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RESEARCH ARTICLE

The demographic collapse of hunting in the Iberian Peninsula

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Abstract

1. Hunting is one of the oldest and most relevant extractive activities performed by humans in nature. Over the last century hunting has experienced profound changes in developed countries, shifting from a consumption to a recreational activity and declining in some countries. However, substantial quantitative information on these trends at large temporal scales, as well as the projection of the number of hunters and their demographic structure under future scenarios is lacking at regional scales.
2. Here we (i) describe the current demography of hunters in a large portion of the Iberian Peninsula, (ii) quantify population and recruitment trends for the last five decades and (iii) starting from those trends, we project the number and structure of hunters for the following decades.
3. At present, the studied hunting population, with nearly 600,000 hunters, is strongly ageing, with the most abundant cohort being that between 61 and 70 years, and its prevalence is eight times higher on the smallest towns than in the large cities. Over the last 15 years hunters have declined by 26%, while over the last 50 years it has declined by 45%. This trend is linked to a steady decline of recruitment of young hunters that has been overall reduced by 89% in the last 50 years.
4. By 2050, if following average trends observed during the last five decades, hunters in the whole study area are expected to decrease by 70%, and the proportion of hunters aged over 60 will increase from 40% to 61%.
5. Overall, our results indicate an ongoing collapse of the population of hunters in the Iberian Peninsula due to lack of recruitment, which began at least five decades ago. This collapse, together with other post-rural abandonment processes (e.g. livestock and wood-collection) is likely having a deep impact on wildlife populations and ecosystems, which is largely understudied. In this new post-abandonment state, approaches to environmental management should be adapted to accommodate these ongoing, long-term socio-ecological shifts.

KEYWORDS
hunting, human–wildlife conflicts, population control, abandonment, social–ecological systems, wildlife management, rural-to-urban transition

1 | INTRODUCTION

The practice of hunting has been inherent to humans throughout our existence. While traditional hunting activities responded to the provision of food and materials (e.g. furs, bones, horns, etc.), the provision of these goods has recently become secondary in many high-income countries and hunting has become more valued as a recreational and cultural activity and as a common management tool for wildlife population control (Brown et al., 2000; Fischer, Sandström, et al., 2013; Heffelfinger et al., 2013; McCorquodale, 1997). Despite motivations behind this activity have shifted over time, hunting has shaped ecosystem functioning for millennia as a top-down regulator of trophic structure (Duncan et al., 2002; Ellis et al., 2021). At first glance, hunting directly alters the abundance of both prey species (Abernethy et al., 2013; Linnell & Zachos, 2010; McCulloch et al., 1992) and competitors such as wild predators (Breitenmoser, 1998; Prugh et al., 2009) which had led to the extirpation of entire functional groups from large areas of the world (Benítez-López et al., 2017; Ripple et al., 2014). Hunting has also ecological consequences that go beyond direct effects on the abundance and population structure of game species. These effects include those resulting from changes in the structure of communities of both game and non-game species, in the form of trophic cascades (Dorresteijn et al., 2015), the behavioural alterations such as those associated to landscapes of fear (Ciuti et al., 2012) or the introduction of non-native species and the restocking of populations (Carpio et al., 2017; Laikre et al., 2010). Hunting is in any case also claimed as a tool to prevent agricultural damage, car accidents and species overpopulation (Conover, 2001). Thus, changes in hunting may have complex ecological responses with controversial social consequences that should be addressed under a socio-ecological perspective.

Over the past decades, many developed countries have experienced a large-scale migration of rural population to urban areas (ESPON, 2017). In parallel, technological development and intensification of means of production have changed the way people perceive and interact with nature (Buijs et al., 2009; De Groot & van den Born, 2003). As a result, traditional socio-ecological systems are experiencing large-scale regression in vast rural areas of developed countries. These abandonment processes are increasingly being studied from an ecological perspective (Daskalova & Kamp, 2023; MacDonald et al., 2000; Queiroz et al., 2014). Hunting can be seen as a fundamental dimension of these traditional subsistence systems (Nóbrega Alves et al., 2018), but the extent and consequences of their regression on this activity remain largely unstudied. As a remnant of a subsistence activity, recreational hunting currently involves a sociocultural framework among participants that is associated with a strong rurality component (Fischer, Kereži, et al., 2013; Heberlein et al., 2002) and a shared collective consciousness (Caro et al., 2017; von Essen et al., 2019). Therefore, in the current context of alternative leisure activities (Robison & Ridenour, 2012), the practice of hunting today largely depends on the recruitment and retention of participants through social mechanisms and awareness-raising efforts (Hansson-Forman et al., 2020; Ryan & Shaw, 2011).

Existing studies addressing the evolution of hunting activity have mainly focused on total hunters' population size (e.g. Boxall et al., 2001; Winkler & Warnke, 2013) and the sociocultural components of hunting (e.g. Larson et al., 2014; von Essen et al., 2019). These works describe heterogeneous trends in the total number of hunters among European countries, with a stable or even negative trend at continental scale (Massei et al., 2015). Conversely, a more widespread negative trend has been observed for decades in North America where is also reported that recruitment of new young hunters is decreasing (National Survey of Fishing, Hunting, and Wildlife-Related Recreation [FHWAR], 2016). Changes in the hunting population beyond its size (i.e. age structure, recruitment, participation) as well as predictions on the trajectories of hunters for the next decades are understudied or only roughly described for most of the existing case studies.

In Europe, the Iberian Peninsula can be a paradigmatic example of the evolution of hunting due to the importance of the activity and the drastic demographic and social changes undergone in the last decades. Rural population of Portugal and Spain has declined sharply over the last century. In particular, the proportion of the population living in rural areas in Portugal and Spain has dropped from 69% and 48% in 1950, respectively, to around 20% at the present time in both countries (United Nations, Department of Economic and Social Affairs, Population Division, 2018). As a result, a gap in environmental and ecological attitudes, sensitivities and interests has emerged between urban and rural populations (Berenguer et al., 2005). The consequences of these processes for hunting may be remarkable considering that south-western Europe (i.e. France, Italy, Portugal and Spain) concentrates the highest number of hunters on the continent. In fact, after France, Spain was the second European country in terms of number of hunters in 2007, with 980,000 hunters and together with Portugal they accounted for a total of 1,210,000 hunters (FACE, 2007). Moreover, these countries see hunting as an economic resource, which in the case of Spain, the Spanish Hunting Federation has estimated in more than 3600 million euros annually (Garrido, 2012).

Here, we aim to describe changes in the demography of hunters from the Iberian Peninsula over the last five decades. Specifically, we (1) assess the current demographic structure of hunters, including age structure, stable age distribution and distribution by municipality size, (2) estimate past recruitment trends and population size over last five decades and (3) make projections of the number and structure of hunters for the coming decades, based on the trends observed in recent decades.

2 | METHODS

Data on the age of hunters by municipality for the years 2005, 2010, 2015 and 2020 were obtained from national and regional agencies for continental Portugal (POR) and six Spanish regions, respectively: Andalusia (AND), Aragon (ARA), Castille-La Mancha (CLM), Madrid (MAD), Murcia (MUR) and Navarre (NAV). These regions were those for which the data required were provided by the regional and national agencies and for which the spatial and temporal resolution was adequate for the analyses. Together, these regions represent 57.70% of the current population of the Iberian Peninsula and 58.80% of its total area (Figure 1).

Age data were used to classify hunters into age cohorts of 5 years (ARA, MAD, NAV, MUR and CLM) and 10 years (POR and AND), depending on the resolution of these data for each region. From this cohort-based demographic data, we analysed total number of hunters, changes in the age structure and changes in recruitment for each region between the given years. A global analysis for all the regions was performed using a common 10-year cohort classification. In addition, we calculated municipal hunting participation rates in relation to the population size of the municipality (i.e. the percentage of hunters in the total population of a given municipality) and test for differences in participation between predefined municipality-size categories using the Kruskal–Wallis test and a post hoc analysis using the Dunn's test.

For the regions studied in our work, in many cases there were no digitalized data of hunting licences prior to the last two decades. Therefore, in order to analyse historical recruitment trends before 2005, we inferred them by means of a back-calculation approach. Data from MUR had to be reconstructed also for years 2005 and 2010 due to incomplete information for those years in the received data. Starting from the data on the age of hunters in 2005, 2010, 2015 and 2020, we obtained the age-structured distribution in terms of total number of hunters and participation (i.e. ratio between the number of hunters in a given age cohort divided by the total population in the same cohort). This participation metric was later used to assess the trend in hunter recruitment, using the participation of the youngest cohort (i.e. the ratio of the number of hunters in the youngest age cohort divided by the total population of that cohort). From the number of hunters in each cohort, we calculated the transition rates (i.e. survival rates) between successive cohorts and for the different transition periods (i.e. 2005–2010, 2010–2015 and 2015–2020). The average transition rate for each cohort across the three periods was used to obtain the stable age distribution of the population of hunters (see Appendix S1). This stable age distribution represents the theoretical age distribution of the hunters under constant recruitment and survival (Keyfitz & Caswell, 2005). Transition rates between cohorts were also used to estimate recruitment rates on the different time periods. Here, we assumed that the number of hunters on a given cohort for the present time, is the result of the accumulated transition rates on the original recruited population. We considered recruitment cohort as the group of 19–23 years old for regions with 5-year resolution and of ≤20 for those with 10-year resolution. This approach allowed us to reconstruct the evolution of past recruitment up to the 1970s, and to calculate the rate of change in recruitment using two metric during the last five decades: the total number of new hunters and the participation in hunting of the youngest cohort. In addition, from past recruitment estimation, we reconstructed past hunting population size following transition rates from the stable age distribution. A validation analysis of inferred

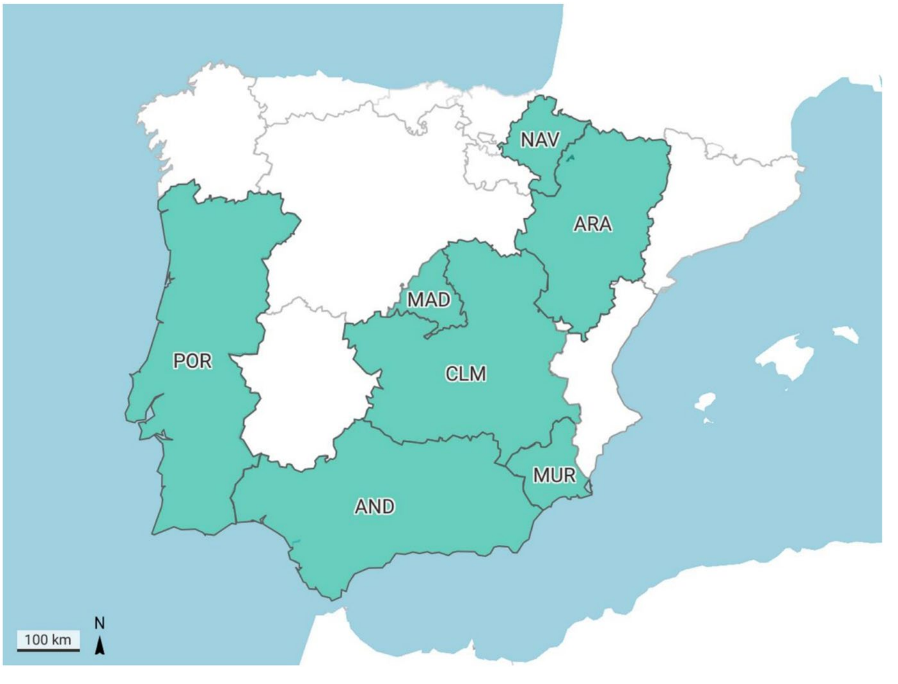

FIGURE 1 Map of the regions studied. The data analysed cover the whole of continental Portugal (POR) and six Spanish regions: Andalusia (AND), Aragon (ARA), Castille-La Mancha (CLM), Madrid (MAD), Murcia (MUR) and Navarre (NAV).

past recruitment was performed to assess the appropriateness of our approach (Appendix S2). These analyses were carried out both separately for each of the regions and for all the regions surveyed pooled together as a whole dataset.

The evolution of the hunting population was projected for the next three decades up to 2050 in order to predict possible future scenarios for the age structure and abundance of hunters. Projections were carried out by means of a stochastic demographic model (Bansaye & Méléard, 2015). In this model, recruitment rates were randomly selected from a distribution following the observed mean and standard deviation observed for the last 50 years, since recruitment rates showed no significant trend for this period (linear regression $p > 0.05$ for all regions). Transition rates between cohorts were kept constant following the stable age distribution (see Appendix S1). Similarly, stochastic models were performed both for each region separately and for the entire population pooled together. Results shown are the average of 200 random iterations, as the minimum sample size for a 95% confidence interval was of 113 iterations, given the normal distribution and standard deviation of our data (Desu & Raghavarao, 1990).

3 | RESULTS

3.1 | Current hunting population

The total number of hunters in all the regions studied in the Iberian Peninsula in 2020 was 583,575, with the largest ones such as POR, AND and CLM contributing the most. The most abundant age cohort was of hunters aged between 61 and 70 years (23%) while the less abundant was that of aged ≤20 years (0.92%). Hunters older than 60 years represent 41% of the hunting population whereas those younger than 40 years were 18%. The obtained stable age distribution of the hunting population shows that hunters are added until 40 years old (see Appendix S1). Starting from this age, the number of hunters start to decline with a steeper hunting abandonment starting at 65 years old. Under this stable age structure, if recruitment is constant the most abundant hunting cohort should be that of 21–30 years old. Stable age distributions show some differences between regions. While CLM and tend to reach their maximum abundance in younger age cohorts, ARA, NAV, POR and MUR show a more aged stable distribution.

At present, hunting participation rate for the whole study area (i.e. ratio between total hunters divided by the total population) is 2.20%, ranging from 2.82% in NAV to less than 1% in MUR. The current age-structured participation shows a widespread ageing of hunters with minimum participation rates found in the youngest cohorts: 0.20% participation among those aged ≤20 and 0.74% among those aged 21–30. Conversely, maximum participation rate is found among those aged 61–70, with 3.57% participation. This lower participation of the youngest cohorts (i.e. ≤30 years) holds across the different regions (Figure 2), with rates below 2% in all cases. Similarly, participation rates are higher for those aged between 50 and 80 in all regions, with an average of up to 17 times the rate of the youngest cohort (Figure 2).

Analysis of hunter data in each municipality showed a clear relationship between hunting participation and municipality population size (Figure 3). Municipalities with less than 100 inhabitants presented an average participation rate of around 8% and those between 100 and 1000 inhabitants of around 6.50%. On the contrary, highly populated municipalities (i.e. with more than 100,000 inhabitants) showed much lower participations with an average rate of ca. 1%. According to our non-parametric and post hoc analysis, these differences were statistically significant between all size categories considered ($p < 0.05$), except between the two smaller size categories (Figure 3). Municipalities with less than 1000 inhabitants show similar and highest hunting participation rates. Beyond these categories, hunting participation decreases significantly with municipality size, reaching the lowest values in the largest cities (i.e. >100,000 inhabitants).

3.2 | Past and future hunting population trends

From 2005 to 2020 the number of hunters dropped from 793,683 to 583,575, a reduction of 26%. Analysis of historical trends inferred a hunting population of 1.061.951 by 1970, indicating a decline of 45% in the last 50 years. Analyses of hunting recruitment indicated a quick decline during the last decades. The extent of this decline is massive, with recruitment falling by more than 89% in 50 years in the regions studied: from an estimated aggregate of ca. 44,000 new hunters in 1970–1979 to less than 5000 in the decade 2010–2020 (Figure 4). Furthermore, the largest reductions in recruitment were reported

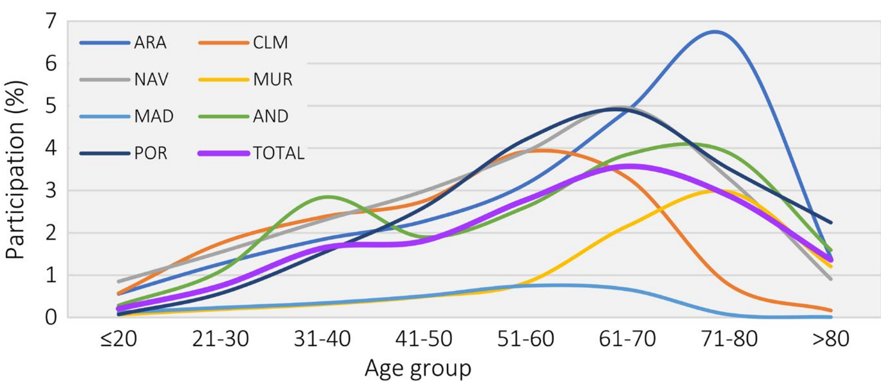

FIGURE 2 Age-structured participation rates (i.e. ratio between the number of hunters of a given age cohort divided by the total population of the same cohort) for individual regions studied and as a whole ('Total' label) in 2020.

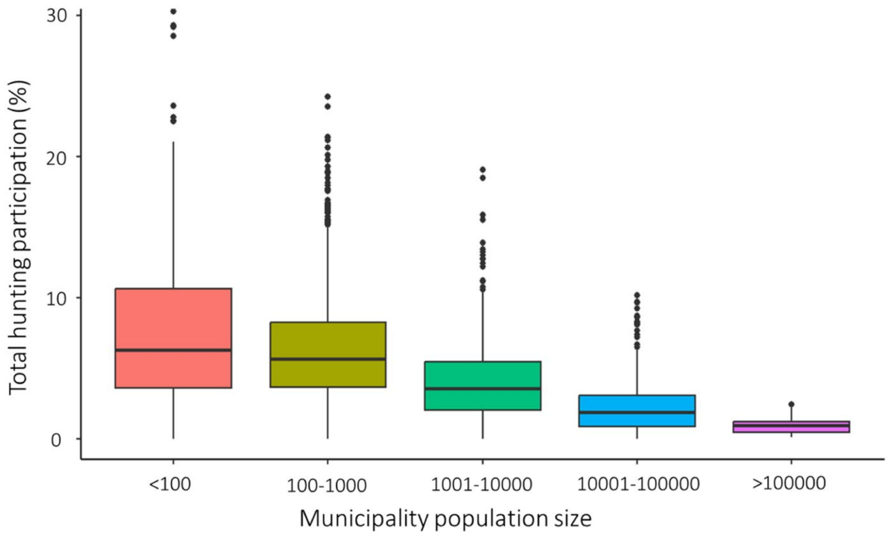

FIGURE 3 Municipal hunting participation (i.e. percentage of hunters in the total population of each municipality-size category). Statistically significant differences are found between all categories except those corresponding to the two smallest size categories.

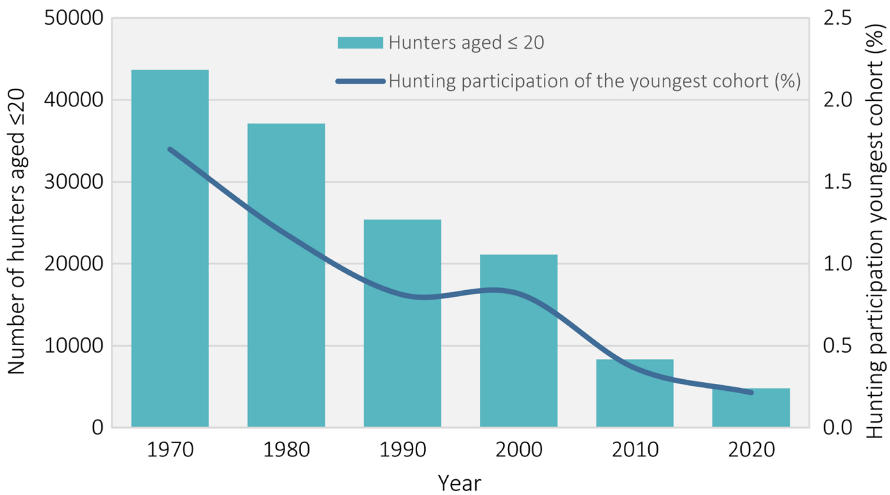

FIGURE 4 Recruitment trend over the years for the whole study area, as described by the number of new young hunters (age ≤20 years) entering hunting on each decade and the hunting participation of the youngest cohort (i.e. ratio between the number of hunters aged ≤20 divided by the total population aged ≤20).

in some of the regions that contribute most to the total number of hunters, such as POR and CLM, with reductions ranging from 92% to 94%, respectively. Overall, recruitment trends over the last 50 years have remained constant with an average loss of 40% per decade (min = 23.65%, max = 60.65%). A validation analysis of this approach is present in Appendix S2. In agreement with these findings, hunting participation of the youngest cohort has also fallen to historical minimum values from 1.70% to 0.22% in the last 50 years for the entire study area (Figure 4). This decline in young participation is consistent across all regions studied over the last 50 years (see Appendix S3). Besides, our results show statistically significant differences in the proportion of young hunters in relation to total hunters between municipality sizes. According to our post hoc analysis (i.e. Dunn's test), the rate of young hunters is significantly different among all categories of municipality size, except for the two categories representing sizes above 10,000 inhabitants. According to this result, the proportion of young hunters increases with decreasing municipality size and is, therefore, lowest in larger cities. Municipalities with less than 100 inhabitants have an average proportion of young hunters of 14%, while municipalities with more than 10,000 inhabitants have a proportion of young hunters of less than 1%. This contrasts with the distribution of the total number of hunters, as most hunters are concentrated in large municipalities, especially those between 10,001 and 100,000 inhabitants, while the total contribution of the smallest municipalities is almost marginal (Figure 5).

The stochastic demographic model, assuming the observed recruitment rates in the last 50 years, indicates that the size of the hunting population for the entire study area will have fallen to 176,815 hunters (SD ± 8824) by 2050. This means a 70% reduction compared to the present time and a 83% reduction compared to 1970. The expected decline of hunters in comparison to the present time (see current age structures in Appendix S5) varied among regions, from 56% decline in NAV to 95% in MUR (see future projections of all regions in Appendices S4 and S6). In addition to this decline in total numbers of hunters, our models also showed a notable ageing of the population, given that percentage of hunters aged >60 is expected to shift from the current 40% to 61% by 2050, whereas the percentage of hunters aged ≤40 will drop from ca. 19% to 16% (Figures 6 and 7). This projected ageing process is particularly pronounced in the regions of AND and POR, which are among the most

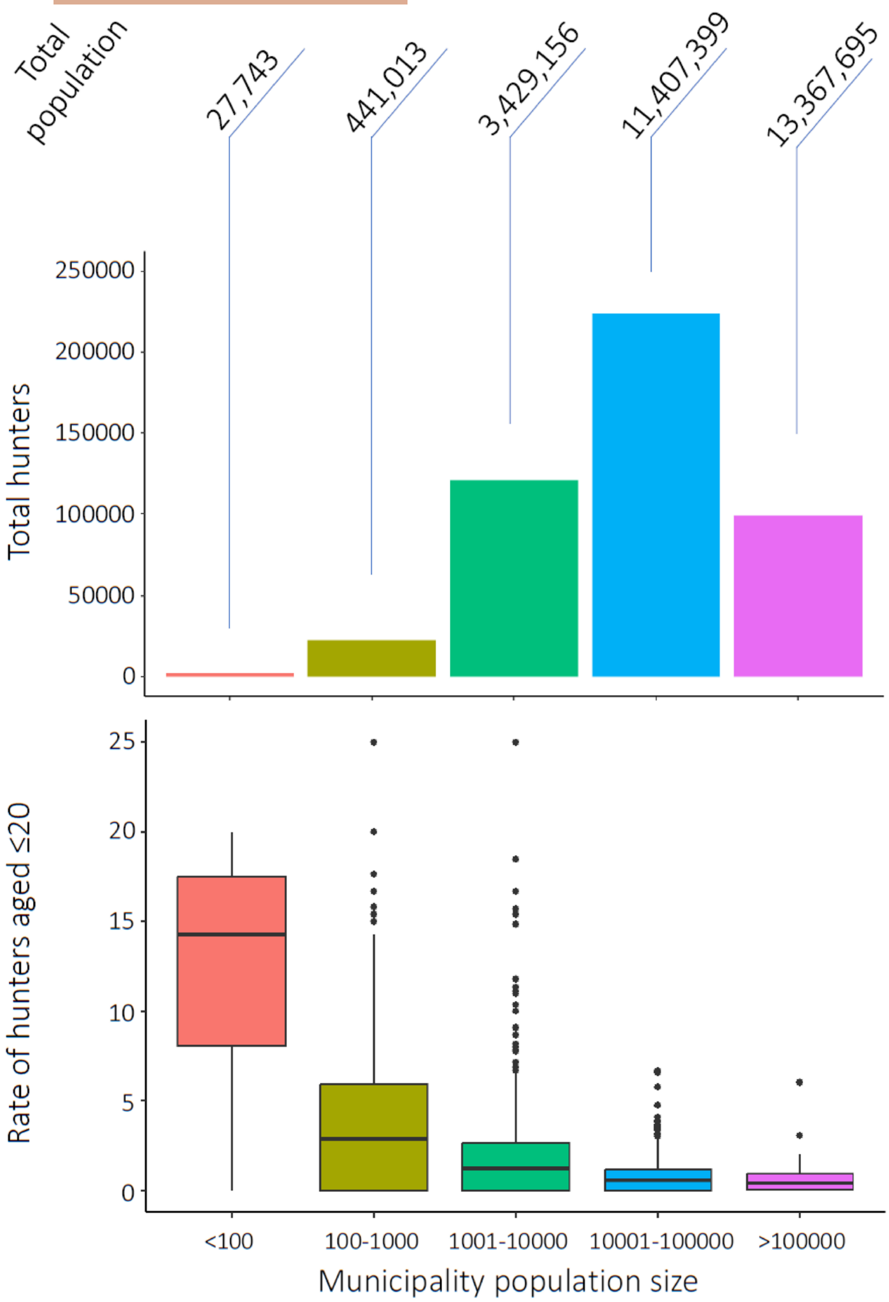

FIGURE 5 Proportion of young hunters in relation to total hunters between municipality sizes. All differences in the rate of young hunters between categories of municipality are statistically significant, except for the two categories representing sizes above 10,000 inhabitants. Hunters from NAV were excluded from the test and boxplot representation of young hunters' proportion by municipality as data for this age cohort was not available at municipal scale in this region. Hunters from different Iberian regions of those studied and foreigners were excluded from the barplot representation of total hunters by municipality size as they cannot be associated with municipalities considered.

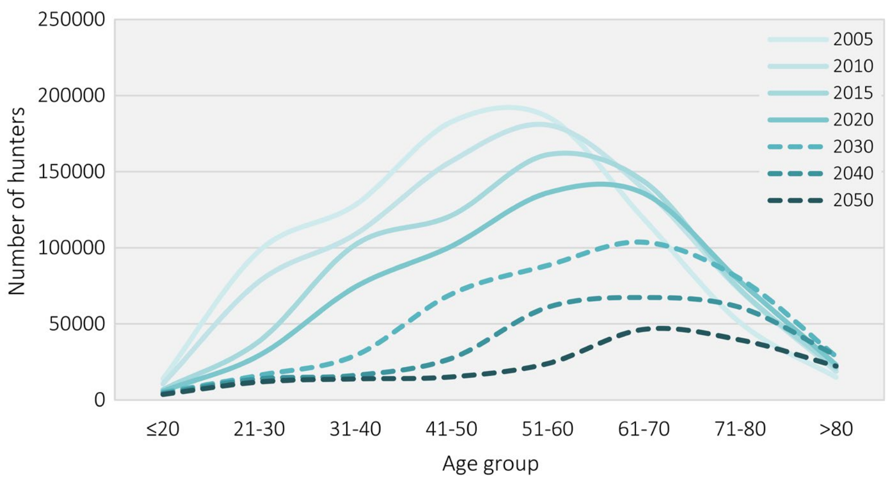

FIGURE 6 Evolution of hunter's age structure and abundance for the entire study area from 2005 to 2050. Age structure from 2005 to 2020 (continuous lines) is based on reported data, whereas from 2030 to 2050 (dotted lines) is based on projections.

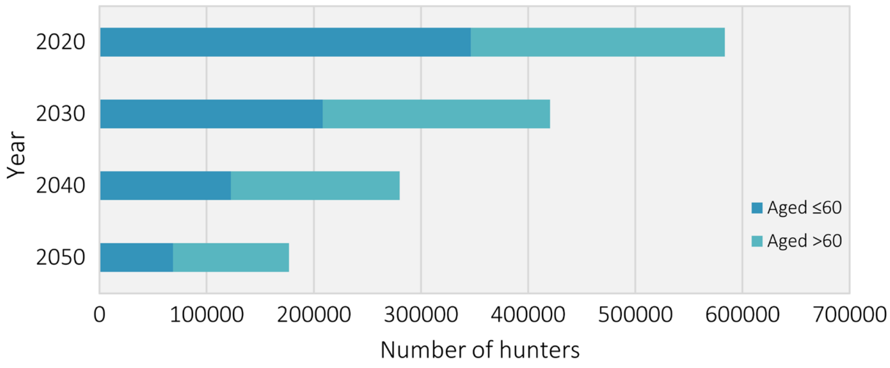

FIGURE 7 Future projection of total number of hunters and ageing for the whole study area.

populated regions studied, while it is less pronounced in less populated regions such as CLM and NAV (see Appendix S6).

4 | DISCUSSION

4.1 | The collapse of the hunting population

Our study shows that in the Iberian Peninsula, which contains one of the largest population of hunters of Europe (FACE, 2007), the hunting population has declined by 26% in the last 15 years and by 45% in the last half century, resulting in a current hunting participation of 2.20% (i.e. ratio between total hunters divided by the total population). Taking into account the current life expectancy of around 80 years for men and 86 years for women of the target human population (Spanish Health Ministry, 2019), these decline numbers can be described in demographic terms as a population collapse (Cumming & Peterson, 2017). It should be noted that the actual decline rates in the entire Iberian Peninsula are probably even larger, since the regions not included in our study, mostly located in NW Spain, are those more aged and where hunting is likely to have declined more. Besides the decline in total size, a striking and related dimension of these trends is the ageing of the hunting population, both linked to a lack of recruitment at the youngest ages. All studied regions showed very similar overall patterns pointing out the strength of the sociocultural trends behind this collapse. In fact, our results for the hunting participation of the youngest cohort point to the importance of these sociocultural processes as its decline proves that the stagnation of recruitment is not linked to a decline of young population (Figure 4). Our analyses of hunting participation by municipality size reveals how this sharp decline in recruitment is linked to the rural-to-urban societal transition that has taken place in the last half century (Collantes, 2007). Our data indicates that most hunters (69%) are residents in the more urban environments (i.e. municipalities with more than 10,000 inhabitants). These hunters are to a large extent first- or second-generation rural immigrants that have moved from rural areas since the 60s. In these more urban areas however, hunting is much less popular and recruitment hampered (Heberlein & Ericsson, 2005). On the contrary hunting is still popular and recruitment probably still holds in the more rural areas that, however, comprise a smaller fraction of the hunting population likely due to immigration of hunters to urban areas (Figure 5).

According to the consistent decline on recruitment, projected hunting population for 2050 shows a 70% reduction in total size compared to present. As relevant as the shrinking in size is the ongoing ageing of the population; if recruitment rates resemble the same of the last half century, by 2050 a 61% of the hunting population will be older than 60 years, and only 16% (ca. 29,500 hunters) will be aged ≤40 years, at least in the regions included in this study. Our projections are based on a relatively simple stochastic model and should be taken with caution, as we only consider scenarios where the trends of the last 50 years are maintained. In fact, demographic dynamics are likely to be much more complex as they depend on many socioeconomic factors affecting recruitment. Further research to identify and describe these factors would be of great interest as it would allow more precise management strategies. Furthermore, the development of parameterized models incorporating these factors would lead to a richer and more accurate predictions of future hunting demographic scenarios. Nonetheless, it should be noted that projected future scenarios may even underestimate the loss of recruitment, since we have chosen to follow the average trends of the last 50 years, which are more optimistic than those of recent decades (if only the recruitment trends of the last two decades are taken into account, some regions will show a significant increase in recruitment loss). In addition, the underlying societal changes below the decline of recruitment, basically the transition from rural to an urban society, are extremely unlikely to reverse or even to slow down in the coming decades. Therefore, we consider that the projected results, with their logical uncertainties, might be sensible considering current conditions and observed trends.

Our work contributes to the understanding of the dynamics of the population of hunters at regional scales. Contrasting patterns among world regions or countries on hunting dynamics have been identified previously. First it is worth noting that, in low-income countries, illegal hunting is carried out by a large proportion of the population (Nuno et al., 2013), motivated by bushmeat consumption and trade, which poses a first-order conservation problem (Benítez-López et al., 2017; Lindsey et al., 2013; Rija et al., 2020). This contrasts with the current paradigm of hunting as a recreational activity in middle and high-income countries addressed in our work. In these developed countries, populations of hunters have been described to be declining in European countries such as Italy, France and Sweden (Lindberg, 2010; Massei et al., 2015), as well as in North America (Adams et al., 2004; Boxall et al., 2001; Poudyal et al., 2008;

Winkler & Warnke, 2013), whereas some east-central European countries (e.g. Germany, Hungary or Poland) have tended to maintain or increase their number of hunters (Massei et al., 2015; Ristić et al., 2013). However, few studies had focused on the causes and extent of key features of hunting population such as changes in recruitment (Enck et al., 2000; Hansen et al., 2012; Larson et al., 2014), ageing or participation, particularly over long-time and large-scale windows. Similarly, the relationship between the decline of hunting and rural depopulation has received little attention in these countries. Our results support the idea that southern Europe is likely one of the areas where hunting population is declining more consistently and faster (see also Cerri et al., 2018 for a more local case study in Italy). This marked dynamic matches, and can be explained by, the more accentuated socioeconomic processes of rural depopulation and population ageing occurred in southern Europe since the 1950s in comparison to other developed countries (Hospers & Reverda, 2014; United Nations, Department of Economic and Social Affairs, Population Division, 2018). Further analyses should include other aspects of hunting decline such as gender and game type in order to obtain a more nuanced understanding of hunters' dynamics.

Overall, this work represents a notable contribution to understanding the long-term demography of hunters, including recruitment rates, over the last 50 years in an entire region. In order to achieve our objectives, we built a comprehensive database of approximately 600,000 hunting licences, covering more than half of the Iberian Peninsula in terms of area and population. It is important to recognize that this database is not entirely free of potential bias. For example, the number of licences does not necessarily correspond to the number of hunters, since a hunter may have more than one licence if he hunts in more than one region. In any case, at least three of the regions have a common licensing system (ARA, MAD and MUR), so overlap between them is not possible. In addition, our data may be incomplete because residents of the regions we studied may have licences in regions not included in our study. Nevertheless, these potential sources of noise are relatively small compared to the strength of the declining patterns we found.

4.2 | Ecological implications

Hunting has historically altered the trophic structure and dynamics of wildlife (Milner et al., 2007; Strong & Frank, 2010), with wide consequences for ecosystem functioning and biodiversity. At present, hunting directly impacts the abundance and demography of game species, and also has an effect on the dynamics of predators due to changes in the abundance of prey and competitors (Graham et al., 2005; Prugh et al., 2023) as well as by means of predator-control activities (Liberg et al., 2012; Murgui, 2014). In addition, recreational hunting also has a wide range of indirect effects on the dynamics of both game and non-game species and overall wildlife conservation (see Section 1).

Assessing the quantitative effect of the decline of hunters on game and non-game species is not straightforward (Bengsen & Sparkes, 2016; Virgós & Travaini, 2005). First, both top-down and bottom-up dynamics are likely to play a role (Gandiwa, 2013) and the relative importance of these dynamics will likely vary with the game species, the hunting system or the sociocultural context of hunting. In those cases where bottom-up processes dominate, the decline of hunting might have less pronounced impact on species dynamics. This can be the case of small mammals such European rabbit *Oryctolagus cuniculus* and other small game species, with demography strongly driven by climatic and disease-related interannual oscillations (Flowerdew et al., 2017). On the contrary, other larger game species such as some wild ungulates might be much more dependent of top-down control and thus linked to hunting dynamics (Frank, 2008). In these cases, the decline of hunting might lead to diminished ability to manage populations (e.g. Keuling et al., 2013). Even in the simplest case of the direct effects of hunting on game species where top-down effects are relevant, the exact relationship might not be easily predictable. For example, hunting could decline with the number of hunters, but it is also plausible that hunting pressure remains constant with declining hunters (i.e. fewer hunters but hunting more preys) up to a given level of decline (Apollonio et al., 2010; Burbaitė & Csányi, 2010). In addition, it has been also reported that hunting can destabilize the structure of wild hunted populations (e.g. Milner et al., 2007) and, consequently, the response of game species to the decline of hunters may exceed the effects in terms of abundance alone (Mysterud, 2011).

From a broader perspective, independently of the exact shape of the impact of hunting decline on the demography of game a non-game species, hunting decline can be understood as a perturbation release process that is expected overall to contribute to move ecosystems towards refaunation, which is already occurring in some areas of developed countries. In parts of Europe, for example, most ungulates are experiencing notable populations increases (Carpio et al., 2021; Ledger et al., 2022) while apex predators are recovering their historical distribution ranges (Chapron et al., 2014). This involves the recovery of functional groups that had been almost completely removed from ecosystem functioning, which in turn leads to the recovery of associated ecosystem services (Malhi et al., 2016; Pascual-Rico et al., 2021; Ripple et al., 2014). Therefore, a reduction of hunting pressure could be understood as part of this passive rewilding process (Pereira & Navarro, 2015), acting synergistically with other co-occurring dimensions of abandonment over the last half century, such as the expansion of forest and natural areas due to the abandonment of marginal crops, the end of firewood collection or the decline of extensive livestock (Daskalova & Kamp, 2023; Martínez-Abraín et al., 2020; Schnitzler, 2014). Under this framework, a critical research challenge is to assess the distinct and unique contribution of hunting decline to current passive rewilding and refaunation processes, and more generally to disentangle the effects of each one of the processes that jointly conforms rural abandonment.

AUTHOR CONTRIBUTIONS

José D. Anadón conceived the idea and approach. Pelayo Acevedo, Eneko Arrondo, Juan Herrero, Roberto Pascual-Rico and José D.

Anadón collected the data. Mario Gaspar analysed the data with significant contributions from Ignacio García-Martínez and José D. Anadón. Mario Gaspar and José D. Anadón led the writing of the manuscript with significant contributions from all co-authors. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Employed data are not publicly published. However, they can be requested to the Portuguese and Spanish national and regional agencies.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1. Stable age distributions for all studied regions, reconstructed from 100 initial hunters in the youngest cohort.

Appendix S2. Validation analysis of inferred past hunter recruitment.

Appendix S3. Historical evolution of the hunting participation of the youngest cohort (i.e., ratio of hunters aged ≤20 divided by the total population of the same age) for all studied regions.

Appendix S4. Current and future evolution of abundance and age structure of hunters for all studied regions.

Appendix S5. The age structure of the hunting population in 2020, presented for each studied region and as an aggregate (Total).

Appendix S6. Current and future changes in abundance and ageing of hunters for all studied regions.

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