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O lince-ibérico como um caçador de cervídeos: ecologia trófica e impactos sociais de um grande carnívoro reintroduzido

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Ecologia Aplicada, realizada sob a orientação científica do Doutor Eduardo Loureiro Ferreira, Investigador do Centro de Estudos do Mar e da Atmosfera (CESAM) da Universidade de Aveiro e sob coorientação científica do Doutor Pedro Bernardo Marques da Silva Rodrigues Sarmento, Coordenador de Projetos e Técnico Superior do Instituto da Conservação da Natureza e das Florestas (ICNF).

o júri

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palavras-chave

Dieta, *Lynx pardinus*, Gamo, Predação de gado, Atitudes, Criadores de gado, Gestores de caça, Conhecimento, Conflito Homem-Homem

resumo

O lince-ibérico (*Lynx pardinus*) representa um caso de sucesso na recuperação de um grande carnívoro ameaçado através de um processo de reintrodução. No entanto, desde as primeiras libertações na região do Vale do Guadiana, Portugal, em 2014, têm sido verificados ataques frequentes a ungulados selvagens, algo não expectável de um predador especialista em coelho, e que tem levantado preocupações por parte dos residentes relativamente aos prejuízos desta espécie para a criação de gado e para a atividade cinegética. Com este trabalho procurou-se perceber a importância de ungulados selvagens na dieta da população portuguesa de lince-ibérico e se este comportamento alimentar teve repercussões nas atitudes dos residentes locais em relação aos linces. O primeiro estudo consistiu na análise da dieta de três núcleos populacionais de lince-ibérico em áreas com diferente densidade de ungulados selvagens. Os resultados demostraram que o lince ibérico consome preferencialmente coelho-bravo (Frequência de ocorrência, FO: 75.9% - 88.9%; Biomassa consumida, BIOc: 59.1% - 98.4%). Observou-se diferenças significativas na dieta entre as três áreas amostradas devido ao elevado consumo de ungulados selvagens particular da área das Romeiras (FO: 27.6%; BIOc: 24.2%), dos quais se destaca o gamo (FO: 19.0%; BIOc: 20.0%). Foram identificados três fatores que podem influenciar essa diferença: abundância relativa de ungulados, vulnerabilidade e a exposição a uma elevada densidade de ungulados durante a aclimatização dos indivíduos reintroduzidos com o método de “soft-release”, aplicado apenas na área das Romeiras. Destaca-se também a primeira confirmação de consumo de ungulados domésticos por lince-ibérico em Portugal. Esta análise revela a importância da monitorização da ecologia trófica do lince-ibérico para uma melhor gestão adaptativa das populações reintroduzidas. Através do segundo estudo procurou-se compreender as atitudes relativamente ao lince-ibérico dos perfis sociais mais afetados pela presença deste predador, os criadores de gado (LO) e os gestores cinegéticos (HM). Foram feitas medições de três variáveis: Perceção de Impacto de Predadores, Conhecimento sobre o Lince, e de Perceção da Agência de Conservação Local, de modo a testar a sua correlação com as atitudes dos entrevistados. Com base numa abordagem não-aleatória anteriormente usada na região, foram realizadas 33 entrevistas semiestruturadas (LO: N = 26; HM: N = 7). Observou-se a prevalência de atitudes positivas entre os proprietários, sendo mais fortes para os HM. Um conhecimento mais completo sobre a espécie e uma opinião mais positiva sobre o Parque Natural do Vale do Guadiana (PNVG) provocaram atitudes mais positivas relativamente ao lince. As atitudes menos positivas dos LO aparentaram estar relacionadas com a sua elevada perceção de risco devido a uma maior exposição indireta a casos de ataques de lince a animais domésticos, corroborada pelo efeito “Not in my back yard” (NIMBY) verificado. A predação de ungulados selvagens não produziu efeito sobre as atitudes dos residentes, mas pode ter contribuído para o aumento do risco sentido pelos LO. As opiniões dos entrevistados realçaram a necessidade de uma comunicação mais próxima e eficaz com os trabalhadores do PNVG, especialmente para com os LO, de modo a preservar e a incrementar as atitudes positivas em relação à presença do lince, indispensáveis para a sua conservação a longo termo.

keywords

Diet, *Lynx pardinus,* Fallow deer, Livestock predation, Attitudes, Livestock owners, Hunting managers, Knowledge, Human-Human conflict

abstract

The Iberian lynx (*Lynx pardinus*) represents a success case on the recovery of an endangered large carnivore through reintroduction. However, since the first releases in 2014 in the Vale do Guadiana region, Portugal, there have been frequent attacks on wild ungulates, something unexpected from a rabbit specialist, and which has raised concerns by residents regarding damages on livestock breeding and hunting. The present work aimed to understand the importance of wild ungulates for lynx's diet in Portugal and if this feeding behaviour had any repercussions on local resident's attitudes towards lynxes. The first study consisted in the diet analysis of three population nucleus of Iberian lynx in areas differentiated by their different wild ungulate density. The results demonstrated that European rabbit was lynxes' main prey (Frequency of occurrence, FO: 75.9% – 88.9%; Consumed biomass, BIOc: 59.1% - 98.4%). It was observed significant differences between the three sampled areas due to the high consumption of wild ungulates particular to the Romeiras area (FO: 27.6%; BIOc: 24.2%), of which fallow deer was predominant (FO: 19.0%; BIOc: 20.0%). Three possible factors were identified that would explain said differences: ungulate relative abundancy, vulnerability and the exposition to high densities of ungulate during acclimatization period of soft-released individuals, used only in Romeiras area. It's also highlighted the first record of domestic ungulate consumption by Iberian lynx in Portugal. This analysis reveals the importance of monitoring the trophic ecology of Iberian lynx to help the adaptive management of this reintroduced population. Through the second study, it was aimed to understand the attitudes towards Iberian lynx of the social sectors most affected by this predator presence: livestock owners (LO) and hunting managers (HM). The variables of Perceived Predator Impact, Knowledge about the Lynx and Perception on Local Conservation Agency were measured to test their correlation with interviewee's attitudes. Using a non-random approach previously used in the region, 33 semi-structured interview were done (LO: N = 26; HM: N = 7). It was observed overall positive attitudes among landowners, being stronger for HM. A more complete knowledge about the species and more positive opinions regarding Parque Natural do Vale do Guadiana (PNVG) induced more positive attitudes towards lynx. The less positive attitudes of LO seemed to be a result of high risk perception due to a high indirect exposure to lynx attacks on livestock, corroborated by the observed Not in My Back Yard (NIMBY) effect. The wild ungulate predation didn't provoked effects on residents' attitudes, but it may have contributed to an increase of the risk felted by LO. Interviewee's opinions highlighted the necessity of a closer and more effective communication with PNVG staff, especially with LO, in order to preserve and increase positive attitudes regarding lynxes' presence, indispensable to their long-term conservation.

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Introduction

Recovering large carnivores through reintroduction

Currently, large carnivores are ongoing a process of re-colonization of their lost territory throughout Europe (Chapron et al., 2014; Fernandez-Gil et al., 2018). This recent recovery comes after centuries of persecution, prey decline and habitat degradation, that culminated on the near extinction of this apex predators (Breitenmoser, 1998; Linnell et al., 2009). Most of their current re-expansion has been natural, originating from remnant populations (Kaczensky et al., 2012; Linnell et al., 2009) as many factors have coincided to create a positive environment for the revival of the large carnivores species, such as the revision of hunting regulations, the creation of legal protection for this endangered species, the reversal of general public attitudes, the increase in forest cover due to urban migration and abandonment of pasturelands, and the increase in numbers and range of wild prey (Boitani & Linnell, 2015; Chapron et al., 2014; Cimatti et al., 2021; Navarro & Pereira, 2012). Nevertheless, direct conservation measures, like reintroductions, have also had an important role in this process (Breitenmoser et al., 1998; Linnell et al., 2009; Samojlik et al., 2018).

A reintroduction process consists in an intentional translocation of an organism into a part of its historical range and from which it has disappeared (Armstrong & Seddon, 2008). It has been used for conservation purposes all over the world for more than a century (Samojlik et al., 2018), but with a low rate of success on recovering endangered and sensitive species (Griffith et al., 1989). Only recently, because of more detailed protocols, an increase in knowledge about the endangered species and an extensive monitorization, the number of success cases have grown, resulting in a significant change for the conservation status of many species (Armstrong & Seddon, 2008; Soorae, 2016). That is an important accomplishment for this type of conservation measures, as the high cost and complexity of reintroductions could compromise the preservation of a species in case of failure (Berger-Tal et al., 2020). However, even in well-funded and well planned reintroduction projects, wildlife managers frequently face problems regarding animal behaviour in the new environment, especially in mammals (Berger-Tal et al., 2020). The climate conditions, the habitat suitability, the origin of the individuals (whether born in captivity or in the wild) and intraspecific variability can contribute to a decline in the survival and persistence of the reintroduce population (Berger-Tal et al., 2020; Hunter & Rabinowitz, 2009; Jule et al., 2008; Ovenden et al., 2019), imposing a greater need for more research to allow adaptative and preventive management.

Species selection for reintroduction is based on a series of criteria, the degree of threat and risk of total extinction being just one (Seddon et al., 2005). In part, this selection process takes in consideration the possible surrogate role that the species will play towards conservation goals as a representative of other species and aspects of the environment (Caro & O'Doherty, 1999). In the case of large carnivores, their charismatic nature attracts public attention, support and funds towards conservation, stimulating awareness and action (Albert et al., 2018; Sergio et al., 2008). Also, top predators, such as large carnivores, can regulate and restore the ecosystems trough their impact on the trophic chains and their competitive behaviour over the remaining carnivore guild (Ripple & Beschta, 2012; Ripple et al., 2014; Samojlik et al., 2018; Vynne et al., 2022). These factors have led to an overrepresentation of carnivores in reintroduction projects (Seddon et al., 2005).

Yet, the release of large carnivores is, in most cases, followed by controversy (Lozano et al., 2019). Firstly, the actual effects of their reintroduction are still poorly documented, leaving the question if their restorative role on the ecosystem, mentioned above, does occur (Allen et al., 2017; Alston et al., 2019). Despite some positive evidence of significant cascading effects (ex. Moseby et al., 2019 and Wilmers et al., 2003), it's not a predictable event, usually it's context-dependent (Kuijper et al., 2016) and it could instead generate undesirable consequences, such as the depletion of prey species in an ecosystem that evolved for a long period in the absence of this top predator (Ferretti et al., 2014).

Furthermore, large carnivores can still be regarded as unrestrained killers of wildlife and livestock by local human population, capable of damaging property and sometimes posing a risk to human life, leading to their frequent involvement in human-wildlife conflicts (Breitenmoser, 1998; Broekhuis et al., 2017; Červený et al., 2019; Lescureux et al., 2011). This perceived risk, as in the degree to which individuals believe they are threatened by some hazard or danger (Watkins et al., 2021), is an important factor that influences people's attitudes regarding large carnivores, especially in the context of a reintroduction (Williams et al., 2002), as the local communities usually had experienced long periods without the predator and the associated conflicts. Since human-wildlife conflicts can also originate from disagreement between stakeholders (Frank & Glikman, 2019), the confidence that local communities have in these wildlife management agencies - meaning the people's belief of their capacity to successfully mitigate threats originated from the reintroduced carnivores based on past experiences (Siegrist et al., 2000; Watkins et al., 2021) - can determine their acceptance to conservation efforts proposed and thus block the recovery of those predators.

Attitude can be defined, according to Human Dimensions authors, as a positive or negative evaluation of a person, object or action (Bath & Buchanan, 1989; Glikman et al., 2010; Manfredo et al., 1995). It comprises two components: i) cognitive, referring to the beliefs and thoughts that is held about an entity (e.g., lynx), which reflects the information that is known about it, whether it may or may not be true (Glikman et al., 2012; Manfredo et al., 1995); and ii) affective, that consists of the emotions, feelings and moods that emerge in relation to an entity or behaviour (Glikman et al., 2012; Manfredo, 2008). In large carnivore reintroductions, attitudes are shown to ultimately determine the behaviour and of an person, whether in support of the recovery of a species or intolerance to their presence (Bruskotter & Wilson, 2014; Manfredo et al., 1995). The conflict that arises when people harbour negative attitudes towards top predators is usually the greatest challenge to a successful reintroduction, since it could lead to widespread illegal killing, preventing the stabilization of the released population and undermining its long-term survival (Berger-Tal et al., 2020; Clark et al., 2002; Davoli et al., 2022; Linnell et al., 2009).

The extent to which people are exposed to (i.e., experiences they had with the species) and informed (i.e. ecological knowledge) about the predator that is being reintroduced can affect their attitudes (Arbieu et al., 2019; Williams et al., 2002), mainly because it often changes the perceived risk of the reintroduction. Taking as well in consideration the local social context and the usual practices regarding predators (Lopes-Fernandes, 2018b), assessing knowledge, perception and concerns that local populations have about species, conservation actions and agencies that

implement them provides valuable information for a collaborative decision-making process, essential to re-establish endangered large carnivores (Lopes-Fernandes et al., 2018).

The Iberian case of large carnivore reintroduction: the Iberian Lynx

The Iberian Lynx (*Lynx pardinus* Temmick, 1827*)* is a sister species of the Eurasian Lynx (*Lynx lynx* L. 1758), distinguished by its smaller size and a darker brown fur (Figure 1). It is an endemic species of the Iberian Peninsula, where it co-evolved with the European rabbit (*Oryctolagus cuniculus* L. 1758) it's main prey, by adapting both its weight and energy needs to coincide with the abundance of rabbits in the Mediterranean area (JAldama et al., 1991; Ferrer & Negro, 2004). Palomares et al. (2001) found that to sustain a breeding female territory, that cares for 2-4 kittens (Sarmento et al., 2004), the abundance of rabbits needs to be of 1-4.6 individuals/km^2 (during autumn and spring respectively). The mean home range size of a male (11.18km^2) is slightly bigger than one of a female (9.87km^2) (Sarmento et al., 2019).

Figure 1: Two Iberian lynxes resting under a cork oak tree. Source: Victor Bandeira, 2013.

The Iberian Lynx represents an interesting case study of a successful recovery of a large carnivore species through reintroduction. During the 20th century, most of the populations of this felid were decimated, because a great part of their habitat, the Mediterranean shrublands, was converted to pasturelands and forests (Castro & Palma, 1996), and rabbit populations were declining abruptly due to newly viral pathologies (Ferreira & Delibes-Mateos, 2010). The high rate of non-natural deaths of lynxes, trough predator control activities, shootings and accidental deaths in leghold traps, also played an important role in this extirpation (Rodríguez & Delibes, 2004). By the beginning of the 21st century, the Iberian lynx was declared "Critically Endangered" (Nowell, 2002) and the most endangered feline in the world (Nowell & Jackson, 1996), since the remnants of the species were constrained to around 100 individuals concentrated in two populations in Andalusia, southern Spain (Andújar-Cardeña and Doñana-Aljarafe; Figure 2) (Guzmán et al., 2004).

In Portugal, by 2001, the detection of indirect signs of lynx presence was very scarce, and thus the species was considered to be locally extinct (Pires & Fernandes, 2003; Sarmento et al., 2009, 2004).

Figure 2: Distribution of Iberian lynx during the beginning of the 21st century. (1) Doñana-Aljarafe and (2) Andújar- Cardeña. Retrieved from Guzmán et al. (2004).

The steady range contraction and the lack of natural recolonization by lynxes (Rodríguez & Delibes, 2003) implied that the recovery of this apex predator could not be possible without reintroducing animals to their historical areas (Sarmento et al., 2005). Supported by an Iberian captive breeding program, the reintroduction project, launched in the early 2000's, has been releasing lynxes in Andalusia since 2011 (Simón et al., 2012) and in Baixo Alentejo, Portugal, since 2015 (Sarmento et al., 2019). The conservation efforts have also been focusing in minimizing the threats to the persistence of lynxes in the territory, namely the lack of rabbits, through habitat improvement and artificial restocking; and the risk of road kill, by increasing safety for crossing animals using underground passages (Simón et al., 2009). All while finding common points of interest among local stakeholders: they facilitate the use of their proprieties for the conservation endeavours and the preservation the Mediterranean shrubland, which is beneficial for lynxes, due to an increase of their main prey, and for owners as well, as it increases revenue from rabbit hunting (Simón et al., 2012).

The results of more than 10 years of structured efforts to preserve this predator couldn't be more hopeful. It led to the establishment of 13 sub-populations in Spain and Portugal, where is estimated to exist near 1400 individuals, from which 277 are reproductive females, dispersed throughout almost 4 500 km^2 (LIFE LYNXCONNECT, n.d.). In Portugal, the new subpopulation, formed 7 years ago in the region of Vale do Guadiana, has reached more than 200 lynxes and, with the help of continuous translocations, has started to disperse to other areas (Sarmento et al., 2019). This current population trend has led to an actualization of its risk of extinction assessment to "Endangered" (Rodríguez & Calzada, 2015).

The most noticeable repercussion in the ecosystem stemming from this recovery has been the interspecific competition between the lynxes and the other carnivores already present in the area (Sarmento et al., 2021). In many cases, in the presence of a top predator, the smaller carnivores are affected by competition, often direct aggression that can result in death, leading to a change in space use, temporal activity and/or social behaviour in order to avoid lynx predation risk (Palomares & Caro, 1999), in a phenomenon denominated as super-predator effect. Before the implementation of the reintroduction plan, this behaviour was reported in the Doñana National Park, one of the reservoir populations of lynxes. Small carnivores, like common genets (*Genetta genetta* L. 1758) and Egyptian mongooses (*Herpestes ichneumon* L. 1758), avoided areas with higher densities of lynxes (Palomares et al., 1998; Palomares et al., 1996), while red foxes (*Vulpes vulpes* L. 1758) had a tendency to use habitats not frequented by lynxes during the activity period (Fedriani et al., 1999). The same competitive exclusion of foxes and Egyptian mongooses was evidenced after the reintroduction of lynxes in Portugal and Spain (Jiménez et al., 2019; Sarmento et al., 2021), revealing the capacity of this felid to exert top-down pressure in the meso-carnivores after a long period of absence in the region and to stimulate the increase of small game abundance. However, Garrote & de Ayala (2019) also reported interference competition with wildcat (*Felis silvestris* Schreber, 1777), another felid that is currently facing a great threat of extinction (Matias et al., 2021).

• Iberian Lynx feeding habits and its impacts on human perceptions

The feeding habits of the Iberian lynx, as a large carnivore, are important to understand its potential role in the ecosystem and impact on prey populations (Klare et al., 2011). This is especially true in this case, since this species is being reintroduced after being absent in some areas for a long period, during which the prey adaptive behaviours in response to lynxes may have been dulled (Tambling et al., 2015). Moreover, the diet of large carnivores is often at the centre of tensions between humans and predators, due to the influence of predation on game and livestock (Garrote et al., 2013; Wagner et al., 2012). Carnivore diet studies are usually done through scat analysis, as they are easy to apply, less expensive, allow large sample sizes and because it is an indirect and non-intrusive method, compatible with endangered and elusive species, such as the Iberian lynx (Ciucci et al., 1996; Klare et al., 2011).

Several factors can determine the selection of a prey, such as the abundance, accessibility and vulnerability (Imbert et al., 2016; Meriggi et al., 1996), that allow the predator to find and kill prey more easily without having to expend a lot of energy (Mattioli et al., 2011). Still, some recent studies have pointed out the influence of experience and learning of an individual in shaping its diet (Shipley et al., 2009; Wagner et al., 2012). This can create a phenomenon designated as “niche variation”, defined as when co-occurring individuals of a species actively select different prey types in their shared environment (Araújo et al., 2011). This individual specialization can be a response to intra and interspecific competition and ecological changes that affect prey availability (Araújo et al., 2011; Costa et al., 2008).

To my knowledge, with the exception of some restricted studies in Serra da Malcata, Portugal, (Palma 1980, as cited in Gil-Sánchez et al., 1997; Castro 1994) all the feeding ecology

studies of the Iberian lynx were carried out in Spain, mainly in Doñana National Park (Beltran et al., 1985; Beltrán & Delibes, 1991; Delibes, 1980; Palomares et al., 2001) and Sierra Morena (Delibes et al., 1975; Gil-Sánchez et al., 2006), where they concluded that the European rabbit was its main prey, making up 70%-100% of their diet composition. The niche breadth of this species, defined by the proportion of each resource used regarding total consumed resources (Smith, 1982) is therefore considered small and thus the Iberian lynx was deemed a trophic specialist (Ferrer & Negro, 2004), that relies on European rabbit regardless of its abundance (Gil-Sánchez et al., 2006). As supplementary prey, lynxes usually consume other small mammals, e.g. wood mouse (*Apodemus sylvaticus* L. 1758) and garden dormouse (*Eliomis quercinus* L. 1766) (Delibes, 1980; Gil-Sánchez et al., 2006); wild ungulates, e.g. red deer (*Cervus elaphus* L. 1758), fallow deer (*Dama dama* L. 1758) and European mouflon (*Ovis aries musimon* Pallas 1811) (Beltran et al., 1985; Delibes, 1980); and also birds, mainly red-partridges (*Alectoris rufa* L. 1758) and mallards (*Anas platyrhynchos* L. 1758) (Delibes, 1980).

However, there have been evidence that the relative importance of prey species, usually consumed in lower proportions, can increase when the availability of rabbits decreases (Alfaya et al., 2020; Beltran et al., 1985; Beltrán & Delibes, 1991; Delibes et al., 1975; Sáez-Gómez et al., 2018). This adaptation of trophic behaviour by the Iberian lynx has been firmly rejected so far, and is not considered in the current management of the species (Alfaya et al., 2020). The knowledge of this diet plasticity and niche breadth of lynxes is, however, crucial for their long-term conservation. Not only it allows to assess the transferability of results obtained in a certain area of their distribution to another, as it helps to identify the best areas for further reintroductions, where the lack of rabbit can be overcome with other more abundant supplementary prey (Terraube & Arroyo, 2011).

Similarly, the Iberian lynx is often viewed as a species that is not prone to enter in conflict with humans (Inskip & Zimmermann, 2009) due to its preference for rabbits as prey and to the lack of information about attacks on livestock and to the absence of reports on livestock attack, which leads to the assumption that these do not occur (Garrote et al., 2013). This was an important factor that shaped the support for lynx reintroduction, as the potential conflict was not often mentioned by local communities in a previous attitudinal studies implemented in both countries (Castro et al., 2014; Delibes-Mateos et al., 2022; Lopes-Fernandes et al., 2018) Yet, as a result of the close monitoring of the Iberian lynx population as part of the reintroduction project, several lynx attacks on poultry (chicken, doves and turkey) and lambs were recorded in Spain, of which the predation of lambs brought bigger economic losses (Garrote et al., 2013). In their study in Andújar-Cardeña, Garrote et al. (2013) stated that, despite the attacks on lambs couldn't be considered as very serious in the region, since only a few free-ranging flocks exist, other reintroduction areas, where the presence of extensive flocks is common, could face a bigger incidence of lynx depredation. Moreover, under this lynx population expansion scenario, more individuals may start to disperse to and occupy areas with low abundance of rabbits, which can facilitate the increase of attacks. These attacks have a potential to generate negative attitudes towards the Iberian lynx among the local population, which could threaten its survival (Garrote et al., 2013).

Since the first couple of Iberian lynxes, "Jacarandá" and "Katmandú" were released from the soft-release encloser located in the Guadiana Valley Natural (PNVG), Portugal, in 2015, there

have been reports of an unusual feeding behaviour. As stated by the Instituto da Conservação da Natureza e da Floresta (ICNF), in the proximity of the enclosure where the couple established their territory, there have been sightings of consistent predation upon fallow deer, averaging 1 deer for every 15 days (P. Sarmento, personal communication, October 2021). Given that this predation is supposedly higher than what was observed in Spain (Beltran et al., 1985), the potential impact for this game species in the region could be perceived as important. Even more, the lynxes' attacks on deer have started to resonate in the public opinion regarding the feline, not only because of the damage inflicted on this important revenue stream from some of the local hunting estates, but also because of the increased perceived risk for livestock, seen as more vulnerable than wild ungulates to predation by carnivores. Even though no lynx' attack has been confirmed so far in Portugal on sheeps or lambs, attacks on chicken coops have been reported (C. Carrapato, personal communication, November 2021). In fact, during 2021, in one village situated within the PNVG, the death of at least 400 chickens was attributed to one reintroduced lynx. These events, that are predicted to increase with the current expansion of the lynx population threatens the general support of local people to the presence of this endangered species in the region, assessed prior the reintroduction (Lopes-Fernandes et al., 2018).

Aims

As Armstrong & Seddon (2008) argue, one of the key questions that need to be addressed in a reintroduction setting, specifically of large carnivores, is "How will the ecosystem be affected by the target species?", both in the social and ecological context. So, to prevent speculations and exaggerations about the impacts of the reintroduction of lynxes, this study aims to provide important and robust information on the diet composition of the expanding Iberian lynx population resulting from the current reintroduction program in Vale do Guadiana. This work intended to i) assess the importance of wild ungulates game species to the diet of the lynx; and ii) the seasonality of the consumption of those species. To do that, the food habits of the lynxes were analysed for three different areas that were differentiated according to their abundance in game ungulates.

Additionally, through a social survey inspired by a previous ethnographic approach (e.g. Lopes-Fernandes et al., 2018), it was sought to comprehend local key actors' attitudes towards the Iberian Lynx, namely the social groups that tend to have more proximity with carnivores and also often conflictive perceptions about them, as in livestock breeders and hunters (Lopes-Fernandes et al., 2022). It was sought to understand how these residents have been interpreting external information regarding this short period of coexistence with the Iberian lynx and to highlight some occurring and potential future problems to the goal of reaching a self-sustainable population of Iberian Lynx in Portugal. Based on previous studies with reintroduced large carnivores (Delibes-Mateos et al., 2022; Glikman et al., 2012; Inskip et al., 2016; Lopes-Fernandes et al., 2018; Watkins et al., 2021), it was aimed to describe and understand livestock owners and hunting managers' present attitudes. Additionally, the influence of different variables on attitudes towards lynxes were tested, such as i) the previous negative experiences/perceptions of people with predators, ii) the knowledge about biology of lynxes, III) and their opinions regarding local conservation agencies.

Material and Methods

Study area

The current geographic distribution of the Iberian lynx in Portugal extends for around 850 km^2 in the southeast province of Baixo Alentejo and in adjacent province of Algarve. It encompasses the Guadiana Valley Natural Park (PNVG; c. 700 km^2), the Site of Community Importance Guadiana (PTCON0036), the Special Protection Area Castro Verde (PTZPE0046) and their surroundings (Figure 3). It includes territory from four municipalities: Mértola, Serpa, Alcoutim and a portion of the east side of Castro Verde. For this study, the focus was restricted to the municipalities of Mértola and Serpa.

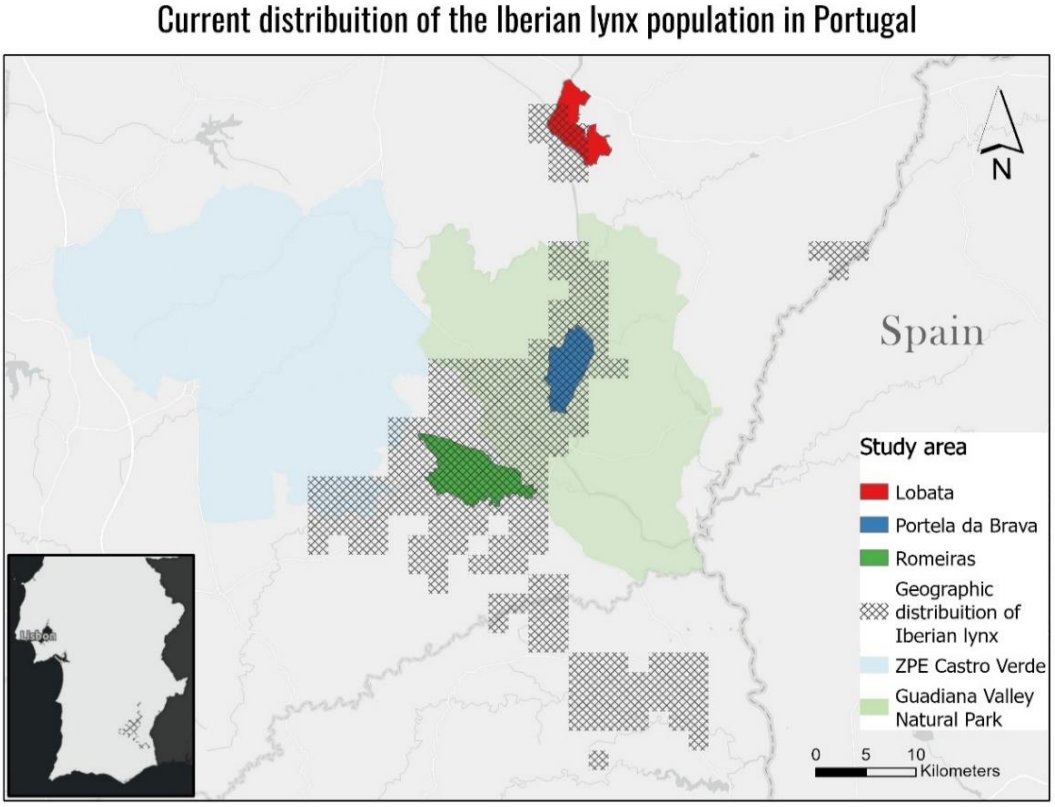

Figure 3: Location of the sub-areas of the diet study in Baixo Alentejo region. They are included in the current geographic distribution of Iberian lynx in Portugal (ICNF 2022). Base map retrieved from Esri.

The Mediterranean climate that characterizes this region is especially dry, with a mean annual temperature of 16.5ºC and a mean monthly precipitation that ranges from of 2.9 mm (Jully) to 100.9 mm (December) (Intituto Português do Mar e da Atmosfera, n.d.). The dry and hot summers facilitate the development of a Mediterranean shrubland vegetation cover, dominated by the *Myrto communis–Querceto rotundifoliae sigmetum* series, although sometimes being replaced with other species, such as *Genista hirsute* (Vahl.)*, Cistus ladanifer* (L.), *Cistus monspeliensis* (L.) and *Rhamnus lycioides* (L.) *subsp.* oleoides (Sarmento et al., 2019). The Mediterranean shrubland is fragmented with patches of cereal, pasturelands and forestations, mostly comprised of *Pinus pinea* (L.), *Olea europaea* (L.), *Eucalyptus globulus* (Labill.), *Quercus suber* (L.) and *Q. rotundifolia* (L.)

subsp. ballota. This vegetation patches occur mainly on the Guadiana riverbanks, in the neighbouring valleys and mountain sides (Direção Geral do Território, 2020).

Wild rabbits, contrarily to the reality in most of Portugal, are abundant in most of this region, with spring densities reaching > 4 individuals/ha (Sarmento et al., 2019). Red partridges are also abundant throughout the study area. Wild ungulates are common, namely the wild boar, red-deer and the fallow-deer. The European mouflon is also present in this area, but its population is concentrated in few hunting estates. Due to the high abundance and prey, this ecosystem harbours a great diversity of meso-carnivores, such as the red fox, the Egyptian mongoose, the European badger (*Meles meles* L. 1758), the stone marten, the wildcat and the common genet.

The region of Mértola municipality is one of the most unpopulated in Portugal, characterized by a populace with an historical high levels of poverty and low level of education, dispersed through a large area (5,4 individuals/km^2). Nonetheless, the anthropogenic disturbance is substantial, as large portion of the territory is dedicated to hunting and/or grazing of livestock, usually belonging to few landowners. In fact, Mértola is considered the "hunting capital" of Portugal due to abundance in game resources, attracting many hunters from all over the country (Lopes-Fernandes, 2018b). The extensive grazing is a preferred practice of almost all shepherds, resulting in large free-ranging cattle and sheep herds roaming in the many pasturelands present in the area.

The sub-areas delineated for the diet study (Figure 3) correspond to three hunting areas that contain a large portion of the Iberian lynx population in Portugal. However, despite being relatively close to each other, they differ not only in the abundance of wild ungulates but also in size and land use. Altogether, the diet sample area consisted of 95.5 km^2.

- ## Romeiras

The hunting estate of Romeiras (**HR**) is one of the largest hunting ground of the region, with 45.8 km^2, and is located west of Mértola town. Limited north by a steep mount, the property is relatively plane, with more than half of its area is occupied by agriculture and pasturelands (62%). Besides an area covered manly by forestation of stone pine and holm oak (15%), the rest of property is covered by shrublands (23%), an area that is an optimum habitat for both the Iberian lynx and its prey. As a result, this was the area chosen by the Iberian lynx conservation experts for the first releases of individuals in Portugal, using a soft-release approach where they were first placed in an enclosure located inside the estate for acclimatization. This same part of the property is mostly reserved for big game management, where a large population of fallow deer and, in fewer numbers, red deer was introduced for hunting purposes. Currently, this area contains the centre of activity of 17 identified lynxes.

- ## Portela Brava

Contrary to **HR**, Portela Brava (**HPB**, 25.2 km^2) has heavily irregular terrain, as is flanked to the east by the Guadiana River. Located north of Mértola town, this is the only sub-area whose territory is included in the PNVG and is composed of three hunting grounds that are managed by the same entity. It is mainly comprised of forests of holm oak and stone pine (58%) and agroforestry

systems of holm oak (23%), having also some parcels dedicated to agriculture and grazing of livestock (12%) and a small portion of shrubland (7%). In these estates, the population of fallow deer and red deer is scarce, probably originated from individuals that escaped from **HR** hunting grounds and reproduced in this property. After the foundation of the lynx population, subsequent reintroductions have taken place on this location to avoid dispersion of individuals due to territorial exclusion by already established lynxes. It is now home to 16 identified lynxes. Outside of these properties, a small area corresponding to a portion of the municipality's forest perimeter was also sampled (Figure), where 1 other lynx has established its territory. Due to its proximity to the hunting grounds, it was combined in the same sub-area.

• Lobata

Contrary to the other sub-areas that are in Mértola municipality, Lobata (**HL**, 24.5 km^2) is located in the outskirts west of Serpa city. Similarly to **HPB**, this territory is comprised of several hunting grounds flanked by the Guadiana River, but in this case owned by different parties. This territory has a small percentage of agroforestry system of holm oak (11%), and forest area composed mainly by holm oak (22%), that are contiguous to the river. They are surrounded by a large area of intensive olive groves (47%), areas dedicated for dryland farming, specifically of sunflowers (18%) and pasturelands (2%). Lynxes are relatively recent in this area, compared to the other sub-areas, and in smaller number. Seven lynxes were confirmed to use this area. Besides the occurrence of wild boar, an ungulate species well distributed throughout all country, there are no wild ungulate species using this area.

Food habits of the Iberian Lynx

• Scat collection

The scats were collected monthly between November 2021 and June 2022 in each sub-area. Sampling occurred in two ways: by visiting previously georeferenced latrines (Gil-Sánchez et al., 2006) and opportunistically, along roads and trails within the properties (Alfaya, de Pablo, et al., 2020; Sarmento et al., 2009), during the regular monitoring activities of the lynx population. This opportunistic collection was carried out by vehicle (<10 km/h) or by foot (Torres et al., 2015). When scats from the same latrine/location appeared to be of the same age and constitution, only one of the scats (the first) was sampled, to avoid pseudoreplication (Krofel et al., 2011).

Scat identification was performed in the field by experienced professionals, using reference materials and field guides (e.g. Navarro, 2004), and was based on the size, shape, content, smell and position of the dropping (Iglesias & España, 2010). This morphologic identification has been associated with a high error probability (Alexandre et al., 2020; Alfaya et al., 2020), implying a need for genetic confirmation of the predator to avoid biased results (Monterroso et al., 2019; Morin et al., 2016). In the Iberian lynx case, it's feces may be mistaken with ones from wildcat or red fox (Palomares et al., 2002). However, due to the competitive exclusion exerted on this species by lynxes (Garrote & Pérez de Ayala, 2019; Sarmento et al., 2021), in areas with a high density of lynxes such as the ones being sampled, the probability of a scat collected not being from lynx is residual.

In previous scat collections done during monitoring activities, the success rate in field identification, confirmed through fecal DNA analysis, was almost 90%, (P. Sarmento, personal communication, November 2021), assuring a non-biased sampling even without genetic confirmation. When in doubt, the scat was discarded.

Each scat collect was stored in a polytene bag identified with a unique alphanumeric code. The GPS coordinates and date of sampling were recorded in a GPS Garmin device. The samples were then stored in a freezer (-20ºC) for preservation until further analysis (Alexandre et al., 2020; Bacon et al., 2011)

- ## Scat analysis

Prior to processing, the scats were thawed and dried in an oven at 90ºC for 24h, after which their dry weight was measured (0.01g precision). After weighing, each scat was submerged in water for at least 30 minutes to facilitate their disaggregation. Thereafter, the undigested components of the scats (e.g. hairs, bones, teeth, hooves, feathers) were separated through washing with running water, using a 0.5mm mesh sieve (Krofel et al., 2011). In scats with more than one prey item, a visual estimation of the relative volume of each item was done in order to deduce the dry weight of the components separately. The components with no nutritional value, either accidentally ingested (e.g. stone fragments, leaves) or consumed to purge the intestinal tract (e.g. *Gramineae*) were not accounted for the analysis (Ciucci et al., 1996).

Whenever possible, the identification of the prey items was done down to the species level. Mammals were identified mainly through guard hair analysis. The macroscopic characteristics of those hairs, such as the colour, shape, length, and thickness, were first compared with a reference collection of potential Iberian lynx prey hairs (Karanth & Sunquist, 1995). Subsequently, the recovered hairs were subjected to a microscopic analysis, to observe the structure of their cuticle, medulla and cortex. First, for each scat, about 20 guard hairs were taken and washed, following the procedures described in Valente et al. (2015), in order to remove the wax coating the hairs and any other debris that could impede the observation. Cuticle slides were prepared using the imprint principle: the hairs were placed upon a thin layer of clear nail polish and, after drying, were removed from the slide. That way, the shape of the cuticular scales was transferred to the nail polish and could be observed. To visualise the medulla of the hairs, the same hairs were cut into sections, suspended in a few drops of cedar oil and covered with a coverglass. While penetrating inside the hairs, the oil increases the contrast of the medulla cellules, highlighting their pattern. When the identification of prey species was not possible with the previous methods, the cortex was observed via cross sections, using a rubber electric cable and fishing line to fix the bundles of hair while sectioning in particular segments of the hairs (Valente et al., 2015). All of these characteristics were observed with an Olympus CX43 optic microscope (100x-400x) and compared with illustrated atlas (Barja Núñez et al., 2020; Teerink, 1991; Valente et al., 2015) and the observations of De Marinis & Asprea (2005), as well as with a reference hair collection. Bones, hooves and cell tissue fragments of mammals were identified by association with surrounding hairs (Corbett, 1989).

Due to the high degradation of birds' feathers in the scats, their identification through comparison with reference material or illustrated atlas was not possible. Hence, this group of prey

species was identified through next-generation gene sequencing, using the mitochondrial gene 12S as a marker, as it allows the study of sequence data from a large number of DNA molecules retrieved from the sample in a complex mix (Shehzad et al., 2012). During scat handling, the undigested remains from birds were stored in a plastic tube with alcohol at 96%, with a proportion of 1/3, and sent to the Centre for Molecular Analysis (CTM), where they were analysed. In some scats, this methodology was also used for identification of mammal prey species, when the microscopic identification of hairs was unsuccessful. When the species identification was not possible, food items were grouped (e.g. unidentified rodent, unidentified bird) or referred to a higher taxonomic level (e.g. Rodents, Galliformes).

- ## Data analysis

Identified prey were categorized into the following food items: rabbit, Iberian hare, red deer, fallow deer, wild boar, domestic ungulates, garden dormouse, wood mouse, rat (*Rattus sp.*), red fox, badger, domestic dogs, domestic/wild cat, birds. While carnivores were excluded from previous diet studies for this species (Delibes, 1980), as the consumption of these animals was not confirmed, they were included in the present study, since new evidence was reported of intraguild predation by the Iberian lynx (Nájera et al., 2019).

The composition of Iberian lynxes' diet was expressed using both qualitative and quantitative measures, i.e. frequency vs amount (Krofel et al., 2011), since determining only the frequency of certain food item tends to overestimate the role of small prey, as they produced more undigested matter per unit of mass consumed (Ciucci et al., 1996; Klare et al., 2011). Therefore, the frequency of occurrence per scat (FO) and the percentage of consumed biomass per prey were calculated. All these calculus did not include trace food items, that contributed < 5% of total volume of scat.

FO (%) was determined by calculating the proportion of number of scats containing a given food item:

$$FO(\%) = \frac{ni}{N} \times 100$$

Where: ni = number of scats containing a prey type;
N = total number of scats.

Consumed biomass was calculated using two different approaches. Firstly, the conversion factors of digestibility (**BIOc**) determined for Eurasian lynx by Rühe et al. (2007) were used, because according to the authors they may also be applied for Iberian lynx. For bird species, the factor provided by Sunde et al. (2000) was utilized. This conversion factors were defined during feeding trials and represent the conversion of fresh mass of prey eaten to dry mass of scat excreted. Because ungulates that are predated by Iberian lynx are almost exclusively fawns and juveniles, therefore having similar weights, and because these large prey species are expected to have the same coefficient of digestibility (Baker et al., 1993), the mean conversion factor for all these species was used in this study (see Krofel et al., 2011), with the exception of wild boar, that had a substantially lower coefficient of digestibility during the feeding trials. For other mammals that

were not included in the feeding trials, the conversion factor was calculated the using the regression equation provided by Rühe et al. (2007):

$$y = 15.06 + 1.330x$$

Where y = conversion factor for the consumed prey
x = average weigh (kg) of prey species identified in the scats.

Average body weights of the following prey species were estimated based on the literature (Argente et al., 2021; Bertolino et al., 2003; Calzada et al., 2003; McClune et al., 2015; Sarmento, 1996): European rabbit (1.10 kg), Iberian hare (2.30 kg), garden dormouse (0,0775 kg), domestic/wild cat (4.75 kg), European badger (8.44 kg).

All the conversion factors used for this study are presented in Table 1. **BIOc** was then obtained by multiplying the conversion factor (CF) of each prey item by their estimated dry weight in all the scats (kg).

Table 1: Conversion factors (CF) and prey item-specific quotients of digestion of different food items found in scat sample form Iberian lynx population.

Prey items	**CF**	**Prey item-specific quotient (kg/scat)**
Red deer	35.0	0.313
Fallow deer	35.0	
Wild boar	24.0	
Domestic ungulate	35.0	
European rabbit	16.5	0.318
Iberian hare	18.1	
Garden dormouse	15.2	0.027
Wood mouse	14.0	
Rat (*Rattus sp.*)	15.5	0.065
Red fox	23.0	—
European badger	26.3	
Domestic/Wild cat	21.4	
Birds	18.7	0.180

The other approach consisted of using the prey type-specific quotient of the eaten prey mass per scat, determined by Delibes (1980) for the Iberian lynx (**BIOq**) (Table 1). Due to small number of prey species tested in the feeding trial, the reliability of the results depends on the assumption that the conversion of biomass consumed to scats for one prey species is similar to other prey from the same taxonomic family (in the case of rodents) and order (for all other prey species). Since carnivores were not included in the feeding trial designed by the authors, the consumed biomass of these species wasn't assessed with this approach. For this calculus, the

number of scats that were produced through the consumption of the prey item was used (e.g. 110 scats produced with rabbit remains). For scats with more than one prey item, the relative portion of scat containing each item was used. This value was then multiplied by the respective category prey type-specific quotient in order to obtain the **BIOq** (Table 1):

The difference between the FO of each prey item in lynx's diet from each area was tested using a Fisher's exact test, with a significance level of 0.05, since the small FO of most food items didn't allow for an analysis through a χ^2-test. To enable a more precise statistical test, the different food items were grouped into five categories: lagomorphs (rabbits, Iberian hare and unknown lagomorph), ungulates (fallow deer, red deer, wild boar, domestic ungulates), rodents (garden dormouse, wood mouse, *Rattus sp.* and unknown rodent), carnivores (red fox, domestic/wild cat, badger and unknown carnivore) and birds. To assess if the predation upon ungulates was significantly different between areas, a χ^2-test (significance level of 0.05) was performed. Furthermore, the seasonal variance of lynx diet was calculated through a Fisher's exact test (significance level of 0.05). For that, the collected scats were separated into two seasons: Autumn/Winter (October-February) and Spring (March-June).

Social survey

• Data collection

During a period of 24 days between May 2022 and August 2022, semi-structured interviews were conducted, focused mainly on the municipality of Mértola, territory on which the lynx population is more stable and widespread, but also covering a small portion of lynx distribution area in the municipality of Serpa (Figure 4). The goal was to get a representative sample among key actors that are expected to be more impacted by the recent reintroduced population of Iberian lynx, specifically landowners from the stakeholder groups of livestock owners (**LO**) and hunting managers (**HM**) (Delibes-Mateos et al., 2022), and that had a social/professional position that could influence the local community as a whole (Lopes-Fernandes et al., 2018). As Lopes-Fernandes, (2018b) defined, they are "people with the interests and capacity for decision-making over the appropriate sub-areas for lynx reintroduction. These key actors are not necessarily representative of all locals but are particularly significant for conservation." (page 250). Therefore, a previous identification of possible interviewees was made, rather than a random selection. Livestock owners were selected from a list provided by the Guadiana Agricultural Cooperative CLR. Hunting managers were chosen from the group of hunting properties that harboured lynxes in their territory, whose contacts were facilitated by the ICNF. Some of the interviewee were designated thorough a "snowball" method (Bernard, 2018) indicated during the interviews.

The interviews were mostly in person at the landowner's property or in a nearby village. For two individuals, due to logistical incompatibilities, the interview was done through online video conference. Before starting the interview, a standardized overview of the study was presented to the interviewees, and only after they had given a formal verbal consent, the questions were asked. On average, each interview last for 1 hour and the answers provided were written down for posterior transcription and analysis.

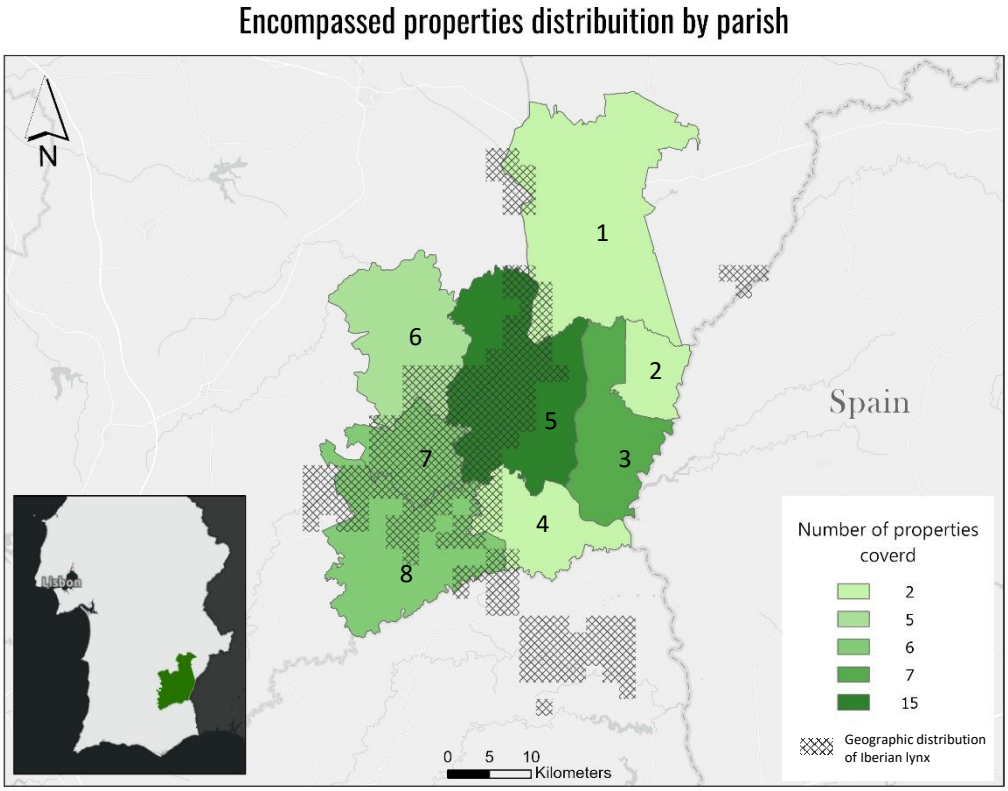

Figure 4: Distribution of interviewee's properties throughout the parishes included in the study area. Some landowners may use more than one property. The numbers represent different parishes: **1** - Serpa; **2** - Corte de Pinto; **3** - Santana de Cambas; **4** - Espírito Santo; **5** - Mértola; **6** - Alcaria Ruiva; **7** - São João dos Caldeireiros; **8** - São Miguel do Pinheirinho, São Sebastião dos Carros and São Pedro de Solis. Base map retrieved form Eris.

The questions employed in this social study were based on previous social surveys in Vale do Guadiana: the interview guide used in Lopes-Fernandes (2018b), the script used to interview livestock owners (Lopes-Fernandes, 2018a) and the script currently being used in Alcoutim and Vale Perditos area (LIF Lynxconnect, Centro em Rede de Investigação em Antropologia (CRIA)). Language and specific questions were adjusted to each social group. They consisted mainly of open-ended questions, with the inclusion of some closed-ended questions to allow a quantitative analysis of some variables of interest through a Linkert-scale. The guide contained questions that allowed the description of various variables: a characterization of the livestock practices (only used for **LO**); the previous experiences with depredation by wild predators; the personal experiences with lynxes; beliefs about lynxes; interviewee's tolerance of lynxes; and the most relevant opinions regarding local conservation agencies, in particular the PNVG/ICNF (not distinguishable in the resident's perspective).

• Data analysis

The answers obtained were first codified, using comprehensive nominal categories which could represent all the variability in the responses. These categories were then used to perform a descriptive analysis of the variables assessed and to compare them between individuals and social groups. Additionally, a quantitative analysis was preformed to further explore the variables, based

on the computation of four indexes: perceived predator impact, perception of local conservation agencies, attitudes towards lynx and basic knowledge about the species (see Table 2 and Table 3 for the questions codification of answers used). Predator impact was based on the level of significance for the interviewees of the described damages on livestock/game, using a four-item scale (Table 2). The opinions towards the PNVG/ICNF's actions in the region freely mentioned by interviewee were used as a measure for their attitudes regarding the agencies (Table 2). Those attitudes were retrieved from an open question, where interviewees were asked to enumerate positive and negative aspects of PNVG's actions in the region, which were then categorized and codified according to their direction (positive, neutral or negative). The final score was obtained through the sum of all the scores from mentioned aspects. Attitudes regarding lynxes were measured based on the interviewee's level of agreement with 9 belief statements about the species and their presence in the region (Table 2). The answers were gauged using a five-point Linkert scale and the score resulted from the arithmetic mean of the responses. Due to the way that some statements were constructed, they were reverse coded before scoring, so that the same direction were maintained throughout all the belief statements.

Table 2: Wording and codding used to assess the interviewee's perceived predator impact, perception of local conservation agencies and attitudes towards lynxes.

Question	***Answer category***
Perceived predator impact	
How do you classify those damages (from predators)?	No damages = 0 Not significant = 1 Harmful, but not important = 2 Significant = 3
Perception of local conservation agencies	
Thinking about the closest protected area (PNVG), please identify positive and negative aspects of their action, if important.	For each aspect: Positive aspect = +1 Neutral aspect = 0 Negative aspect = -1
Attitude towards lynxes	
The lynx can live freely in this region (PNVG and surroundings).	5-point Linkert scale where: 1=Strongly disagree and 5= Strongly agree
The lynx can live freely in Portugal.	
In the future, I would like for my grandchildren to see a lynx here on the field.	
It should be authorized killing lynxes in certain situations. [a]	
Lynxes should disappear from this region (PNVG and surroundings). [a]	
Lynxes should disappear from Portugal. [a]	
The lynx is an important species for nature's balance.	
The lynx is a species that should only exist in fenced areas. [a]	
I would like for lynxes to use the properties where I have my activities.	

[a] *Reversed code*

The local knowledge about lynx's biology was measured through 7 open-ended questions regarding aspects of the species biology and presence in the region (Table 3). Answers were categorized and evaluated as "correct" (2), "partially correct" (1) and "incorrect" or "don't know" (0). The knowledge index score was then calculated by adding all the questions' scores. This approach is limited, since the registered answers were conditioned to certain aspects of the lynx biology but was used to compare with scientific knowledge about the lynx.

For a statistical analysis, the correlation between the attitude index and each one of the other three indexes was assessed, using a Spearman's rank correlation coefficient. Additionally, it was explored the differences in attitudinal scores between individuals that reside in two distinct geographical areas: "East" and "West", that constituted each side of the study area divided by the Guadiana River. Since the most relevant confirmed lynx attacks on livestock (chickens) happened on the east side, and the deer predation by lynxes appears to be focused on the west territory, these different experiences that locals had with lynxes could exerted influence in their attitudes towards the species. These differences were tested using a Kruskal-Wallis H test, with a significant level of 0.05. Both of this analysis were carried out using RStudio software (Version 1.1.456).

Table 3: Wording and codding used to assess interviewee's knowledge about lynxes in comparison with scientific knowledge.

Question	Answer category
Knowledge about lynxes	
"Do you have an idea about what lynxes eat?"	Eats meat/Don't know = 0 Rabbits and other prey = 1 Rabbit specialist/Mainly rabbit = 2
"Do you know when did lynxes started to be reintroduced in Portugal?"	Other answers/Don't know = 0 At least 6 years = 1 In 2015 = 2
"How many cubs do they have?"	Other answers/Don't know = 0 Between 1 and 5 =1 Between 2 and 4 = 2
"When is their reproductive season?"	Other answers/Don't know = 0 January-March = 1 March-April = 2
"Do you think lynxes have influence over other predators?"	Other answers/Don't know = 0 Maybe = 1 Yes = 2
"Do you know the size of one lynx's territory?"	Other answers/Don't know = 0 More than 5 km2 =1 Around 10 km2 = 2
"Do you think lynxes had already existed in Portugal?"	Other answers/Don't know = 0 Maybe = 1 Yes = 2

Results

Diet composition

A total of 167 scats were collected throughout the study area, 58 belonging to lynxes from **HR**, 91 to lynxes from **HPB,** and 18 to lynxes from **HL** (Figure 5). Due to a lack of timely results of samples genetic sequencing, all bird remains were classified as "birds". The results, expressed in FO of prey remains in the scats, confirmed a diet mainly composed of rabbit in all the sub-areas, with a higher importance for lynxes of **HPB** and **HL** areas (84.6% and 88.9%, respectively), compared to the **HR** area (75,9%) (Figure 5). This importance may be slightly higher, as some lagomorphs remains that couldn't be identified to the species level were also present (**HR** = 1.7%; **HPB** = 4.4&; **HL** = 5.6%). Besides rabbit, the lynx nuclei of **HR** preyed mostly upon fallow deer (19.0%), followed by birds (8.9%) and wild boar (5.2%) (Figure 5). Other food items were found but had minor importance for lynxes' diet (< 5.0%), such as red deer, garden dormouse, red-legged partridge, *Rattus sp.*, domestic ungulate and red fox. For the lynx sub-population of **HPB**, there was no secondary prey that stood out, with the garden dormouse being the most consumed food item after the rabbit (5.5%), and the third most preyed item being birds (4.4%) (Figure 5). Wild boar, wood mouse, fallow deer, *Rattus sp.* and badger were also present in the scats from this area, with residual importance. Similarly, for the lynx sub-population of **HL**, all secondary prey had a small FO of 5.6% and were comprised of wild boar, domestic ungulate, garden dormouse and domestic/wild cat (Figure 5). Unknown carnivore remains were found in scats throughout all the study areas (**HR** = 3.4%; **HPB** = 2.2%; **HL** = 5.6%). The Fisher's exact test confirmed that the differences between the FO of prey in the three areas were significant ($p < 0.01$). χ^2-test analysis also revealed that the predation on ungulates was significantly different between areas ($\chi^2 = 15.635$, df = 2, $p < 0.01$).

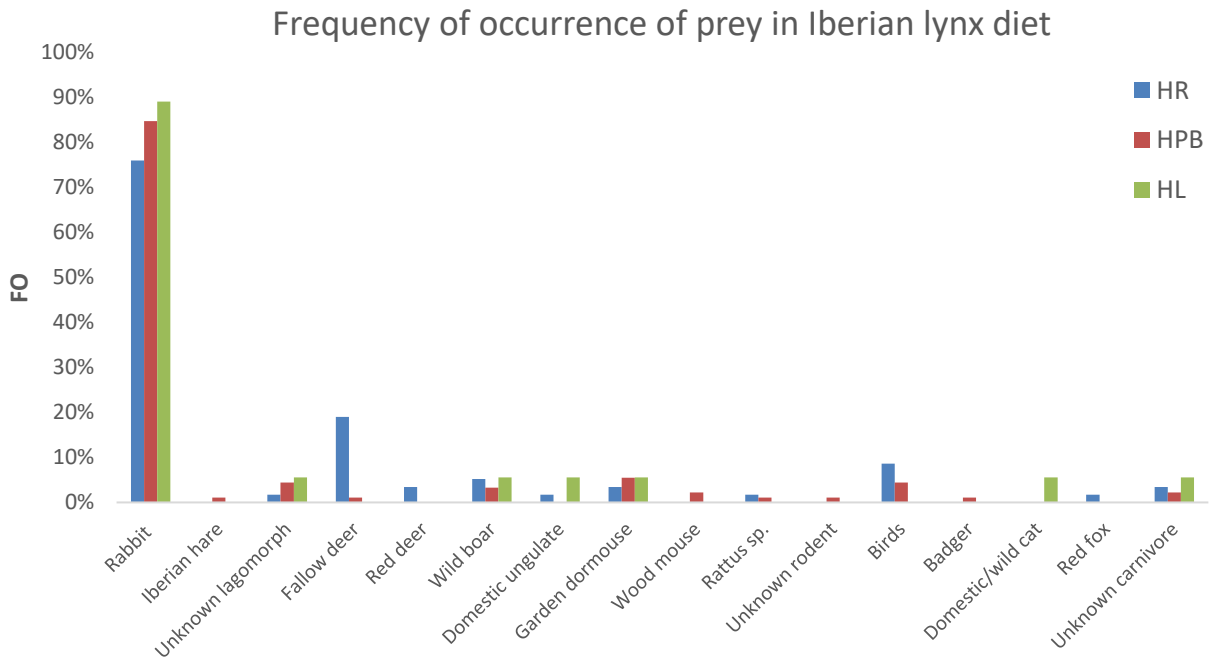

Figure 5: Composition of Iberian lynx diet expressed in frequency of occurrence (FO) in the three study areas: Romeiras (HR) – 58 samples; Portela Brava (HPB) – 93 samples; Lobata (HL) – 18 samples; ($\chi^2 = 15.635$, df = 2, $p < 0.01$).

When considering the consumed biomass, the two measurement approaches produced different results, with the **BIOq** showing a greater gap between the major contributor for lynx's diet in each area, i.e. the rabbit, and the remaining food items (Table 4). Since the weight of each scat collected for this study varies greatly ($\bar{x}$ = 8.39 ± 5.33 g), and because the **BIOq** calculus uses the number of scats produced by each food item instead of the total estimation of dry weight of those remains, this measurement was assumed to be unsuitable for a correct analysis of the consumed biomass of prey by lynxes with the current study sample. According to the **BIOc**, rabbit was the most consumed prey (**HR** – 59.1%; **HPB** – 94.4%; **HL** – 98.4%) (Figure 6, Table 4). In **HR**, the following most consumed food item was the fallow deer (20.0%), and in lower percentages the red deer (5.6%), and domestic cattle (5.5%) (Figure 6, Table 4). In **HPB** and **HL**, all the supplementary prey items were rarely eaten, never exceeding 5% of the biomass consumed by the sub-populations of lynxes (Table 4). Nevertheless, garden dormouse was the most consumed secondary prey in both areas (**HPB** – 1.6%; **HL** – 2.6%) (Figure 6, Table 4).

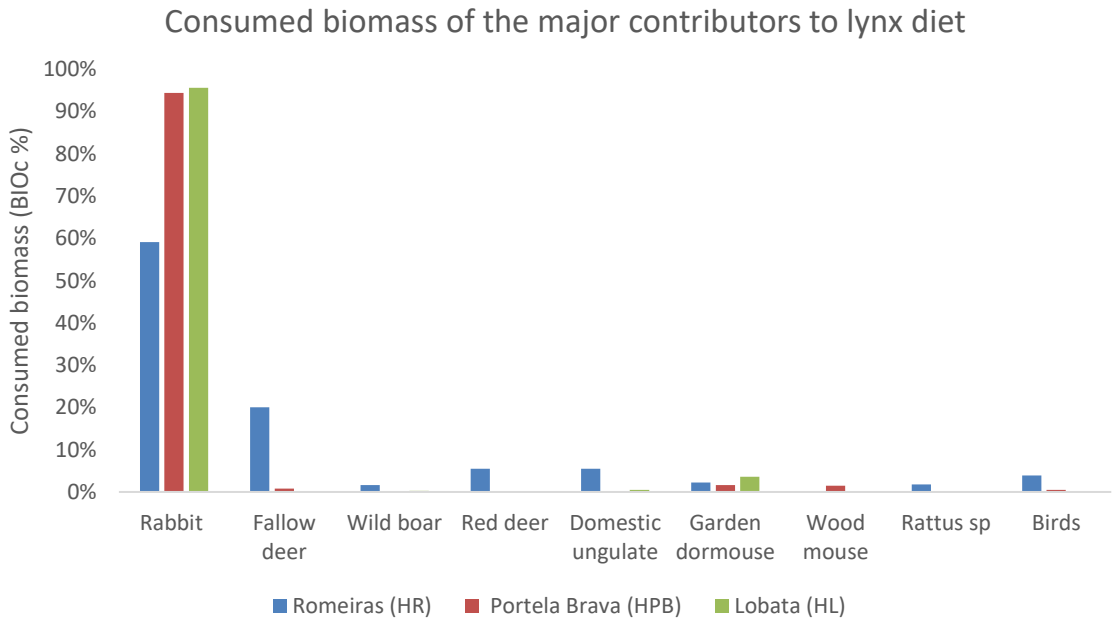

Figure 6: Percentage of biomass consumed (BIOc) from each of the relevant prey types (> 1 %) identified in Iberian lynx diet in each of the three study areas.

- ## Seasonal variation

Regarding seasonal variation of lynxes' diet (expressed in FO), rabbit remained the main prey in both seasons in all areas (Figure 7). However, there was a tendency for increasing in importance during Spring in both **HR** an **HPB** (Autumn/Winter: 73.5% and 81.7%; Spring: 79.2% and 90.3%, respectively). Ungulates showed an inverse tendency in **HR**, where the FO was higher during Autumn/Winter (35.3%) comparatively to during Spring (20.8%) (Figure 7). In **HPB**, the most pronounced change in FO for the supplementary prey occurred with rodents, that were more consumed during Autumn/Winter than Spring (13.3% and 3.2%, respectively) (Figure 7). For the **HL** area, rabbit appears to be more consumed during Autumn/Winter (100%) comparatively to Spring (84.6%). The secondary prey found in the scats from this area differ between season, as rodents only occurred in lynx's diet during Autumn/Winter (20.0%), were replaced by ungulates and carnivores (15.4%) during Spring (Figure 7). The Fisher's exact test revealed that the differences in the FO of prey items between seasons were not significant in every area (**HR**: p = 0.463; **HPB**: p = 0.552; **HL**: p = 0.375).

Table 4: Consumed biomass of prey fond in Iberian lynx scats throughout the three study areas, according to the BIOc and BIOq measurements. Values are expressed in kg of fresh mass of prey and in percentage of consumed biomass (inside parenthesis).

	Romeiras (HR)		*Portela Brava (HPB)*		*Lobata (HL)*	
Food items	**BIOc**	**BIOq**	**BIOc**	**BIOq**	**BIOc**	**BIOq**
Rabbit	4,959 (59,1%)	11,4639 (72,8%)	10,959 (94,4%)	24,041 (96,0%)	2,526 (95,6%)	4,802 (98,4%)
Iberian hare	0,000	0,000	0,114 (1,0%)	0,318 (1,3%)	0,000	0,000
Fallow deer	1,678 (20,0%)	2,69 (17,1%)	0,097 (0,8%)	0,313 (1,2%)	0,000	0,000
Red deer	0,466 (5,5%)	0,595 (4,8%)	0,000	0,000	0,000	0,000
Wild boar	0,135 (1,6%)	0,360 (2,3%)	0,024 (0,2%)	0,172 (0,7%)	0,007 (0,3%)	0,031 (0,6%)
Domestic ungulate	0,460 (5,5%)	0,297 (1,9%)	0,000	0,000	0,013 (0,5%)	0,031 (0,6%)
Garden dormouse	0,185 (2,2%)	0,046 (0,3%)	0,182 (1,6%)	0,111 (0,4%)	0,069 (3,6%)	0,014 (0,3%)
Wood mouse	0,000	0,000	0,177 (1,5%)	0,030 (0,1%)	0,000	0,000
Rattus sp.	0,150 (1,8%)	0,065 (0,4%)	0,001 (0,0%)	0,007 (0,0%)	0,000	0,000
Birds	0,329 (3,9%)	0,225 (1,4%)	0,057 (0,5%)	0,063 (0,3%)	0,000	0,000
Badger	0,000	-	0,004 (0,0%)	-	0,000	-
Domestic/wild cat	0,000	-	0,000	-	0,027 (1,0%)	-
Red fox	0,025 (0,3%)	-	0,000	-	0,000	-

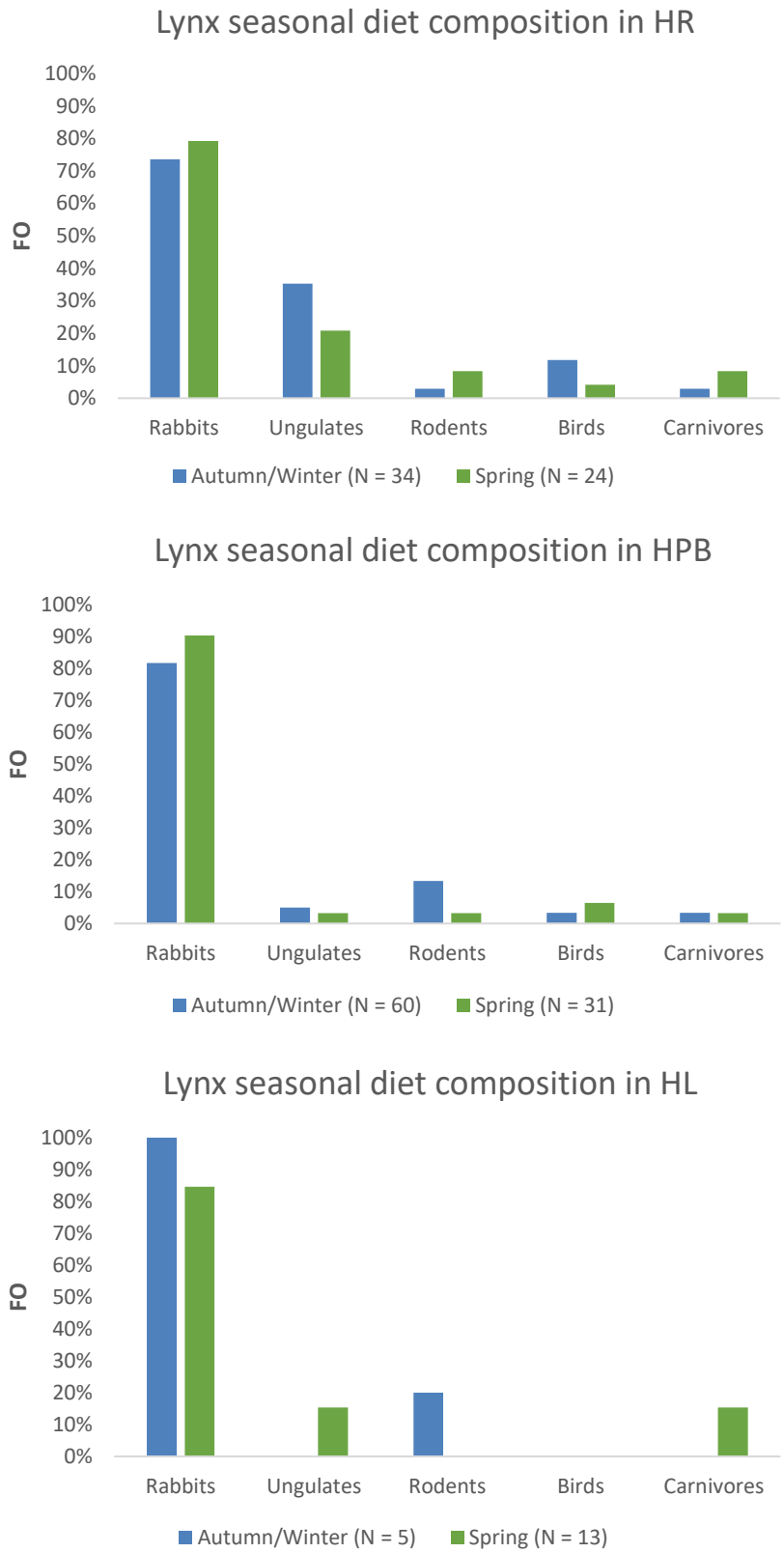

Figure 7: Composition of Iberian lynx diet, expressed in frequency of occurrence (FO), in HR (top), HPB (middle) and HL (bottom) between Autumn/Winter and Spring seasons.

Social survey

From a total of 36 interviews led during the study period, three were discarded due to the individuals not answering all the questions required for the analysis. The remaining 33 interviews were mostly centered on **LO** (n=26) since interview effort towards **HM** (n=7) was lower and this profile had less availability to be interviewed. Two interviewees were from both groups simultaneously, but their answers were pooled with the **LO**'s group to avoid data duplication. Most of the interviewed were male (except for three women), aged between 29 and 76. The properties where they developed their activities were distributed throughout all parishes covered in the study, displaying a greater concentration in the parish of Mértola, where lynx population is more stable (Figure 4).

• Characterization of livestock practices

All the interviewed **LO** followed an extensive practice, with their animals divided in smaller herds that graze in different subareas of the properties of their own or rented. In total, the interviewee manage 13894 sheeps, dispersed throughout 24623 ha of territory. Beyond sheeps, some of the owners had also other types of livestock, such as goats and cows, but present in residual number. The relative proportion of the number of sheeps owned and the area used for these livestock explorations is presented in the Figure 8A and B.

In general, the lands where herds are maintained were delimitated by simple fences, 1m to 1.30m high, which aren't predator proof. The protection against depredation by carnivores is mainly based on the confinement of the animals in or close to sheepfolds and the use of guard dogs (Figure 8C). Sheltering the sheeps was the most frequent adopted measure (n=21; 81%), in particular during lambing periods (varied between LO, often between December and March), when 62% of the LO said to keep the herd safe inside a sheepfold for a certain period, ranging from 2 days to 2 months, before releasing them again into the field (Figure 8D). Also, 8% of the interviewed said they store their herds in fenced areas close to the sheepfold in the same period (Figure 8D). Sheepfolds were also often used during the night (15%), when owners referred that their animals are more vulnerable to attacks. Two interviewee (8%) mentioned that they shelter the sheep every night. The use of dogs for conducting sheeps between pastures, specially from the Border Collie race, is common among the interviewed. Still, only 12 (46%) admitted having at least one guard dog with the herd permanently or during lambing period, when the animals are more vulnerable to predation (Figure 8C). For most cases, the dogs used were Rafeiros Alentejanos, a race of dogs traditionally used in the region to protect livestock and considered as "*a great help for the prevention of damage (by predators)*". Other protection measures were scarce; however predator control was pointed out by 58% sheep farmers as the best possible measure, but unpractical due to several technical and legal constrains: *"Box-traps don't catch old foxes, neither can we use them all year round. They (PNVG) only let us use them when it's harder to catch foxes."; "It's not easy. There is no time to do driving hunts and the box traps do not work well"; "I don't gain nothing by taking measures. I have been complaining with the Park (PNVG) but they don't authorize putting traps.".*

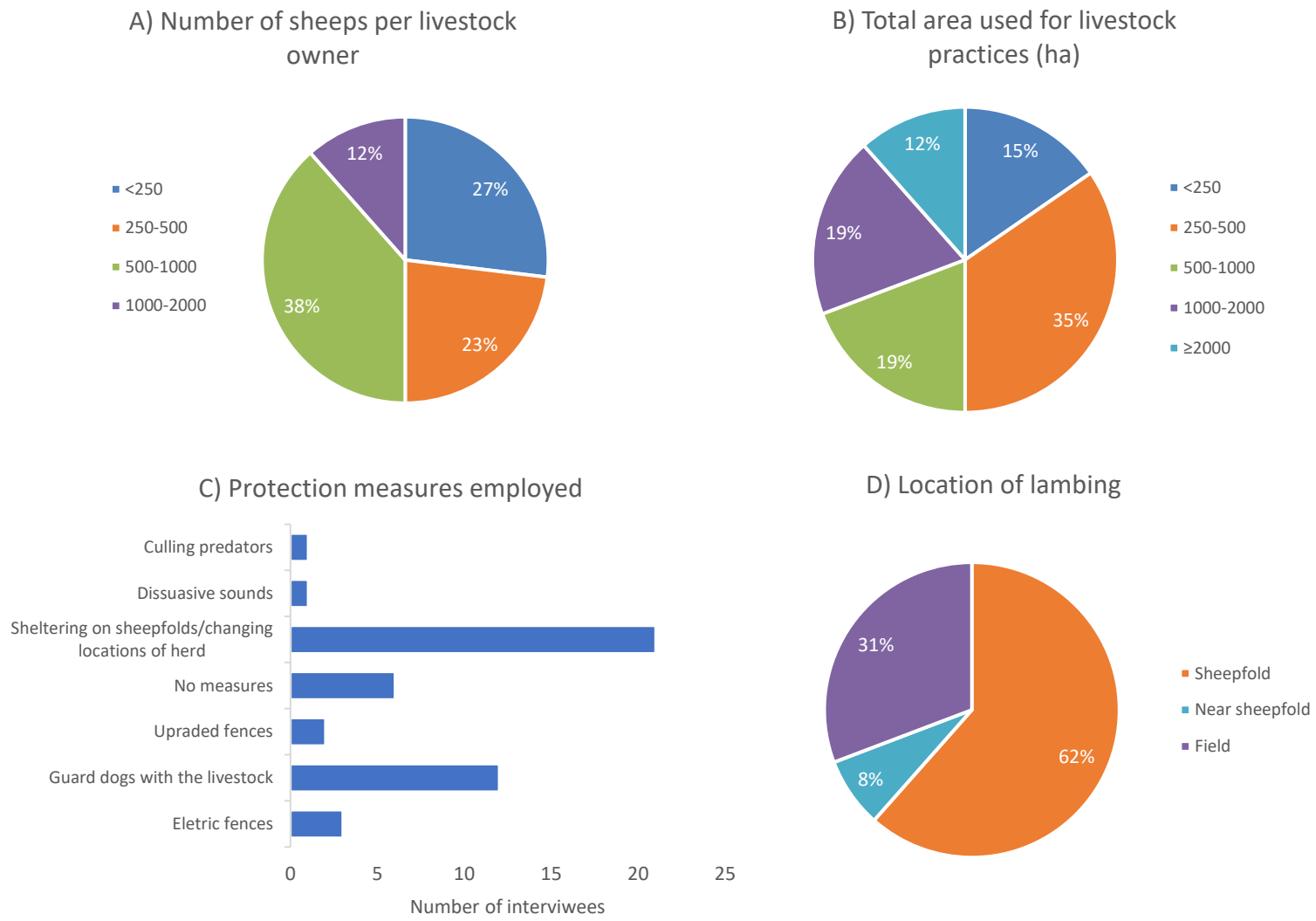

Figure 8: Characteristics of livestock practices in the study area based on the approach used in Lopes-Fernandes (2018a). A) Frequency of LO owning different sized sheep herds; B) Frequency of LO that dedicate a different total area to the livestock practice; C) Predator protection measures applied. Note that the total sum is superior to the number of LO because each individual may use more than one measure; D) Frequency of LO per location of lambing of their herds.

- ## Perceived Predator Impact

Almost all **LO** (92%) expressed to suffer annual losses of sheeps, mainly young lambs, to predators. There were two exceptions: one owner had only loss chickens and ducks and other didn't considered attacks by dogs as predator damages. Red foxes were pointed out the most as the cause of damages on the livestock (96%), followed by Egyptian mongooses (67%). Attacks by dogs had also happen at least once to the majority of the sheep farmers, but only 33% had experienced frequent attacks (Figure 9A). Although it was mentioned few times, it's important to highlight that two interviewees refer to Iberian lynx as a predator responsible for attacks on sheep. From their discourse, those interviewees showed to have experience in identifying predator damage. However, at the time of the interviews, no official report to local authorities of sheep predation by this species had been made.

In regard to the **HM**, the predator species mentioned as most problematic were different (Figure 9A). From the six individuals (86%) that described annual damages in game, all of them mentioned the lynx as a main contributor, while foxes were only mentioned by 83% of the interviewed and Egyptian mongoose by 67%. Instead of domestic dogs, domestic/feral cats were mentioned by the interviewed managers (50%). Those managers, however, described the damages created by this predator as very high: "*Domestic cats are the worse. They eat a lot of rabbits during the night; they kill everything, even if it is not for feeding*."

The perceived predator impact shown by the **LO** was high, represented by an average index score of 2.15, within a range of 0 to 3. As shown in Figure 9B, most sheep farmers considered that the livestock predation they endure is significant or harmful. The index score was slightly higher for **HM**, with a 2.23, as all the managers that had previously suffer damage from predators classifying those damages as harmful or significant (Figure 9B).

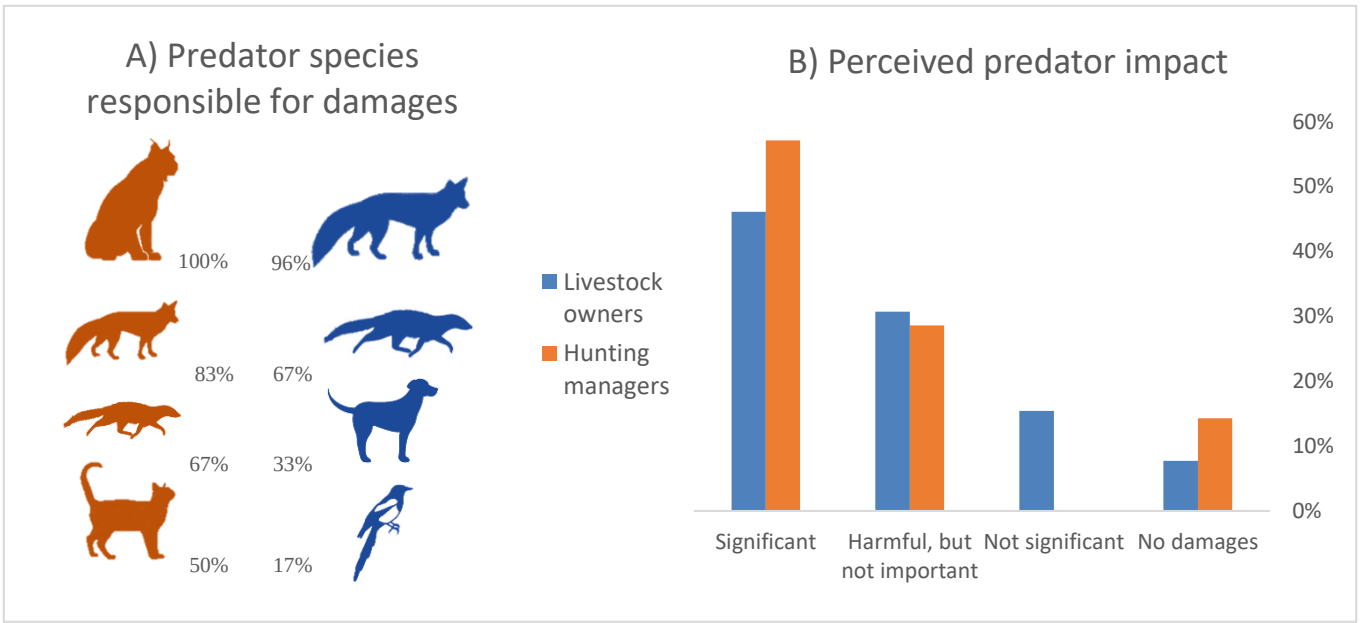

Figure 9: A) Frequency of mentions of the main predator species indicated as responsible for damages in livestock (blue) and hunting activities (orange) by interviewees. The percentage represented is in relation to the total of interviewees from each group that admitted suffering damages from predators; B) Frequency of interviewees included in each perceived predator impact index category.

- ## Knowledge about lynxes and reintroduction

The Iberian lynx has become a known species in the PNVG and surrounding areas, which has led to a more direct contact with the local population. All the **HM** and near 70% of all **LO** interviewed had already encounter this species in the wild at least once. This appears to have partially transpired to the general knowledge about this species' biology and reintroduction, as it is shown in the Figure 10.

In general, **HM**'s knowledge was closer to what is described in the literature (Figure 10). The lynxes' dietary habits were known by most interviewees from both groups (**LO** – 1.69; **HM** –2). Both groups also shared an almost total unfamiliarity with the species home range area (**LO** – 0.08; **HM** – 0). Yet, a substantial discrepancy was found between the interviewee's groups regarding the species super-predator effect, since contrarily to the **LO**, most of the **HM** had experienced this phenomenon directly (**LO** – 1.15; **HM** – 2). Similarly, more **HM** knew when the beginning of the lynx releases in the region took place (1.43), compared to **LO** (0.65). As a result, the average knowledge index, that ranged from 0 to 14, was moderately low for **LO**, with a score of 6.27, and moderately high for **HM**, with a score of 9.29.

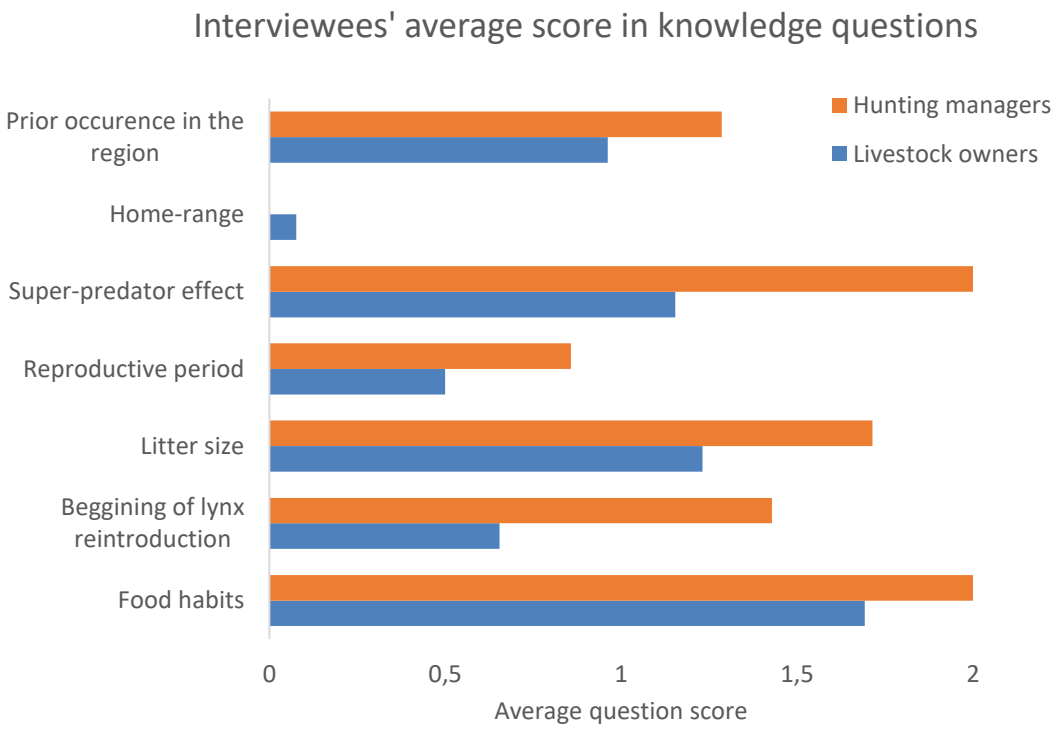

Figure 10: Average knowledge question score for each social group.

- ## Attitudes towards lynxes

The perceived risks associated with the presence of the Iberian lynx in their lands were widespread between the interviewees. The dependency of lynxes on rabbits concerned some of **HM** (43%), as they argue that, due to the competition with this predator, they have been

experiencing or believe that they will endure in a near future a lack of revenue through hunting, aggravated by the current sanitary crises in the rabbit population. The predation of livestock was already a major concern for **LO**, since the recounts of witnesses of such attacks on sheep are often spread within this profile, including the two interviewed in this study. Additionally, this species has been pointed as the responsible for attacks on coops in one village. Two of the interviewed **LO** also mentioned to witness lynxes killing some of their chickens and ducks. As a result, 81% of the interviewed **LO** believed that lynxes could cause damages to livestock, from which 15% said to be specifically to chickens. When asked, most sheep owners justified their risk perception on the lack of rabbits and on the exponential growth of the lynx's population. However, one individual referenced the predation on deer as an indication for potential attacks on sheeps.

In general, the interviewees freely mentioned more advantages than disadvantages regarding the presence of the Iberian Lynx in the region (Table 5). Yet, regarding **LO**, a substantial portion of interviewed (30%) didn't stated any advantages or didn't share their opinion. From the 6 categories of benefits pointed out by the interviewees, the most prevalent were the increase of tourism and regional valorization and the effect of natural control over other predators, more relevant for **LO** (35% and 30%) and **HM** (14% and 100%), respectively (Table 5). When referring to disadvantages, most of the **HM** (71%) didn't mention any disadvantages, while the same only occurred for 35% of **LO**. However, some managers did revert their concerns to the approach taken by PNVG/ICNF during the reintroduction process (Table 5). Both social groups presented different important disadvantages (Table 5), with the exception of the competition for rabbit (**LO** – 15%; **HM** – 14%). The most common concern revealed by **LO** was livestock predation, mentioned by 27% of the interviewee. Meanwhile, besides competition with rabbit, only deer predation was also mentioned as a disadvantage of lynx presence by **HM** (14%).

Interviewees also expressed their opinions regarding the persistence of the Iberian Lynx in the region, after almost decade of coexistence with the species. Most individuals believed that lynxes could continue to prosper in the region (**LO** - 88%; **HM** – 100%), with only three **LO** (12%) affirming that it would not be possible, or that they had doubts (Box 1).

Do you believe that lynxes can continue to live freely in this region?

- *"Yes, it helped to return some animals back to the fields, like partridges, and removed foxes, that only do harm."*
- *"Yes, because it's an impoverished place, a lot of land and enough rabbit."*
- *"No, because they (lynxes) will increase to much, due to not being controlled, and it will lead to the decrease of rabbit and the other prey. It will collapse because people take care of damages in their own way (killing)."*
- *"No, because it didn't bring, nor will It bring any benefits."*
- *"I have doubts if they can stay for many years. They are looking for food and here there's less and less."*

Box 1: Transcription of some of the interviewees' answers to the question "Do you believe that lynxes could continue to live in this region?". For this box, it was selected the discourses that expressed the opinions of interviewees that answered "Yes" or "No".

Table 5: Frequencies with which interviewees mentioned a specific advantage and disadvantage regarding Iberian lynx presence in the region.

	Citations	LO (n=26)	HM (n=7)
Advantages			
Tourism and regional valorization	"There are more visits, more interesting things happening"	35%	14%
Predator control	"In a place where before I had 30 foxes, now I just have 1."	30%	100%
Economic benefits	"(Lynxes) brough money to the community."	15%	0
Species preservation	"It's the only (big) feline we have."	12%	29%
Ecosystem balance	"It's a key species to the ecosystem, which is what is needed to maintain its balance"	8%	0
Aesthetical appreciation	"It's an interesting thing for people.", "They are beautiful to see."	8%	0
No disadvantages	"I don't know anyone that had problems with lynxes", "There are none. It's the authorities' approach that is wrong."	35%	71%
Disadvantages			
Competition for rabbit	"They (lynxes) eat the rabbit that we are supposed to hunt."	15%	14%
Social inequality	"There are some people (big landowners) that made money by putting lynxes"	8%	0
Less predator control, due to prohibition of snares	"We have to be more alert, because we can't use snares."	4%	0
Excessive attention, to the detriment of other aspects	"The media attention is too much. They only care about lynxes, ignoring everything else in the region, including people."	4%	0
Attacks on livestock	"It has made problems in coops."; "Livestock owners fear a little for their animals, due to the possible attacks of lynxes."	27%	0
Deer predation	"It became a fallow deer hunter."	0%	14%
No advantages	"Absolutely none"	15%	0
Neither advantages nor disadvantages	"It didn't bring any changes"	15%	0

Still, in majority for both groups of interviewees, the successful future maintenance of lynxes in the territory could only be possible if some conditions were to be meet. The most frequent conditions were the upkeep of the number of rabbits (**LO** - 15%; **HM** – 29%) and a limitation of lynxes' abundance in the region (**LO** - 15%; **HM** – 14%). One **LO** expressed an inability to remove lynxes from the region and that was the reason for their assumed future prevalence (Box 2).

Do you believe that lynxes could continue to live freely in this region?

- *"The lynx can live in the region as long as the habitat for rabbits is kept, so that they have food. If not, it would cause damages."*
- *"Yes, but there needs to be a control of their numbers. Because like this, they will disappear. While people with riches can support damages, poor people can't."*
- *"Yes, as long as it is sustained by the base of the food chain."*
- *"Yes, if we don't let them accumulate."*
- *"Yes, because if they (ICNF) put them here, now it's hard for them to disappear."*

Box 2: Transcription of some of the interviewees' answers to the question "Do you believe that lynxes could continue to live in this region?". For this box, it was selected the discourses that expressed the opinions of interviewees that answered "Yes, as long as there are rabbits", "Yes, as long as there aren't too many" and "Yes, it's inevitable ".

According to the Likert results, interviewee's attitudes towards the Iberian lynx were overall positive, moderately positive for **LO** and strongly positive for **HM**, with an average attitude index score of 3.94 and 4.44, respectively (ranging from 1 to 5). No single individual presented a negative attitudinal score (< 3), but clear differences between social groups can be deduced through the analysis to individual questions (Figure 11). Figure 11A, B and C represents the level of agreement of interviewees regarding the presence/disappearance of lynxes from areas of different spatial scale, from Portugal to the properties where they develop their activities. For **LO**, while no individual agreed to the statement that lynxes should disappear from Portugal, this value increased to 8% when referring to the region of Vale do Guadiana and to 23% of interviewed saying that they wouldn't like to have lynxes in their properties. For **HM**, this pattern was not present. This lower tolerance towards lynxes by **LO** can also be seen in Figure 11D, where 47% of sheep owners interviewed agreed to the legal culling of lynxes, compared to only 14% of **HM**.

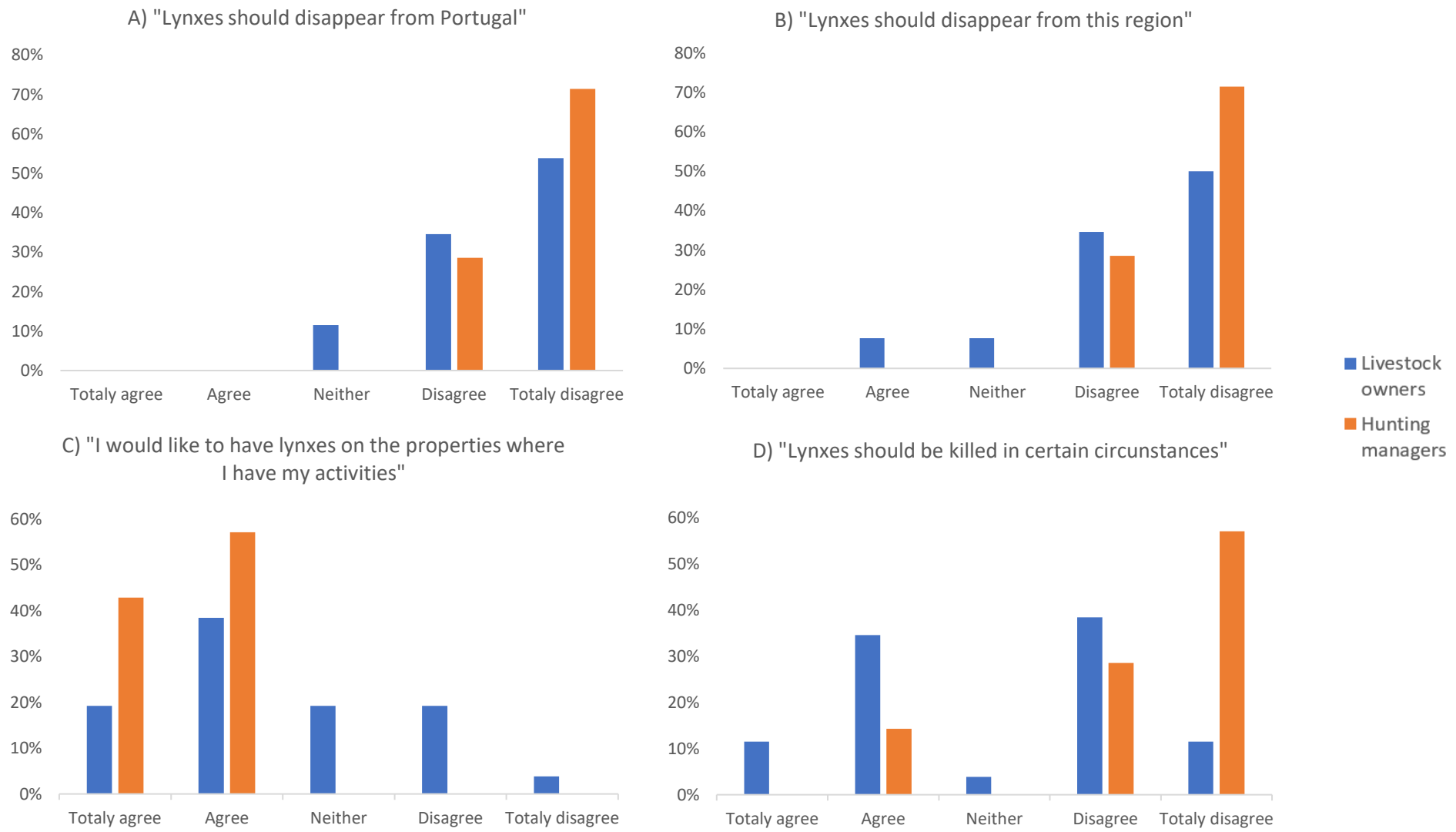

Figure 11: Interviewees level of agreement with some of the attitude statements regarding the Iberian lynx presented during the interviews (the full set of attitude statements are displayed on Table 2). The answers were expressed on a 5-point Linkert scale.

When comparing overall attitude index between geographic areas, I found no significant differences between the attitudes from East and West residents (H = 0.633, df =1, p = 0.426), despite most of the West individuals presenting a more positive score comparatively to the East residents (Figure 12).

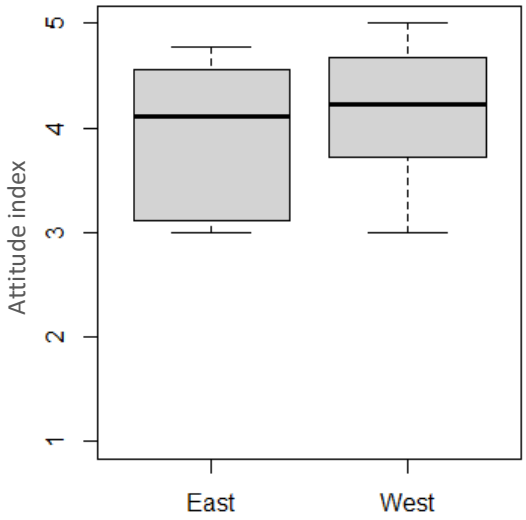

Figure 12: Attitude index scores of interviewees from the East (N=13) and West (N = 20) areas. The median scores were 4.11 for East and 4.22 for West.

- ## Opinions about conservation agencies

The perception about local conservation agencies index ranged from -4 to 4, as a reflection of all the opinions expressed by the interviewees. There was a contrasting general opinion of the PNVG/ICNF actions in the local territory between groups (Figure 13). **HM** perception was overall moderately positive, revealing an average score of 1.00. While this group had individuals which expressed the highly positive impressions towards the park and ICNF (43% with score ≥ 3), a considerable percentage had a neutral view, expressing as much negative opinions as positive (29% with score = 0). **LO** perception was more variable, but a majority (62%) had a critical view about the park and their conservation actions (score < 0), of which 27% conveyed a higher discontentment (score ≤ -3). With an average score of – 0.62, **LO** showed therefore a moderately negative perception of park actions.

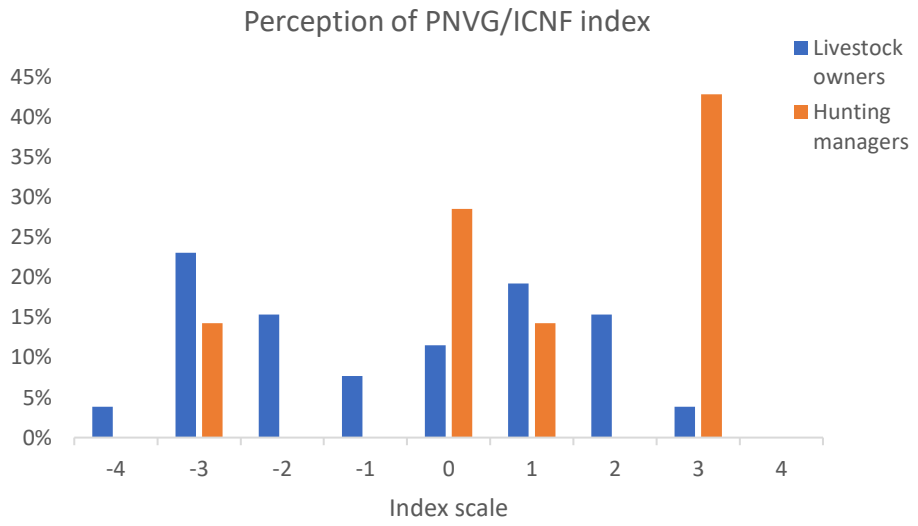

Figure 13: Frequency of interviewees included in each perception of PNVG/ICNF index score. Overall perception was slightly negative, with an average score of -0.27.

From the respondent's positive opinions about the PNVG, the good relations with the staff, as in the technicians and the nature rangers, was prominent (42%), as well as the belief that actions promoted by the park benefits the environment (21%) (Table 6). However, they were overshadowed, specialty for LO, by several complaints. The most mentioned was the overall poor management of the territory (30%), in which interviewees highlighted a perceived incompetence and lack of responsibility of the agency in the areas they oversee (Table 6). Interviewees also showed some dissatisfaction with the bureaucratic procedures that constitutes an obstacle to their activities (27%) and with the restrictions imposed due to the protection area classification (24%) (Table 6). PNVG staff were also criticised by some of the interviewees due to their apparent detachment and lack of communication with residents (24%) and because they are viewed as "strangers" that came into the territory to rule over them (12%).

- ## Index correlation

For this analysis, I used the overall average score of each index since the goal was to determine the potential influence of the measured variables in the individual attitudes. In the case of the perceived predator impact index, there was no clear correlation with interviewees' attitude (rho = -0.305; p = 0.08). However, both the knowledge about the species and the perception of conservation agencies index showed a significant positive correlation with the attitude index. With a rho = 0.539 ($p < 0.05$), there was a clear tendency for individuals with a higher biological knowledge about the lynx to have a more positive attitude towards the species. Nonetheless, the correlation between perception of conservation agencies and attitude was stronger (rho = 0.668; $p < 0.05$), revealing that residents with a more positive opinion about the PNVG/ICNF were more likely to show a more positive attitude towards lynxes.

Table 6: Summary of opinions expressed by the interviewees regarding PNVG/ICNF and their actions in the territory. The top lines (above the double line) represent the positive opinion categories, while the bottom lines (bellow the double line) the negative opinion categories. Occurrence is expressed in number of interviewees that had this type of opinion and the respective relative frequency. One interviewee may have more than one opinion and from the same category.

Opinions categories	Citations	Occurrence in discourses (N = 33)
Control poaching and surveillance	"The surveillance that the Park does on the terrain is important"; "It helped to avoid poaching"	3 (9%)
Positive relation with staff	"I like having them here"; "5 stars"	14 (42%)
Environmental protection and improvement	"They have some work towards the improvement of the ecosystem, as well of animals"	7 (21%)
Good territory management	"The forest workers help to clean roads"; "The Park management helps the territory"	4 (12%)
Economic aids	"They also give money to Park residents"; "The Natura 2000 and these measures for endangered species protection allows to collect subsidies"	4 (12%)
Good for tourism	"The lynx observation points and the interpretation centre that the Park developed are very positive"; "It made possible to do activities (of tourism) that outside of the Park can't be done"	2 (6%)
Employment	"It makes jobs"	1 (3%)
Lack of communication	"The relation with ICNF staff is good, but I would like for them to give a heads up when they come to my property" "They only care about me when they need something"; "There is a lot of information censorship until reaching the general public"	8 (24%)
They release wild predators	"They release foxes on the field, despite denying it"	4 (12%)
Are an obstacle for locals	"I wanted to construct (….), but with all the complications and bureaucracy required, I ended up giving up"	9 (27%)
Restrict our activities	"It blocked the regional development"; "It restricts the agricultural activities without any compensation"	8 (24%)
Employs mainly "outside people"	"Outside people come here to tell us how to run our territory"; "Park technicians are mainly not from here and they come to earn enormous pay checks. If 10 of those positions could stay to people from the region, it would create more jobs"	4 (12%)
Inequal relationship with landowners	"Don't help hunting grounds, only the richest landowners"	1 (3%)
Overall poor management and incompetence	"They don't have competence (…), protect only the species they were paid to do so"; "The Park doesn't take responsibility for damages that people suffer"	10 (30%)

Discussion

Wild ungulates as the next best meal

The Iberian lynx is considered a super specialist in terms of diet due to its inability to change its predominant consumption of rabbits to an alternative species (Ferrer & Negro, 2004). Most of the previous studies on the Spanish's lynx populations corroborated this classification (Beltrán & Delibes, 1991; Delibes, 1980; Gil-Sánchez et al., 1997; Gil-Sánchez et al., 2006; Palomares et al., 2001), finding that the FO of rabbits in lynx diet was high, regardless of season and abundance of rabbit. As the first diet study of the reintroduced lynx population in Portugal, while my results support the knowledge collected for the Spanish populations, revealing a minimum FO of rabbit of 75.9% in all the study area, they also showed a higher consumption of alternative prey, specifically fallow deer. In Romeiras (**HR**), wild ungulate remains were found in 27.6% of the scats throughout all study period (fallow deer = 19.0%; wild boar = 5.2%; red deer = 3.4%), and rabbits, despite being the most consumed prey with an FO of 75.9%, had a smaller contribution to the diet comparatively with the other two areas of this study. This is the highest record of wild ungulate consumption by Iberian lynx, as the previous highest value had been observed by Delibes (1980), where an average FO of 7.6% was registered during the same time period in the Biological Reserve of Doñana. The diet composition in **HPB** and **HL** showed a less balanced prey consumption, where rabbit was overrepresented (**HPB** = 84.6%; **HL** = 88.9%) and other food items were found in small proportions (< 6%). The results from these two areas were consistent with the majority of diet studies on the Spanish population of lynxes, although the rabbit FO in those studies was slightly higher: 88.3% (Delibes, 1980); 93.9% (Gil-Sánchez et al., 2006); 96.2% (Gil-Sánchez et al., 1997); 99.3% (Palomares et al., 2001). It's important to note that the very small number of collected samples in **HL** (n = 18), which could not be enough for a correct representation of the real composition of lynx diet in the area.

In terms of biomass consumption, the same pattern was visible, where rabbits were almost the only source of ingested biomass in **HPB** (**BIOc** = 94.4%; **BIOq** = 96.0%) and **HL** (**BIOc** = 95.6%; **BIOq** = 98.4%), while in **HR** it played a less important role (**BIOc** = 59.1%; **BIOq** = 72.8%). Delibes (1980) was the only other diet study that measured the biomass consumption by the Iberian lynx, using the **BIOq** method applied in present study. As pointed out previously, this method uses the relative proportions of scats containing a prey item instead of dry mass of the remains, which could result in a biased analysis of fresh mass of prey ingested, using the samples collected in this study. However, in a simple comparison between studies, the percentage of wild ungulate consumed in Doñana appears to be substantially lower (8.0%) than in **HR** (24.2%), while the inverse was observed for rabbits, whose consumption represented 80.4% of all biomass intake for the Spanish population. Cervids, such as the fallow deer, when killed, can fill the energy requirements of an individual lynx for several days. It has been reported events of one lynx feeding from 1 to 4 times from the same deer, consuming between 1 to 3 kg of meat in each meal (Beltran et al., 1985). Even without considering the different energy content of each prey type, this consumed biomass is higher than the one assumed to be the average intake of a free-living Iberian lynx, that for a male with an average body weight of 13kg corresponds to 962g/day (Delibes, 1980).

A higher consumption of alternative prey is a recurring event in different Iberian lynx populations. According to Palma (1980, as cited in Gil-Sánchez et al., 1997), the lynx population in Malcata, Portugal, which has since been extirpated, had a substantially high consumption of rodents and insectivores (FO = 39.5% and 21.0%, respectively). The veracity of this data is, however, dubious as it could be a result of wrong scat identification since, in the sampled area, wild cat densities were very high and no genetic confirmation of scats was obtained. Delibes et al. (1975) found similar results of rodent consumption (26.9%) throughout different mountain ranges in western Spain, and Alfaya et al. (2020) reported a particular case of small mammals replacing rabbits as the most consumed prey by lynxes, regarding a population in Madrid province. Consumption of birds species, such as red-legged partridges, were also reported to be substantial (13.0%) for the lynx population of Sierra Morena (Gil-Sánchez et al., 2006). Other studies revealed unusual feeding behaviour by lynxes, like the predation upon Red-necked Nightjar (*Caprimulgus ruficollis,* Temminck 1820) eggs (Sáez-Gómez et al., 2018) or domestic cat (Nájera et al., 2019). All of the mentioned studies attributed the change in lynx diet composition to a response to a decline in rabbit abundance. However, this behaviour response was not present in my study area, since rabbit abundance was similar in all surveyed areas, while alternative preys were mostly consumed in **HR**. Even though there was no data available for rabbit density during the study period, previous data shows that rabbit density is higher than the minimum necessary to support a breeding female territory (Palomares et al., 2001), with spring densities > 4 individuals/ha (Sarmento et al., 2019). Still, because there was no information regarding abundance of prey species besides ungulates, it's not possible to explain the observed differences in their consumption comparatively with the literature.

The differences between the predation on wild ungulates between areas could be a response to three factors, that may act synergistically. Firstly, there was a (i) higher abundance of wild ungulates in **HR** comparatively to the other two areas, becoming, therefore, more available for lynxes. Additionally, the more levelled terrain of **HR** allows for ungulates to be more accessible to lynx predation than in the more steep and rocky terrains of **HPB** and **HL** areas. Similarly, Beltrán & Delibes (1991) found that the emergence of greylag goose (*Anser anser,* L. 1758) as an important alternative prey in lynx diet in Doñana was due to a threefold increase of their abundance in the area, combined with the an increase of their accessibility, since in response to an extended drought season, gooses were seen more often using the pastures near water, where lynxes liked to hunt.

(ii) The higher vulnerability of the cervids populations in **HR** could also be important for the observed differences, since it's the only sampled site where big game is a main focus of the hunting practice (excluding wild boar, that is hunted throughout the study area). This translates in an increasing number of injured/dead deer that may be left behind by hunters and become available for lynxes. According to Beltran et al. (1985), there is no preference in the individual physical condition of deer killed by the Iberian lynx. Still, despite this might be true for fawns and young deer, the predation upon adult cervids may depend heavily on weaker individuals, as it was showed for the Iberian lynx's sister species, the Eurasian lynx (Okarma, 1984). Delibes (1980) found the vulnerability to be the main reason for mallards' predation by lynxes during the mating season, when they tend to use more dry land and produce more noise through their vigorous mating calls. Moreover, there were sightings of lynxes consuming cervid carrion in **HR** during the study period,

after the prey died most likely due to a hunting event. Although it isn't common, Aldama & Delibes (1991) had previously reported a similar occurrence of consumption of a wild boar carcass. Since the scat analysis only reveal what lynxes ate and not necessarily the prey they killed (Ciucci et al., 1996), the carrion feeding behaviour could lead to an overrepresentation of wild ungulates in the diet of **HR** area. The vulnerability of lynx' prey may have been further exacerbated by an extreme drought that happened during the study period. Similar events had been observed before in Doñana, where ungulates and other prey became more vulnerable and even died of starvation, becoming easily available for consumption by lynxes (Beltrán & Delibes, 1991; Delibes, 1980).

Finally, the different food behaviour in **HR** may be a consequence of (iii) the method used for lynx reintroduction, since most of the individuals that occur in this area were reintroduced by soft-release, spending a considerate amount of time in an acclimatization enclosure inside the property, or are descendants of individuals that were reintroduced with this method. During the months of acclimatization to the new site, lynxes were exposed to a large number of wild ungulates grazing around the enclosure, which may have triggered a recognition of ungulates as a good and available food source. Young (1997) described that providing live prey to zoo-captive predators will develop food recognition and foraging skills, which was confirmed in the case of mustelids (Reading et al., 2013) and big felines (Williams et al., 1996). However, the data collected in this study is inappropriate to draw any conclusions, as the identity of the individuals that produced the analysed scats were not assessed.

The preference for fallow deer in detriment to other ungulates was also observed by Beltran et al. (1985) and Delibes (1980), that reported a proportion between red deer and fallow deer found in lynxes' scats of 1 : 2.66, in an area where fallow deer were less abundant. Beltran et al. (1985) considered that the different size, rutting season and habitat use between species could explain this pattern. The Iberian lynx is one of the smallest felid from the *Lynx* genus, and thus the size of their prey could be an important factor for selection. The smaller fallow deer would be easily killed by a single lynx, while the generally bigger red deer would be more difficult to capture. The rutting season of cervids corresponds to a period of weaker parental care, as the fawns, which are generally preferred by lynxes, are left behind hidden and become more vulnerable to predators (Lent, 1974). This period occurs later for fallow deer (October) than for red deer (August-September), and coincides with the period when rabbit availability is at its minimum (Palomares et al., 2001), when consequently lynxes have to look for alternative prey (Delibes, 1980). Finally, the fallow deer is a more accessible species, as it tends to use more open spaces in between ecotones (Apollonio et al., 1998), which are preferred by lynxes for ambushing prey (Beltran et al., 1985), while the red deer are seen using shrublands (Alves et al., 2014). Comparing the proportion of consumption of these cervids in the **HR** area, where predation on wild ungulates was significant, with the proportion obtained in Beltran et al. (1985) and Delibes (1980), the selection of fallow deer by lynxes from Vale do Guadiana appears to be more evident. This may be because of the higher abundancy of fallow deer comparatively to red deer in my study area, as opposed to what occurred in Doñana (Beltran et al., 1985), resulting in a higher availability of this prey for lynxes. However the small sample size for the present study and the fact that the sampling period doesn't cover all seasons must be taken in consideration.

Predation upon young wild boar piglets was previously reported in Doñana (Valverde, 1963, as cited in Delibes, 1980), but to my knowledge, there is no information on the species importance to the diet of Iberian lynx. The low consumption of wild boar, consistent throughout my study area, despite their high abundance, may be related to different parental care strategies. Contrarily to cervids, that hide their litter when foraging or matting, wild boar young's follow their progenitors (Fisher et al., 2002; Lent, 1974). This behaviour leads to a higher risk of confrontation and injury for lynxes while foraging for piglets, which may result in a more pronounced avoidance of this food item (see Mukherjee & Heithaus, 2013).

Similarly, this is the first study in Portugal that evidenced the consumption of domestic ungulates by Iberian lynx, although in small proportions, occurring only in two scats, one form **HR** and the other from **HL**. Predation on domestic ungulates was already reported in Sierra Morena (Garrote et al., 2013) and Córdoba (Simón et al., 2012), with low number of attacks as well. Due to the small number of scats containing this food category, it was not possible to deduce the seasonality of predation events. However, Garrote et al. (2013) observed a preferred selection for young lambs during lambing period. Since the extensive livestock activity is a common practice in Vale do Guadiana, with a considerate number of flocks with large amounts of animals grazing in the region (see Figure 8A and B), the predation on domestic ungulates is expected to increase as lynxes expand to areas where livestock practices are more intense (Garrote et al., 2013).

In my study, the seasonal diet variation was not significant. However, for **HR** and **HPB** areas, rabbit intake showed a clear tendency to be higher during Spring comparatively to during Autumn/Winter, while the main supplementary prey consumption in those areas differed inversely between seasons. This could be a response to the population dynamics of rabbits, that creates a > 3x difference in abundance between the density maximum (April/June) and minimum (December-January) (Delibes, 1980; Palomares et al., 2001). This suggests that the alternative prey (**HR**: ungulates and birds; **HPB**: rodents) were being selected when rabbit availability diminishes. The findings of Delibes (1980) support this possibility, as it was observed an increase on ungulates predation in Autumn/Winter, due not only to the scarcity of rabbits but also because of the higher vulnerability of fawns during matting season of adults (September/October). However, my results showed a slight increase as well on the consumption of other supplementary prey during the Spring (**HR**: rodents and carnivores; **HPB**: birds). Likewise, Delibes (1980) reported an intensive predation on ducks during spring, mainly because of an increased vulnerability of the population when matting in dry land; and Gil-Sánchez et al. (2006) showed a similar variation for red-legged partridges. Therefore, the seasonal variations in lynx's diet seems to be a response to rabbit availability and vulnerability of alternative prey. The results from **HL** presented an overly gross evaluation of lynx diet seasonality because of an extremely low number of scats for Autumn/Winter, and as thus no conclusion could be drawn.

Acceptance of lynx

The results from this social study revealed overall positive attitudes towards the Iberian lynx by local key actors, while showing differences between stronger positive attitudes of **HM** (score = 4.44) and the more moderate positive attitudes displayed by **LO** (score = 3.94). Nonetheless,

almost every individual interviewed believed that lynxes could continue to live freely in Vale do Guadiana. These results are aligned with data obtained previously in the same area by Lopes-Fernandes (2018a), which indicated that livestock owners showed a less positive position regarding the presence of lynxes than other social groups. Similarly, farmers appear to represent the negative end of the attitudinal spectrum (or least positive) for other large carnivores, such as the wolf (Bath & Buchanan, 1989), leopard cat (Best & Pei, 2020) and the Eurasian lynx (Bath et al., 2008). As it is evidenced in the answers given in present study, hunting managers, despite generally thought to be negative towards large carnivores, sometimes can be strongly supportive of their expansion and conservation. Williams et al. (2002) and Bath et al. (2008) found the same pattern regarding wolves and Eurasian lynxes, respectively. Moreover, Delibes-Mateos et al. (2022) revealed that the hunters' support for Iberian lynx reintroduction in Southern Spain was consistently high throughout several years of coexistence. This evidence, however, contradicts the contestation of hunters found in Vale do Guadiana before the release of lynxes was initiated (Lopes-Fernandes et al., 2018). Although it's difficult to assess a change in attitudes since the hunting managers sample was very restricted in the present study (see Majicá & Bath, 2010), the different context in which the interviews were done may provide a possible explanation on the differences between both studies (Arbieu et al., 2019; Dickman, 2010). Lopes-Fernandes et al. (2018) found a general atmosphere of impasse between administration and hunting managers and landowners, during the same time as the announcement of the decision to reintroduce lynx was made public, mainly due to the hunter's perception of lynxes as competitors for rabbits. The sense of ownership that hunters felt towards rabbits, as they claimed to be responsible for the upkeep of rabbit in the region due to their investment on increasing the species density, resulted in an increase of contestation for lynx's reintroduction (Lopes-Fernandes & Frazão-Moreira, 2017). In the present study, the concern for the depletion of rabbit due to lynx predation was also significant, however, the more positive attitudes that hunting managers displayed could be explained in light of the current reintroduction process context, after seven years of experiencing living with lynx, observing his effect on other carnivores, knowing about several project agreements and benefits established with the administration. Delibes-Mateos et al. (2022) also concludes for the Spanish case, not noticing major negative impacts of lynx reintroduction.

- ## Benefit/risk perception of lynx presence

The interviewed' attitudes towards lynx appear to be predicted by the perceived benefits and risks of lynx presence, with **HM** demarking less disadvantages and more benefits compared to **LO** (Table 5). This link between benefits/risk and attitude is common in large carnivore conservation settings (Delibes-Mateos et al., 2022; Glikman et al., 2012; Hiroyasu et al., 2019; Inskip et al., 2016). A majority of **HM** (71%) only recognized the benefits of lynx's presence, and all of the interviewed **HM** mentioned predator control as an important advantage, compared to its lower incidence in **LO**'s discourse (30%). This ecosystem service provided by lynxes was previously not relevant for local stakeholders (7%; Lopes-Fernandes et al., 2018) nor for **LO** specifically (11%; Lopes-Fernandes, 2018a) in the same region. Several studies have pointed out the impact of this super predator effect of large carnivores, i.e. the competitive exclusion of smaller carnivores by bigger predators, in the recovery of prey by reducing predation (Elmhagen et al., 2010; Suraci et al., 2016). The same effect

has been observed as well for the Iberian lynx (Jiménez et al., 2019; Palomares et al., 1996). In the context of Vale do Guadiana region, where the impacts of mesocarnivores (red fox and Egyptian mongoose) in livestock and game are extremely significant for the interviewees (Figure 9), the restoration of this ecological function can bring broad socio-economic benefits, through mitigation of direct damages to livestock and hunting practices and by removing the necessity of predator control (Jiménez et al., 2019; Sarmento et al., 2021). The observed change in residents perception of this benefit, particularly for **HM**, may have influenced their attitudes towards lynxes (Jiménez et al., 2019). Wildlife tourism and regional valorization were also mentioned by many interviewees (**LO** = 35%; **HM** = 14%), similarly to what was observed before (Lopes-Fernandes, 2018a; Lopes-Fernandes et al., 2018). This reflects not only a sense of pride of having an endangered species that confers distinctiveness to the territory, but also the perspective of economic development to be gained with lynx presence (Lopes-Fernandes et al., 2018; Rode et al., 2021). Caruso & Pérez (2013) reported that the high support of jaguar reintroduction in Corrientes, Argentina could be explained by the connection of this species with the cultural roots of local community and by the economic development of the province through eco-tourism, in which jaguars are a main attraction. In fact, several studies point out the influence of social and cultural values as well as predator tourism exerts on attitudes (e.g. Ainsworth et al., 2016; Álvares et al., 2011; Arts et al., 2012; Ohrens et al., 2021).

Regarding concerns and risk perception of lynx presence, the position of both social groups appears to be inverted. Less than half of the interviewed **HM** (43%) expressed apprehension towards lynx due to their perceived competition for rabbits, of which only one (14%) referred as an important disadvantage. This proportion is similar to what was found for the Doñana lynx population (Delibes-Mateos et al., 2022). Meanwhile, 27% of **LO** mentioned livestock predation as an important set back of lynx presence, out of 81% of **LO** that admitted to the possibility. Despite it being a low proportion compared to other large carnivores (e.g. Inskip et al., 2016), this is still important reason for concern, since there still exist an historic lack of information about livestock attacks by Iberian lynx (Garrote et al., 2013). Comparatively, Lopes-Fernandes et al. (2018) in the same area and the same approach revealed that attacks on livestock were only mentioned by 6% of all the key actors interviewed regarding lynx reintroduction in Portugal in 2014, and later Lopes-Fernandes (2018a) found that only 43% of **LO** interviewed in Vale do Guadiana believed that lynxes could damage their explorations. The perceived impact of predators, especially regarding livestock predation, is often the main factor that determines the scale of the human-wildlife conflict (Inskip & Zimmermann, 2009), as it is evidenced that can influence the affective component of attitudes (Glikman et al., 2012).

All **HM** and 70% of **LO** recounted at least once having encounter a free-ranging lynx, and all **HM** mentioned lynxes as an important predator of game in their hunting grounds. Additionally, the absence of statistical differences between interviewees' attitudes from both geographic areas (East and West; Figure 12) may indicate that the direct experiences with lynxes could have a week influence over the interviewee's attitudes, since most of the so far known livestock attacks (chickens) by lynxes occurred on the East area. It's likely that attitudes are strongly influenced by indirect experiences in this study area. This could also explain why 15% of **LO** mentioned the competition for rabbit to be an important disadvantage of lynx presence despite not being affected

directly. Arbieu et al. (2019) found that indirect exposure to wolf depredation (i.e. stories, accounts from people directly involved) had a stronger influence on respondents' attitudes than direct experiences. Since most of the interviewees had previously heard about the attacks on chickens that had occurred on the East area, it's possible that the story had already spread across all the region. Still, a distinction between interviewees' positive and negative direct experiences with lynxes was not made during the interviews. Relating different types of direct experiences with attitudes could be an important correction made in following surveys, as it could provide deeper analysis on the type of experiences and their influence over the attitudes.

However, this relation between direct experiences and attitudes might not be the same in both groups. When analysing the answers of interviewees to the questions that served as the basis for the attitude score, it was found that while the **LO** group was against the extirpation of the Iberian lynx from Portugal, their acceptance of the presence of lynxes decreased the closer they perceived them from their properties and animals. The same pattern was not perceptible for **HM**. This phenomenon is called NIMBY (Not In My Back Yard) and its reflected in attitudes towards various large carnivores, where predators are tolerated and accepted by people as long as they aren't too close (Lopes-Fernandes & Frazão-Moreira, 2017; von Essen & Allen, 2020; Yirga et al., 2021; Zimmermann et al., 2001). The different response of **LO** and **HM** may also be explained by their emotional attachment to the animals they manage (higher for **LO**) instead of financial losses (higher for **HM**). In this sense, Vittersø et al. (1998) found a direct relation between strong attachment with livestock and negative attitudes towards large predators. These results confirmed the predictions of Lopes-Fernandes et al. (2018a) regarding **LO** attitudes, that the more frequent attribution of livestock attacks to lynxes (even though no official record by administration was found), has resulted in a tendency for a higher perceived risk and low tolerance towards lynx amongst this social group. In other perspective, it seems there was a clear improvement in the protection of livestock compared to what was confirmed in 2016-2018 (more sheep farmers having the lambing period of their herds inside the sheepfold and a more general use of guard dogs; Lopes-Fernandes, 2018a). This difference could however result from the sample from the present study having covered **LO** with higher resources. As it was observed by Miller et al. (2016), when people experience attacks on livestock, they express a higher interest in changing their protection measures. This reality can be used by conservation agencies to work directly with affected or fearful **LO** to improve the effectiveness of protection measures and thus mitigating the conflict-generating negative attitudes. While no specific measure has been confirmed as effective in long-term mitigation of conflict between the Iberian lynx and farmers, in an extensive practice context, as it is common in Vale do Guadiana, the use of guard dogs is proven successful for the deterrence of other large carnivores (e.g. Soofi et al., 2022) and electric fences has shown some positive results for lynx attack dissuasion (Garrote et al., 2015).

- ## Different predator, different problem

Some of the interviewees, when asked to describe the Iberian lynx, referred to them as "just another predator", as thus implying that lynxes are perceived the same way as the other predators in the region, that tend to do damages to hunting and livestock activities. However, the general discourse observed in the interviewees contradicts this felling, since it was not found a

correlation between the perceived predator impact and attitudes towards lynxes. In other words, interviewees appear to distinguish the impacts of different predator species. Numerous studies on large carnivore attitudes confirms this observation, finding that attitudes were negatively affected by the magnitude of damages caused by the species (Augugliaro et al., 2020) and by their unappealing aesthetic (van der Meer & Dullemont, 2021). This explains why in my sample, especially for **LO**, Egyptian mongooses trigger the harshest negative feelings, even more than for red foxes, the predator that attacks livestock more frequently in the area (Figure 9A):

"Mongooses ruin everything, whether it being game, sheeps or lambs."
"The Egyptian mongooses are a terrible creature." "They are a plague."

Furthermore, there is some evidence that species specific behaviour influences local perceptions of this species, through the nature and frequency of the interactions (Kleiven et al., 2004; Lescureux & Linnell, 2010; Lopes-Fernandes et al., 2022). Similarly in this study area, domestic/feral cats are seen as a major predator for game by only 50% of **HM**, but their attacks are viewed as disproportionate because they "*hunt even without being hungry*", "*kill everything but not to eat*". Meanwhile, lynxes, besides being aesthetically pleasing (mentioned by 8% of **LO**) and not being yet associated to a high livestock predation, they are identified as a potential territory emblem of conservation (Delibes-Mateos et al., 2022; Lopes-Fernandes & Frazão-Moreira, 2016), resulting in their segregation from views on other predators in the region. However, the increasing perception of lynxes as a predator capable of killing larger prey like fallow deer may result in a newly source of fear for **LO**, as it was pointed out by one of the interviewees: "*If a lynx can kill deer, it can also kill my lambs*".

- ## The role of knowledge

The collected data revealed a positive relation between scientific knowledge of lynxes and interviewee's attitudes. This is commonly found in several studies regarding attitudes towards carnivores (Augugliaro et al., 2020; Ericsson & Heberlein, 2003; Glikman et al., 2012; Lescureux et al., 2011; Van Der Meer & Dullemont, 2021). Contrarily to this data, Lopes-Fernandes et al. (2018) argued that the association between opinions about lynx conservation and knowledge was not mandatory in the same region, as some of the variables of knowledge assessed showed no correlation with attitudes. It's important to note that this first study in the area was done previously to lynx reintroduction so local residents' knowledge of lynxes could be assumed as lower. In a similar situation with bears in California, Hiroyasu et al., (2019) found that in an environment of low knowledge about the predator, attitudes were more influenced by more general factors, like value orientations. It can be hypothesized that the increasing familiarity with lynxes by residents in Vale do Guadiana during the 7 years since the beginning of the reintroduction may have built the knowledge role of moderating the relationship between beliefs and feelings (Glikman et al., 2012). In this context, it was found during the interviews a higher knowledge about lynxes' super predator effect compared to the results from Lopes-Fernandes (2018a) and Lopes-Fernandes et al. (2018). This may be linked to an increase of local actors experiencing and referring to predator control as one of the main advantages of lynx presence in the territory.

- ## Dissonant opinions regarding PNVG

From the three variable measured, the local perception of conservation agencies (PNVG/ICNF) was the one that explained better the interviewees' attitudes towards lynxes, confirming the argument that conflicts between conservation and human activities are an important part of human-wildlife conflicts (Redpath et al., 2015). Interviewees generally gave more criticism than positive opinions, especially in the case of **LO** (Figure 13; Table 6). Most criticism pointed out the restrictions and obstacles of living inside a protected area (51%), highlighting the felling of an imposed model of nature conservation in which residents feel disempowered over the land use of their own properties (Lopes-Fernandes et al., 2018). Some did also mentioned the employment of people from Lisbon and other big cities as the problem of the PNVG (12%), supporting the previous arguments of a sense of social disempowerment to central political and urban authorities. This can generate animosity between residents that is then reflected in their attitudes towards large carnivores, similar to what Kleiven et al. (2004) observed in Norway, where a felling of lack of personal control to an external locus was negatively associated with wolf and bear acceptance.

Moreover, interviewees perceived an overall incompetence in the management of the PNVG (30%), referring an inadequate problem solving and lack of accountability for the damages that people suffer, saying that "*is important to match economic activity and the environment*". This can be seen as a somewhat lack of confidence in the capacity of the PNVG to manage the territory, in which the lynx reintroduction program is included, since as Siegrist et al. (2003) points out, confidence is based on a history of successful past experiences that lead individuals to believe that future events will go as expected. Watkins et al. (2021) found that confidence in the managing agency can play a key role in reducing risk perceptions and gathering long-term support for wildlife reintroductions, playing the larger role towards the local support of the reintroduction of elk in Tennessee, USA.

An important opinion mentioned by some of the interviewees was the lack of communication with staff (24%), particularly regarding their unannounced presence in their properties during monitoring activities and the lack of transparency. These individuals described a sense of alienation of what was being done in their terrains, which may have prompted an attitude of opposition (Lautenschlager & Bowyer, 1985). Interestingly, the positive relation with staff was also the main positive opinion of interviewees regarding PNVG (42%), which reflects the potential of a close communication with certain technicians and other staff to create a positive perception of residents towards the park. A participatory conservation strategy is a crucial tool to shape the residents' attitudes towards endangered species, though a dialogue in order to collectively agree upon goals that bring befits to every party involved (Htay et al., 2022; Sandström et al., 2015). The observed differences between perception scores of each stakeholder group may be related to dissimilarities in this relationship with wildlife managers, that was substantially better for **HM**. In fact, the reintroduction process was developed taking in consideration the concerns and agreements with **HM**, while practical measures where not directed at **LO**. More recently, an effort of improvement of coops that were under attack by one lynx was made, but was not mentioned by

interviewees, meaning that it could had been perceived as insufficient and more measures should be discussed and proposed for this profile.

Final considerations

This study aimed to help the current efforts of Iberian lynx conservation by complementing some of the research gaps in the Portuguese population, namely the lynx' diet and local stakeholders' perception of this predator. It was found a distinct feeding behaviour of a population nucleus in Romeiras (**HR**), where wild ungulates were the main alternative prey, representing the higher consumption of this prey type ever registered for the Iberian lynx, particularly during the Autumn/Winter. This was also the first confirmed case of consumption of domestic ungulates by Iberian lynxes. Contrarily to what has been described regarding the consumption of supplementary prey by this felid, rabbit abundance appears to not be an influential variable of this behaviour. Instead, it was hypothesized that lynx consumption on wild ungulates may happen due to a higher abundance, vulnerability and/or due to a specialization of some individuals as a result of a long period of acclimatization exposed to an abundant deer population, although the available data didn´t allow for the confirmation of any of these hypotheses. These results reflects the need of a continuous monitoring of the food consumption of lynxes from this population nucleus, while obtaining a more complete dataset regarding abundance of prey. Moreover, the biomass conversion factors specified for Iberian lynx are flawed, derived from a single feeding test that occurred more than 40 years ago and carried out with conditions that don't correspond to what is currently known for the feeding behaviour of the species, such as not accounting for necrophagy and the revisiting of a previously eaten carcass. In order to assess the real impact of lynx predation on ungulates and other prey, it's imperative that a more complete assessment of feeding behaviour is carried out in order to attain a more exact measurement of the consumed biomass.

The possibility of the diet composition of Iberian lynx being a consequence of the acclimatization of individuals to the new environment is an important factor to consider, since it could affect the subsequent reintroductions of lynxes in other areas. The use of a locally abundant alternative prey like wild ungulates may be an important step towards Iberian lynx conservation due to the continuous decline in rabbits' abundance throughout the Iberia Peninsula. Thus, further studies are necessary to identify which individuals have been attacking deer and if there is a filial relation with the soft-released lynxes, through the study of population genetics. The use of genetic methodologies should also be applied for analysis of scats containing domestic ungulate remains, to determine if the depredation is done by the same problem animal(s) (Linnell et al., 1999), or a widespread behaviour within the population.

The social survey that was preformed allowed for a new assessment of current attitudes and opinions of local livestock owners (**LO**) and hunting managers (**HM**) regarding Iberian lynx presence. It was found that, similarly to previous studies in the region and in Spanish territory, both of these social profiles expressed positive attitudes towards lynx, with **HM** presenting more positive attitudes than **LO**. Interviewees' attitudes were positively related to their knowledge about the species and their opinions about PNVG/ICNF. In this study, the social-economical aspects of the individuals were not taken into consideration. However, since the study area was characterized by

a history of social inequalities (Lopes-Fernandes et al., 2018), this could be an important variable to test in further monitoring of local attitudes. While this information is important on its own, the chosen approach and the semi-structured interviewed employed were adequate to the social context and allowed for a more detailed analysis of the position taken by interviewees. The awareness of the benefits regarding lynx presence, specifically the super predator effect, is still poorly disseminated, being more common knowledge for **HM**. In the midst of a social environment where people tend to objectify nature and wild species are considered resources for exploitation (Lopes-Fernandes et al., 2018), the divulgation of these benefits throughout all residents that reside inside the geographic distribution of lynxes can help to increase their tolerance. Although this information is already accessible through educational campaigns, a more frequent direct interaction with the population should be considered. In fact, the lack of communication was already one of the main critics pointed out towards the staff of PNVG. Despite other concerns, such as the management of the territory and restrictions on activities being mentioned as important by a larger percentage of individuals, the communication can build the fundamentals of trust and confidence that can shape attitudes towards the protected species as well help to mitigate other conflicts of interest.

Finally, the results of both studies can also be interpreted together. The high predation on wild ungulates observed in **HR** didn't seem to affect the resident's perception of lynxes, mainly because few people in the study area were dedicated to the exploration of big game. However, the awareness of these attacks may result in an increase of **LO**'s fear of attacks to their sheep and lambs. While the presence of domestic ungulates in diet of lynxes cannot provide a confirmation of attacks, since it could stem from the consumption of carrion, it highlights the high probability of these attacks occurring. It is therefore important to continuously monitor the livestock breeders' occurrences and practices. There is a crucial need for PNVG to allocate more efforts towards planning a strategy for mitigation of conflicts, whether in preventive measures of attacks or in compensatory measures, before more negative attitudes towards lynx start to become entrenched and difficult to reverse.

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