of the Cantabrian brown bear (*Castanea sativa*, *Fagus sylvatica*, *Quercus faginea*, *Quercus petraea*, and *Quercus pyrenaica*), using Sentinel-2 image time series from 2017 to 2026 and climate data from ERA5-Land. The objective was to characterise the phenological patterns of these species and to assess the influence of altitude and climate on seasonal vegetation dynamics.

The results showed that the different species exhibited similar phenological calendars, although differences were observed in the timing of the onset and completion of the different phases. Chestnut was the species with the earliest development, whereas sessile oak and Pyrenean oak showed the latest phenological patterns. Overall, the onset of growth occurs between April and early May, leaf maturity between late May and early June, senescence at the beginning of September, and the end of the growing season between late October and early November.

The temporal analysis revealed phenological changes consistent with the effects of climate change. Several species showed an earlier onset of the growing season and, particularly, a significant advancement of autumn phases, including senescence and the end of the growing season. Consequently, some species exhibited a reduction in the overall duration of their vegetative period. In parallel, altitude significantly influenced phenology, generally delaying the onset of vegetative activity and other developmental phases as elevation increased.

Mean temperature prior to phenological events was the climatic variable with the greatest explanatory capacity. Higher temperatures during the months preceding the onset of growth promoted advances in budburst of several days per degree Celsius of thermal increase. Temperature shaped the subsequent dynamics of the growing season, confirming its role as the main driver regulating phenology in the analysed species. Neither precipitation, chilling hours, nor accumulated degree days showed comparable explanatory power.

The results obtained in this study suggest that current climatic changes may alter the temporal availability of fruits and seeds used by brown bears during the hyperphagia period. Since beech, oak, and chestnut trees constitute key food resources for the species, the observed phenological shifts could affect the production and availability of dry fruits. Although specific studies on fruiting patterns will be required to confirm these effects, this study highlights the importance of incorporating phenological dynamics into assessments of climate change impacts on Cantabrian forest ecosystems and the species that depend on them.

Objective 5.2

A5.2. Assessment of cultivated apple varieties selection by brown bears: comparison of parameters determining preference levels

This study analysed the use of cultivated apple varieties by the Cantabrian brown bear, combining the spatial analysis of 207 damage reports recorded between 2018 and 2023 with an assessment of the organoleptic characteristics of fruits from trees consumed and not consumed by the species. The objective was to improve understanding of the factors determining the selection of this food resource and its potential role in the brown bear diet.

The results showed that damage events were mainly concentrated in the mosaic agroforestry landscapes characteristic of the Cantabrian Mountains, where apple trees are typically located in family orchards, meadows, and areas close to small rural settlements. Affected trees were usually

found near houses, livestock sheds, and paths, as well as in environments where chestnut, hazel, oak, or beech stands were also present, these species constituting key food resources for bears during the hyperphagia period. The spatial proximity of many recorded damage events further suggests that some individuals may return to areas where they have previously found food successfully.

A total of 24 apple samples from six municipalities in Asturias and León were analysed, with clear evidence of bear consumption found in 21 of them. The mean fruit content was 14.26 °Brix and 0.88% malic acid, with high variability observed both among trees and within individual trees. This heterogeneity reflects different degrees of fruit ripening within the canopy and may contribute to extending the temporal availability of this food resource.

Most of the analysed samples showed sweet or balanced sensory profiles, specifically 54.16% of fruits were classified as sweet and 41.66% as balanced, whereas only 4.16% were classified as acidic. These characteristics are particularly relevant from an ecological perspective, as fruits with higher energetic content may represent an important resource for bears during the accumulation of fat reserves prior to winter.

Furthermore, eleven traditional apple varieties included in the Protected Designation of Origin (PDO) Sidra de Asturias were identified as having characteristics similar to those observed in the analysed fruits: Chata Blanca, Cristalina, Dura, Ernestina, Montés de Flor, Paraguas, Raxila Dulce, Raxina Dulce, Raxona Dulce, Verdialona, and Verdosa. Most of these varieties show late flowering and ripening during November, making them potential candidates for management actions aimed at increasing the availability of food resources away from human settlements and reducing conflicts associated with damage to home orchards.

Overall, the results indicate that apples represent a complementary food resource within landscapes with abundant availability of dry fruits, with bears preferentially consuming fruits with sweet or balanced characteristics. This study provides useful information for understanding the feeding ecology of the Cantabrian brown bear and for designing management measures compatible with species conservation and the reduction of conflicts with human activities.

Objective 6.1

A6.1. Integrated water resources management in the cantabrian brown-bear areas A tool for the ecosystem services of forests and pastures and for combating depopulation

The mountains of the Cantabrian range inhabited by the brown bear act as genuine «water towers»: their headwaters give rise to a strategically valuable resource whose quantity, quality and regime depend directly on the condition and management of the forests and pastures. Yet a single mountain area brings together several river basins, several public administrations and numerous municipalities, which hinders coherent management. This research examines how improving

Integrated Water Resources Management (IWRM) can simultaneously enhance the ecosystem services provided by forests and pastures and strengthen the fight against depopulation, by proposing instruments to coordinate the water and territorial administrations. Its specific objectives address the maintenance of environmental (ecological) flows and the adaptation of irrigation works to environmental requirements, as well as the role of water in the prevention and suppression of forest fires.

The study area comprises the five brown-bear Biosphere Reserves —Laciana Valley, Babia, the Omaña and Luna Valleys (Castile and León), Somiedo (Asturias) and the Picos de Europa (Asturias, Castile and León, and Cantabria)—, which together cover some 2,348 km² and span three river-basin districts (Western Cantabrian, Duero and Miño-Sil), three autonomous communities and twenty municipalities. It is precisely this convergence of basins, administrations and territories that justifies an integrated, coordinated approach.

The work combines legal and documentary analysis —with legislation checked against official sources and case law verified— with a cartographic study and Geographic Information System (GIS) processing developed as a pilot project. It reviews the scientific literature on mountain water, forests and pastures and the applicable planning instruments (hydrological, forestry, environmental and protected-areas, urban and spatial planning, civil protection against fires, and demographic-challenge planning); identifies the competent administrative bodies and the economic actors —chiefly livestock farmers and foresters—; and integrates and analyses official geospatial information to characterise land use, the grazing base, river continuity, fires, population and depopulation. The technical diagnosis was further tested through a participatory process addressed to local actors, whose contributions are offered as a qualitative complement to the analysis.

The cartographic study yields notable empirical findings. In Babia, 86% of the territory is pasture —mostly woody— yet only 69.5% is eligible for Common Agricultural Policy (CAP) support; detailed analysis shows that it is traditional irrigation, sustained by weirs and channels, that determines this eligibility. Cross-referencing fires with land use confirms that fire mainly consumes the woody pasture left by land abandonment (over 76% of the burned area in the Laciana-Somiedo belt). This corroborates that restoring extensive grazing and traditional irrigation is, at once, a measure of water management, fire prevention and population retention.

The participatory process, based on twelve questionnaires from qualified actors across the three basin districts, paints a coherent diagnosis: a structural deficit in inter-administrative coordination and in water-user participation —acknowledged by the basin authorities and by the biosphere reserves themselves—; hydrological planning that reasonably addresses environmental flows but undervalues traditional mountain irrigation; and marked institutional weakness, aggravated by depopulation. It follows that the core problem is fragmentation —of basin districts, autonomous communities, legal regimes and user organisations— set against a territory that is unitary, so that the main area for improvement is coordination.

On this basis, the report puts forward regulatory, organisational and management proposals

centred on loyal cooperation between administrations. These include securing the water supply of Natura 2000 sites through nominative water reservations and binding «water fact-sheets»; using each district's Committee of Competent Authorities as the channel for integration; and a cooperative model equipped with a subsidiary closing clause. The Biosphere Reserves are proposed as laboratories and potential coordinators, with IWRM as the connecting thread, on the horizon of a large Cantabrian-wide reserve. The preparation of the fourth hydrological planning cycle (2028-2033) opens the ideal window to incorporate these measures.

Improving Integrated Water Resources Management is a necessary but not sufficient condition for meeting the demographic challenge: without generational renewal, profitability and services, water management alone will not halt abandonment, yet without efficient use of the resource it is impossible even to contemplate retaining population or sustaining new bioeconomy ventures. The conservation of the brown bear and its habitat, the upkeep of forests and pastures, fire prevention and the survival of mountain communities thus converge on a single objective of general interest. Against fragmentation, the answer is not centralisation but stable, voluntary coordination with a light administrative burden that recognises —and, where appropriate, remunerates— the water-related ecosystem services provided by mountain livestock farmers and irrigation communities, the true guardians of water in the brown-bear areas.

4. CONCLUSIONS

The project has significantly expanded scientific knowledge on the conservation of the brown bear and the factors influencing its coexistence with human activities. The research carried out has addressed aspects related to individual monitoring, poaching prevention, social perceptions, climate change and integrated territorial management, highlighting the importance of incorporating different scientific disciplines to address conservation challenges. The combination of wildlife monitoring techniques, GIS-based cartographic analyses, artificial intelligence, communication studies, legal analysis and ecological assessments has provided a more comprehensive understanding of the challenges associated with the recovery of the brown bear.

The results obtained have therefore provided useful tools to improve management and decision-making processes, enabling future actions to be planned with greater precision in areas such as conflict prevention, habitat conservation, environmental restoration, water resource management and climate change adaptation. In addition, technical and outreach materials have been developed, permanent exhibition spaces have been created, and at least one scientific article is currently in the publication process in a high-impact international journal, contributing to the dissemination and transfer of the knowledge generated to both the general public and the scientific community.

Overall, the project has achieved its expected objectives and has also provided valuable support for the design of public policies and initiatives aimed at promoting brown bear conservation and sustainable development in bear-inhabited territories.

