U.PORTO

MESTRADO
ECONOMIA E GESTÃO DO AMBIENTE

Economic Potential of the Iberian Ibex (*Capra pyrenaica*) in landscape management – Rewilding with an iconic animal species in Portugal

Inês Serrano Borges e Silva

M

2022

FACULDADE DE **ECONOMIA**

U.PORTO
FACULDADE DE ECONOMIA
FEP UNIVERSIDADE DO PORTO

Economic Potential of the Iberian Ibex (*Capra pyrenaica*) in landscape management – Rewilding with an iconic animal species in Portugal

Inês Serrano Borges e Silva

Dissertation
Master's in Environmental Management and Economics

Supervised by
Manuel Castelo Branco
Daniel Veríssimo

2022

Acknowledgments

I would like to thank my Professor Manuel Castelo Branco for sharing this internship opportunity, give me guidance, being helpful and always available to answer my questions. To my supervisor Daniel Veríssimo for helping me decide this dissertation scope and focus, provide valuable advice and critical comments, for the regular meetings that kept me motivated and allowed me to become more comfortable with this thesis' development process, which can sometimes be stressful. Also, cannot forget the incredible opportunity of travelling to Sierra de Francia Natural Park so that I would be able to see the Iberian Ibex with my own eyes, so I am very grateful to the effort Daniel has made for me. To Rewilding Portugal for giving me the opportunity to work and develop a theme that matches so much my personal beliefs, and for showing me their impactful mission in Portugal. To my parents for believing in my capacities and giving me the tools that allowed me to get here. A warm hug to my sister that makes my life more colourful but also for sometimes distracting me and make my mind clear a bit. A lovely kiss for my grandmother that has always inspired me to be creative and chase my dreams. A big thank you to Alice and Carlos for being the best second parents I could as for and provide me with love, support and comfort. Additionally, thanks to Manuela for wise counsel and sympathetic ear. All the love for my friends Marta, Ana Margarida and Tomás for bringing the fun into my life and supporting me along this journey. Also, could not forget Inês, the best friend I could ever ask for, the one who I share so much of my life important moments and lessons with, that listens to all my doubts and lifts me up. Finally, a special gratitude to my incredible boyfriend Diogo for being the best partner, the person that has always believed in my potential and inspires me to be my best, with whom I shared so much of this journey with, giving me confidence and supporting me in my good and bad moments.

Resumo

Ecossistemas na Europa estão seriamente danificados (em biodiversidade e abundância) pelos distúrbios provocados pelo homem, como é o caso das paisagens em Portugal afetadas pelo abandono agrícola e escassez de vida selvagem, levando à invasão de mato, homogeneidade da vegetação e solos pobres. Programas de gestão da paisagem são assim vistos como essenciais, mas o problema dos incêndios florestais continua a criar perdas socioeconómicas, com tendência para aumentar devido às alterações climáticas. A cabra-montesa é um herbívoro da Península Ibérica, afetado por distúrbios humanos que quase levaram à sua extinção. Atualmente está presente nas paisagens espanholas e Pirenéus, devido a programas de restauro, mas em Portugal está restrita a uma zona no Norte. Este estudo procura avaliar o potencial que a espécie apresenta enquanto ferramenta para futuros programas de gestão e restauro da paisagem, pelo seu potencial em poupar custos e fornecer vários benefícios ambientais. O trabalho compara do ponto de vista económico-ambiental, uma abordagem de gestão ativa através de intervenções humanas no terreno e um método de gestão passiva com a reintrodução da cabra-montesa em várias áreas do território português, na forma de uma iniciativa rewilding.

Em primeiro lugar, é fornecida uma visão geral sobre as condições para a reintrodução desta espécie em Portugal. A parte central do trabalho desenvolve uma estimativa económica baseada no potencial para desta espécie para poupar custos em gestão da paisagem, bem como avaliar possíveis despesas de gestão e fundos necessários para a sua reintrodução. Por último, são apresentados os prováveis efeitos no ecossistema pela sua presença, com base em dinâmicas documentadas.

Os resultados mostram condições favoráveis para que esta espécie regresse a mais áreas do território português. A partir da análise económica, foi possível determinar que os benefícios associados à presença da espécie na paisagem superam os custos. Os efeitos globais sobre a paisagem denotam ser positivos, uma vez que favorece outros animais e criar oportunidades ao ecoturismo. A presença da cabra-montesa nas paisagens portuguesas tem potencial para prevenir incêndios florestais, permitir que a vida selvagem prospere, prestar uma vasta gama de serviços de ecossistemas e ajudar a desenvolver futuras paisagens resilientes que possam combater as alterações climáticas.

Palavras-chave: Rewilding, Reintrodução, Cabra-montesa, Restauro de ecossistemas, Gestão da Paisagem, Economia

Abstract

Ecosystems in Europe are seriously damaged (in biodiversity and abundance) by man-made disturbances, which is the case of landscapes in Portugal affected by agricultural abandonment and wildlife scarcity, leading to bush encroachment, vegetation homogeneity and poor soils. Landscape management programs are therefore seen as essential, but the problem of forest fires continues to persist and create socioeconomic losses, with tendency to increase due to climate change. The Iberian Ibex is an herbivore from the Iberian Peninsula, affected by human disturbances that almost led to its extinction. Currently, it is present in Spanish landscapes and the Pyrenees due to restoration programs, but in Portugal is restricted to only one area in the North. This study seeks to evaluate the potential of this animal species has a tool in future landscape management and restoration programs, by its potential to save costs and deliver several environmental benefits. The work compares from an economic and environmental perspective, an active management approach through human interventions on the land and a passive management method with the reintroduction of the Iberian Ibex to several areas on the Portuguese territory, as a rewilding initiative.

First, an overview on the conditions for the reintroduction of this species in Portugal is provided. The core is the economic estimation based on the potential for this animal to save landscape management costs, as well as assessing possible management expenses and funds required for its reintroduction. Lastly are presented likely landscape effects by its presence in the landscape, based on documented dynamics.

The results show favourable conditions for this species return to many Portuguese areas. From the economic analysis, it was possible to determine that the benefits associated with the species presence in the landscapes outweigh the costs. Overall effects on the landscape should be positive as it favours other fauna and opportunities for ecotourism. The presence of the Iberian Ibex in Portuguese landscapes has the potential to prevent forest fires, allow wildlife to thrive, deliver a wide range of ecosystem services and help to develop future resilient landscapes that can tackle climate change.

Keywords: Rewilding, Reintroduction, Iberian Ibex, Ecosystem restoration, Landscape management, Economics

Index

List of Figures

List of Tables

Acronyms

CBA Cost-Benefit Analysis

ES Ecosystem Services

FFP Fundo Florestal Permanente

ICNF Instituto da Conservação da Natureza e das Florestas

IUCN International Union for Conservation of Nature

MEA Millennium Ecosystem Assessment

NBS Nature Based Solutions

SBS Shifting Baseline Syndrome

WEF World Economic Forum

WWF World Wide Fund

1. Introduction

1.1. Context

Overexploitation of natural resources and habitat fragmentation and destruction have led to the degradation of many ecosystems, rising environmental problems that can severely affect the future of humanity survival (IPBES, 2019; IPCC, 2019; Vitousek et al., 1997).

Ecosystems are a fundamental part for the balance of our planet by providing biological cycles that are essential to support life (United Nations Decade on Ecosystem Restoration 2021-2030, 2021). Many, like forests, "provide vital habitats for millions of species, and important sources for clean air and water, as well as being crucial for combating climate change" (United Nations Development Programme [UNEP], 2021, para. 1).

With climate change and biodiversity loss, many important ecosystems have been damaged, leading to insecurity, conflicts and corruption (United Nations Development Programme [UNEP], 2021). Now, more than ever, it is urgent to act and restore damaged ecosystems. In alliance with this statement, the United Nation has defined the 2021-2030 as the "Decade on Ecosystem Restoration" that "aims to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean. It can help to end poverty, combat climate change and prevent a mass extinction" (United Nations Decade on Ecosystem Restoration 2021-2030, 2021, para. 2). The European Commission has published, on June 22 of this year, the proposal for a first new restoration law, which can be a huge step for a legally binding and cohesive biodiversity restoration, showing its magnitude of importance in a future European economy (European Commission, 2022).

Human activities have pressed biodiversity loss, land use and shifts in ecological cycles that pushes the Earth system beyond the boundaries that allow the human generations to come, to be able to develop and thrive. By restoring ecosystems, we can giveback functional habitats that contribute to the biosphere integrity and diversity, land-system change, biochemical flows, ocean acidification and climate change mitigation – all of these are defined planetary boundaries that regulate the Earth system and can contribute to its resilience and stability (Steffen et al., 2015). New perspectives look at this journey of ecosystem restoration as a positive narrative that projects a future with "wild and natural areas, sustainable production and humans coexisting peacefully with wildlife" (Sandom, 2018, para. 16).

The economic field (mainly represented by students) and society has been expressing new visions for accounting environmental problems and advocating for more practical approaches that move away from theoretical abstract models and the standard economic narrative, to frameworks that explore economic concepts viable to thrive on a sustainable development perspective (Earle et al., 2016; Fischer et al., 2017). The Doughnut Economy defines an economic framework where minimum societal needs are meet while not exceeding planetary boundaries, incorporating the problems complexity that the economy needs to consider and giving open answers on how to address them, while taking part on the ecological economics in stating that economy is manifestly linked to the biosphere and the society (Raworth, 2017).

Rewilding is a progressive approach to nature conservation that has a strong potential to help as a tool to restore landscapes and mitigate climate change consequences, by re-establishing fauna that leads to the restoring of natural ecosystem processes, and once they become functional, allow nature to regulate itself (Pereira & Navarro, 2015).

In Europe, most managed nature reserves are uncapable of restoring landscapes as they rely on similar agricultural practices done in the past, which has opened the door for the study of ecologically functioning ecosystems, revealing that large herbivores have a key role in "maintaining structural diversity in the vegetation and so biological diversity" by having the capacity to transform landscapes, create resilient habitats and food sources for other species (VanWieren, 1995, p. 11). This is particularly relevant in pasture or woodland zones, where we benefit from having large herbivores for extensive grazing (VanWieren, 1995).

The Iberian Ibex (*Capra pyrenaica*) – presented in Figure 1 and 2, is a charismatic ungulate native from the Iberian Peninsula. Hunting, habitat destruction and fragmentation, and competition with domestic herds forced the disappearance of this species in most of all its historical distribution. Yet, in the last two decades it has been expanding and gaining back some territories, mainly thanks to rural abandonment and active conservation measures like reintroduction programs in Spain (Acevedo et al., 2021; Herradón, 2015). Currently it is present in one region of Portugal – "Parque Nacional da Peneda Gerês" – and thanks to a Spanish reintroduction program, in several parts of Spain and in France, on the region of the Pyrenees (Acevedo et al., 2021). In the Iberian Peninsula, the Iberian Ibex has particularly relevance, being one of the two only herbivores capable of grazing rugged areas (the other one is the Chamois) (Torres et al., 2017), which makes it a key species for providing ecosystem dynamics in Mediterranean mosaic landscapes, particularly the high-altitude rocky mountains with cliffs (Acevedo & Cassinello, 2009a; Danell et al., 2006).

Figure 1 - Females and yearlings of the Iberian Ibex species (captured in Las Batuecas - Sierra de Francia Natural Park)

Figure 2 – Male Iberian Ibex (*Capra pyrenaica*) (Widstrand, 2019)

The domestication of the goat changed the landscapes from which the Iberian Ibex used to inhabit in a time when the development of rural communities was based on agriculture and livestock. With rural abandonment becoming now more of a reality, the loss of grazing and browsing ungulates have left the landscapes defective, with highly concentrated inflammable vegetation and poor soils, so the effort to control biomass quantities to mitigate and avoid the effects of forest fires has relied mainly on mechanic and manual human work (Batáry et al., 2015; Schou et al., 2021). The program of the Forest Sappers, controlled by the ICNF ("Instituto da Conservação da Natureza e das Florestas"), is the most relevant source of landscape management in the Portuguese territory, aiming to protect the forest and reduce the occurrence of forest fires by applying natural and artificial methods for forest regeneration that meet society needs (known as silviculture) (Decreto Lei nº 44/2020, 2020). Yet, existing gaps in these ecosystems still remain, the outcomes are difficult to meet desirable necessities and costs are high and similarly constant each year (ICNF/FFP, 2021b). Ecosystems are incomplete and ecological cycles still need to be re-established in order to create adaptable and resilient landscapes. For that, the inclusion of fauna that play significant ecological roles in landscapes can be the answer to bring back ecosystems that can function harmoniously and help mitigate climate change consequences as well as human well-being and safety (Aronson et al., 2016).

1.2. Motivation and Relevance

The rewilding approach is still underexplored in the literature, which makes this strategy for restoration of ecosystems innovative and with high pertinence for the times we live in, where we do not only need to fix ecosystems but also restore biological diversity and abundance. It has been considered a cost-efficient approach to obtain the results that human intervention has been trying to achieve unsuccessfully and with high investments – low returns (Schou et al., 2021; Veríssimo, 2020). In Portugal, we can benefit from the farmland abandonment areas to reintroduce herbivores like the Iberian Ibex and help restore wildlife at the same time we initiate a step into landscape restoration in our territory (Ceaușu et al., 2015).

Having the Iberian Ibex, the almost exclusive ability to graze and browse on rugged areas, the only possibility to replicate that currently is by human management actions, which takes high costs of management and labour and is constantly needed, since the natural cycles of the ecosystems remain damaged for the absence of players like large mammals (Batáry et al., 2015; Hobbs, 2006). From that, the reintroduction of the Iberian Ibex will give back a species that helps to complete those cycles. The species ecosystem dynamics like the grazing and browsing behaviour (increasing vegetation heterogeneity, transforming biomass in dung and incorporating more carbon into the soil, which reduces the risk of forest fires and improves carbon sequestration), makes this approach promising for climate change mitigation (Schmitz et al., 2014). Can also serve as a relevant prey to the Iberian Wolf and help solve conflicts with livestock owners and save money from compensatory costs (Álvares et al., 2015). Yet, far too little attention has been given to this animal species in Portugal, with no perspectives on its restoration being expressed, which contrasts with the Spanish and French positions (Fonseca et al., 2017; *Le Retourn du Bouquetin dans les Pyrénées*, 2022). No study evaluates the suitability for the Iberian Ibex to return to more areas in Portugal based on social, environmental and economic terms (only one study develops a suitability model based on environmental criteria for its return to the Côa Valley (Torres et al., 2017)). Population dynamics in the Iberian Ibex are described in the literature (García-González et al., 2020), but concrete potential for landscape restoration and economic analysis of possible landscape management actions and respective costs, supported on a practical case, has not been carried out.

Ultimately, the reintroduction of the Iberian Ibex in the Portuguese territory is significantly relevant to the future targets on grasslands, forests and rocky habitats of the EU Restoration Law, which will include "improving and re-establishing biodiverse habitats on a large scale, and bringing back species populations by improving and enlarging their habitats" (European Commission, 2022, Section Targets, para. 2).

The study findings should also be a significant contribution to economic and environmental fields by exploring the economic involvement of reintroducing an iconic species that has potential to act has a landscape engineer and show the benefits of rewilding, a passively managed conservation approach. Such an experimental work is one of the first practical investigations in Portugal to provide information on how rewilding measures (reintroductions/translocations) might save ecosystem management costs.

Nevertheless, it is important to note that is beyond the scope of this dissertation to study all possible indirect costs and benefits that the reintroduction of the Iberian Ibex in other

Portuguese areas might generate and detailed conditions for its possibility, which tends to only be possible to evaluate after the development of a reintroduction program (Seddon et al., 2007). Also, these programs rely on advanced habitat suitability models, social and cultural context in each zone and other specific research (IUCN/SSC, 2013). Even so, this study presents pioneering likely results and opens the debate about a possible return of the Iberian Ibex to the Portuguese territory, given the fact that the only Portuguese place that the Iberian Ibex currently inhabits does not have a strategic plan for population development and neither the ICNF or the Portuguese Government have implemented any measures for an expansion of this animal species, with only three studies discussing the Iberian Ibex state in Portugal (Fonseca et al., 2017; Moço et al., 2006; Torres et al., 2017).

By working directly with Rewilding Portugal, this internship gave me the opportunity to gain experience with the rewilding approach and better know the work they do, namely in economic development of local communities through the so-called nature-based economy. I also had the chance to collaborate with a multidisciplinary team and discover the Greater Côa Valley, which made the process of developing the master dissertation very rich, both personally and professionally.

1.3. Objectives

The main objective of this dissertation is to explore the economic argument for the reintroduction of the Iberian Ibex in areas of Portugal by its potential to save landscape management costs. Additionally, two goals complement the proposal: to evaluate the suitability for Iberian Ibex's return to the Portuguese territory through a range of factors and to examine the Iberian Ibex potential for enhancing ecosystem services and improve the resilience of landscapes. This study will help provide scientific content to complement a future proposal for the reintroduction of the Iberian Ibex in Portugal.

1.4. Report structure

The present study is structured as follows, inspired on the work of Veríssimo (2020). Chapter 2 offers a literature review to explore the main concepts and theoretical information related to the field of study, emphasising the importance of restoring ecosystems, as well as a critical review on economic analysis of landscape management followed by a critical analysis of the Forest Sappers program and considerations for rewilding, namely with the Iberian Ibex in Portugal. The methodology (chapter 3) presents the research question that leads to an explanation of the chosen structure for this study. Chapter 4 provides an exploratory analysis on the conditions for the Iberian Ibex to return for more Portuguese landscape areas. Then, the core of this dissertation - the case study, compares from an economic perspective two strategies for landscape management: firstly, by an active way, in the form of direct human actions based on the guide and program of the "Sapadores Florestais" (forest sappers); and secondly, by a passive way, with a rewilding approach that rehabilitates the ecosystem functions by restoring the wild populations of the Iberian Ibex. In chapter 6 the Iberian Ibex effects on the landscape are examined in terms of improving ecosystem services. Thereafter follows a chapter devoted to a final discussion that evaluates the state of EU institutions and Portuguese Government on behalf of nature restoration and brings the final arguments for the reintroduction of the Iberian Ibex in Portugal based on the study findings, as well as a moral consideration on this matter. Finally, the concluding chapter expresses the final remarks on the dissertation, which includes main findings of this study, limitations, and recommendations for possible future research.

2. Literature Review

2.1 Theoretical framework and Key Concepts

In this section of the literature review the main concepts that sustain this study are presented, considering an economic perspective, as well as the theoretical dimensions of the research. Concepts such as ecosystem restoration, rewilding, and ecosystem services will be presented. The highlight will be for the role of apex predators and keystone species in ecosystems and their economic benefits, with a specific focus on medium/large herbivores and their landscape management capacity.

The Convention on Biological Diversity defines ecosystem restoration as "the process of managing or assisting the recovery of an ecosystem that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity" (Convention on Biological Diversity [CBD], 2019, p. 4). Nevertheless, it is important to note that conservation of biological diversity and ecosystems should be the priority, to maintain ecological stability and provide ecosystem services, through reducing pressures or disturbances (Convention on Biological Diversity [CBD], 2019). In this way, ecosystem restoration acts as a complement to conservation actions, and tends to use a native ecosystem as a reference to establish the restoration objectives. Despite that, we need to take into consideration that changes in biotic and environmental conditions is part of the natural dynamics of ecosystems and climate change has caused variations on certain patterns, so the recovery of an ecosystem can rely on their historical state as a guide, but aim to provide resilience to the circumstances in the present and predicted future (CBD Secretariat and Society for Ecological Restoration, 2019; Higgs et al., 2014; Hobbs & Harris, 2001).

Jones et al. (2018) presented a meta-analysis on documented ecosystem recovery from large-scale disturbances and suggests that a passive way (without human intervention) can be the best option, in some cases, with just ending the disturbances that are causing most damages, although it's relevant to note that some methods of this study have been questioned (Larkin et al., 2019).

The economic studies on ecosystem restoration show economic benefits from taking actions and more predictable economic costs from inaction (Stafford et al., 2017). According to the United Nations Environment programme and the Food and Agriculture Organization of the United Nations, "between now and 2030, the restoration of 350 million hectares of degraded terrestrial and aquatic ecosystems could generate 9 trillion dollars in ecosystem services" and "the economic benefits of such interventions exceed nine times the cost of investment, whereas inaction is at least three times more costly than ecosystem restoration" (UNEP & FAO, 2021, para. 3). At the same time, ecosystem restoration can offer opportunities for job creation, regulate diseases, reduce risk of climate disasters and provide more food security (UNEP, 2019). The World Economic Forum (WEF) on the "New Nature Economy Report II: The Future of Nature and Business" affirms that "over half of the global GDP, 44 trillion dollars, is potentially threatened by nature loss" (WEF, 2020, p. 8). This indicates that economy depends clearly on nature and stable ecosystems to thrive. The World Wide Fund for Nature (WWF) also notes that Portugal will be one of the main affected countries in terms of a negative impact on the national GDP % resulting from the changes and loss of essential ecosystem services (WWF, 2020).

It is also necessary to clarify the concept of ecosystem services (ES), which is often referred in the context of ecosystem restoration projects or studies. While a variety of definitions and approaches of this concept have been suggested since the 1970s (Johnston, 2018), depending on how its link to human well-being is viewed, Costanza et al. (1997, p. 253) define the term of ES as "the benefits human populations derive, directly or indirectly, from ecosystem functions".

To capture the meaning of this benefits, it is important to quantify them in monetary terms, and for that, the quantification began in formal economic methods with environmental economics, with Costanza et al. (1997) estimating 17 ecosystem services to range from 16 to 54 trillion per year. Later more research started to discuss how to value ES, being really amplified in the last decade (Birkhofer et al., 2015), questioning more deeply the relationship between ecological and socioeconomic systems to measure the impacts on human welfare, and evaluating the values of different types of ES to understand to what extent should this values by quantified in monetary terms or just by his value on its own (Blahna et al., 2017; Johnston, 2018)

The "United Nations Millennium Ecosystem Assessment" (Millennium Ecosystem Assessment [MEA]) evaluated the consequences of ecosystem change and presented a classification to categorize the ES: provisioning services (such as food and fresh water), regulating services (like climate and disease regulation), cultural services (educational, aesthetic, etc.) and supporting services (cycling nutrient, soil formation, and others) (Millennium Ecosystem Assessment [MEA], 2005). Later, the European Environment Agency developed the "Common International Classification of Ecosystem Services" to provide a reference international classification and make the connections between different classification systems, in a way to make it simpler to measure, account for, and evaluate ES, so that it can offer some standardisation. It consists of a hierarchic classification divided in three major sections: Provisioning (nutritional, non-nutritional material, and energy), Regulation and Maintenance (ways in which living organisms can mediate the environment that consequently affects human well-being, like air quality), and Cultural (non-material outputs of ecosystems that affect physical or mental health, such as cultural landscapes and tourism) (Haines-Young & Potschin, 2018).

Regarding the concept of Rewilding, it is something that despite being relatively new, it has been defined and approached in various forms. The founder of the Rewilding Institute and cofounder of the Wildlands Network, Dave Foreman, was the first to create the term (Foote, 1990; Foreman, 2003), on a purpose to apply "a North American system of connected strictly protected areas able to support ecologically effective populations of all native species" (Johns, 2019, p. 12). It is originally focused on three pillars: large core protected areas for covering the needs of a variety of animals, like foraging, and create heterogenicity that decreases the risk for diseases to proliferate; connectivity through nature corridors that insure long-term viability of animal species by enabling them to expand, perform migratory movements and create the opportunity for a more species diverse habitat; and the presence of keystone species (mainly large predators - carnivores), which provides essential trophic interactions for the resilience of diverse ecosystems (Macdonald & Willis, 2013; Pettorelli et al., 2019; Soulé & Noss, 1998). This made rewilding a concept of large-scale that served as an argument for continental-scale conservation (Johns, 2017; Soulé & Terborgh, 1999). Further discussions since the 2000s made the term and concept more expansive. Now, the pillar of keystone species has more meaning if thought on the reintroduction of species to restore ecosystem functioning, being them a species on top of the food chain or not (Macdonald & Willis, 2013). Rewilding is now referred to "action on the landscape level with a goal of reducing human control and allowing ecological and evolutionary processes to reassert themselves" (Klyza, 2001, p. 285). Nevertheless, some active interventions may be appropriate, like restoring regionally extinct species, regulate hunting or to control invasive species (Pereira & Navarro, 2015). It brings a balance between restoring autonomous ecological processes and human dynamics (Perino et al., 2019).

Instead of improving the conditions for specific threatened species to re-establish viable populations like target habitat restoration, rewilding seeks to "restore missing or dysfunctional ecological processes and ecosystem function via a process of species reintroduction" (Macdonald & Willis, 2013, p. 431), making it a prospective alternative to the common human managed approach to conservation that has been used especially in Europe (Ladle & Whittaker, 2011).

At present, the scenario of rewilding in Europe has particularities and much different than in the United States. In America, nature conservation is well distinguished by operating in protected areas for wildlife, separated from human pressures. Animal species are commonly hunted outside protected areas. Europe, being a densely populated continent where the landscape is crossed by roads, villages and farmland, space for nature is scarce. Yet, nowadays, the ecological and social conditions have changed considerably (like soil composition, humidity, average temperature), and the fact that people live close or even inside the potential rewilding areas (which are preferably protected areas) requires these types of projects to take into account the coexistence between wildlife and human life, which makes them susceptible to affect the status quo of the populations (Pereira & Navarro, 2015; Perino et al., 2019). Nevertheless, by managing this animals-human relation and educating society to the benefits of rewilding, the social acceptance is likely to increase and contribute to the success of these projects (Perino et al., 2019).

The present situation in Europe brings opportunities to implement this kind of approach in such a continent. Farmland abandonment has become a big reality since the globalization of agricultural markets that made agriculture less profitable, raising social implications (for example, aging of rural communities and decrease of basic public services for the populations that lived in the abandoned regions) and ecological problems (loss of biodiversity and ecosystem services) (Pereira & Navarro, 2015). The most common policy approaches has been economic instruments like agro-environmental subsidies included in the Common Agricultural Policy of EU and financial support to the least preferred areas, to maintain some kind of low intensity farming that provides semi-natural grasslands to keep the ecosystems functioning, and to protect some habitats with species that benefit from extensive farmland (Ceauşu et al., 2015; Pereira & Navarro, 2015).

Rewilding in Europe hopes to bring an alternative, better approach to the practices mentioned above, calling it the ecological rewilding. The focus is to create an on-going process, that starts with historical baselines and think of alternative management strategies, yet recognizes that we live in a "complex socio-ecological system where humans are an integral component of our landscapes" and takes into consideration that ecosystems are dynamic and constantly changing (Pereira & Navarro, 2015, p. vi).

The Rewilding approach has been successful where implemented, being able to restore target species and others, as well as bringing back ecosystem functions (C. Sandom et al., 2013), which also provides ecosystem services with considerable socioeconomic benefits (Sukhdev et al., 2010), namely flood prevention, carbon sequestration and recreation services like tourism (Pereira & Navarro, 2015), and with potential to help mitigate climate change (Bakker & Svenning, 2018).

Although the progress of Rewilding has been satisfying, there are some concerns around the concept. Lack of some scientific knowledge about past scenarios can make it difficult to establish effective baseline conditions as well as knowing which baseline to choose, social barriers that create conflict when the reintroduction of large predators is required to complete the ecosystem cycles, and the need of sometimes large portions of land to create reserves which can be unrealistic in some countries (Ladle & Whittaker, 2011). Jorgensen (2015, p. 487) claims that the term can have many meanings, turning it into a "plastic word", and the practice of it dissociates humans from nature, relying on "historical ecologies prior to human habitation". However, the inaccuracy of the definition that not take the quality that is at the core of rewilding, "non-human autonomy" (Prior & Ward, 2016, p. 133), and that rewilding practices "requires a paradigm shift in the co-existence of humans and nature (…) to create new sustainable economic opportunities, delivering the best outcomes for nature and people" (Rewilding Thematic Group [RTG], 2021, p. 4), by creating rewilding projects that include work with locals and regional companies for support, as an example.

A key to make rewilding work, is creativity. Soulé and Noss (1998, p. 26) argues that "The greatest impediment to rewilding is an unwillingness to imagine it". Can be something small like putting hedgerows for birds, or large-scale to restore locally extinct species and make ecological corridors of long distances viable for large mammals (Pereira & Navarro, 2015; Perino et al., 2019).

Two types of fauna are crucial for rewilding projects to thrive: apex predators and keystone species (Pereira & Navarro, 2015; Terborgh & Estes, 2010). Apex predators are species at the top of the food chain that maintain ecosystem stability and protect other species through the establishment of natural trophic cascades. Keystone species have a highlighted impact on the ecosystems they are present, by performing pivotal roles that allow the ecosystems to be resilient (Bond, 1994; Tanasescu, 2017).

Despite some conservationists and wildlife scientists arguing that putting this label on some animal or plant can overestimate their role in complex ecosystems, it's a great social strategy to reach the public and demonstrate the importance this species can have in maintaining the survival of many others and keep ecosystems from breaking apart or being dominated by invasive species (National Geographic Society [NGS], 2013).

This keystone species can have different important actions, being most divided on literature in three types: the apex predators, ecosystem engineers or mutualists (National Geographic Society [NGS], 2013). One example of apex predator can be the wolves, the main predators of several animals like medium/small herbivores such as goats and rabbits (Bond, 1994). The ecosystem engineers are the ones that have the abilities to create, change or destroy habitats to adapt them to the current circumstances, like the beaver with his work along riverbanks, creating dams with old and dead trees, which allows new trees to grow and also diverts water to create wetlands, creating habitat for many animals and plants. Finally, the mutualists, are the species that work in a symbiotic way, like the bees that collect pollen and spread it, which allows for greater flower growth and at the same time produce pollen as a source of food for themselves (National Geographic Society [NGS], 2013).

Several keystone species provide positive effects on biodiversity and social or economic benefits. The reintroduction of beavers in Scotland is projected to be worth 2 million pounds to the local economy by creating opportunities in nature-based tourism (Brown et al., 2011). The sea otter in the United States West Coat, responsible for keeping kelp forests thriving as an important food source and shelter to marine systems, by controlling the number of species that feed from the seaweed, enhancing various ecosystem services for human, like gains in carbon sequestration and tourism, outweighing the costs by seven times (Gregr et al., 2020).

Some authors even argue that developing alternative states for situations where the apex predators became extinct, can became unbearable in ecological and economic costs (Terborgh & Estes, 2010).

Humans need to compensate when an ecosystem is not complete and execute actions as alternatives to the ecological roles previously done by certain species that are now absent. An example can be the lack of scavengers like vultures, which leads to more costs for processing dead animals (Pereira & Navarro, 2015). From these problems, National Geographic Society has expressed the opinion that "the vital role of keystone species in an ecosystem is not fully appreciated until that species is gone" (National Geographic Society [NGS], 2013, para. 9)

Turning now to the importance of landscape restoration. In the past, wild herbivores were responsible for creating a certain type of landscape through grazing, which helped to keep tree biodiversity, enrich the soils, and serve as prey to predators like the lynx or the wolf. Human activity replaced this kind of natural disturbances and shaped landscapes in another way, with the use of domestic animals to graze and controlled fires. But now, with agricultural activities decreasing progressively, and large herbivores functionally extinct in Europe, to maintain those "disturbance-dependent habitats" is a challenging process (Pereira & Navarro, 2015, p. 144).

The combination of rural depopulation, climate change (more hot and dry areas), lack of tree diversity (with mostly dense scrub and flammable species e.g., eucalyptus) and encroachment of shrubland on urban areas, has led to an increase in wildfires. This causes not only economic damage, but also takes away people's lives and destroys habitats for many fauna and flora. One notable example is the severe fires Portugal suffered in 2017. The Mediterranean region is the most affect European region by this phenomenon, accounting for 85% of the total burned areas on the continent every year (Rewilding Europe, 2020b).

The current way to landscape management for mitigating wildfire risk relies on active human disturbance, which tends to be expensive and very complicated (Rewilding Europe, 2020b). The main programs focus only on vegetation and not on animals (Pereira & Navarro, 2015).

For this issue, a better and sustainable solution has been emerging: a rewilding solution that brings back grazing with wild and semi-wild herbivores, which "can be a far cheaper and far more natural, low-impact way of controlling wildfire, while boosting local biodiversity at the same time" (Rewilding Europe, 2020b, para. 5).

In Europe, the number of initiatives focused on the reintroduction of keystone species to bring back natural processes has been growing considerably in the past 15 years (e.g. ,Burton, 2011; C. J. Sandom et al., 2013) These projects work as a "key conservation approach, as opposed to active human management" (Pereira & Navarro, 2015). Rewilding Europe, founded in 2011, is a European wide initiative created to make the possibility for these kind of projects on European countries to work across borders and ally the rewilding approach with collaboration, bringing success (Sylven et al., 2010; Tanasescu, 2017).

2.2. Relevant literature

In this section is presented a review on landscape management literature considering also economic valuations, a critical analysis of Forest Sappers program and orientation guide and overall understandings about rewilding with the Iberian Ibex. Some ethical considerations on ecosystem restoration and economic valuation of nature are explored in the end.

To develop landscape management and restoration programs, we must understand it takes significant socio-economic implications (Adams et al., 2014). Some positive social benefits can be employment or the reintroduction of valuable wild species that can contribute to better human wellbeing (Aronson et al., 2016). In practice, these programs consist mainly on agri-environmental schemes funded by the European Union, like subsidized grazing (with for example, domestic goat/sheep/cow), mowing semi-natural areas, do controlled fires and clean vegetation with machines (Batáry et al., 2015; Schou et al., 2021). It's important to keep in mind that this kind of programs are very expensive (it's the biggest source of fundings for nature conservation) and have not proven to mitigate sufficiently the issue of biodiversity loss (Batáry et al., 2015; Schou et al., 2021).

Economic considerations around the issue of landscape restoration are being increasingly discussed, but still with a focus on the costs of restoration projects. This happens mostly because of the difficulties in measuring and giving an economic value to benefits, with passive use values of citizens not being considered for example (Valasiuk et al., 2018). Nevertheless, in some studies, the value of ecosystem services provided with restoration has been higher than the direct costs of some practices like control bush encroachment (Stafford et al., 2017).

The most used methods for economic valuation of landscape restoration are the stated preference methods, namely contingent valuation and discrete choice experiment (Bonnieux & Le Goff, 1997; Valasiuk et al., 2018). Some studies have implemented CBA (cost-benefit analysis) as a tool for economic analysis of landscape restoration, but most of them lack quality, by for example not covering opportunity costs and non-use values. The fact that studies are in very limited number, also lacks quantity to explore stronger CBA (Wainaina et al., 2020).

There are a number of programs on the active that contribute to management of landscapes, but in the scenario of Portugal we can highlight the one that has been given greater importance: "Plano Nacional de Gestão Integrada de Fogos Rurais 2020-2030", the National Plan for Integrated Management of Rural Fires (AGIF, 2022). According to Resolução do Concelho de Ministros nº 45-A/2020 (2020), this program was created to substitute a previous one that demonstrated to be inefficient in reducing fire risk, build a more resilient landscape and rehabilitate ecosystems. On the conclusion that Portugal has a landscape that needs a complex planning and management, that involves the cooperation of a series of public and private entities, the "Estratégia Nacional para as Florestas"- National Strategy for the Forests, brings also new orientations and plans of action for the sustainable management of our forests (Resolução do Concelho de Ministros nº 6-B/2015, 2015).

For the implementation of practical landscape management measures on the ground, there is a specific group with emphasis: forest sapper brigades. The formation of these teams and their activity is established by a national program of forest sappers that serves the purposes established by the "Plano Nacional de Gestão Integrada de Fogos Rurais" and "Estratégia Nacional para as Florestas". The brigades are coordinated by the ICNF (Instituto da Conservação da Natureza e das Florestas) and funded by the FFP (Fundo Florestal Permanente), a relevant financial instrument created with the purpose of supporting the National Strategy for the Forests (Decreto Lei nº 44/2020, 2020; ICNF, 2017b). The main goals of this program are to mitigate effects of forest fires and decrease their frequency by improving the ecological state of landscapes in Portugal (ICNF/FFP, 2021a). Even though it is a program that complements direct action on the ground with awareness, education and other management activity to build a more interdisciplinary approach, a major drawback apposes – the program does not address the root causes of landscape degradation which leads to the missing ecological processes to remain and landscape restoration continues to not be achieved (ICNF/FFP, 2021b). Also, in recent years the human resources willing to operate direct landscape management actions on the ground has been decreasing and work safety conditions have been discussed (Rewilding Europe, 2020a). The outlines of these jobs are of no interest for the majority. From this, clearly other alternatives need to be created, more appealing for young generations and inspiring an actual ecosystem restoration for dynamic landscapes.

The rewilding alternative, in the areas it has been proposed (far much less in theory and in practice) can hypothetically be more cost-efficient and promote better biodiversity conservation (Schou et al., 2021).

The Iberian Ibex is an iconic species, considered to be a key species in the Iberian Peninsula. By providing natural grazing systems, (Torres et al., 2017) is able to create mosaic landscapes with open spaces for successful firebreaks, consume plant matter that decreases the accumulation of fuel, enrich the soil to promote more biodiversity and stimulate decomposition of organic matter (Rewilding Europe, 2020b). This can also enhance ecosystem services like carbon sequestration. Reintroducing the Iberian Ibex may also be a chance to boost populations of other species, being a more available prey for the Iberian Wolf, which in some parts Portugal relies on domestic livestock as the main food source (and this takes considerable economic costs in the form of compensations) (Álvares et al., 2015).

In the case of Portugal, active introduction might be needed, (there are no populations of Iberian Ibex on frontier regions) being a tool for ecological restoration of many landscape areas (Pereira & Navarro, 2015).

No other study has analysed the potential of the Iberian Ibex to save landscape management costs by replicating human management actions and restoring ecological roles in the ecosystem, avoiding costs on adaptative measures. Moreover, the literature about the Iberian Ibex in Portugal is limited comparably with Spain, raising questions about lacking of interest for this species in Portugal. For that reason, this work explores the case for the Iberian Ibex to return to the Portuguese landscape and brings an innovative approach by building a case study for rewilding with an economic lens, complementing with potential enhancement of ecosystem services like biodiversity effects.

Human beings have proven to influence nature in a way no other living being can. History is documented, and our present is a reflection of the power of our actions as societies. We now assist a time where wildlife is more of a concept rather than a reality for the majority of the human populations (Sandom et al., 2014; Trouwborst, 2021). The destruction of ecosystems by human beings has actively contributed to the extinction of substantial species (Benítez-López et al., 2017). But this also proves that we, as a species, have the tools for reversing biodiversity loss and influence nature in a positive way (Galetti et al., 2021). A hopeful perspective is essential to follow this path, and some cases of successful ecosystem restoration helps to bring strength to this movement.

Habitat destruction and fragmentation, hunting and other human activities, have consequently eliminated the Iberian Ibex from Portugal and almost extinct the species from the Iberian Peninsula (Pérez et al., 2002). Spain and France already initiated reintroduction programs in their territory and the Iberian Ibex has proven to be thriving in those areas (Acevedo et al., 2021; García-González et al., 2020). So, this study helps to open the discussion that we can now have an active position by returning this species to its previous Portuguese range, hopefully being the beginning of more biodiversity valorisation and progressive approaches for ecosystem restoration in Portugal.

New economic frameworks have been discussed, and social and scholars voices have been raising around the inadequacy of old economics theory for the circumstances of the current times (Ellen MacArthur Foundation, 2022; WEF, 2020). The doughnut economy is a good example of a new, fresh and progressive economics framework that develops an approach for economic development while ensuring social needs and not exciding planetary boundaries (Raworth, 2017). Ethical considerations regarding attitudes towards the environment can be judged in two different views: "ecocentrism - valuing nature for its own sake" and "anthropocentrism - valuing nature because of material or physical benefits it can provide for humans" (Gagnon & Barton, 1994, p. 149).

3. Methodology

Taking in consideration the main objective of this study, the research question is: Which approach makes more economic sense in landscape management, an active approach through direct human actions or a passive approach in the form of rewilding with the reintroduction of the Iberian Ibex?

The Forest Sappers Program is a great example for the case study because it provides data which tends to be hard to find in the context of landscape management for environmental analysis. Also, it is the most relevant entity in Portugal for taking direct actions that contributes to landscape management and fire risk reduction, with various teams working on many regions.

The core of this work is focused on the investigation of the Iberian Ibex potential to substitute the landscape management actions and develop an economic comparison to assess the saving costs from it. Then, to complement the analysis, data taken from literature provides possible monetary values for reintroduction and management costs for this animal species in order to perceive if it does not exceed the savings.

The following chapters will present a more complex analysis of methodology:
Chapter 4 provides the context for the return of the Iberian Ibex in possible areas of the Portuguese territory, beginning with a study of its biology, followed by its past and present status, habitat requirements and dietary strategy, interaction with other fauna and even with humans, the EU legal framework of this species, possible reintroduction areas, as well as some notes regarding the lack of interest for this species in Portugal. This compiles necessary information on crucial factors needed to consider for when proposing a reintroduction program, as well as hints for the Iberian Ibex capability to create different ecosystem-level effects. No previous study has provided an analysis that aggregates this information to explore the conditions for a reintroduction of the Iberian Ibex in Portugal. Chapter 5 develops the core of this dissertation by providing the case study of the active vs passive landscape management approaches with an economic analysis. Chapter 6 explores the landscape effects an Iberian Ibex population can create, providing a positive environmental impact, including the enhancement of various ecosystem services. This complements the economic costs that this species can avoid (by replacing human-made landscape management actions) with an environmental long-term solution.

4. The case for reintroduction of the Iberian Ibex in Portugal

This chapter explores the case for the reintroduction of the Iberian Ibex in Portugal, presenting the most relevant factors to take in consideration when advocating for the return of this animal species. It consists of a qualitative data analysis in the structure of literature research, providing the necessary context: Current and Historical Status with records from its past presence in Portugal; Climate and Habitat requirements based on well-established populations in Spain, including feeding preferences; Social attitudes and cultural background towards this species in Portugal and Spain; Possible benefits and conflicts with other species they can share their habitat with and their dynamics on the ecosystem; Legal framework through an analysis of the Habitat Directive legal instrument and a proposal on suitable areas in the Portuguese territory for this species is presented. Data was collected using Web of Science, Scopus and Google Scholar, and searched in three languages: Portuguese, English and Spanish. Articles, technical reports and academic theses or dissertations were considered.

This information was addressed in accordance to the IUCN Reintroduction Guides which is one of the most reliable frameworks to asses translocations of wildlife, "designed to provide guidance on the justification, design and implementation of any conservation translocation" (IUCN/SSC, 2013, p. 7).

The absence of habitat continuity between established populations of Iberian Ibex in north/central Spain and inland areas of Portugal with potentially suitable habitat, makes natural expansion events to new Portuguese territories unlikely. Moreover, the absence of ecological functions performed by the Iberian Ibex in many Portuguese landscapes leaves the ecosystem prone to the risks of forest fires and climate change. Thus, the necessity for a restoration plan for the Iberian Ibex in Portugal. This work can serve as an incentive for rising public and scientific opinion around the appreciation of this species in terms of their potential role on fixing ecological cycles and returning dynamic and resilience landscapes, but also appreciating the social and cultural value of the species. This effect should be felt on the Portuguese government, institutions dedicated to ecosystems management (e.g., ICNF) and other NGOs to not only consider a management plan for the small population habiting in North of Portugal but also the development of a plan to restore this animal species in more areas and create an integrated approach that benefits the environment with economic and social advantages.

4.1. Biological Characteristics and Species Dynamics

The Iberian Ibex is scientifically described as *Capra pyrenaica* (Schinz, 1838). The common name found on scientific literature can differ, with the usual ones being "Iberian Ibex", "Spanish Ibex" and "Iberian Wild Goat". Discussions around the correct common name have been expressed (García-González et al., 2020). For this study, the term "Iberian Ibex" was chosen.

This animal species presents a well-defined sexual dimorphism. The adult females can reach a body length of 130 cm and weight about 30-50 kg, and in turn, adult males can go to 160 cm in body length and weight 50-90 kg, only exciding to 120 kg in "Sierra de Gredos" (Alados & Escós, 2017). They develop horns that grow in rings, with each one representing one life year, but their length is visibly different according to the sex, with males presenting horns that can go to 1 m and females only reaching 13 to 30 cm. Their pelage changes according to seasons. In summer they exhibit a shorter coat with a colour between brown and reddish, and in winter the coat is denser and tends to be darker. Males present black patches in limbs, flanks and neck, that expand with age (García-González et al., 2020). They possess tissue between digits and a specific hooves format that allows them to navigate through rugged and sloped terrains (García-González et al., 2020).

The phenotypic characteristics – life history traits, are influenced by environmental factors, harvesting of selective males and diseases (Carvalho, 2019; Fandos, 1995).

In terms of reproduction, this species is polygamic and reaches their sexual maturity at around 1-2 years old, with better female productivity between 4 to 13 years. Matting season occurs from November to January, with fights between males to establish the hierarchy. Gestation lasts 22 to 24 weeks, which makes end of April to beginning of June the times of birth, when food availability and climacteric conditions present the better survival scenario (Alados & Escós, 2017). With a normal rate of 1 goatling per female and 10-20 % chances of having twins, this leads up to a 20 % population growth per year, in expanding cases (Préfet De La Région Midi-Pyrénées, 2014).

The lactation period takes about 3 to 4 months, but yearlings stay with their mothers for long periods of time, exhibiting a relation that enables their development. This leads to the establishment of common female-juvenile groups, showed on Figure 3 (Fandos, 1991).

The Iberian Ibex is a gregarious species, and their population dynamics change according to densities, seasons and habitat features (García-González et al., 2020). They form mixed groups, females with juveniles, and male groups (showed on Figure 4). Figure 5 shows a yearling after climbing a big rock cliff, which demonstrates they learn this ability already in their first year of life. The rutting season is the one that exhibits more mixed groups, with a common sexual segregation in the rest of the year, although high-density populations tend to exhibit higher percentages of mixed groups throughout the seasons (40% to 80% during the rut). The oldest individuals tend to assume a more vigilant attitude in the groups and activity peaks are on dawn and on sunset (Acevedo & Cassinello, 2009a). Group size vary, with the mixed ones tending to be bigger (mean of 7 individuals) than male groups (around 4-5 individuals) and female-kid groups (4-6 individuals). More open habitats lead to a higher number of animals per group then closed ones (Granados et al., 2020).

Figure 3 - Iberian Ibex female-juvenile group (captured in Las Batuecas - Sierra de Francia Natural Park)

Figure 4 - Two male Iberian Ibex's with different ages (captured in Las Batuecas - Sierra de Francia Natural Park)

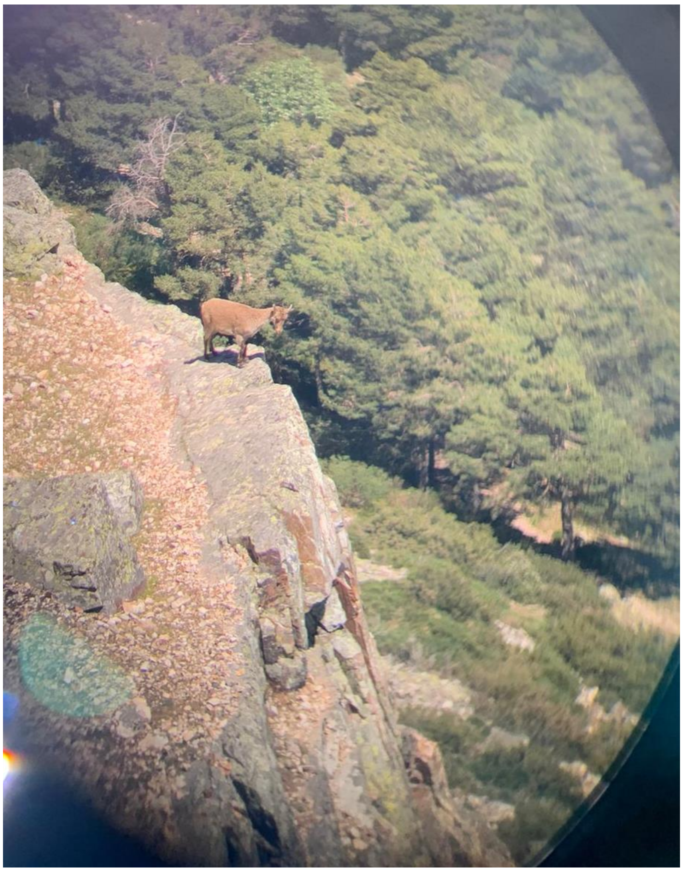

Figure 5 - Iberian Ibex yearling (captured in Las Batuecas - Sierra de Francia Natural Park)

Life expectancy is between 19 to 22 years to females and a maximum of 14 years for males, with females reaching their body growth sooner than males, around four years old and nine years old, respectively (Acevedo & Cassinello, 2009a).

4.2. Historical Distribution and Status

There used to be four subspecies of the Iberian Ibex (*Capra pyrenaica*), two of them are still present in the Iberian Peninsula and other two have gone extinct. The taxonomical classification of the species is currently the following one (Fonseca et al., 2017; García-González et al., 2020):

- *C. pyrenaica hispanica*, present in Southern and Eastern Mountain ranges of Spain and is the more abundant subspecies (described in 1848 by Schimper);
- *C. pyrenaica victoriae*, present in the North and Central mountain system of Spain, translocated to the French Pyrenees, and north of Portugal – Parque Nacional Peneda-Gerês (described in 1911 by Cabrera);
- *C. pyrenaica lusitania*, that used to be present in the northern mountain ranges of Portugal (described in 1872 by Schlegel);
- *C. pyrenaica*, the original subspecies to inhabit the Pyrenees (described in 1838 by Schinz).

This taxonomy shows that the subspecies classification is based on mainly geographical criteria (but also considers differences on horns and black pelage patterns) (Acevedo & Cassinello, 2009a).

This is an animal species that used to occupy many mountain ranges in the Iberian Peninsula during Holocene, but habitat fragmentation, hunting and sarcoptic mange outbreaks depleted considerably the presence of this species, with the Portuguese subspecies becoming extinct in the end of the 19th century and the Pyrenees populations in early 2000s, maintaining their range only in some Central and South mountains of Spain (Pérez et al., 2002). Since the beginning of the 21st century the Spanish populations have been increasing due to conservation and reintroduction programs (that include regulated trophy hunting and control of diseases), law changes and rural abandonment. France also initiated a restoration plan that successfully returned the Iberian Ibex to the Pyrenees region (García-González et al., 2020; *Le Retourn du Bouquetin dans les Pyrénées*, 2022; Moço et al., 2006).

Currently, the species is classified as “Least Concern” by the IUCN Red List (Herrero et al., 2021) but is considered by the Portuguese Red Data Book as “Critically Endangered” (Cabral et al., 2005) due to an extremely reduced population in a restrict area of the Peneda-Gerês National Park.

Now we focus on the distribution of the Iberian Ibex in Portugal and their local extinction, followed by a recent small recolonization. Palaeontological data refers the presence of this animal species in many regions, especially on the principal mountain ranges. Fossil records and rock engravings from the middle and upper Palaeolithic era proves that this species habited places like low latitude Atlantic mountains. Fossil remains have been found in caves from North to the South of the country : “Gruta Nova da Calumbeira” (Bombarral, north of Torres Vedras), “Gruta da Figueira Brava” (Parque da Arrábida), “Gruta do Caldeirão” (north of Tomar), “Gruta das Salemas” (Lousã) and “Pego do Diabo” (Loures), palaeolithic paintings in the Côa and Douro River Valleys, in Casais Robustos (a village that is part of Natural Park of Serras de Aire e Candeeiros), Algar of João Ramos/”Gruta das Redondas” (in Serras de Aire e Candeeiros) and Vale Boi archaeological station (Algarve, close to Sagres) (Aguiar & Pinto, 2007; Baptista & Reis, 2008; Cardoso, 2006; López, 2019; Valente, 2004). Serving as an example, Figure 6 shows rock paintings of the Iberian Ibex from the Neolithic era, in a rock shelter located in “Las Batuecas - Sierra de Francia Natural Park”.

Figure 6 - Iberian Ibex rock engravings located in "Canchal de las cabras pintadas", a rock shelter in Las Batuecas - Sierra de Francia Natural Park

Then, with agricultural development, habitat losses and fragmentation in addition to hunting pressures resulted in progressive decreases on the main population. Peneda-Gerês National Park was the only place where the Iberian Ibex persisted until 1890, the time when the last individual was sighted and documented (Fonseca et al., 2017).

In 1992, a translocation program in Galicia placed individuals of *C. p. victoriae* from Gredos National Reserve to Invernadeiro Natural Park that with time developed to a population of seventy-one individuals and in 1997 eighteen of them were translocated to Serra do Xurés Natural Park which makes border with the Peneda-Gerês National Park (PGNP) in Portugal. On the same year, sixteen individuals enclosed in two location sites of the Spanish Park escaped and by natural dispersion they established themselves in the Portuguese Territory, on the PGNP. At the end of 1998, these animals were first observed, and a defined population was then documented in 2001. In 2003, the first monitoring program recorded a minimum of 75 individuals, but the following years did not have consistent monitoring going on, until 2011 to 2012 that other survey counted for an abundance of 576 individuals in a total area of 15 417 hectares. Three founder nuclei are now delineated - one in "Serra Amarela" (1 235 ha), and two in "Serra do Gerês", one in the centre (13 840 ha) and the other on the eastern side in "Castro Laboreiro" (343 ha). Although this population seems to be geographically expanding and the presence of juveniles confirm the natural reproduction, some threats to the population's conservation have been discussed, like poaching, inbreeding that causes low genetic variability, competition with livestock, and habitat fragmentation that leads to isolation. This last one is more related to the nucleus in "Castro Laboreiro" that has the Lima River and Lindoso dam possibly acting as a disperse barrier and, highlighting the necessity of natural corridors for the achievement of satisfactory genetic variability that can lead to a better success in developing a stable population of this animal species in the North of Portugal (Bencatel J. et al., 2019; Fonseca et al., 2017; Moço et al., 2006).

4.3. Climate and Habitat Requirements

It is a fact that the Iberian Ibex was part of our mountains, canyons and smooth hills in the past, yet the Portuguese landscapes have suffered a lot of changes since them, which makes it appropriate to study the present conditions and evaluate if it suits the Iberian Ibex.

Studies carried out in the Spanish populations show that this species can habitat forested areas, temperate shrublands, natural and artificial pastures and some agricultural land (Cabral et al., 2005; García-González et al., 2020). Rocky outcrops and high-altitude cliffs seem to be a preferential location for home range (Acevedo et al., 2011; Bencatel J. et al., 2019), but their habitat plasticity is proven in semi-arid Mediterranean areas with small cliffs and bushes, being hypostasised as buffer areas for their protection (Lucas et al., 2016).

The habitat range changes significantly with season and according to sex. Males present higher range areas of movement, reaching higher altitudes than females. The species has seasonal patterns of habitat use, especially in areas where the climate varies significantly throughout the year, displacing to northern slopes in summer and southern one in winter, and seem to spend their activity time in more sunny slopes in spring and autumn (Escós & Alados, 1992a). The Iberian Ibex also shows a preference in summer to move to the highest-altitude sites in their habitat area, explained by the flourishment of better-quality vegetation (García-González et al., 2020). During the rut season, males can reach movement dispersals over 7 km (Escós & Alados, 1992b)

Portugal can be described with four climatic types. Atlantic, Continental, Mediterranean and Semi-arid. The most common are the Atlantic in north-west areas and Mediterranean and Semi-arid environments in south-east ones. These types of climates are also the ones present in Spain, where the Iberian Ibex habits all of them, which suggests that this species could be translocated to several areas in Portugal based only on simple climate analysis (Torres et al., 2017). Despite this affirmation is just based on their past and present presence in Portugal and population studies in the Spanish side, one study has been conducted to evaluate the suitability of a western Iberia landscape – the valley of the River Côa. This location offers a mostly dry and Mediterranean climate with some Atlantic influence particularly on the north and west side. The results showed several areas with favourable conditions for a population of the Iberian Ibex to establish itself and develop with great possibilities of dispersal by vital habitat connectivity, mainly in central and northern spots (Torres et al., 2017).

The two subspecies present biogeographical differences between them, which can give us conclusion about the most favourable one to successfully expand in the Portuguese territory. *C. p. victoriae* is mainly located in central Spanish mountains and their populations growth has been stable but restricted, leading to the hypotheses that this subspecies seems to be more susceptible to environmental conditions. On the other side, *C. p. hispanica* show a better expansion process by habiting more and largest areas in south and eastern Spain and presenting well-established populations (Escós et al., 2008). Having in consideration that the *C. p. victoriae* is more area restricted (with IUCN proposing translocation processes that can found other populations of this subspecies in more areas), has a better suitability for the north-western side of the Iberian Peninsula (Acevedo & Real, 2011), and is the subspecies already habiting the PGNP, it is reasonable to assume that this subspecies should be the one to choose when forming a reintroduction program in Portugal.

4.4. Foraged Species

The Iberian Ibex is an herbivore, mixed-feeder, which means it shows different feeding behaviours – browsing and grazing (Acevedo & Cassinello, 2009a). Studies show that this animal species exhibits a significant feeding plasticity, being more of a grazer or a browser according to the vegetation available on the habitat areas, which shows great adaptability (Fandos et al., 1993). Forage selectivity changes throughout the year, so a diverse landscape with woody and herbaceous species is preferred, with the spring-summer zone being the best for diet quality and diversity (Cuartas & Garcia-Gonzalez, 1992).

Table 4.1 presents a list of woody species, shrubs and herbaceous strata that possibly will be dietary sources for the Iberian Ibex in Portugal, based on documented foraged species for this animal, taken from several studies (Martínez, 2000; Martínez, 2009; Martínez, 2010; Martínez, 1993; Moço et al., 2013; Moço et al., 2014), and considering the species available in the Portuguese territory (ICNF, 2016; Jardim Botânico da UTAD, 2022; Marchante et al., 2014).

Table 4.1 - Tree, shrub and herbaceous species present in Portugal know to be foraged by the Iberian Ibex

Scientific name	Common Portuguese name
Phillyrea angustifolia	Lentisco
Phillyrea latifolia	Aderno-de-folhas-largas
Arbutos unedo	Medronheiro
Quercus faginea	Carvalho-português
Juniperus oxycedrus	Oxicedro/Zimbro
Erica arborea	Urze-arbórea
Dactylis glomerata	Dactila
Pinus sylvestris	Pinheiro-silvestre
Viburnum tinus	Folhado
Quercus coccifera	Carrasco
Juniperus communis	Zimbro-comum
Acer monspessulanum	Zelha
Pistacia terebinthus	Cornalheira
Festuca arundinacea	Festuca-alta/Erva-carneira/Sargasso-bravo
Brachypodium phoenicoides	Braquipódio
Poa bulbosa	Poa bulbosa/Erva-cebola
Amelanchier ovalis	Nespereira-das-rochas
Cytisus spp.	Giestas/Giesteiras
Pterospartum tridentatum	Carqueija
Thymelaea broteriana	-
Armeria spp.	-
Sedum spp.	Erva-do-cão/Cachos-de-rato/Arroz-dos-telhados

The Iberian Ibex can potentially consume other shrub and herbaceous species that are considered as invasive in Portugal. These suggestions of possible palatable vegetation based on similarity with other ungulates and goats are described on Chapter 5 – section 5.3.

4.5. Social attitudes and Threats

Social attitudes and threats need to be analysed when equating a possible species reintroduction (IUCN/SSC, 2013). Human conflicts mainly come from Iberian Ibex diet competition with livestock, especially sheep and goat, but does not seem to be so much relevant and for the case of land abandonment is not something with need to evaluate. Trophy hunting in Spain has brought some discussion in terms of sustainability of the species (Carvalho et al., 2018; Moço et al., 2006), and poaching is already a problem for the Population present in the PGNP (Cabral et al., 2005). Sarcoptic mange is the disease that has been proven to affect more significantly the populations of the Iberian Ibex and in many cases it spreads from domestic ungulate. The most sensitive populations seem to be the ones smaller and with less genetic variability or with restricted habitat areas, affecting not only the individuals themselves but also the population dynamics (Pérez et al., 2015). Hybridization can occur with feral goats, so the management of these animals, are essential for allowing a healthy Iberian Ibex population to develop (García-González et al., 2020; Moço et al., 2006).

Despite some human conflict and other threats described, the magnitude of this factors are not a barrier for a reintroduction proposal and if well accounted and managed will not impede a population of Iberian Ibex's to successfully establish in Portuguese land, as seen in other cases like the Pyrenees restoration program (Préfet De La Région Midi-Pyrénées, 2014).

4.6. Impacts on other species – Interspecific Dynamics

The interspecific dynamics represents the interactions between different species that share the same habitat (Begon & Townsend, 2021). In this case, competition with other herbivores and potential predation are assessed.

The Iberian Ibex has been described has a prey for the Iberian Wolf, Golden Eagle and Red Fox. In Portugal, the expansion of the Iberian Wolf can be compromised by low availability of wild prey, which generates conflicts with humans because of many cases of livestock losses due to this animal that lead to the necessity of compensatory costs by the government (Álvares et al., 2015; Despacho n.º 9727/2017, 2017). The Iberian Ibex could partially attenuate this problem when a well-developed population intersects the range area of this carnivore (Alados & Escós, 2017; Fonseca et al., 2017). Golden Eagle and Red Fox reportedly prey for the Iberian Ibex, with more success on juveniles (Fandos, 1991; García-González et al., 2020). It should also be a benefit for the vultures' or other scavengers' populations as their food sources have become significantly limited since the legislation on livestock carcasses removal took place in 2001, with reintroduction projects of large herbivores in areas habited by these animals and without legal constrains related to carcasses, already showing success (Beekers et al., 2017; Margalida et al., 2010).

Finally, a hypothesis can be made of another potential predator based on the reports of the Golden Eagle and Red Fox - the Iberian Lynx. This carnivore species, despite not sharing the same habitat in the present, can have the ability to occasionally prey on the Iberian Ibex, most probably on its juvenile phase. This would be great for the success of the conservation of this animal species in Portugal and could even contribute for the expansion of its range.

When it comes to sharing the same habitat as other wild herbivores, competition can create impacts on these species. The relation of Red Deer with the Iberian Ibex do not seem to develop a niche overlap (Acevedo & Cassinello, 2009b), and cohabiting with the Wild Boar has demonstrated to not be a problem for the spread of diseases (Navarro-Gonzalez et al., 2015). In Spain, areas occupied by the Mouflon and the Iberian Ibex have shown overgrazing, but this is applicable for the cases where the populations do not have predators and their densities are higher than the habitat capacity (Pérez et al., 2002), as in other areas the cohabitation of these two species has been sustainable (Torres et al., 2014). Nevertheless, advantages can come when a habitat is shared between multiple mammal herbivores, complementing the ecosystem and leading to a functional landscape, so the sharing of space and some level of diet competition does not have to be assumed as a negative factor (Jepson & Blythe, 2020).

Studies on the dynamics of Iberian Ibex's sharing the same areas as livestock present cases where the competition is low and others where the spread of diseases or diet competition leads to the Iberian Ibex to change to a more grazing behaviour and negatively impacting the ecosystem (Chirichella et al., 2014; García-González et al., 2020).

Wild ungulates, such as the Iberian Ibex, can be referenced as ecosystem engineers by shifting habitats by grazing, browsing, wallowing, urinating, excreting and some other behaviours that with time lead to changes in soil, water and plant composition. They have been proven to positively affect arthropod and amphibian communities, as well as insect and bacterial richness (Baruzzi & Krofel, 2017; van Klink et al., 2020; H. Zhu et al., 2012).

4.7. Legal framework

Legal framework is another aspect to consider when considering a translocation (IUCN/SSC, 2013). For this case in Portugal, European Union legislation is worth to explore. The Habitat Directive is the Council Directive 92/43/CEE relative to the preservation of natural habitats and wild fauna and flora, transposed to the Portuguese Law by the "Decreto-Lei nº 140/99" (Decreto-Lei nº 140/99, 1999). Despite the fact that this directive was created in 1992, it continues to be suitable and the main European tool for assessing wildlife thriving necessities (European Commission, 2016). The following articles can be emphasized:

- Article 2, point 2 and 3: "Measures taken pursuant to this Directive shall be designed to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of community interest (…) shall take account of economic, social and cultural requirements and regional and local characteristics." (Communities, 1992, pp. 3-4).
- Article 12, point 1: "Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV (a) in their natural range" (Communities, 1992, p. 6).
- Article 22 (a) and (c): "In implementing the provisions of this Directive, Member States shall study the desirability of re-introducing species in Annex IV that are native to their territory where this might contribute to their conservation, provided that an investigation, also taking into account experience in other Member States or elsewhere , has established that such re-introduction contributes effectively to re-establishing these species at a favourable conservation status (…) promote education and general information on the need to protect species of wild fauna and flora and to conserve their habitats and natural habitats." (Communities, 1992, p. 9).

The Iberian Ibex is listed in the Annex II, IV and V, designated as a priority species (Communities, 1992). This animal species in native to Portugal so a reintroduction program should be pondered based on the Habitat Directive.

4.8. Possible areas with suitable habitat

In Portugal, many mountains with more or less altitude gradient can be suitable for the Iberian Ibex (Acevedo & Real, 2011; Bencatel J. et al., 2019; Lucas et al., 2016). Listed below are some suggested areas with prospect to suit this species climate and habitat requirements. Nevertheless, habitat suitability analysis would still be required, except for the valley of Côa River which already has been proven to be a great area for a translocation program for this animal (Torres et al., 2017).

- Mountain ranges: Serra da Estrela, Serra da Malcata, Serra de Montesinho, Serra da Lousã, Serra da Gardunha, Serra de São Mamede, Serra de Aire e Candeeiros, Serra da Peneda, Serra de Arada, Freita e Montemuro and Serra do Alvão.
- Canyons: Douro and Tejo International Park, canyons of the Côa and around the canyons of Sabor River.
- Smooth hills: Parque da Arrábida, Serras Algarvias (Caldeirão and Monchique), Serra de Montejunto and Serra d'Ossa.

The choices were based on the know ecology of this species, past habitats in Portugal and its presence on similar climates and habitats, as explored in section 4.2 and 4.3. Given the adaptability of the species it is possible that many areas with suitable habitat exist.

4.9. Lack of interest in the Iberian Ibex

On the contrary to Spain that has shown a significant care for the Iberian Ibex, with several studies being conducted since 2000 regarding multiply aspects related to this species biology, ecology, ecosystem dynamics and others, in Portugal the scenario has been drastically different. Despite this species being of particularly importance to preserve and recover based on the Habitat Directive, the Portuguese government, ICNF (the Portuguese agency in charge of nature conservation) and the Portuguese scientific community have not been expressing interest in supporting studies on habitat suitably or ecosystem dynamics, consistent monitoring measures and even reinforcement of the only present Iberian Ibex population in Portugal (Fonseca et al., 2017; Moço et al., 2006).

The Member States' assessment of conservation status of the species with community interest as part of the Habitat Directive Article 17 reporting process, corroborate the affirmation above, as the Portuguese report for the time 2013 to 2018 (the most recent one) does not present vital information such as habitat range and suitability and future prospects for the status of the Iberian Ibex in Portugal. On the other hand, Spanish and French reports show commitments in preserving the species and restoring populations (European Environmental Agency [EEA], 2013-2018).

5. Case Study – Active vs. Passive landscape management

5.1. Method

To estimate the economic valuation of a landscape restoration program and compare the two different approaches, the costs and benefits of both ways was assessed. The values for the proposed interventions contained on the Forest Sappers Guide were compared with costs and benefits of Iberian Ibex reintroduction for landscape management. The analysis starts with the Iberian Ibex potential for saving costs in landscape management actions, followed by a description of possible Iberian Ibex management costs and finishes with a discussion on reintroduction costs for the Iberian Ibex.

In this study, the term "intervention" refers to a certain group type of landscape management actions, while an "action" is the actual human-made disturbance measure, like fertilizing a tree or doing controlled fire.

To be able to estimate saving costs from the Forest Sappers 2021 Program by reintroducing the Iberian Ibex, the proposed actions in the Forest Sappers 2019 Technical Guide were evaluated and its potential to be complemented or substituted by the Iberian Ibex ecosystem dynamics analysed, in order to assess if the Iberian Ibex can perform actions that present equal or similar outcomes to the Forest Sappers work. To better estimate the results and take into account the variability/uncertainty of the Iberian Ibex to replicate different actions, three categories were established: low degree, medium degree, and high degree of probability for an action to be replicated by the Iberian Ibex. Considering that the number of times a certain action needs to be performed depends on the site, a value interval was used to account for uncertainty based on the likely restoration outcomes of a small population made up of three groups: mixed, females with juveniles, and males, totalling 16 individuals. The price interval of each action was multiplied by their quantity interval in order to obtain an interval of potential avoided costs. This interval is represented in four different scenarios: low cost – low quantity; low cost – high quantity; high cost – low quantity; high cost – high quantity.

To estimate the Iberian Ibex management costs, despite the fact that needed measures depend on various circumstances and factors (for example, quantity of animals or characteristics of the habitat area), a review on possible management measures was performed and costs were obtained. Reintroduction/translocation programs on Spain and Pyrenees were analysed to find reliable costs for the potential reintroduction of a small Iberian Ibex population in Portugal. The total cost estimation provides a view on possible associated costs regarding the use of the Iberian Ibex as a tool to manage a landscape.

The Forest Sappers 2019 Orientation Guide is used as a proxy for the interventions defined in the Forest Sappers 2021 Program. In order to simplify this analysis, interventions described in the program that were not related to land disturbance work (for example, awareness campaigns) or labour costs were not included. Also, there is the possibility that some landscape actions implemented by the program were not included in the orientation guide, although this guide presents a well-designed framework with a wide range of most necessary measures in the context of landscape management in Portugal.

5.2. Data

To obtain the necessary qualitative and quantitative data related to direct human management actions, in order to build the case for the named "active management approach", three reports and one project were consulted. The first report, "Guia Técnico de Cartografia para o programa de Sapadores Florestais", which provides the framework for the forest sappers teams to develop their forest management plans and reports. In the context of this study, it served as an orientation guide for the main landscape management actions that take place in the Portuguese territory (ICNF, 2019). The other two are the "Matriz de (Re)Arborização 2015/2016" and "Matriz de Beneficiação 2015/2016" (CAOF, 2015/2016a, 2015/2016b). Both were developed by the "Comissão de Acompanhamento para as Operações Florestais – CAOF", a commission created with the purpose to provide a database of information related to forest operations, including a matrix with minimum and maximum reference prices of forest operations in the relevant units (which includes the main landscape management actions) (ICNF, 2017a). The Spanish silvopastoral project "Red de Áreas Pasto-Cortafuegos da Andalucía" (Junta de Andalucía, 2022) served as a proxy to obtain reference values on specific action related to the use of herds for forest fuel management.

On the subject of data for the Iberian Ibex, extensive bibliographic research was made, and some sources were considered as reliable. Being this study about a specific species that is only present in the Iberian Peninsula, concrete information related to their impact on ecosystem dynamics and capability to provide important landscape effects for a balanced landscape environment, is limited. Nevertheless, selected sources provide a satisfactory level of content related to this species that makes it possible to consider certain characteristics and evaluate with confidence their ecosystem effects. For example, a book on large herbivores ecology and ecosystem dynamics with focus on ungulates (a former scientific group which includes the Order Artiodactyla, where the Iberian Ibex belongs) (Danell et al., 2006) and research articles that focus on a variety or specific interactions and effects of wild ungulates/goats on the ecosystem (Lovreglio et al., 2014; Pascual-Rico et al., 2021; van Klink et al., 2020). Previous reintroduction/restoration and management programs were consulted to assess information and likely costs related to that matter (Granados et al., n.d; *Le Retourn du Bouquetin dans les Pyrénées*, 2022; Préfet De La Région Midi-Pyrénées, 2014).

5.3. Iberian Ibex potential for landscape management

The Forest Sappers Technical Guide presents a range of simple (e.g., plant fertilization) to more complex (e.g., emergency stabilization) human-made actions, designated by their type of intervention:

1. Reforestation
2. Fuel Management
3. Control of exotic/invasive Species
4. Post Fire Management
5. Leftover Treatment
6. Inventory
7. Plant Health

These actions also vary a lot in terms of price, one's cost some cents while others can go up to more than a thousand euros (detailed info provided on Annex, Table 9.3 and 9.4). The actions were evaluated according to this species documented effects on the ecosystem. Despite the fact that Iberian Ibex's role on the ecosystem is not as established and well-documented, as for example the European beaver (Campbell-Palmer et al., 2016), information on this matter is well studied for groups of related animals that tend to have similar behaviours on their habitat (Danell et al., 2006). Some sources also provide information from related species on a Mediterranean climate, which helps to bring more confidence on the possibility for the Iberian Ibex to perform ecosystem disturbances that function as tools for landscape management in Portugal. Figure 7 summarizes the ecosystem functions of large herbivores, serving as an example for the ecological interactions the Iberian Ibex can create. The Figure 8 shows the effects of natural grazing on landscapes, serving as a proxy for a representation of the transformations can be able to replicate on landscapes.

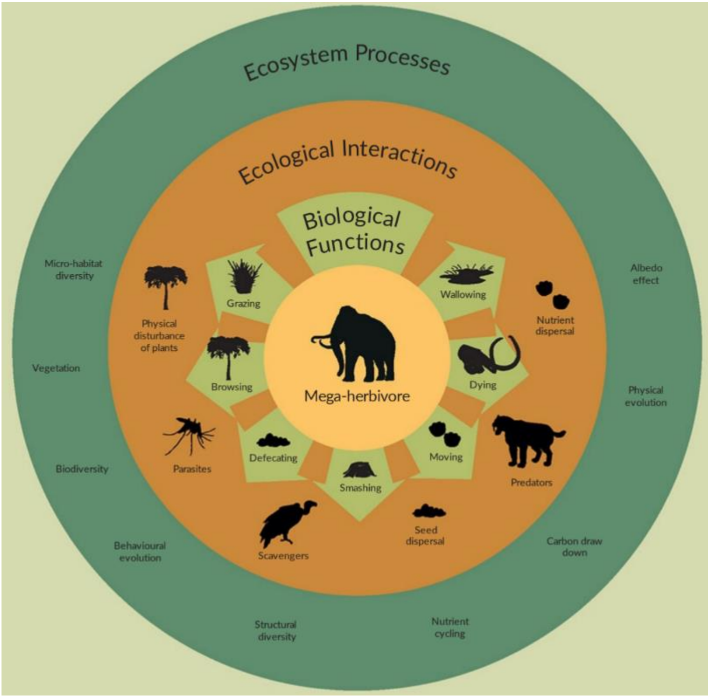

Figure 7 - Large Herbivores in a functioning ecosystem (Jepson & Blythe, 2020)

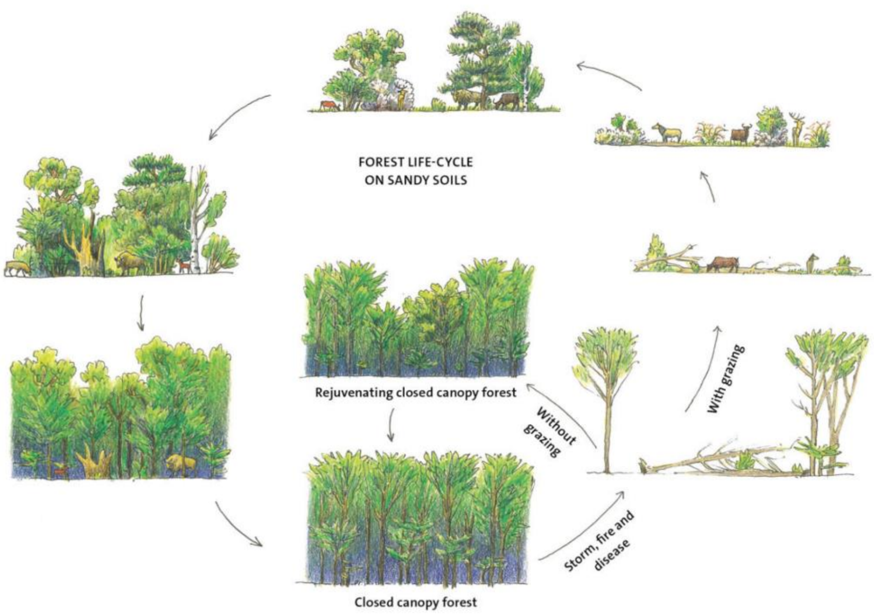

Figure 8 - The impact of grazers on vegetation (Rewilding Europe, 2021b)

For this economic analysis to be well-weighted, the actions were divided in three categories according to different levels of confidence on the Iberian Ibex potential to replicate them. "High degree" represents the actions with high potential for being similarly replicated by the Iberian Ibex or have equivalent landscape outcomes; "Medium degree" contains actions that Iberian Ibex's can somehow perform but not at the same scale, which means it could need human intervention in order to achieve the same landscape target; "Low degree" includes actions that are probability difficult for the Iberian Ibex to execute or have not yet been described in the literature. The actions that do not show any relevance of being replicated by the Iberian Ibex, based on this species normal behaviour and interactions, are also provided. Next is presented a list of the actions, organized by different degrees.

- High degree of probability

  - Plantation as the Iberian Ibex can promote seed dispersal by their faeces or transport them on their fur and hoofs by their browsing behaviour. Also enhances fertility by the replacement of nutrients to the soil through urine/faeces (example on Figure 9) and digestion. Also their carcasses can create a high soil fertility zone around them, increasing landscape heterogeneity (Hobbs, 2006; Pascual-Rico et al., 2021; Vermeulen, 2021).

    [actions: 1.4, 1.5]

Figure 9 - Iberian Ibex faeces (captured in Las Batuecas-Sierra de Francia Natural Park)

- Capability to manage fuel and control excessive densities by mixed feeding behaviour (indicated to be the most effective herbivory type) which reduces grass and shrub biomass. By grazing the Iberian Ibex decreases the amount of herbaceous fuel and by browsing it lowers biomass fuel (Hobbs, 2006; Rouet-Leduc et al., 2021; Vermeulen, 2021).

[actions: 2.1, 2.1.1, 2.4]

- Ungulates can consume parts of a plant (e.g., leaves) or even kill them by chipping them to a point that impedes the regeneration of the plant. This phenomenon increases the inputs of a leftover, the woody litter, to the soil (Pastor et al., 2006).

[action: 5.2]

- Medium degree of probability

- The action of digging holes has the objective of improving aerification of the soil and promote new plantation site. Herbivores like the Iberian Ibex use their hooves to walk, and by trampling the soil they break some biotic crust and can fracture mineral crust to a level it helps to increase soil aerification and infiltration. Also, goats sometimes show the behaviour of wallow (for thermoregulatory purposes and to relieve from possible insect bites), which leads to the formation of some small holes. Nevertheless, for this behaviour to perform the same potential outcomes of human action, other herbivore species like bison or boar may be needed (Hobbs, 2006).

[action: 1.2]

- Goats are able to reduce weed by consuming seedling stems, which impedes their seeds release. Yet, for the grazing effects to have similar outcomes as human weed clean-ups, could need other herbivore species to dwell on the same area as the Iberian Ibex (Hobbs, 2006; Lovreglio et al., 2014).

[action: 1.8]

- The behaviour of grazing and browsing contributes to removal of plant tissue, keeping plants in early phenological stages, which increases productivity instead of these compounds to remain on structure material, as goats in particular consume terminal wigs and bark specially during winter. The Iberian Ibex also scratches on trees as part of their cleaning behaviour, especially males with their horns (Sarasa et al., 2011). Examples of these behaviours are shown on Figure 10 and 11.

This way, nutrients return to the soil and are decomposed by invertebrates, which facilitates the process of nutrient absorption by plants. Also, as said before, their hooves trample the soil and help to accumulate and compress dead plant material for future soil enrichment promotion and better chances for a prosperous plant development. These processes may not cover all the habitat areas (Baraza et al., 2007; Gordon, 2006; Hobbs, 2006; Lovreglio et al., 2014).

[actions: 1.7, 2.1.2]

Figure 10 - Effects of consuming terminal wigs and horn-scratching on trees, by the Iberian Ibex (captured in Las Batuecas-Sierra de Francia Natural Park)

Figure 11 - A tree barked by the Iberian Ibex (captured in Las Batuecas - Sierra de Francia Natural Park)

- The fact that the Iberian Ibex has the potential to do fuel management was already established before. Nevertheless, when we consider a mechanic reduction of biomass, the results of that can overcome the potential of this species to deliver the same results, depending on the area and if there is other large herbivores co-habiting (Rouet-Leduc et al., 2021).

[action: 2.2]

- The Iberian Ibex, as well as many other ungulates, create mosaic landscapes by grazing, creating open corridors on the landscape that helps to induce firebreaks in a controlled space. This is a trigger for the life cycle of typical Mediterranean landscapes to thrive and increase their ecological productivity level, working perfectly when in interaction with other large herbivores like horses (Roldán, 2012; Vermeulen, 2021).

[action: 2.3]

- Herbivores consume a variety of herbaceous and woody plants, but from all of them, goats seem to have a greater weed control. Many studies across different landscapes in the world have shown that exotic and invasive plant species can diminish in the presence of goats grazing. By being more diverse on food preferences and consuming a wide variety of plants, goats can eat invasive species that are actually palatable and nutritious to them, when normally cannot be eaten by cattle or sheep. They also have the particularity of having some preference to consume leaves and terminal twigs of woody species. If we look at invasive species present in the Portuguese territory, some of them have potential to be grazed by the Iberian Ibex, according to demonstrated palatable weeds for goats and their distribution in potential habitats for this animal, like: *Acacia karroo, Acacia mearnsii, Agave americana, Ageratina adenophora, Ailanthus altissima, Allium triquetrum, Amaryllis belladonna, Arctotheca calendula, Bidens frondosa, Cortaderia selloana, Gleditsia triacanthos, Hydrangea macrophylla, Lantana camara, Lonicera japonica, Myoporum laetum, Nicotiana glauca, Oxalis latifolia, Oxalis pes-caprae, Pennisetum villosum, Ricinus communis, Robina pseudoacacia, Solanum mauritianum, Sorghum halepense,* . For the case of this mentioned species, the Iberian Ibex can be an alternative for the application of herbicides and mechanical cutting. Nevertheless, cannot be expected for this animal to have an eating effect with similar outcomes of human action, because in some cases may be needed a stronger chemical approach. Also there is other invasive plants in Portugal that we currently do not have reliable information to know if the Iberian Ibex could potentially control them (Lovreglio et al., 2014; Marchante et al., 2014; Rosa García et al., 2012).

[actions: 3.1, 3.2]

- Ungulates are known for their preference in foraging burned areas. The recovery of land implicates several measures, from plantation and plowing to cutting of burned trees and constructions for water drainages. The question to what measures are necessary, is dependent to the type and range of the damaged area, which could require actions that this species cannot provide, especially the ones related to water lines. Even if the necessary measures could be replicated by this species, because it is an intervention that needs to be done in short/medium term, the Iberian Ibex could not provide outcomes at the same level as the human actions for that period of time (Hobbs, 2006; Pascual-Rico et al., 2021; Rouet-Leduc et al., 2021).

[action: 4.1]

- It was already established before that the Iberian Ibex can stop the regeneration of plants and increase the input of woody leftovers to the soil, but the human process of burning these leftovers can serve other purposes (e.g., energy biomass) this animal species cannot replicate, but provide other benefits like the enrichment of soil and enhancing of the nitrogen cycle (Pastor et al., 2006).

[action: 5.1]

- Through feeding behaviour, seed dispersal capacity and their urine/faeces/carcasses, large herbivores enhance the resistance of plants by improving plant diversity and heterogenicity. This can create more prosperous landscapes and less subject to pests, avoiding at some level the necessity of spending high amounts of money on chemical/biological phytosanitary treatments, especially the ones for insects or weed. In some areas of Europe has already been observed the capacity of grazing to reasonably impede the spread of ticks and tick-borne diseases (Lovreglio et al., 2014; Rewilding Europe, 2021b).

[action 7.2]

- Low degree of probability

  - As explained before, the Iberian Ibex have a medium potential to simulate the manual process of digging holes by their wallowing and trampling behaviour, but human mechanical ways serve scenarios where the present need for soil aerification and necessities of plantation are higher, and in this cases the Iberian

Ibex will probably not be able to replicate the same circumstances, having just a low interference (Hobbs, 2006; Houston et al., 2007).

[action: 1.3]

- Large herbivores can shed twigs and branches of plants by their browsing behaviour, which sometimes can replicate the human action of pruning but in other cases will promote slow growing of plants or even kill them (which is also important for maintaining the contrast of grown woody plants and open meadows). Nevertheless, this animal species will not be able replicate the same outcomes because the process of pruning can be very selective and strategic to certain meeting landscape standards or serve a phytosanitary purpose (Gordon, 2006; Lovreglio et al., 2014).

[actions: 2.1.3, 7.2]

- Actions the Iberian Ibex cannot perform

  - Marking of trees, place stakes to limit areas of certain plant growth and do selective cutting of the ones that are not on an optimal stage of development.

    [actions: 1.1, 7.4]

  - Place individual protectors on certain plants.

    [action: 1.6]

  - Do an emergency stabilization post big firebreaks, which implicates the control of erosion, protection of slopes with forestry residue barriers and opening of ruts, as well as many other diverse measures. This needs to be done in a short time, right after the fires, to not compromise the security of the surrounded areas and water lines.

    [action: 4.2]

  - Inventory on flora species development.

    [action: 6.1]

  - Place and/or maintain traps for animals to not destroy plants of interest.

    [action: 7.1]

The action 4.1 – "recovery of burned areas" includes several sub-actions. For this case, were only considered the sub-actions the Iberian Ibex has potential to replicate. Then, to avoid double accounting, the sub-action "plantation" was not considered. So, the sub-actions considered were sowing, subsoiling, moderate ripping and harrowing. The action 7.2 – "application of cultural phytosanitary treatments" can vary in the measures applied, but for this case it was considered the most common sub-action, which is the sanitary pruning.

For a total of [26] twenty-six actions, [19] nineteen were found to have potential for being replicated by the Iberian Ibex. [6] Six actions can be replicated with high certainty and [11] eleven with medium, while [3] three have low probability and other [6] six will probably not be replicated. In the annex, Table 9.1 and 9.2 provide a list of this actions by degree of certainty.

The quantity value interval of each action was defined according to a small population of this species (16 animals), which includes a mixed group of two adult males and three adult females, a group with three females and three juveniles and an only-males group made up of four animals. This numbers were decided according to this species well-documented population dynamics, demographic trends and initial population densities in areas where it has a solid presence (e.g. Sierra Nevada, Spain)(Granados, 2021; Granados et al., 2001; Granados et al., 2020). With an initial population density of 6 Iberian Ibex per square kilometer, the value interval of actions was also though according to an area of 300 rounded hectares, which was consider as the initial area for a reintroduction. Considering this area, two different approaches were taken in order to establish the value intervals: for the actions with cost per unit, the value interval represents the number of times that action will be potentially replicated by the Iberian Ibex, in those 300 hectares; for the actions with cost per hectare, the value interval represents for how many of those 300 hectares will the Iberian Ibex be able to potentially replicate such action or similar outcomes. As the action 4.1 includes four different sub-actions, like explained before, one is quantified by unit and the other three are quantified by hectare. Details on value intervals of each action can be found in Tables 9.3 and 9.4, on Annex.

Table 5.1 presents an overview of the estimated avoided costs scenarios. (LC – LQ) refers to the Low cost – Low quantity scenario, (LC – HQ) for Low cost – High quantity, (HC – LQ) to the High cost – Low quantity one and (HC – HQ) High cost – High quantity. These values were obtained by multiplying the price interval with quantity value intervals, and then allocating the results per probability of the Iberian Ibex to replace them. The values are in euros and rounded by unit. The detailed calculations for each action and scenario can be viewed on Annex - Table 9.5.

Table 5.1 - Iberian Ibex potential to save landscape management costs - Scenarios estimations

	SCENARIOS			
Probability	LC - LQ	LC - HQ	HC - LQ	HC - HQ
High	54 241 €	162 865 €	247 557 €	742 953 €
Medium	66 087 €	229 741 €	151 593 €	518 855 €
Low	14 859 €	45 108 €	51 324 €	155 647 €
High + Medium	120 327 €	392 606 €	399 149 €	1 261 808 €
High + Medium + Low	135 186 €	437 714 €	450 473 €	1 417 455 €

Regarding the scenarios presented on the Table, "Medium" includes the biggest number of actions, followed by "High" and lastly "Low". "High" includes the biggest share of actions priced per hectare, which are the ones more costly. For this reason, the scenarios for high probability are a bit inflated when projected to the highest price range. "Medium" presents the highest number of actions, with cost variability going from unit cents to almost six hundred euros, which makes the corresponding scenarios to contribute more significantly for the results (except the scenarios for high cost, given the "High" inflation case explained before). "Low" includes three actions, two are very low cost (unit cents to around five euros per unit cost) and one is more expensive (several hundred euros per hectare) which accounts for the majority of the cost forecast.

The results from all these scenarios show, with various degrees of certainty, the Iberian Ibex potential to avoid management landscape costs. Not all scenarios have the same likelihood to be replicated. As an example, if the Iberian Ibex only performed on a given site, "low" probability actions and some from "high" would be unusual. This categories are made to grasp avoided costs per category, putting them together allows for a more complete analysis. The scenarios presented in green are the ones that will depict with more probability the reality on the ground, because it includes the two probability scenarios with the highest chances for being replicated, substituted or complemented by the Iberian Ibex and the more reasonable scenarios "LC – HQ" and "HC – LQ". Nevertheless, it is important to note that these scenarios present a possible reality of avoided costs in a small scale, with sixteen animals. Also, landscape management interventions can vary from site to site depending on the necessary actions, and normally not all of them will be performed together. If we multiply this on a landscape area with dozens of sites the potential is huge to avoided ecosystem management costs.

The following sections proposes the costs associated with the Iberian Ibex, in order to compare them with these scenarios of avoided costs.

5.4. Iberian Ibex reintroduction costs

The case on the reintroduction of the Iberian Ibex in the Pyrenees can serve as a great proxy for a possible future proposal in Portugal. In 1910 the species became extinct in the French area, with the subspecies (*C. p. pyrenaica*) being declared extinct in 2000 by the IUCN, but since the 80's various French organizations and administrative establishments have been pressuring for the comeback of stable populations of this animal. The two nature parks are the target habitat for their return, "Parc National des Pyrénées" and "Parc Naturel Régional des Pyrénées Ariégeoises". The active phase of this project initiated in 2014, with the development of a plan to restore populations of specific species in order to value biodiversity in the Pyrenees region by the French Ministry of ecology, sustainable development and energy – "La Stratégie Pyrénéenne de Valorisation de la Biodiversité", which presents a section only dedicated to the return of the Iberian Ibex, in collaboration with the Spanish and Andorran environmental ministries. This project has the support of the European Union through financing by the FEDER - European Regional Development Fund (*Le Retourn du Bouquetin dans les Pyrénées*, 2022).

The animals for the initial translocations were selected from "Sierra de La Pedriza" as part of the Sierra de Guadarrama National Park in central Spain, and belonged to the subspecies *C. p. victoriae*, the one more suitable to the Pyrenees environment, and also the one to choose for the case in Portugal. The selection process of individuals has in consideration genetic variability, absence of population diseases and great similarity in terms of size/pelage/horns to prior Pyrenees subspecies. This project has proven to be successful, with now more than 480 animals habiting several areas of the two parks (*Le Retourn du Bouquetin dans les Pyrénées*, 2022).

According to the data, between 2014 and 2015, [63] sixty-three individuals (26 males and 37 females) were translocated to nine central places in the Pyrenees National Park (known as the high Pyrenees) and [55] fifty-five (22 males and 33 females) in six launch locations of the Ariège Pyrenees Regional Nature Park. The next two years, other [45] forty-five individuals (18 males and 27 females) reinforced the presence of this species in the Pyrenees National Park and a second population nucleus was created in the Ariège Pyrenees Regional Nature Park by the release of [40] forty individuals (22 females and 18 males) on a different site. In 2019 a different area of the Pyrenees National Park was chosen in order to expand this species to habited places in the past, by the translocations of more [22] twenty-two individuals (15 females and 7 males) in the Atlantic Pyrenees. Nex year, [10] ten animals (7 females and 3 males) for the Ariège Pyrenees Regional Nature Park and other [9] nine (6 females and 3 males) for the Atlantic Pyrenees region of the Pyrenees National Park. The 2021 was marked by the launch of more [8] eight females in the region mentioned before. No information about releases for the present year has been published (*Le Retourn du Bouquetin dans les Pyrénées*, 2022). That is, since 2014, [252] two hundred and fifty two individuals have been reintroduced in the French Pyrenees, and [336] three hundred and thirty six births have been observed, with now the total population reaching more than [480] four hundred and eighty Iberian Ibex's (*Le Retourn du Bouquetin dans les Pyrénées*, 2022).

The present plan, accepted in October 2012, develops a restoration of this species population with active interventions for a duration of nine years, from 2014 to 2022. It contains an overall financial estimation for each of the two parks, including price values for the action of capture, transport and release of the animals. Despite the fact that in this plan, the quantity of translocated individuals taken into consideration for the price calculations were different from the actual number of released animals, it still provides an orientation for possible reintroduction costs in Portugal. For a release of [20] individuals in the first three years and another [5] five each following year, the plan provisioned a price interval from 3 000 to 130 000 euros (Préfet De La Région Midi-Pyrénées, 2014) Taking these values into consideration, and pondering costs of buying this animal from North or Central Spain, each individual could have a cost interval of translocation measures from 500 to 5 000 euros, theoretically. If accounted for the establishment of a reintroduction program in Portugal, the reintroduction costs would most probably be on a spectrum of 50 000 to 150 000 euros.

These price intervals can change a lot, according to the capture method used (tele-anaesthesia with a syringe gun – because it requires veterinarian skills is the most expensive one, drop nets or a trap cage, with this last one being the cheapest and less efficient in capturing specifically selected individuals), difficulty on accessing the area of capture and release, necessities of sanitary treatments or other preparation before releasement, and land transport requirements according to the distance from the original site to the reintroduction one.

5.5. Management costs of the Iberian Ibex

Some factors when taking into consideration the reintroduction of a species, can lead to the necessity of implementing management measures for conflict with other fauna or humans. The Iberian Ibex can compete for feed with wild herbivores or livestock that habit the same areas, but at the same time, their dietary plasticity and capability to reach steep or rough areas (known as altitudinal migrations) turns this interspecific competition less relevant (Garnier et al., 2021; Préfet De La Région Midi-Pyrénées, 2014). For the case of reintroduction in areas of land abandonment, this factor will probably not be a concern.

Nevertheless, some factors are known as the main ones that can influence the success of reintroduced populations of the Iberian Ibex. One of them is poaching. Their cliff rockfill defence strategy works very well for predators but makes them vulnerable to human hunting as they find themselves in a no escape zone and it is an optimal scenario for the use of precise weapons. Also, recently introduced populations that are still acclimatized can suffer from the hunting of other animals that share the same habitat areas, like the boar and chamois. To reduce this problem, management actions like better hunting regulations, awareness campaigns with hunters' associations and locals and field surveillance can be effective (Préfet De La Région Midi-Pyrénées, 2014). The Iberian Ibex can also interfere with human activities and generate economic losses by browsing species with high economic value, like pines, but this is only significant in high density population pressures (which is more of a no predators problem) as this species tends to prefer more herbaceous plants and bushes and stay away from the most dense woody tree production areas (Perea et al., 2015; Préfet De La Région Midi-Pyrénées, 2014; Zamora et al., 2001). Besides that, this a species that tends to create very few problems with human related activities.

Other main concern is the spread of diseases of which the populations of Iberian Ibex's can be propense to. Habiting the same areas as domestic goat and sheep, as well as other wild herbivores, can lead to contagion of diseases that place a great risk of death for recently introduced populations with a small number of individuals or small habitat areas, which has mainly to do with less genetic variability and constant contact with each other. The sarcoptic mange is the most common disease among this species. For this, it is important to plan a sanitary approach from which the chosen individuals for the reintroduction come from areas free of the main diseases and present a satisfactory genetic variability, as well as optimal animal densities for the territory which can decrease chances of contagion and create better resistance among the Iberian Ibex populations (Granados Torres et al., 2012; Préfet De La Région Midi-Pyrénées, 2014). The contrary can also happen with some specific diseases being transmitted to livestock and domestic species or even with impact for human health (e.g., tuberculosis), leading to human-wildlife conflict, but most of these diseases are not highly contagious or tend to be more dangerous for the Iberian Ibex than for the herds (Préfet De La Région Midi-Pyrénées, 2014; Valente et al., 2020).

It is also important to take into consideration the possibilities of creating protected zones that bring better living quality to this species and consider their migration necessities between seasons, so that the chosen sites and time of the year for translocations allow the individuals to develop populations that in the future are capable of exploring and disperse. The release of individuals as proven to be better on spring, when the dispersal is minimal and the animals are more accessible to human management control actions, that in a vulnerable stage of establishing a population can be very important for the success of the reintroduction project. Placing them in areas with already established herbivores populations can also influence the species to take those territories as favourable habitats. During the initial years of a reintroduction program, it is also important to release the animals in areas less accessible to tourism and avoid the use of helicopters for vigilance/management reasons (it replicates the shadows of aerial predators) as these tend to increase stress rates when the population is still not accustomed to the new habitat (Garnier et al., 2021; Préfet De La Région Midi-Pyrénées, 2014).

In terms of management costs, the reintroduction project on the Pyrenees can also serve as a proxy. The program is established in two phases. The first one (duration of seven years) is for the establishment of viable population nucleus in both nature parks (in this French case, two for each territory), creating the possibilities for dispersal and connection between them in a mid-term perspective. The second phase takes ten to fifteen years, consists in the extension of the species to other areas of the nature parks that are not as ideal but help to build more diversity and resilience on the populations and to colonize potential past habitat zones of the original French subspecies (Préfet De La Région Midi-Pyrénées, 2014).

Considering this reintroduction plan and the possible human/animal perturbation factors that can affect the Iberian Ibex or vice-versa (as presented before), two types of management interventions are applied, including the following actions (Préfet De La Région Midi-Pyrénées, 2014):

- Population Monitoring

  - Place tracking equipment on individuals. Auricular colourful marks on all individuals, which is less costly and has a lifetime duration, and GPS collars for at least half individuals per nucleus, which can go for 5 000 euros per device but allows great distance animal detection and better research on the populations.
  * [action 11]
  - Population monitoring, like reproduction sites and rates, most common dispersals and fixation areas, to better control the success of the species.
  * [action 12]
  - Foresight on population dynamics (spatial colonization in terms of vital areas or the establishment of corridors and places of populations intersection).
  * [action 13]
  - Mutualization and data exploitation on Iberian Ibex dynamics for the establishment of future actions that can create better proposals for the next years
  * [action 14]

- Conflict solving for cohabitation

  - Communication about the reintroduction operation and population monitoring, making this information available for all publics.
  * [action 15]
  - Capacitation of the institutional representators, employees and partners about all the involved operations and finance instruments, so that territory management can work alongside of the human activities.
  * [action 16]
  - Informing locals, children/students, nature protection association and professionals related to nature activities about species biology, social behaviour

and overall project success, so that the respect for this animal preservation can be sustained.

* [action 17]

- Hunters' awareness to limit possible disturbances on this species populations and to actively include them in the project by helping with animal detection operations.

* [action 18]

The finance values of this actions are presented in the plan, per year and per type of intervention, for both parks (the Pyrenees National Park and the Ariège Pyrenees Regional Nature Park). For the population monitoring the price interval goes from 36 669 to 182 275 euros. The actions for cohabitation success are between 15 980 and 49 200 euros. This leads to a total price interval of 52 649 euros to 231 475 euros (Préfet De La Région Midi-Pyrénées, 2014).

It is important to note that management costs will vary significantly from one place to another because not all disturbance population factors will occur for the same reintroduction program, which will lead to different finance necessities for each possible management measure.

5.6. Results

The ability of the Iberian Ibex to save landscape management costs has been proven, with values ranging from a couple thousand euros to one and a half million euros, for a small nucleus of this species on a well-defined small site of around three hundred hectares. Nevertheless, these costs can fluctuate significantly if we consider a reasonable and stable population of this animal, providing bigger results. On the other side, not all Forest Sappers actions will be performed simultaneously on the same site, with small-scale or less costly ones being the most common actions to apply through the year (e.g., planting trees or pruning).

The reintroduction costs have a substantial value interval going from a few thousand euros to almost half a million euros, which appears to be within landscape management program budgets. The Iberian Ibex can need some control measures when developing its population in a new place, and small-level conflicts may need to be assessed. Those actions reflect in costs that range from half a thousand euros to two hundred and such thousands.

These changes related to the species costs, have a lot to do with circumstances that happen along the translocation process, the community attitudes or the cultural background, disease risk, climate change impacts, among other factors (IUCN/SSC, 2013). For this reason, may not be completely accurate for the Portuguese circumstance.

Nonetheless, financing for reintroductions/translocations is a one-time investment that generates economic returns on a medium-long term perspective. The human actions do not bring ecological balance or nether fulfil the missing role of natural wildlife grazing, as they need to be done year after year with constant high economical costs that do not seem to be getting significant socio-environmental benefits to compensate. Despite the fact that Iberian Ibex impacts on landscape show some degree of uncertainty, ungulates have proven to plug an existing gap in grassland/forest ecosystems with a special role of maintaining natural mosaic landscapes that are the most fitted for the Mediterranean picture and even more important to restore and preserve due to the growing impacts of climate change.

Therefore, the Iberian Ibex appears to be a good investment for landscape restoration, saving significant costs on human landscape management actions, with reintroduction costs within landscape management program budgets and management costs indicating to be relatively low.

5.7. Discussion

The Forest Sappers 2021 Program allocated a spending of around 27.712 million euros for on-the-ground landscape management actions and the necessary conditions for the working of the Forest Sappers Teams across the country, with the goal of defending the forest against fire (suppression actions) and biotic agents, allowing a healthy and safe development. This parcel represents most of the financial investment, with the total compromise being approximately 35.833 euros (includes awareness campaigns, research, forestry cultural/social/environmental functions and forestry planning) (ICNF/FFP, 2021a). Even though the detailed actions for this part of the intervention were not made public, it is safe to presume that those were guided by the Forest Sappers 2019 Orientation Guide.

The landscape results of this program are yet to be published, but the Forest Sappers Activities 2021 Report shows the data for the financial support in fact provided by the FFP though the year. For the parcel of forest management and defence 78% had financial execution, with the total program being financed by 76% (ICNF/FFP, 2021b). This numbers represent a considerable effort to enable the program operations, with not even the whole actions having the necessary finance instruments for their execution. In addition, the problem of fire breakouts is still a major concern in Portugal, with climate change as promoting this tendency (Rewilding Europe, 2020b). Even though some of the actions cannot be substituted by restoring natural grazing (e.g., marking trees or emergency stabilization), most of them could be diminished in great frequency and operate only on selective/specific cases. The impact of active human actions on landscape is contained to the working areas, not spreading their benefits and with constant year by year maintenance to impede the development of the fire problematic (Lovreglio et al., 2014). An insufficient parcel of this program is dedicated to wildlife functions on landscape (ICNF/FFP, 2021a), which reflects the main gap of this programs: it is focused on the remedy, not on the cure. The ecosystems remain fractured, with important missing parts that allow biological cycles to function and promote landscape resilience, such as megafauna (Fricke et al., 2022).

The Iberian Ibex can be represented as an important species for the reestablishment of natural grazing through rewilding initiatives. Could allow natural processes such as nutrient cycling and trophic chain to recover (Danell et al., 2006; Rewilding Europe, 2021b). Funds could be used to bring back this emblematic species instead of focusing only on local landscape management actions, avoiding expenses in attempts to re-establish some natural processes that the Iberian Ibex could perform for less resources, no use of fossil fuel for the mowing and ploughing methods which decreases carbon emissions, more biodiversity benefits and ecosystem services, and substantially decreasing social problems related to firebreaks (Rewilding Europe, 2021a).

To conclude this chapter, we note that by previous reintroduction programs a translocation project for the Iberian Ibex in Portugal would be viable, with a possible budget between 100 thousand euros and 1 million euros, if projected for 10 years, enough time to establish two to four population nucleus with approximately 100 animals each, regarding the early sexual maturity and the 20 to 30% annual growing rate capacity (Préfet De La Région Midi-Pyrénées, 2014). After this year, the Iberian Ibex could move from across around 10 000 hectares, potentially saving dozens of millions of euros in human management costs while promoting biodiversity and landscape resilience alongside providing valuable ecosystem services. Management costs appear to be acceptable and could probably be lower in the context of Portugal if initiative-taking measures are applied. The costs of a possible reintroduction and control management of Iberian Ibex populations could be partially financed by European Union funds as a step for ecosystem restoration. The Portuguese Government should also have an initiative-taking action on this matter and environmental NGOs could also help on the restoration of this animal species to Portugal.

6. Iberian Ibex Impacts in the Landscape

In the previous chapter, Iberian Ibex potential for landscape management and restoration was discussed. This chapter will highlight the possible landscape effects the Iberian Ibex can deliver from its behaviour and activities. Although moral, scientific and cost-effective motivations for functioning ecosystems were presented during this study, other economic benefits remain a central part of policy and decision-making (Fisher et al., 2008). The capacity for the Iberian Ibex to save landscape human-management costs was demonstrated, but ecological shifts from the Iberian Ibex presence in landscapes that leads to the enhancement of environmental and economic benefits remain unexplored. Although monetary valuation and quantification of these impacts on landscapes are difficult to obtain, it is a worthful exercise to explore the Iberian Ibex potential to provide ecosystem services (ES) and help guide future policy proposals.

Several impacts are assessed, considering in a scale of dozens or hundreds individuals forming established populations that can demonstrate considerable effects for landscape restoration and resilience, mainly on mountain ranges, steep slopes areas or even sooth hills in an Atlantic-Mediterranean climate.

The following sub-chapters account the potential impacts of the Iberian Ibex in landscapes, in the form of ecosystem services, vital to ecosystem functionality and human well-being (Stafford et al., 2017). These effects are not directly reported to the Iberian Ibex given the limited literature on this matter, but based on well-stated effects of other large herbivores, mainly mixed feeders like wild goats (Celaya et al., 2022; Rewilding Europe, 2021a; Rouet-Leduc et al., 2021; Silva et al., 2019; Velamazán et al., 2020).

Lastly, some examples on economic valuation of landscape restoration through ecosystem services is presented and a final consideration on monetary valuation of ecosystem services is taken.

6.1. Biodiversity and Habitat Provision

Herbivory as an essential part of most wood-grass-shrublands, creating vegetation structures with significant heterogeneity. The effects of grazing, browsing, excrements and seed dispersal disturbs landscapes and enriches complex biotic communities, boosting biodiversity. The presence of the Iberian Ibex can benefit a wide range of species: other herbivores, mammal carnivores, birds, amphibians and insects (Rewilding Europe, 2021a; Silva et al., 2019; Hui Zhu et al., 2012). On the contrary, human methods like ploughing and mowing have proven to lead to plant homogeneity and present threats to insects like pollinators (Rewilding Europe, 2021b).

6.2. Carbon and Water storage

Extensive grazing can promote carbon storage up to 2 tons of CO_2 per hectare per year in soil and grass by the transformation of vegetation in degradable dung that after leads to the absorption of carbon to the soil by dung beetles. If some predominance of shrubs and trees is maintained and depending on the Iberian Ibex population density, the carbon storage capacity can even reach to more than 5 tons of CO_2 per hectare per year (Lecomte et al., 2019; Rewilding Europe, 2021a; Silva et al., 2019).

Through many herbivory interactions, like those described on chapter 5 – section 5.3, a great vegetation cover tends to store better levels of aboveground water by the diversity of vegetation created with the herbivores disturbances (Rewilding Europe, 2021a). By feeding on grass but also on shrubs and trees, the Iberian Ibex can provide an equilibrium where water retention on soil and plants is significantly improved, being even more important in rocky habitats where water soil and plant scarcity can be a reality and less herbivores have the ability to provide this service (Irob et al., 2022; Tokumoto et al., 2014).

6.3. Soil protection and Floodplain management

With forest fires being more severe and frequent in Portuguese landscapes, the loss of vegetation cover and herbivores has been leading to another problem, the soil erosion. This reality is even more present in mountains with steep slopes. Because this is the preferable type of habitat for the Iberian Ibex, this species can bust plant heterogeneity and more land cover on this area, protecting the soil (Bencatel J. et al., 2019; Papachristou et al., 2005; Rewilding Europe, 2021a).

Floodplains have been affected with climate change and the risk of floods has been increasing, creating socioeconomic problems (Milly et al., 2002). If this areas have proximity to habitats where an Iberian Ibex population can develop itself, may be an attractive option by the possibility of this animal species to graze on that area and optimise water-flow capacity, minimizing the effects of floods (Cornelissen, 2017; Rewilding Europe, 2021a).

6.4. Mitigation of forest fires and Climate migration

Has stated before, land abandonment in Portugal has led to many areas transforming in closed shrublands with young inflammable trees and homogeneous vegetation. Such situation increases the risk, severity and frequency of wildfires, which has been creating socioeconomic problems beyond the dysfunctionality of these landscapes. The Iberian Ibex can help create mosaic landscapes with natural corridors between more and less vegetation dense areas and bring plant heterogeneity back. This way, natural fire breaks have a place to occur in a controlled way, as part of the natural cycle of these ecosystems. Overalls, the carbon emissions would be reduced and it could be a contribute to climate change mitigation (Bond & Keeley, 2005; Celaya et al., 2022; Lecomte et al., 2019; Rewilding Europe, 2021a; Rouet-Leduc et al., 2021; Silva et al., 2019).

One of the main effects already felt in European landscapes due to climate change is the shift in climate zones to the North, with a pace of 4 kilometres per year. This creates problems for many animal species that now have a higher necessity for migration to encounter suitable habitats from season to season. The Iberian Ibex can tackle this climate change issue, by contributing to the establishment of more open and more closed vegetation zones that creates the mosaic landscapes. This type of landscape can deliver microhabitats that facilitate species migration, which can also be seen as a biodiversity contribute (Fricke et al., 2022; Rewilding Europe, 2021a, 2021b).

6.5. Recreational Benefits

In a country like Portugal where land abandonment is accentuated, bringing back large herbivores can be used as a cultural landscape, given the fact that the presence of this animals is still somewhat present in people's minds. This way, ecotourism can be an economic benefit for local communities and more aesthetic landscapes will attract visitors (Celaya et al., 2022; Rewilding Europe, 2021a). The Iberian Ibex has been described as a symbolic flagship species (Perea et al., 2015; Torres et al., 2017), which means the species has higher value for society and even suggest a possible emotional identification (Molina et al., 2019). By this, it is possible to assume a certain society's willingness to pay for the reintroduction programs to be successful or ecotourism initiatives to be profitable and create nature-based solutions for the economy. Eco-services like ecotourism can be a good way to not rely on hunting as an income given the fact its popularity among younger generations has been decreasing and sometimes is not well accepted for the case of iconic species like the Iberian Ibex, as well as culling (Carvalho et al., 2018; Martínez-Jauregui & Soliño, 2021). For the case in Portugal, being this animal considered as a protected species, this argument is even more strong.

In order to create sustainable societies, basing rural livelihoods on eco-services that benefit local products and organizations in a way of retaining natural capital and developing the path for a sustainable development (Cheung, 2012; Reed et al., 2015).

No studies have been published, regarding a monetary valuation of the benefits in ecosystem services the Iberian Ibex can provide by their presence in landscapes. Nevertheless, some examples can be given to elucidate on the importance of landscape restoration. One reality very present in landscapes devoid of disturbances is bush encroachment and invasive species development. A study conducted in South Africa and Namibia estimated that after management of this situation and with grazing animals present, an enhancement on various ecosystem services was valued in 8.7 billion US dollars and 5.8 billion US dollars, respectively, which shows that an effective landscape management will deliver ecosystem services benefits and outweigh the costs (Stafford et al., 2017). Other study focused on carbon services valuation through the conservation of wild animals, namely African elephants, and as estimated a monetary value of 20.8 and 25.9 billion dollars in the next 10 to 30 years for carbon capture services provided by this animal and forest regeneration. Poaching of these animals could lead to economic losses of around 2 to 7 billion dollars, showing the economic and environmental benefits of landscape restoration and biodiversity (Berzaghi et al., 2022).

The constant need for monetary valuation of nature in order to incentivize sustainable livelihoods has been failing, and difficulties in assessing economic value for every possible ecosystem service has also been described. To a successful wide-range landscape restoration, new mechanisms that benefit equally the entire society while acting on the root causes of ecosystem degradation need to implemented. Along with this line of thinking, the considerations around ecosystem services need to transcend monetary valuation for being fairly valued by the societies (Reed et al., 2015).

7. Discussion

This decade is marked in the UN as the "Decade on Ecosystem Restoration" (UNEP, 2019), and the "Biodiversity strategy for 2030" of the UE defines one of its pillars for ecosystem restoration (European Commission, 2020). On a plan to be an example of active effort for protection and restoration of nature, legislative instruments will be implemented soon, such as a reinforcement on EU Birds and Habitats Directives, and a new binding law with clear goals (and recommendations from the Society for Ecological Restoration) for ecological restoration, that also establishes the "ecological restoration principle", a big step in EU Environmental legislation (Conselho Europeu & Conselho da União Europeia, 2022; Society for Ecological Restoration, 2021). The New Restoration Law proposal by the European Commission states that investment in ecosystem restoration is economically beneficial, having the capacity to generate 8 to 38 euros for every euro spent by enhancing ecosystem services that help create resilience and mitigate climate change, at the same time it improves human health and safety (European Commission, 2022).

The Portuguese Republic was found guilty by the European Court of Justice for not preserving ecosystems and biodiversity according to the objectives and rules of the Habitat Directive (*«Incumprimento de Estado — Ambiente — Diretiva 92/43/CEE — Fauna e flora selvagens — Preservação dos habitats naturais bem como da fauna e da flora selvagens — Artigo 4.°, n.° 4 — Anexos I e II — Sítios de importância comunitária — Não designação — Zonas especiais de conservação — Medidas necessárias — Não adoção»*, 2019), reflecting the lack of proactivity and investment on this subject. The reintroduction of the Iberian Ibex makes even more sense in this scenario, acting as an example of hope for the comeback of keystone species that disappeared from parts of the Portuguese territory hundreds of years ago.

This study and specifically the economic analysis, despite being simple, helps to demonstrate the ecosystem dynamics that the Iberian Ibex as the potential to partially rehabilitate: serving as prey for the golden eagle, mitigating Iberian wolf conflicts with livestock owners by also serving as prey, having a generalist diet which can help control invasive vegetation, enhances to plant migration and plant heterogeneity by seed dispersal, contributes to carbon fixation through nutrient cycling from grazing/browsing and urine/faeces, and also enriches soil bacterial populations which in turn rises nitrogen transformation, making this essential chemical element more bioavailable for plants, allowing them to grow successfully (Danell et al., 2006; García-González et al., 2020). It also has the relevant feature of having a great bioclimatic plasticity, with populations growing and expanding in Southern and Central Spain and in the Mountains of the Pyrenees (Acevedo & Real, 2011; Granados et al., 2020; *Le Retourn du Bouquetin dans les Pyrénées*, 2022).

An unsatisfactory amount of money is allocated to nature restoration and conservation, so the projects related to this matter need to have a great cost-benefit, making the restoration of Iberian Ibex's populations in Portugal a good option. Rewilding can play a leading role in establishing long-term viable ecosystems. Human actions can only substitute biodiversity functions and control the problems of degraded ecosystems in short-term, but cannot be the solution for ending ecosystem degradation problems on the long term (Jepson & Blythe, 2020; Sylven et al., 2010).

The fact this animal species can provide a significant upgrade on landscape restoration, other large herbivores, carnivores or even omnivore species (including the ones that habited Europe in the past) will be needed to fully restore these ecosystems (Trouwborst, 2021). Like other species, the Iberian Ibex was extinguished by human causes during historical times (e.g., hunting, pollution, intensive and excessive use of land for agriculture) (Sandom et al., 2014), with rock engravings being a prove of its past presence and representing a symbol of respect, cohabitating gracefully with the pre-historic Men (Aguiar & Pinto, 2007; Baptista & Reis, 2008). Now, there is a moral argument to bring back these animals back to Europe, including the Iberian Ibex, and not continuing to leave the efforts and pressures just on the conservation of wild animals in the Global South (Benítez-López et al., 2017; Trouwborst & Svenning, 2022).

Other current factor that we must consider on this discussion, is climate change. This phenomenon is increasingly visible, so the ecosystems need to be at their fully resilience state in order to be capable of adapting to the effects already impossible to impede, and this requires giving back the fauna that triggers natural cycles and promotes vegetation resilience, like many mammals and birds, where the Iberian Ibex is included (Fricke et al., 2022). The predictable scenarios of climate change show a decrease in an already scarce wildlife, with temperature shifts that can significantly change the ecosystems in which each species is adapted (Dalrymple, 2021). This situation has been putting pressure on conservationists to change their conventional approach of just maintaining ecosystems and just effectuate reintroduction of species that where present on the sites in question in the past, but to act according to the climate crisis where the time for reversibility is limited (Brodie et al., 2021). Help to move species for better suitable habitats given the changes on ecosystems provoked by climate change (known as assisted migration/colonization) and being more proactive on species reintroductions for ecosystem functioning, presents a smaller risk of losing species than keeping a usual conservation approach, along with better chances for human safety health (Brodie et al., 2021; Gilbert, 2022; McLachlan et al., 2007). By helping to create mosaic landscapes, the Iberian Ibex will enhance the capacity for carbon storage. Also, with a more permeable habitat, species will have the possibilities to move between closed or opened areas as climate zones change, being beneficial for the overall fauna (Fricke et al., 2022; Rewilding Europe, 2021b).

This animal species can be the beginning of a revitalization process of our landscapes to return to being functional. Local development can be provided by redirecting rural economies for tourism economy and developing nature-based solutions (Rewilding Europe, 2020a).

The shifting baseline syndrome (SBS) poses as an obstacle for the society to establish a relation with wildlife. A wide variety and abundance of species was mostly reduced after pre-historic times. The younger generations take the "normal state of nature" as what was described by the generation before, but a problem imposes when the generation alive today already did not lived in a close relation to nature, which turns it difficult to perceive a life with wild animals around (Jepson & Blythe, 2020). Nonetheless, these are the species that mostly contribute to the functioning of our ecosystems and their balance, which have been damaged for long, especially in Europe (Hobbs, 2006; Pereira & Navarro, 2015; Trouwborst & Svenning, 2022). Social movements and public opinions have been rising about the ethic and morality of care towards nature, pressuring environmental policy to be more representative (O' Neill, 2022). These questions need to be raised when advocating for biodiversity law and policy, in order to design legal frameworks that allow nature and humans to thrive in harmony. To restore the diversity and abundance of life in Europe, legal obligations need to be implemented on EU governments to amplify wildlife space and their connectivity, as well as taking down legal obstacles to its restoration, like excessive welfare requirements on animal species that fell under the umbrella of domestic animals (e.g., horses and cattle) and the cleaning of carcasses that drastically reduces food availability for scavengers like vultures and carnivores that also feed on carrion (e.g., the Iberian Wolf), a valuable group for food webs (Beekers et al., 2017; Lagos & Bárcena, 2015; Margalida et al., 2010; Trouwborst, 2021; Trouwborst & Svenning, 2022).

8. Conclusion

This study intended to investigate which approach could offer more economic and environmental benefits: an active human management through the forest sappers landscape management program or a passive management in form of rewilding with the reintroduction of a mammal herbivore – the Iberian Ibex (*Capra pyrenaica*). As part of the analysis, was important to evaluate if the scenario in Portugal was suitable to the return of this animal species, as well as potential landscape effects the Iberian Ibex could trigger by its presence in landscapes, considering the improve on ecological status of those habitats.

A key outcome is that the Iberian Ibex can be a cost-effective instrument for landscape restoration, (replacing several human interventions) particularly on the areas affected by landscape abandonment, even when taking into account the possible reintroduction and management costs for the species comeback. Plus, the conditions of its development in the Portuguese territory are primed, given its habitat and feeding necessities plus their suitability for returning to many mountain ranges and benefit trophic cascades. Also, given large herbivores and other ungulates impacts on climate similar landscapes, it is expected that the Iberian Ibex can have the potential to deliver ecosystem services such as water and carbon storage, wildfire prevention, climate mitigation, soil and floodplain protection, and creating opportunities for ecotourism that boost rural economies. By this analysis, it is safe to state that a passive rewilding landscape management centred on the Iberian Ibex reintroduction makes more sense from an economic and ecological view, while promoting a new approach for local communities to thrive. It saves significant costs on active landscape restoration interventions while providing a extensive range of ecosystem services and improves habitat fitness for biodiversity enrichment.

Along the process, it was noticeable the lack of studies around the ecosystem dynamics of this species and possible management methods for their development and expansion in the Portuguese territory, which makes this study a valuable addition in this field.

It is important to understand that this propose can be used for several areas of the Portuguese territory, which makes this study more viable, relevant and flexible to take into consideration for future policy proposals.

Environmental funds can be used in order to prioritize this kind of species reintroductions and biodiversity enhancement, giving more resilience and adaptative ecosystems to adversities like climate change, which will be more economically and socially benefiting on the long-term.

In the current planetary situation we live in, this study helps to expand the line of thinking of going beyond specific conservation of species but choosing a more holistic perspective where the central is to restore missing ecological roles and ecosystem functions. The Iberian Ibex has been proven capable of fulfilling a part of the missing ecosystem dynamics and be the beginning of a rehabilitation process of rocky ecosystems, as well as helping to spread the rewilding approach in Portugal, creating a more resilient future with wildlife where the harmony prevails.

Investment in ecosystem restoration is a measure for all, us and the animals. More economical and political agencies recognize that humans depend on functional ecosystems to have a thriving future.

This study presents some limitations: to predict all the possible benefits and damages the Iberian Ibex can create is necessary an in-depth analysis with precise suitability models, which goes beyond the scope of this work. Economic and ecological factors were considered and evaluated, but it is still necessary to check on political and local contexts to accept a reintroduction of a species to habitats that are now very different from the reality and cultural context it used to live in. Besides, the literature for the Iberian Ibex is limited and reported ecosystem dynamics of similar animals (e.g., wild goats and sheep) or others with similar behaviours in the ecosystem (e.g., horses and cattle) where used as a proxy for the Iberian Ibex case, which can compromise some of the predicted landscape effects and ecological dynamics. The nature of this work is exploratory, but even so, the study presents pioneering likely results with insights on economic and environmental potential of the Iberian Ibex in landscape management and restoration, at the same time it builds a strong case for a possible return of the species to the Portuguese territory.

Given the urgency on ecosystem restoration, more of this studies should already be developed, yet it is still not a reality in Portugal. Moreover, environmental economics are still very attached to the terms of "preservation" or "conservation", disconnected from the present reality where we now need to act for the restoration of biodiversity and ecosystems.

Other questions remain unanswered, which could be suggested as future research: only one area has been identified as suitable for the Iberian Ibex to be reintroduced in the Portuguese territory, so a first step would be to detect more areas in Portugal, through habitat suitability models. Iberian Ibex specific dynamics on rocky ecosystems would bring more consistency and certainty when assessing its impacts on landscapes and capacity to prevent forest fires. Further research might be focused on complementing missing ecological roles that are also necessary to restore our ecosystems, evaluating other circumstances where a passive management approach via a rewilding concept would make sense. As an example, the Barbary macaque *Macaca sylvanus* could be reintroduced to coniferous forests and mountain areas around Portugal, saving costs in planting vegetation and very much contributing to seed dispersal by its fructiferous diet. The Hermann's Mediterranean Tortoise *Testudo hermanni* could be another reintroduced species to similar habitat areas as the Iberian Ibex and contribute to trophic chains, which could allow the viability of other mammals (e.g., wild boar) and birds, complementing the circle of life – an essential piece for the ecosystems to function. Assisted colonization (moving species to new habitats and expand their range, due to temperature shifting from climate change) needs to be considered in the current climate crisis, with less risks than just maintaining the conventional approach of conservation, being a plausible solution for climate-driven wildlife damages.

The findings of this study also address changes in policy and decision-making. The reintroduction of the Iberian Ibex should be taken seriously for its potential in saving landscape restoration costs, preventing the occurrence of the now so present wildfires, creating resilient landscapes that could tackle climate change and contribute to biodiversity, so it could be a tool for future landscape management programs in Portugal. Passive management approaches, like rewilding, need to be more addressed and consider a valid conservation method. Discussions on the EU have been arising, considering the potential and importance of restoring ecosystems to reverse biodiversity loss, and transform nature to better mitigate and adapt to climate change. The savings in ecosystems management interventions plus the benefits in ecosystem services and prevention of environmental disasters that produce social damages, tend to be more substantial than the costs of reintroducing species and managing possible conflicts with humans. The necessity of changing the narrative is imperative to create a future for all. We have in our hands the tools to deliver a future where nature and our species thrive, we just need to choose to invest in it.

9. Bibliography

Acevedo, J., Arnal, P., Luco, M., Sourp, J., Herrero, J., Acevedo, P., Arnal, M., Luco, D., García-González, R., Perez, J. M., Sourpe, E., & Fonseca, C. (2021). Capra pyrenaica, Iberian Wild Goat 2021 IUCN.

Acevedo, P., & Cassinello, J. (2009a). Biology, ecology and status of Iberian ibex Capra pyrenaica: a critical review and research prospectus. *Mammal Review*, *39*(1), 17-32. https://doi.org/10.1111/j.1365-2907.2008.00138.x

Acevedo, P., & Cassinello, J. (2009b). Human-induced range expansion of wild ungulates causes niche overlap between previously allopatric species: red deer and Iberian ibex in mountainous regions of southern Spain. *Annales Zoologici Fennici*, *46*(1), 39-50. https://doi.org/10.5735/086.046.0105

Acevedo, P., Farfán, M. Á., Márquez, A. L., Delibes-Mateos, M., Real, R., & Vargas, J. M. (2011). Past, present and future of wild ungulates in relation to changes in land use. *Landscape Ecology*, *26*(1), 19-31. https://doi.org/10.1007/s10980-010-9538-2

Acevedo, P., & Real, R. (2011). Biogeographical differences between the two Capra pyrenaica subspecies, C. p. victoriae and C. p. hispanica, inhabiting the Iberian Peninsula: Implications for conservation. *Ecological Modelling*, *222*(3), 814-823. https://doi.org/https://doi.org/10.1016/j.ecolmodel.2010.10.006

Adams, W. M., Hodge, I. D., & Sandbrook, L. (2014). New spaces for nature: the re-territorialisation of biodiversity conservation under neoliberalism in the UK. *Transactions of the Institute of British Geographers*, *39*(4), 574-588. https://doi.org/https://doi.org/10.1111/tran.12050

AGIF. (2022). *Plano Nacional de Gestão Integrada de Fogos Rurais 20-30 (PNGIFR)*. Retrieved February 2, 2022 from https://www.agif.pt/pt/plano-nacional-de-gestao-integrada-de-fogos-rurais-20-30

Aguiar, C., & Pinto, B. (2007). Paleo-história e história antiga das florestas de Portugal continental: até à Idade Média. *Árvores e florestas de Portugal: floresta e sociedade, uma história comum*, 15-53.

Alados, C. L., & Escós, J. (2017). Cabra montés–Capra pyrenaica Schinz, 1838. In A. Salvador & I. Barja (Eds.), *Enciclopedia Virtual de los Vertebrados Españoles*. Museo Nacional de Ciencias Naturales. https://doi.org/https://doi.org/10.20350%2FdigitalCSIC%2F8695

Álvares, F., Barroso, I., Espírito-Santo, C., Ferrão da Costa, G., Fonseca, C., Godinho, R., Nakamura, M., Petrucci-Fonseca, F., Pimenta, V., Ribeiro, S., Rio-Maior, H., Santos, N., & Torres, R. (2015). *Situação de referência para o Plano de Ação para a Conservação do Lobo-ibérico em Portugal*. https://www.icnf.pt/api/file/doc/2417caa934cbd53f

Aronson, J. C., Blatt, C. M., & Aronson, T. B. (2016). Restoring ecosystem health to improve human health and well-being: Physicians and restoration ecologists unite in a common cause. *Ecology and Society*, *21*(4), Article 39. https://doi.org/10.5751/ES-08974-210439

Bakker, E. S., & Svenning, J. C. (2018). Trophic rewilding: impact on ecosystems under global change. *Philosophical Transactions of the Royal Society B-Biological Sciences*, *373*(1761), Article 20170432. https://doi.org/10.1098/rstb.2017.0432

Baptista, A. M., & Reis, M. (2008). *Prospecção da Arte Rupestre na Foz do Côa. Da iconografia do Paleolítico superior à do nosso tempo, com passagem pela IIª Idade do Ferro* Actas do III Congresso de Arqueologia de Trás-os-Montes, Alto Douro e Beira Interior, Vila Nova de Foz Côa, Portugal. https://comum.rcaap.pt/bitstream/10400.26/23285/1/Baptista%26Reis2008a.pdf

Baraza, E., Zamora, R., Hódar, J. A., & Gómez, J. M. (2007). Plant–herbivore interaction: beyond a binary vision. In *Functional plant ecology* (pp. 481-514). CRC Press.

Baruzzi, C., & Krofel, M. (2017). Friends or foes? Importance of wild ungulates as ecosystem engineers for amphibian communities. *North-Western Journal of Zoology*, *13*, 320-325.

Batáry, P., Dicks, L. V., Kleijn, D., & Sutherland, W. J. (2015). The role of agri-environment schemes in conservation and environmental management [Article]. *Conservation Biology*, *29*(4), 1006-1016. https://doi.org/10.1111/cobi.12536

Beekers, B., Meertens, H., Reiniers, K., Helmer, W., Colijn, E., Krawczynski, R., & Meissner, R. (2017). *Circle of Life - A new way to support Europe's scavengers*. Rewilding Europe,
ARK Nature,. https://doi.org/10.26763/2017.01

Begon, M., & Townsend, C. R. (2021). *Ecology: from individuals to ecosystems* (5th ed.). John Wiley & Sons.

Bencatel J., Sabino-Marques H., Álvares F., Moura A.E., & A.M., B. (2019). *Atlas de Mamíferos de Portugal* (2ª edição ed.). Universidade de Évora. https://atlasmamiferosportugal.wordpress.com/

Benítez-López, A., Alkemade, R., Schipper, A. M., Ingram, D. J., Verweij, P. A., Eikelboom, J. A. J., & Huijbregts, M. A. J. (2017). The impact of hunting on tropical mammal and bird populations [Article]. *Science*, *356*(6334), 180-183. https://doi.org/10.1126/science.aaj1891

Berzaghi, F., Chami, R., Cosimano, T., & Fullenkamp, C. (2022). Financing conservation by valuing carbon services produced by wild animals. *Proceedings of the National Academy of Sciences*, *119*(22), e2120426119. https://doi.org/doi:10.1073/pnas.2120426119

Birkhofer, K., Diehl, E., Andersson, J., Ekroos, J., Fruh-Muller, A., Machnikowski, F., Mader, V. L., Nilsson, L., Sasaki, K., Rundlof, M., Wolters, V., & Smith, H. G. (2015). Ecosystem services-current challenges and opportunities for ecological research. *Frontiers in Ecology and Evolution*, *2*, Article 87. https://doi.org/10.3389/fevo.2014.00087

Blahna, D. J., Asah, S. T., & Deal, R. L. (2017). An Ecosystem Services Framework. In D. H. Olson & B. Van Horne (Eds.), *People, Forests, and Change: Lessons from the Pacific Northwest* (pp. 62-75). Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-768-1_5

Bond, W. (1994). Keystone species. In *Biodiversity and ecosystem function* (pp. 237-253). Springer.

Bond, W. J., & Keeley, J. E. (2005). Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends in Ecology & Evolution*, *20*(7), 387-394. https://doi.org/10.1016/j.tree.2005.04.025

Bonnieux, F., & Le Goff, P. (1997). Valuing the Benefits of Landscape Restoration: a Case Study of the Cotentin in Lower-Normandy, France. *Journal of Environmental Management*, *50*(3), 321-333. https://doi.org/https://doi.org/10.1006/jema.1997.0127

Brodie, J. F., Lieberman, S., Moehrenschlager, A., Redford, K. H., Rodríguez, J. P., Schwartz, M., Seddon, P. J., & Watson, J. E. M. (2021). Global policy for assisted colonization of species. *Science*, *372*(6541), 456-458. https://doi.org/doi:10.1126/science.abg0532

Brown, C., McMorran, R., & Price, M. F. (2011). Rewilding - A New Paradigm for Nature Conservation in Scotland? *Scottish Geographical Journal*, *127*(4), 288-314. https://doi.org/10.1080/14702541.2012.666261

Burton, A. (2011). Where the wisents roam. *Frontiers in Ecology and the Environment*, *9*(2), 140-140. https://doi.org/10.1890/1540-9295-9.2.140

Cabral, M. J., Almeida, J., Almeida, P. R., Dellinger, T., Ferrand de Almeida, N., Oliveira, M., Palmeirim, J., Queirós, A., Rogado, L., & Santos-Reis, M. (2005). *Livro vermelho dos vertebrados de Portugal*. Instituto da Conservação da Natureza. https://www.icnf.pt/api/file/doc/b7637d557573f522

Campbell-Palmer, R., Gow, D., Campbell, R., Dickinson, H., Girling, S., Gurnell, J., Halley, D., Jones, S., Lisle, S., Parker, H., Schwab, G., & Rosell, F. (2016). *The Eurasian Beaver Handbook: Ecology and Management of Castor fiber*. Pelagic Publishing Ltd.

CAOF. (2015/2016a). *Matriz de (Re)Arborização*. https://www.dgadr.gov.pt/images/docs/CAOF/matriz_Re_Arborizacao_2015_2016.pdf

CAOF. (2015/2016b). *Matriz de Beneficiação*. https://www.dgadr.gov.pt/images/docs/CAOF/matriz_beneficiacao_2015_2016.pdf

Cardoso, J. L. (2006). The mousterian complex in portugal. *Zephyrus*, *59*, 21-50. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84863939005&partnerID=40&md5=0caa9215e546d0bfbe77a9890293a486

Carvalho, J., Fandos, P., Festa-Bianchet, M., Büntgen, U., Fonseca, C., & Serrano, E. (2018). Sustainable trophy hunting of Iberian ibex. *Galemys*, *30*, 1-4.

Carvalho, J. L. O. (2019). *The role of environmental variation, size-selective harvesting and diseases on the life-history traits of Iberian ibex* [Doctoral dissertation, Universidade de Aveiro]. https://ria.ua.pt/bitstream/10773/29243/1/2019%20Carvalho%20PhD.pdf

CBD Secretariat and Society for Ecological Restoration. (2019). *A companion to the Short-Term Action Plan on Ecosystem Restoration - Resources, cases studies, and biodiversity considerations in the context of restoration science and practice*. https://cdn.ymaws.com/www.ser.org/resource/resmgr/custompages/publications/ser_publications/staper_companion.pdf

Ceauşu, S., Hofmann, M., Navarro, L. M., Carver, S., Verburg, P. H., & Pereira, H. M. (2015). Mapping opportunities and challenges for rewilding in Europe. *Conservation Biology*, *29*(4), 1017-1027. https://doi.org/https://doi.org/10.1111/cobi.12533

Celaya, R., Ferreira, L. M. M., Lorenzo, J. M., Echegaray, N., Crecente, S., Serrano, E., & Busqué, J. (2022). Livestock Management for the Delivery of Ecosystem Services in Fire-Prone Shrublands of Atlantic Iberia. *Sustainability*, *14*(5), 2775. https://www.mdpi.com/2071-1050/14/5/2775

Cheung, H. (2012). Tourism in Kenya's national parks: A cost-benefit analysis. *SURG Journal*, *6*(1), 31-40.

Chirichella, R., Apollonio, M., & Putman, R. (2014). Competition between domestic and wild ungulates. *Behaviour and Management of European Ungulates Caithness: Whittles Publishing*, 110-123.

Communities, T. C. o. t. E. (1992). *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora*. Official Journal of the European Communities

Conselho Europeu, & Conselho da União Europeia. (2022). *Biodiversidade: proteção da natureza pela UE*. Retrieved June 13, 2022 from https://www.consilium.europa.eu/pt/policies/biodiversity/

Convention on Biological Diversity [CBD]. (2019). *Decision XIII/5, Ecosystem Restoration: Short-Term Action Plan*. https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-05-en.pdf

Cornelissen, P. (2017). *Large herbivores as a driving force of woodland-grassland cycles: the mutual interactions between the population dynamics of large herbivores and vegetation development in a eutrophic wetland* [Doctoral dissertation, Wageningen University]. Wageningen, NL.

Costanza, R., dArge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., Oneill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., & vandenBelt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253-260. https://doi.org/10.1038/387253a0

Cuartas, P., & Garcia-Gonzalez, R. (1992). Quercus ilex browse utilization by wild and domestic ungulates in Cazorla Sierra. *Vegetatio*, *99*, 317-330.

Dalrymple, S. E. (2021, July 16). Why climate change is forcing conservationists to be more ambitious: by moving threatened species to pastures new. *The Conversation*.

https://theconversation.com/why-climate-change-is-forcing-conservationists-to-be-more-ambitious-by-moving-threatened-species-to-pastures-new-163749

Danell, K., Bergström, R., Duncan, P., & Pastor, J. (2006). *Large Herbivore Ecology, Ecosystem Dynamics and Conservation*. Cambridge University Press. https://doi.org/10.1017/CBO9780511617461

Decreto-Lei nº 140/99. (1999). *Revê a transposição para a ordem jurídica interna da Directiva n.º 79/409/CEE, do Conselho, de 2 de Abril (relativa à conservação das aves selvagens), e da Directiva n.º 92/43/CEE, do Conselho, de 21 de Maio (relativa à preservação dos habitats naturais e da fauna e da flora selvagens)*. Diário da República: Série I-A, nº 96 Retrieved from https://dre.pt/dre/legislacao-consolidada/decreto-lei/1999-34527675-114606114

Decreto Lei nº 44/2020. (2020). *Altera o regime jurídico aplicável aos sapadores florestais, às equipas e às brigadas de sapadores florestais no território continental*. Diário da República: Série I, nº 141 Retrieved from https://files.dre.pt/1s/2020/07/14100/0000400023.pdf

Despacho n.º 9727/2017. (2017). *Plano de Ação para a Conservação do Lobo-Ibérico (Canis lupus signatus) em Portugal*. Diário da República: Série II, nº 215 Retrieved from https://files.dre.pt/2s/2017/11/215000000/2513225149.pdf

Earle, J., Moran, C., & Ward-Perkins, Z. (2016). *The econocracy: The perils of leaving economics to the experts*. Manchester University Press. https://doi.org/10.7765/9781526115492

Ellen MacArthur Foundation. (2022). *What is circular economy?* Retrieved February 1, 2022 from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Escós, J., & Alados, C. L. (1992a). Habitat preference of Spanish ibex and other ungulates in Sierras de Cazorla y Segura (Spain). *56*(3), 393-406. https://doi.org/doi:10.1515/mamm.1992.56.3.393

Escós, J., & Alados, C. L. (1992b). The home-range of the Spanish ibex in spring and fall. *56*(1), 57-64. https://doi.org/doi:10.1515/mamm.1992.56.1.57

Escós, J. M., Alados, C. L., Pulido, A., Romera, J., González-Sánchez, N., & Martínez, F. (2008). Estimating population trends using population viability analyses for the conservation of Capra pyrenaica. *Acta Theriologica*, *53*(3), 275-286. https://doi.org/10.1007/BF03193124

European Commission. (2016). *Fitness Check of the EU Nature Legislation (Birds and Habitats Directives)*. Brussels Retrieved from https://ec.europa.eu/environment/nature/legislation/fitness_check/docs/nature_fitness_check.pdf

European Commission. (2020). *EU Biodiversity Strategy - Bringing nature back into our lives*. P. O. o. t. E. Union.

European Commission. (2022). *Nature Restoration Law*. Retrieved June 23, 2022 from https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en#documents

European Environmental Agency [EEA]. (2013-2018). *Article 17 web tool - Species assessments at EU biogeographical level*

Fandos, P. (1991). *La cabra montés (Capra pyrenaica) en el Parque Natural de las Sierras de Cazorla, Segura y las Villas* (M. d. A. P. y. Alimentación, Ed.). Serie Técnica ICONA.

Fandos, P. (1995). FACTORS AFFECTING HORN GROWTH IN MALE SPANISH IBEX (CAPRA-PYRENAICA). *Mammalia*, *59*(2), 229-235. https://doi.org/10.1515/mamm.1995.59.2.229

Fandos, P., Orueta, J. F., & Aranda, Y. (1993). Tooth wear and its relation to kind of food: the repercussion on age criteria in Capra pyrenaica. *Acta Theriologica*, *38*(1), 93-102.

Fischer, L., Hasell, J., Proctor, J. C., Uwakwe, D., Perkins, Z. W., & Watson, C. (2017). *Rethinking Economics: An Introduction to Pluralist Economics*. Routledge.

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., de Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D., & Balmford, A. (2008). ECOSYSTEM SERVICES AND ECONOMIC THEORY: INTEGRATION FOR POLICY-RELEVANT RESEARCH. *Ecological Applications*, *18*(8), 2050-2067. https://doi.org/https://doi.org/10.1890/07-1537.1

Fonseca, C., Migueis, D., Fernandes, T., Carvalho, H., Loureiro, A., Carvalho, J., & Torres, R. T. (2017). The return of the Iberian wild goat Capra pyrenaica to Portugal: From reintroduction to recolonization. *Journal for Nature Conservation*, *38*, 56-61. https://doi.org/https://doi.org/10.1016/j.jnc.2017.05.006

Foote, J. (1990). *Newsweek*, 24-25.

Foreman, D. (2003). Around the campfire. *Wild Earth*, *13*(4), 2-3.

Fricke, E. C., Ordonez, A., Rogers, H. S., & Svenning, J.-C. (2022). The effects of defaunation on plants' capacity to track climate change. *Science*, *375*(6577), 210-214. https://doi.org/10.1126/science.abk3510

Gagnon, S. C. T., & Barton, M. A. (1994). Ecocentric and anthropocentric attitudes toward the environment. *Journal of Environmental Psychology*, *14*(2), 149-157. https://doi.org/https://doi.org/10.1016/S0272-4944(05)80168-9

Galetti, M., Gonçalves, F., Villar, N., Zipparro, V. B., Paz, C., Mendes, C., Lautenschlager, L., Souza, Y., Akkawi, P., Pedrosa, F., Bulascoschi, L., Bello, C., Sevá, A. P., Sales, L., Genes, L., Abra, F., & Bovendorp, R. S. (2021). Causes and Consequences of Large-Scale Defaunation in the Atlantic Forest. In M. C. M. Marques & C. E. V. Grelle (Eds.), *The Atlantic Forest: History, Biodiversity, Threats and Opportunities of the Mega-diverse Forest* (pp. 297-324). Springer International Publishing. https://doi.org/10.1007/978-3-030-55322-7_14

García-González, R., Herrero, J., Acevedo, P., Arnal, M. C., & Fernández de Luco, D. (2020). Iberian Wild Goat Capra pyrenaica Schinz, 1838. In K. Hackländer & F. E. Zachos (Eds.), *Handbook of the Mammals of Europe* (pp. 1-23). Springer International Publishing. https://doi.org/10.1007/978-3-319-65038-8_33-2

Garnier, A., Besnard, A., Crampe, J. P., Estèbe, J., Aulagnier, S., & Gonzalez, G. (2021). Intrinsic factors, release conditions and presence of conspecifics affect post-release dispersal after translocation of Iberian ibex. *Animal Conservation*, *24*(4), 626-636. https://doi.org/https://doi.org/10.1111/acv.12669

Gilbert, N. (2022). Climate change will force new animal encounters—and boost viral outbreaks. *Nature*, *605*(7908), 20-20.

Gordon, I. J. (2006). Restoring the functions of grazed ecosystems. In J. Pastor, K. Danell, P. Duncan, & R. Bergström (Eds.), *Large Herbivore Ecology, Ecosystem Dynamics and Conservation* (pp. 449-467). Cambridge University Press. https://doi.org/DOI: 10.1017/CBO9780511617461.017

Granados, J. (2021). *Dataset of Iberian Ibex population in Sierra Nevada (Spain)* Version 1.9). https://doi.org/https://doi.org/10.15470/3ucqfm

Granados, J., Pérez, J., Márquez, F., Serrano, E., Soriguer, R., & Fandos, P. (2001). La cabra montés (Capra pyrenaica, Schinz 1838). *Galemys*, *13*(1), 3-37.

Granados, J. E., Castillo, A., Cano-Manuel, J., Serrano, E., Pérez, J. M., Soriguer, R. C., & Fandos, P. (n.d). Gestión de La Cabra Montés. In *La Gestíon en Ecosistemas Andaluces - Ecosistemas de Montaña* (pp. 452-485). https://www.researchgate.net/profile/Paulino-Fandos/publication/266160427_Gestion_de_la_Cabra_Montes/links/5429415e0cf26120b7b5b0ec/Gestion-de-la-Cabra-Montes.pdf

Granados, J. E., Ros-Candeira, A., Pérez-Luque, A. J., Moreno-Llorca, R., Cano-Manuel, F. J., Fandos, P., Soriguer, R. C., Cerrato, J. E., Jiménez, J. M. P., Ramos, B., & Zamora, R. (2020). Long-term monitoring of the Iberian ibex population in the Sierra Nevada of the southeast Iberian Peninsula. *Scientific Data*, *7*(1), 203. https://doi.org/10.1038/s41597-020-0544-1

Granados Torres, J. E., Cano-Manuel, F.-J., & Fandos, P. (2012). Estado sanitario de las poblaciones de cabra montés y jabalí. In *Observatorio de cambio global Sierra Nevada. Metodologías de seguimiento.* https://www.researchgate.net/profile/Jose-E-Granados-Torres/publication/275968205_Estado_sanitario_de_las_poblaciones_de_cabra_montes_y_jabali/links/5554730008ae6fd2d81f485e/Estado-sanitario-de-las-poblaciones-de-cabra-montes-y-jabali.pdf

Gregr, E. J., Christensen, V., Nichol, L., Martone, R. G., Markel, R. W., Watson, J. C., Harley, C. D. G., Pakhomov, E. A., Shurin, J. B., & Chan, K. M. A. (2020). Cascading social-ecological costs and benefits triggered by a recovering keystone predator. *Science*, *368*(6496), 1243-+. https://doi.org/10.1126/science.aay5342

Haines-Young, R., & Potschin, M. (2018). *Common International Classification of Ecosystem Services (CICES) V5.1*. E. E. Agency. https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf

Herradón, I. U. (2015). *Paleogenética de la cabra montés y el íbice alpino: um estudio microevolutivo* [Doctoral dissertation, Universidad Complutense de Madrid]. Madrid, Spain. https://eprints.ucm.es/id/eprint/34591/1/T36671.pdf

Herrero, J., Acevedo, P., Arnal, M. C., Fernández de Luco, D., Fonseca, C., García-González, R., Pérez, J. M., & Sourp, E. (2021). Capra pyrenaica (amended version of 2020 assessment). *The IUCN*

Red List of Threatened Species 2021. https://doi.org/https://dx.doi.org/10.2305/IUCN.UK.2021-1.RLTS.T3798A195855497.en

Higgs, E., Falk, D. A., Guerrini, A., Hall, M., Harris, J., Hobbs, R. J., Jackson, S. T., Rhemtulla, J. M., & Throop, W. (2014). The changing role of history in restoration ecology. *Frontiers in Ecology and the Environment*, *12*(9), 499-506. https://doi.org/10.1890/110267

Hobbs, N. T. (2006). Large herbivores as sources of disturbance in ecosystems. In J. Pastor, K. Danell, P. Duncan, & R. Bergström (Eds.), *Large Herbivore Ecology, Ecosystem Dynamics and Conservation* (pp. 261-288). Cambridge University Press. https://doi.org/DOI: 10.1017/CBO9780511617461.011

Hobbs, R. J., & Harris, J. A. (2001). Restoration ecology: Repairing the Earth's ecosystems in the new millennium. *Restoration Ecology*, *9*(2), 239-246. https://doi.org/10.1046/j.1526-100x.2001.009002239.x

Houston, D. B., Stevens, V., & Schreiner, E. G. (2007). Habitat Relations, Social Behavior, and Physiological Ecology. In *Mountain Goats in Olympic National Park: Biology and Management of an Introduced Species*. National Park Service. https://www.nps.gov/parkhistory/online_books/science/25/chap6.htm

ICNF. (2016). *Espécies Arbóreas Indígenas em Portugal Continental*. https://www.icnf.pt/api/file/doc/adcdbb835d1a032a

ICNF. (2017a). *Custos de referências para arborização, rearborização, a beneficiação e a exploração florestal de povoamentos florestais*. Retrieved April 4, 2022 from https://www.icnf.pt/florestas/arborizacoes/caof

ICNF. (2017b). *Fundo Florestal Permanente*. Retrieved March 24, 2022 from https://www.icnf.pt/apoios/fundoflorestalpermanente/normativosplanoserelatorios

ICNF. (2019). *Guia Técnico de Cartografia para o Programa de Sapadores Florestais - 2019*. https://www.icnf.pt/api/file/doc/3e9ec7cf2045a127

ICNF/FFP. (2021a). *Plano de Atividades 2021*. https://www.icnf.pt/api/file/doc/41eb65d4bc2057e1

ICNF/FFP. (2021b). *Relatório de Atividades 2021*. https://www.icnf.pt/api/file/doc/53a7fb40b2bfbd0a

«Incumprimento de Estado — Ambiente — Diretiva 92/43/CEE — Fauna e flora selvagens — Preservação dos habitats naturais bem como da fauna e da flora selvagens — Artigo 4.°, n.° 4 — Anexos I e II — Sítios de importância comunitária — Não designação — Zonas especiais de conservação — Medidas necessárias — Não adoção», Tribunal de Justiça da União Europeia (2019). https://curia.europa.eu/juris/document/document.jsf?docid=217500&doclang=PT

IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.*

IPCC. (2019). *An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [Technical report]. https://www.ipcc.ch/srccl/

Irob, K., Blaum, N., Baldauf, S., Kerger, L., Strohbach, B., Kanduvarisa, A., Lohmann, D., & Tietjen, B. (2022). Browsing herbivores improve the state and functioning of savannas: A model assessment of alternative land-use strategies. *Ecology and Evolution*, *12*(3), e8715. https://doi.org/https://doi.org/10.1002/ece3.8715

IUCN/SSC. (2013). *Guidelines for Reintroductions and Other Conservation Translocations* (Version 1.0 ed.). IUCN Species Survival Commission.

Jardim Botânico da UTAD. (2022). *Flora Digital de Portugal* https://jb.utad.pt/

Jepson, P., & Blythe, C. (2020). *Rewilding: The Radical New Science of Ecological Recovery* (Vol. 14). Icon Books.

Johns, D. (2017). Rewilding. In *Encyclopedia of the Anthropocene* (Vol. 1-5, pp. 247-256). https://doi.org/10.1016/B978-0-12-809665-9.09202-8

Johns, D. (2019). History of rewilding: ideas and practice. *Rewilding*, 12-33.

Johnston, R. J. (2018). ecosystem services. In *Encyclopedia Britannica.*

Jones, H. P., Jones, P. C., Barbier, E. B., Blackburn, R. C., Benayas, J. M. R., Holl, K. D., McCrackin, M., Meli, P., Montoya, D., & Mateos, D. M. (2018). Restoration and repair of Earth's damaged ecosystems. *Proceedings of the Royal Society B-Biological Sciences*, *285*(1873), Article 20172577. https://doi.org/10.1098/rspb.2017.2577

Jorgensen, D. (2015). Rethinking rewilding. *Geoforum*, *65*, 482-488. https://doi.org/10.1016/j.geoforum.2014.11.016

Junta de Andalucía. (2022). *Red de Áreas Pasto-Cortafuegos de Andalucía (RAPCA)*. Retrieved April 25, 2022 from https://www.juntadeandalucia.es/medioambiente/portal/web/guest/landing-page-%C3%ADndice/-/asset_publisher/zX2ouZa4r1Rf/content/red-de-c3-a1reas-pasto-cortafuegos-de-andaluc-c3-ada-rapca-/20151?categoryVal=

Klyza, C. M. (2001). *Wilderness comes home: Rewilding the Northeast*. UPNE.

Ladle, R. J., & Whittaker, R. J. (2011). *Conservation Biogeography*. https://doi.org/10.1002/9781444390001

Lagos, L., & Bárcena, F. (2015). EU Sanitary Regulation on Livestock Disposal: Implications for the Diet of Wolves. *Environmental Management*, *56*(4), 890-902. https://doi.org/10.1007/s00267-015-0571-4

Larkin, D. J., Buck, R. J., Fieberg, J., & Galatowitsch, S. M. (2019). Revisiting the benefits of active approaches for restoring damaged ecosystems. A Comment on Jones HP et al. 2018 Restoration and repair of Earth's damaged ecosystems. *Proceedings of the Royal Society B-Biological Sciences*, *286*(1907), Article 20182928. https://doi.org/10.1098/rspb.2018.2928

Le Retourn du Bouquetin dans les Pyrénées. (2022). Retrieved March 17, 2022 from https://www.bouquetin-pyrenees.fr/

Lecomte, X., Caldeira, M. C., Catry, F. X., Fernandes, P. M., Jackson, R. B., & Bugalho, M. N. (2019). Ungulates mediate trade-offs between carbon storage and wildfire hazard in Mediterranean oak woodlands. *Journal of Applied Ecology*, *56*(3), 699-710. https://doi.org/https://doi.org/10.1111/1365-2664.13310

López, D. E. (2019). *Quaternary fossil vertebrates from continental Portugal: Paleobiodiversity, revision of specimens and new localities* [Master's Thesis, Universidade Nova de Lisboa/Universidade de Évora]. Lisboa, Portugal. http://hdl.handle.net/10362/74150

Lovreglio, R., Meddour-Sahar, O., & Leone, V. (2014). Goat grazing as a wildfire prevention tool: a basic review [Goat grazing as a wildfire prevention tool: a basic review] [Technical Notes]. *iForest - Biogeosciences and Forestry*, *7*(4), 260-268. https://doi.org/10.3832/ifor1112-007

Lucas, P. M., Herrero, J., Fernández-Arberas, O., Prada, C., García-Serrano, A., Saiz, H., & Alados, C. L. (2016). Modelling the habitat of a wild ungulate in a semi-arid Mediterranean environment in southwestern Europe: Small cliffs are key predictors of the presence of Iberian wild goat. *Journal of Arid Environments*, *129*, 56-63. https://doi.org/https://doi.org/10.1016/j.jaridenv.2016.02.008

Macdonald, D. W., & Willis, K. J. (2013). *Key Topics in Conservation Biology 2* [Book]. https://doi.org/10.1002/9781118520178

Marchante, H., Morais, M., Freitas, H., & Marchante, E. (2014). *Guia prático para a identificação de plantas invasoras em Portugal*. Imprensa da Universidade de Coimbra/Coimbra University Press.

Margalida, A., Donázar, J. A., Carrete, M., & Sánchez-Zapata, J. A. (2010). Sanitary versus environmental policies: fitting together two pieces of the puzzle of European vulture conservation. *Journal of Applied Ecology*, *47*(4), 931-935. https://doi.org/https://doi.org/10.1111/j.1365-2664.2010.01835.x

Martínez-Jauregui, M., & Soliño, M. (2021). Society's preferences when ecological values and health risks are at stake: An application to the population control of a flagship ungulate (Iberian ibex) in Sierra de Guadarrama national park, Spain. *Science of The Total Environment*, *776*, 146012. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.146012

Martínez, T. (2000). Diet selection by Spanish ibex in early summer in Sierra Nevada. *Acta Theriologica*, *45*(3), 335-346.

Martínez, T. (2009). Role of Various Woody Species in Spanish Mediterranean Forest and Scrubland as Food Resources for Spanish Ibex (Capra pyrenaica Schinz) and Red Deer (Cervus elaphus L.). In A. Rigueiro-Rodróguez, J. McAdam, & M. R. Mosquera-Losada (Eds.), *Agroforestry in Europe: Current Status and Future Prospects* (pp. 233-253). Springer Netherlands. https://doi.org/10.1007/978-1-4020-8272-6_11

Martínez, T. (2010). Selección y estrategia alimentaria de los machos, hembras y jóvenes de cabra montés (Capra pirenaica Schinz, 1838) en el suroeste de España. *Galemys*, *22*, 483-515.

Martínez, T. M. (1993). *Estrategia alimentaria de la cabra montes (Capra pyrenaica) y sus relaciones tróficas con los ungulados silvestres y domésticos en Sierra Nevada, Sierra de Gredos y Sierra de Cazorla* Universidad Complutense de Madrid]. Madrid.

McLachlan, J. S., Hellmann, J. J., & Schwartz, M. W. (2007). A framework for debate of assisted migration in an era of climate change. *Conservation Biology*, *21*(2), 297-302. https://doi.org/10.1111/j.1523-1739.2007.00676.x

Millennium Ecosystem Assessment [MEA]. (2005). *Ecosystems and Human Well-being: Synthesis*. I. Press. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Milly, P. C. D., Wetherald, R. T., Dunne, K. A., & Delworth, T. L. (2002). Increasing risk of great floods in a changing climate. *Nature*, *415*(6871), 514-517. https://doi.org/10.1038/415514a

Moço, G., Guerreiro, M., Ferreira, A. F., Rebelo, A., Loureiro, A., Petrucci-Fonseca, F., & Pérez, J. M. (2006). The ibex Capra pyrenaica returns to its former Portuguese range. *Oryx*, *40*(3), 351-354. https://doi.org/10.1017/S0030605306000718

Moço, G., Serrano, E., Guerreiro, M., Ferreira, A. F., Petrucci-Fonseca, F., Maia, M. J., Soriguer, R. C., & Pérez, J. M. (2013). Seasonal dietary shifts and selection of Iberian wild goat Capra pyrenaica Schinz, 1838 in Peneda-Gerês National Park (Portugal). *Galemys*, *25*, 13-27.

Moço, G., Serrano, E., Guerreiro, M., Ferreira, A. F., Petrucci-Fonseca, F., Santana, D., Maia, M. J., Soriguer, R. C., & Pérez, J. M. (2014). Does livestock influence the diet of Iberian ibex Capra pyrenaica in the Peneda-Gerês National Park (Portugal)? [Article]. *Mammalia*, *78*(3), 393-399. https://doi.org/10.1515/mammalia-2013-0139

Molina, J. R., Zamora, R., & Rodríguez y Silva, F. (2019). The role of flagship species in the economic valuation of wildfire impacts: An application to two Mediterranean protected areas. *Science of The Total Environment*, *675*, 520-530. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.04.242

National Geographic Society [NGS]. (2013, September 13, 2013). *Keystone Species*. National Geographic. Retrieved December 9, 2021 from https://www.nationalgeographic.org/encyclopedia/keystone-species/

Navarro-Gonzalez, N., Porrero, M. C., Mentaberre, G., Serrano, E., Mateos, A., Cabal, A., Domínguez, L., & Lavín, S. (2015). Escherichia coli O157:H7 in wild boars (Sus scrofa) and Iberian ibex (Capra pyrenaica) sharing pastures with free-ranging livestock in a natural environment in Spain. *Veterinary Quarterly*, *35*(2), 102-106. https://doi.org/10.1080/01652176.2015.1023404

O' Neill, S. (2022). To respond to the biodiversity crisis, we need an ethic of care. *The Irish Times*. https://www.irishtimes.com/news/science/to-respond-to-the-biodiversity-crisis-we-need-an-ethic-of-care-1.4876639

Papachristou, T. G., Dziba, L. E., & Provenza, F. D. (2005). Foraging ecology of goats and sheep on wooded rangelands. *Small Ruminant Research*, *59*(2), 141-156. https://doi.org/https://doi.org/10.1016/j.smallrumres.2005.05.003

Pascual-Rico, R., Morales-Reyes, Z., Aguilera-Alcalá, N., Olszańska, A., Sebastián-González, E., Naidoo, R., Moleón, M., Lozano, J., Botella, F., von Wehrden, H., Martín-López, B., & Sánchez-Zapata, J. A. (2021). Usually hated, sometimes loved: A review of wild ungulates' contributions to people. *Science of The Total Environment*, *801*, 149652. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.149652

Pastor, J., Cohen, Y., & Hobbs, N. T. (2006). The roles of large herbivores in ecosystem nutrient cycles. In J. Pastor, K. Danell, P. Duncan, & R. Bergström (Eds.), *Large Herbivore Ecology, Ecosystem Dynamics and Conservation* (pp. 289-325). Cambridge University Press. https://doi.org/10.1017/CBO9780511617461.012

Perea, R., Perea-García-Calvo, R., Díaz-Ambrona, C. G., & San Miguel, A. (2015). The reintroduction of a flagship ungulate Capra pyrenaica: Assessing sustainability by surveying woody vegetation. *Biological Conservation*, *181*, 9-17. https://doi.org/https://doi.org/10.1016/j.biocon.2014.10.018

Pereira, H. M., & Navarro, L. M. (2015). *Rewilding european landscapes*. Springer Nature. https://doi.org/10.1007/978-3-319-12039-3

Pérez, J. M., Granados, J. E., Soriguer, R. C., Fandos, P., Márquez, F. J., & Crampe, J. P. (2002). Distribution, status and conservation problems of the Spanish Ibex, Capra pyrenaica (Mammalia: Artiodactyla)† [https://doi.org/10.1046/j.1365-2907.2002.00097.x]. *Mammal Review*, *32*(1), 26-39. https://doi.org/https://doi.org/10.1046/j.1365-2907.2002.00097.x

Pérez, J. M., Serrano, E., Soriguer, R. C., González, F. J., Sarasa, M., Granados, J. E., Cano-Manuel, F. J., Cuenca, R., & Fandos, P. (2015). Distinguishing disease effects from environmental effects in a mountain ungulate: Seasonal variation in body weight, Hematology, And serum chemistry among Iberian ibex (Capra pyrenaica) affected by sarcoptic mange. *Journal of Wildlife Diseases*, *51*(1), 148-156. https://doi.org/10.7589/2014-01-008

Perino, A., Pereira, H. M., Navarro, L. M., Fernández, N., Bullock, J. M., Ceauşu, S., Cortés-Avizanda, A., Van Klink, R., Kuemmerle, T., Lomba, A., Pe'er, G., Plieninger, T., Benayas, J. M. R., Sandom, C. J., Svenning, J. C., & Wheeler, H. C. (2019). Rewilding complex ecosystems [Review]. *Science*, *364*(6438), Article eaav5570. https://doi.org/10.1126/science.aav5570

Pettorelli, N., Durant, S. M., & du Toit, J. T. (2019). Rewilding: a captivating, controversial, twenty-first-century concept to address ecological degradation in a changing world. In J. T. du Toit, N. Pettorelli, & S. M. Durant (Eds.), *Rewilding* (pp. 1-11). Cambridge University Press. https://doi.org/DOI: 10.1017/9781108560962.001

Préfet De La Région Midi-Pyrénées. (2014). *Plan de restauration du bouquetin (Capra pyrenaica) dans les Pyrénées Françaises 2014-2022.* https://www.pyrenees-pireneus.com/Faune-Pyrenees/Bouquetins/Pyrenees/Introductions-Bouquetins-Pyrenees/2014-03-17-Plan-reintroduction-Capra-pyrenaica-2014-2022.pdf

Prior, J., & Ward, K. J. (2016). Rethinking rewilding: A response to Jorgensen. *Geoforum*, *69*, 132-135. https://doi.org/10.1016/j.geoforum.2015.12.003

Raworth, K. (2017). *Doughnut economics: seven ways to think like a 21st-century economist.* Chelsea Green Publishing.

Reed, M. S., Stringer, L. C., Dougill, A. J., Perkins, J. S., Atlhopheng, J. R., Mulale, K., & Favretto, N. (2015). Reorienting land degradation towards sustainable land management: Linking sustainable livelihoods with ecosystem services in rangeland systems. *Journal of Environmental Management*, *151*, 472-485. https://doi.org/https://doi.org/10.1016/j.jenvman.2014.11.010

Resolução do Concelho de Ministros nº 6-B/2015. (2015). *Aprova a Estratégia Nacional para as Florestas.* Retrieved from https://files.dre.pt/1s/2015/02/02401/0000200092.pdf

Resolução do Concelho de Ministros nº 45-A/2020. (2020). *Aprova o Plano Nacional de Gestão Integrada de Fogos Rurais.* Retrieved from https://www.agif.pt/app/uploads/2021/07/RCM-45A_2020_PNGIFR.pdf

Rewilding Europe. (2020a). Nature-Based Economies: A business case for the wild. https://rewildingeurope.com/rewilding-in-action/nature-based-economies/

Rewilding Europe. (2020b). *Rewilding - the natural way to minimise wildfire risk*. Retrieved December 10, 2021 from https://rewildingeurope.com/blog/rewilding-the-natural-way-to-minimise-wildfire-risk/

Rewilding Europe. (2021a). *GRAZELIFE - Grazing for wildfire prevention, ecosystem services, biodiversity and landscape management.* https://www.rewildingeurope.com/wp-content/uploads/publications/grazelife-practitioners-guide-en/index.html

Rewilding Europe. (2021b). *GRAZELIFE Report - Supporting effective grazing systems for wildfire prevention, biodiversity, climate adaptation and other ecosystem services*. https://www.rewildingeurope.com/wp-content/uploads/publications/grazelife-recommendations/index.html

Rewilding Thematic Group [RTG]. (2021). *Principles of Rewilding.* https://www.iucn.org/sites/dev/files/content/documents/principles_of_rewilding_cem_rtg.pdf

Roldán, J. C. (2012). El paisaje en mosaico del Mediterráneo y su supervivencia: de la ganadería extensiva al papel desempeñado por las especies exóticas. *Lychnos*(9), 48-56.

Rosa García, R., Celaya, R., García, U., & Osoro, K. (2012). Goat grazing, its interactions with other herbivores and biodiversity conservation issues. *Small Ruminant Research*, *107*(2), 49-64. https://doi.org/https://doi.org/10.1016/j.smallrumres.2012.03.021

Rouet-Leduc, J., Pe'er, G., Moreira, F., Bonn, A., Helmer, W., Zadeh, S., Zizka, A., & van der Plas, F. (2021). Effects of large herbivores on fire regimes and wildfire mitigation. *Journal of Applied Ecology*, *58*(12), 2690-2702. https://doi.org/10.1111/1365-2664.13972

Sandom, C. (2018). Forget environmental doom and gloom – young people draw alternative visions of nature's future. *The Conversation.* https://theconversation.com/forget-environmental-doom-and-gloom-young-people-draw-alternative-visions-of-natures-future-102004

Sandom, C., Donlan, C. J., Svenning, J.-C., & Hansen, D. (2013). Rewilding. In *Key Topics in Conservation Biology 2* (pp. 430-451). https://doi.org/https://doi.org/10.1002/9781118520178.ch23

Sandom, C., Faurby, S., Sandel, B., & Svenning, J. C. (2014). Global late Quaternary megafauna extinctions linked to humans, not climate change. *Proceedings of the Royal Society B-Biological Sciences*, *281*(1787), Article 20133254. https://doi.org/10.1098/rspb.2013.3254

Sandom, C. J., Hughes, J., & Macdonald, D. W. (2013). Rooting for Rewilding: Quantifying Wild Boar's Sus scrofa Rooting Rate in the Scottish Highlands. *Restoration Ecology*, *21*(3), 329-335. https://doi.org/10.1111/j.1526-100X.2012.00904.x

Sarasa, M., Pérez, J. M., Alasaad, S., Serrano, E., Soriguer, R. C., Granados, J.-E., Fandos, P., Joachim, J., & Gonzalez, G. (2011). Neatness depends on season, age, and sex in Iberian ibex Capra pyrenaica. *Behavioral Ecology*, *22*(5), 1070-1078. https://doi.org/10.1093/beheco/arr092

Schmitz, O. J., Raymond, P. A., Estes, J. A., Kurz, W. A., Holtgrieve, G. W., Ritchie, M. E., Schindler, D. E., Spivak, A. C., Wilson, R. W., Bradford, M. A., Christensen, V., Deegan, L., Smetacek, V., Vanni, M. J., & Wilmers, C. C. (2014). Animating the Carbon Cycle. *Ecosystems*, *17*(2), 344-359. https://doi.org/10.1007/s10021-013-9715-7

Schou, J. S., Bladt, J., Ejrnæs, R., Thomsen, M. N., Vedel, S. E., & Fløjgaard, C. (2021). Economic assessment of rewilding versus agri-environmental nature management [Article]. *Ambio*, *50*(5), 1047-1057. https://doi.org/10.1007/s13280-020-01423-8

Seddon, P. J., Armstrong, D. P., & Maloney, R. F. (2007). Developing the science of reintroduction biology [Review]. *Conservation Biology*, *21*(2), 303-312. https://doi.org/10.1111/j.1523-1739.2006.00627.x

Silva, V., Catry, F. X., Fernandes, P. M., Rego, F. C., Paes, P., Nunes, L., Caperta, A. D., Sérgio, C., & Bugalho, M. N. (2019). Effects of grazing on plant composition, conservation status and ecosystem services of Natura 2000 shrub-grassland habitat types. *Biodiversity and Conservation*, *28*(5), 1205-1224. https://doi.org/10.1007/s10531-019-01718-7

Society for Ecological Restoration. (2021). *Scientists in support for an ambitious EU Nature Restoration Law* 12th European Conference on Ecological Restoration, https://www.sere2021.org/media/attachments/2021/09/10/declarationsere2021_eu_restoration_law.pdf

Soulé, M., & Noss, R. (1998). Rewilding and biodiversity: complementary goals for continental conservation. *Wild Earth*, *8*, 18-28.

Soulé, M. E., & Terborgh, J. (1999). *Continental conservation: scientific foundations of regional reserve networks*. Island Press.

Stafford, W., Birch, C., Etter, H., Blanchard, R., Mudavanhu, S., Angelstam, P., Blignaut, J., Ferreira, L., & Marais, C. (2017). The economics of landscape restoration: Benefits of controlling bush encroachment and invasive plant species in South Africa and Namibia. *Ecosystem Services*, *27*, 193-202. https://doi.org/https://doi.org/10.1016/j.ecoser.2016.11.021

Steffen, W., Richardson, K., Rockström, J., Cornell Sarah, E., Fetzer, I., Bennett Elena, M., Biggs, R., Carpenter Stephen, R., de Vries, W., de Wit Cynthia, A., Folke, C., Gerten, D., Heinke, J., Mace Georgina, M., Persson Linn, M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Sukhdev, P., Wittmer, H., Schröter-Schlaack, C., Nesshöver, C., Bishop, J., Brink, P. t., Gundimeda, H., Kumar, P., & Simmons, B. (2010). *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB*. UNEP, Ginebra (Suiza). https://policycommons.net/artifacts/1375223/the-economics-of-ecosystems-and-biodiversity/1989484/

Sylven, M., Widstrand, S., Schepers, F., Birnie, N., & Teunissen, T. (2010). Rewilding Europe—Bringing the variety of life back to Europe's abandoned lands. In. Nijmegen, The Netherlands: Rewilding Europe.

Tanasescu, M. (2017). Field Notes on the Meaning of Rewilding [Article]. *Ethics, Policy and Environment*, *20*(3), 333-349. https://doi.org/10.1080/21550085.2017.1374053

Terborgh, J., & Estes, J. A. (2010). *Trophic cascades: predators, prey, and the changing dynamics of nature*. Island press.

Tokumoto, I., Heilman, J. L., Schwinning, S., McInnes, K. J., Litvak, M. E., Morgan, C. L. S., & Kamps, R. H. (2014). Small-scale variability in water storage and plant available water in shallow, rocky soils. *Plant and Soil*, *385*(1), 193-204. https://doi.org/10.1007/s11104-014-2224-4

Torres, R. T., Carvalho, J., Serrano, E., Helmer, W., Acevedo, P., & Fonseca, C. (2017). Favourableness and connectivity of a Western Iberian landscape for the reintroduction of the iconic Iberian ibex Capra pyrenaica. *Oryx*, *51*(4), 709-717. https://doi.org/10.1017/s003060531600065x

Torres, R. T., Herrero, J., Prada, C., Garcia-Serrano, A., Fernandez-Arberas, O., & Garcia-Post, R. (2014). Estimating the population density of Iberan wild goat Capra pyrenaica and mouflon Ovis aries in a Mediterranean forest environment [Article]. *Forest Systems*, *23*(1), 36-43. https://doi.org/10.5424/fs/2014231-03322

Trouwborst, A. (2021). Megafauna Rewilding: Addressing Amnesia and Myopia in Biodiversity Law and Policy. *Journal of Environmental Law*, *33*(3), 639-667. https://doi.org/10.1093/jel/eqab016

Trouwborst, A., & Svenning, J.-C. (2022). Megafauna restoration as a legal obligation: International biodiversity law and the rehabilitation of large mammals in Europe [https://doi.org/10.1111/reel.12443]. *Review of European, Comparative & International Environmental Law*, *n/a*(n/a). https://doi.org/https://doi.org/10.1111/reel.12443

UNEP. (2019). *New UN Decade on Ecosystem Restoration offers unparalleled opportunity for job creation, food security and addressing climate change* https://www.unep.org/news-and-stories/press-release/new-un-decade-ecosystem-restoration-offers-unparalleled-opportunity

UNEP, & FAO. (2021). *What is ecosystem restoration?* Retrieved November 18, 2021 from https://www.decadeonrestoration.org/what-ecosystem-restoration

United Nations Decade on Ecosystem Restoration 2021-2030. (2021). *Preventing, Halting and Reversing the Degradation of Ecosystems Worldwide.* Retrieved November 8, 2021 from https://www.decadeonrestoration.org/

United Nations Development Programme [UNEP]. (2021). *The SDGS in action.* Retrieved November 8, 2021 from https://www.undp.org/sustainable-development-goals?utm_source=EN&utm_medium=GSR&utm_content=US_UNDP_PaidSearch_Brand_English&utm_campaign=CENTRAL&c_src=CENTRAL&c_src2=GSR&gclid=Cj0KCQiAsqOMBhDFARIsAFBTN3dHUJ3kmeAGlWtvlF6vsiYpbfRZwpKtHCrIi-K0ZB2MoincYmtzrtMaApHBEALw_wcB#life-on-land

Valasiuk, S., Czajkowski, M., Giergiczny, M., Żylicz, T., Veisten, K., Landa Mata, I., Halse, A. H., Elbakidze, M., & Angelstam, P. (2018). Is forest landscape restoration socially desirable? A discrete choice experiment applied to the Scandinavian transboundary Fulufjället National Park Area. *Restoration Ecology*, *26*(2), 370-380. https://doi.org/https://doi.org/10.1111/rec.12563

Valente, A. M., Acevedo, P., Figueiredo, A. M., Fonseca, C., & Torres, R. T. (2020). Overabundant wild ungulate populations in Europe: management with consideration of socio-ecological consequences. *Mammal Review*, *50*(4), 353-366. https://doi.org/https://doi.org/10.1111/mam.12202

Valente, M. J. (2004). Humanos e carnívoros no Paleolítico Superior inicial em Portugal: arqueozoologia e tafonomia da gruta do Pego do Diabo (Loures). *Promontoria, Revista do Departamento de História, Arqueologia e Património da Universidade do Algarve*(2), 107-141.

van Klink, R., van Laar-Wiersma, J., Vorst, O., & Smit, C. (2020). Rewilding with large herbivores: Positive direct and delayed effects of carrion on plant and arthropod communities. *PloS one*, *15*(1), e0226946.

VanWieren, S. E. (1995). The potential role of large herbivores in nature conservation and extensive land use in Europe. *Biological Journal of the Linnean Society*, *56*, 11-23. https://doi.org/https://doi.org/10.1111/j.1095-8312.1995.tb01114.x

Velamazán, M., Perea, R., & Bugalho, M. N. (2020). Ungulates and ecosystem services in Mediterranean woody systems: A semi-quantitative review. *Journal for Nature Conservation*, *55*, 125837. https://doi.org/https://doi.org/10.1016/j.jnc.2020.125837

Veríssimo, D. (2020). *Rewilding with the beaver in Portugal: an economic analysis* [Master's thesis, Iscte]. Lisboa, Portugal. http://hdl.handle.net/10071/21154

Vermeulen, R. (2021). *Natural grazing: Practices in the rewilding of cattle and horses. Rewilding Europe*. Rewilding Europe. https://www.rewildingeurope.com/wp-content/uploads/publications/natural-grazing-practices-in-the-rewilding-of-cattle-and-horses/index.html

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, *277*(5325), 494-499. https://doi.org/10.1126/science.277.5325.494

Wainaina, P., Minang, P. A., Gituku, E., & Duguma, L. (2020). Cost-Benefit Analysis of Landscape Restoration: A Stocktake. *Land*, *9*(11), 465. https://www.mdpi.com/2073-445X/9/11/465

WEF. (2020). *New Nature Economy Report II: The Future of Nature and Business.* https://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf

Widstrand, S. (2019). WildLife. In *Wild Wonders of Europe*.

WWF. (2020). *Global Futures: Assessing the global economic impacts of environmental change to support policy-making*. https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/75p5cvk0ul_Summary_Report.pdf

Zamora, R., Gómez, J. M., Hódar, J. A., Castro, J., & García, D. (2001). Effect of browsing by ungulates on sapling growth of Scots pine in a Mediterranean environment: consequences for forest regeneration. *Forest Ecology and Management*, *144*(1), 33-42. https://doi.org/https://doi.org/10.1016/S0378-1127(00)00362-5

Zhu, H., Wang, D., Wang, L., Bai, Y., Fang, J., & Liu, J. (2012). The effects of large herbivore grazing on meadow steppe plant and insect diversity. *Journal of Applied Ecology*, *49*(5), 1075-1083. https://doi.org/https://doi.org/10.1111/j.1365-2664.2012.02195.x

Zhu, H., Wang, D. L., Wang, L., Bai, Y. G., Fang, J., & Liu, J. (2012). The effects of large herbivore grazing on meadow steppe plant and insect diversity. *Journal of Applied Ecology*, *49*(5), 1075-1083. https://doi.org/10.1111/j.1365-2664.2012.02195.x

10.Annex

Table 10.1 - List of Forest Sappers landscape management actions the Iberian Ibex can perform, by degree of certainty – part 1

High Degree	Medium Degree
1.4 Plant Fertilization	1.2 Digging Holes (manual)
1.5 Plantation	1.7 Replacement of Dead Plants
2.1 Manual Fuel Management	1.8 Control of weed and Pile
2.1.1 Control of Excessive Densities	2.1.2 Desramation
2.4 Fuel Management using Silvopasture	2.2 Mecanin Fuel Management
5.2 Collection and Chipping of Leftovers	2.3 Controlled Fire Management
	3.1 Control of exotic/invasive species (manual/mechanic)
	3.2 Control of exotic/invasive species (chemical)
	4.1 Recovery of Burned Areas
	5.1 Collection and Burning of Leftovers
	7.3 Application of Chemical and/or Biological Phytosanitary Treatments

Table 10.2 - List of Forest Sappers landscape management actions the Iberian Ibex can perform, by degree of certainty – part 2

Low Degree	No Relevance
1.3 Digging Holes (mechanic)	1.1 Marking and Stake Placement
2.1.3 Pruning	1.6 Placement of Individual Protectors
7.2 Application of Cultural Phytosanitary Treatments	4.2 Emergency Stabilization
	6.1 Inventory
	7.1 Placement and/or Maintenance of Traps
	7.4 Marking and Punctual Cutting of Trees

Table 10.3 - Forest Sappers actions - unit cost and Iberian Ibex replication potential in value intervals

Type of intervention	Forest Sappers Action	Probability	unit cost		value interval	
1. reforestation	1.2 Digging Holes (manual)	medium	0,39	1,46	50	150
	1.4 Plant Fertilization	high	0,09	0,11	100	1000
	1.5 Plantation	high	0,23	0,59	50	500
	1.8 Control of weed and Pile	medium	0,20	0,29	50	500
2. fuel management	2.1.2 Desramation	medium	0,42	1,60	50	500
	2.1.3 Pruning	low	0,64	4,79	25	250
	2.3 Controlled Fire Management	medium	93	467	1	5
3. exotic/invasive species	3.1 Control of exotic/invasive species (chemical)	medium	176	351	25	250
4. post fire management	4.1 Recovery of Burned Areas	medium	0,20	0,23	12,5	125
5. leftover treatment	5.1 Collection and Burning of Leftovers	medium	1,95	5,85	25	250
7. plant health	7.2 Application of Cultural Phytosanitary Treatments	low	2,40	4,79	25	250

Table 10.4 - Forest Sappers actions - hectare (ha) cost and Iberian Ibex replication potential in value intervals

Type of intervention	Forest Sappers Action	Probability	ha cost		value interval	
1. reforestation	1.3 Digging Holes (mechanic)	low	493	1703	30	90
	1.7 Replacement of Dead Plants	medium	157	455	100	300
2. fuel management	2.1 Manual Fuel Management	high	383	1150	100	300
	2.1.1 Control of Excessive Densities	high	96	1150	100	300
	2.2 Mecanin Fuel Management	medium	89	148	50	150
	2.4 Fuel Management using Silvopasture	high	42	90	100	300
3. exotic/invasive species	3.1 Control of exotic/invasive species (manual/mechanic)	medium	288	575	50	150
4. post fire management	4.1 Recovery of Burned Areas	medium	513	1089	50	150
5. leftover treatment	5.2 Collection and Chipping of Leftovers	high	42	170	50	150
7. plant health	7.3 Chemical and/or Biological Phytosanitary Treatments	medium	26	119	50	150

Table 10.5 - Iberian Ibex potential to save landscape management costs

Forest Sappers Action Number	LC -LQ	LC -HQ	HC - LQ	HC - HQ
1.2 Digging Holes (manual)	20 €	59 €	73 €	219 €
1.3 Digging Holes (mechanic)	14 783 €	44 348 €	51 084 €	153 252 €
1.4 Plant Fertilization	9 €	90 €	11 €	110 €
1.5 Plantation	12 €	115 €	30 €	295 €
1.7 Replacement of Dead Plants	15 708 €	47 124 €	45 465 €	136 395 €
1.8 Control of weed and Pile	10 €	100 €	15 €	145 €
2.1 Manual Fuel Management	38 336 €	115 008 €	115 008 €	345 024 €
2.1.1 Control of Excessive Densities	9 584 €	28 752 €	115 008 €	345 024 €
2.1.2 Desramation	21 €	210 €	80 €	800 €
2.1.3 Pruning	16 €	160 €	120 €	1 198 €
2.2 Mecanin Fuel Management	4 451 €	13 352 €	7 418 €	22 253 €
2.3 Controlled Fire Management	93 €	467 €	467 €	2 337 €
2.4 Fuel Management using Silvopasture	4 200 €	12 600 €	9 000 €	27 000 €
3.1 Control of exotic/invasive species (manual/mechanic)	14 376 €	43 128 €	28 752 €	86 256 €
3.2 Control of exotic/invasive species (chemical)	4 388 €	43 883 €	8 777 €	87 765 €
4.1 Recovery of Burned Areas	25 672 €	77 032 €	54 466 €	163 419 €
5.1 Collection and Burning of Leftovers	49 €	488 €	146 €	1 463 €
5.2 Collection and Chipping of Leftovers	2 100 €	6 300 €	8 500 €	25 500 €
7.2 Application of Cultural Phytosanitary Treatments	60 €	600 €	120 €	1 198 €
7.3 Application of Chemical and/or Biological Phytosanitary Treatments	1 300 €	3 900 €	5 935 €	17 804 €