
ARTICLE

HISTORICAL WOLF *CANIS LUPUS* DISTRIBUTION IN THE SOUTHERN PYRENEES AMONG 19TH, 20TH, AND 21ST CENTURIES

Distribución histórica del lobo *Canis lupus* en el sur del Pirineo entre los siglos XIX, XX y XXI

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Abstract: The wolf (*Canis lupus*) population in the Iberian Peninsula faced a severe decline during the 19th and 20th centuries, primarily due to human persecution. This led to a near-extinction crisis in the 1960s-70s in some historical distribution areas and the extent of species decline remained unclear in certain regions, especially the Pyrenees. This study delves into the historical and contemporary distribution of Iberian wolves in the Pyrenees across three periods: 1850, 1950, and 2000-2021. The data for the first two periods were obtained from surveys of qualified informants and those for the third period were provided by the autonomous communities and collected from literature reviews. All data, categorized as “presence” or “absence,” underwent transformation into 10x10 km UTM grids for interpretation. Results unveil a significant change in wolf presence: 68.2% in 1850, 25.2% in 1950, and 18.3% in 2000-2021, indicating significant inter-period differences. Despite interpretational challenges in historical data, the study concludes that there has been a decline in wolf populations between the 19th and 20th centuries. Notably, data absence from the 1950s raises concerns about regional disappearance until a resurgence in the 2000s.

Keywords: Iberian Peninsula; wolf hunting; historical sources; large carnivores.

Resumen: La población de lobo (*Canis lupus*) de la Península Ibérica sufrió un grave declive durante los siglos XIX y XX, debido principalmente a la persecución humana. Esto condujo a una crisis de casi extinción en los años 60-70 en algunas áreas de distribución histórica y el alcance del declive de la especie seguía sin estar claro en algunas regiones, especialmente en los Pirineos. Este estudio profundiza en la distribución histórica y contemporánea del lobo ibérico en los Pirineos a lo largo de tres periodos: 1850, 1950 y 2000-2021. Los datos de los dos primeros periodos se obtuvieron a partir de encuestas a informantes cualificados y los del tercer periodo fueron facilitados por las comunidades autónomas y recogidos de las revisiones bibliográficas. Todos los datos, clasificados como «presencia» o «ausencia», se presentan en cuadrículas UTM de 10x10 km (31.809,7 km²) para su interpretación. Los resultados revelan un cambio significativo en la presencia del lobo: 68,2% en 1850, 25,2% en 1950 y 18,3% en 2000-2021. A pesar de los retos interpretativos de los datos históricos, el estudio concluye

que ha existido un declive de las poblaciones de lobo entre los siglos XIX y XX. En particular, la escasez de datos a partir de la década de 1950 hace temer una desaparición regional hasta un resurgimiento en la década de 2000.

Palabras clave: Península Ibérica; caza del lobo; fuentes históricas; grandes carnívoros.

Received: 07-09-2024 / **Accepted:** 13-04-2026 / **Published:** 14-07-2026

Citation: Quero, A., Torrente, J.P., Llaneza, L., (2026). Historical wolf *Canis lupus* distribution in the southern Pyrenees among 19th, 20th, and 21st centuries. *Pirineos*, 181 e093. <https://doi.org/10.3989/pirineos.2026.181.390>

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Supplementary information ↓

1. INTRODUCTION

Originally, wolf (*Canis lupus*) populations were distributed all over the northern hemisphere, in suitable habitats where large wild ungulates were present (Dawes *et al.*, 1986; Mech, 1995) and for hundreds of years, wolves in Europe have lived in areas with a virtual absence of wild ungulates, precisely such as in Iberia (Llaneza & López-Bao, 2012). During the 19th and early 20th century, wolf populations declined dramatically, mainly due to human persecution along with habitat loss and fragmentation and prey reduction (Cimatti *et al.*, 2021; Fernández & Azua, 2010; Flagstad *et al.*, 2003; Khalil *et al.*, 2014; Núñez-Quirós *et al.*, 2007; Wang *et al.*, 2016). Although the wolf growth rates are higher compared to most other mammal species of similar size, as a large carnivore, is characterized by low densities and slow rates of population growth (Liberg *et al.*, 2012), although population increases are observed in several European countries (Chapron *et al.*, 2014). Thus, if mortality exceeds the expected values, it may impact its ability to form stable social groups, compromising the persistence of its populations, and therefore determining its response to habitat changes (Flagstad *et al.*, 2003; Rico & Torrente, 2000). Given that, it is quite sensitive to illegal hunting effects and, like almost all large carnivore species, it also suffered a history of human persecution leading to a considerable contraction of its population's previous distribution (Boitani & Linnell, 2015; Flagstad *et al.*, 2003; Liberg *et al.*, 2012; Llaneza *et al.*, 2012).

The eradication of these animals advantaged landholders, rural communities, the Treasury, and the ecclesiastical estate by bolstering the agrarian and pastoral economy, guaranteeing tax revenue, and averting rural depopulation. Additionally, it safeguarded individuals and their assets, enhancing commerce and the mobility of individuals and commodities (Torrente, 1999). So, if wolves preyed on domestic animals instead of wild ungulates could mean loss of money for livestock owners or cause conflict with hunters for shared prey, as well as being perceived as a threat to humans themselves (Blanco *et al.*, 1992; Boitani & Linnell, 2015; Chapron *et al.*, 2003; Mech, 1995; Torrente, 1999). Considering that, administrative institutions implemented policies that encouraged the persecution of harmful animals –wolves included– through a bounty system (Martínez-Abraín *et al.*, 2020; Núñez-Quirós *et al.*, 2007; Rico & Torrente, 2000). This intense conflict between human and wolf populations led to the tremendous decline of North American and Eurasian wolf populations (Boitani & Linnell, 2015; Mech, 1995; Rosas-Artola, 2009). In Europe, the impact was such, that it almost led to the extinction of the species, leaving few populations relegated to parts of Italy, the Iberian Peninsula, Greece, and some Eastern European countries (Mech, 1995). In particular, it is commonly accepted that the Iberian Peninsula's wolf population reached its lowest numbers in 1960-70, with a small population mainly located in the northwest of the territory (Blanco *et al.*, 1990b; Clavero *et al.*, 2023; Delibes, 1990; Grande del Brío, 1985, 1983; Llaneza *et al.*, 2012; Rico & Torrente, 2000; Valverde, 1971).

Among other reasons, the wolf population decrease contributed to the emergence of regulations at different levels that promoted biodiversity conservation (Chapron *et al.*, 2014), and probably because of the resemblance to the dog (*Canis lupus familiaris*), wolves were given some protection (Boitani & Linnell, 2015). Since this species was wanted for fur trading in most regions (not the case in Spain), the global 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Trouwborst, 2015) contributed greatly to reducing its persecution. European regulations, such as the 1982 Bern Convention and the 1992 Habitats Directive, do not protect the individuals themselves but present some strategies requiring healthy populations (Boitani & Linnell, 2015; Chapron *et al.*, 2003, 2014; Trouwborst, 2015), so they encouraged the different national legislative institutions to enforce some internal regulations to protect many carnivore populations.

At the same time, socioeconomic changes also occurred, for instance, the large-scale movement of people from the countryside to major cities (i.e., rural exodus since 1950), hence leaving vast areas with low human population density (Chapron *et al.*, 2014; Martínez-Abraín *et al.*, 2020; Martínez-Abraín *et al.*, 2019). As a result, the landscape was modified as well: while the grassland decreased, the number of shrubs and forests increased (Cimatti *et al.*, 2021), either occupying former cropland that was no longer being used (Boitani & Linnell, 2015; Roura-Pascual *et al.*, 2005) or causing an expansion of the forests that already existed (Cimatti *et al.*, 2021; Martínez-Abraín *et al.*, 2020; Martínez-Abraín *et al.*, 2019). Concerning the history of Spain, however, the effects of the clearing and expansion of cultivated land in the 19th and early 20th centuries on wolves, and on wildlife in general, are a subject yet to be studied. In addition to these transformations, the concepts of land sharing and coexistence approach gained much more relevance. Although this model involves an increase in the contact between humans and wildlife, it also allows them to create active and dynamic relationships to mitigate the hostile effects that human beings cause to ecosystems (Boitani & Linnell, 2015).

The landscape transformations, besides the much-improved public attitude towards wolves (i.e., ceasing of persecutions) (Martínez-Abraín *et al.*, 2019; Munilla, 2019), led to a great recovery of the wolf population in most of its former distribution range (Boitani & Linnell, 2015; Chapron *et al.*, 2003, 2014; Mech, 1995). For instance, in Germany wolves are showing an extraordinary increase in individuals after being eradicated from this area even though the landscape in this region is highly fragmented (Reinhardt *et al.*, 2019). Furthermore, there is evidence that due to these alterations, the rate in which many animal populations are leaving remote habitats with minor human disruptions in which they were isolated –known as ecological refuges– is increasing (Martínez-Abraín *et al.*, 2019, 2020).

Even so, it was unlikely to have been possible if it were not for its ability to adapt to a wide range of environments (Chapron *et al.*, 2003, 2014; Cimatti *et al.*, 2021; Llaneza *et al.*, 2012). Several authors claim that habitat type is not the problem, as wolves are not a habitat selective species, and that as long as they can access food, shelter, and are tolerated by humans, their continued coexistence is possible (Chapron *et al.*, 2003; Cimatti *et al.*, 2021). Many studies have proved the remarkable capacity of wolves to recolonize, persist, and even thrive in highly human-dominated landscapes (Chapron *et al.*, 2014; Cimatti *et al.*, 2021; Dennehy *et al.*, 2021; Llaneza *et al.*, 2012; Mech, 1995; Rosas-Artola, 2020). For example, Llaneza *et al.* (2012) mention that in Eurasia, wolves are used to live in areas where human densities are especially high (up to 30 people per km²). Moreover, this may vary within different regional scenarios, suggesting a local variation in the species' sensitivity to humanized landscapes (Llaneza *et al.*, 2012). Beckmann & Lackey (2008) demonstrated that human activities in urban areas had been associated with the impact they can have on the viability of carnivore populations. However, even though habitat fragmentation might increase the home range area of several species, human activity may also concentrate food resources at specific regions or create movement barriers resulting in a reduction of these areas (Gabriel Hernando *et al.*, 2020).

These examples uphold the ideas of land sharing and coexistence model and they are opposed to the frequently idealized insight of wolves in wilderness hunting wild prey, and where they, as apex predators, play an essential role in the ecosystems (Fernández & Azua, 2010; Khalil *et al.*, 2014; Martínez-Abraín *et al.*, 2021; Zielinski *et al.*, 2005). Both scenarios are conceivable, but they differ spatially since, at least in the Iberian Peninsula, wolves successfully contend with highways and paved roads, settlements,

habitat fragmentation, and other several human perturbations (Dennehy *et al.*, 2021; Mech, 1995). For instance, wolves in Galicia, in the NW of the Iberian Peninsula, persisted during the last decades despite the high proportion of human density (e.g., 80-90 inhabitants/km²) and activity (Llaneza *et al.*, 2012).

To appropriately comprehend these past and recent changes, as well as the evolution of any species through time, it is necessary to carry out a historical analysis. These are crucial since they establish historical baselines (Kittinger *et al.*, 2013) which allows us to understand what is possible within the context of certain landscapes and their dynamics (e.g., the causes of the wolf's regression) (Swetnam *et al.*, 1999; Uzal & Llaneza, 2010). Thus, they increase our knowledge of the past and help us to properly manage ecosystems in the present and future, as well as to assist conservation effort (Clavero *et al.*, 2023; Nores & López-Bao, 2022; Nores & Naves, 1993; Núñez-Quirós *et al.*, 2007). Moreover, “the use of systematic historical information eases long-term perspectives and prevents anomalies such as shifting baselines (i.e., the intergenerational loss of information about species abundances or its range)” (Nores & López-Bao, 2022). Many studies show the evolution of wolf populations through the last two centuries at a European level (Boitani & Linnell, 2015; Chapron *et al.*, 2014), and even regional level (Blanco *et al.*, 1990a, 1992; Clavero *et al.*, 2023; Petrucci-Fonseca, 1990; Garzón, 1974; Grande del Brío, 1983; Nores & López-Bao, 2022; Núñez-Quirós *et al.*, 2007; Reig *et al.*, 1992; Rico & Torrente, 2000; Rosas-Artola, 2020). However, of those that took place in Spain, some (Blanco *et al.*, 1990a, 1992; Delibes, 1990; Garzón, 1974; Grande del Brío, 1983; Valverde, 1971) did not mention any stable wolf population in the north-eastern mountains of the Iberian Peninsula at least since the 1970s. So, even though historical studies about wolf distribution have been carried out in many regions, there are few studies (Grau *et al.*, 1990; Manent, 2004; Massip 2011) about the wolf's past biogeography in eastern Iberian Peninsula.

Taking into consideration all the issues mentioned above, the main objective of this study is to carry out an updated approach of the interpretations made to date, for this purpose we will review and extract the information about the wolf's former range from several historical sources, as well as its current distribution. Therefore, we shall assess the wolf's distribution in the Spanish Pyrenees over the last two centuries, examining three periods: 1850, 1950, 2000-21. We will also review the existing data about the historical distribution of the wolf in the Pyrenees, and compare the extracted information with our results.

2. MATERIALS AND METHODS

2.1. Study area

The study area includes Pyrenees mountain range within the autonomous communities (AACC) of Aragon (including part of the Huesca and Zaragoza provinces), Catalonia (including part of the Lleida, Barcelona, and Girona provinces), and part of Navarre located in the north-eastern region of the Iberian Peninsula, covering 563 municipalities which amount to a total area of 31,809.7 km² (Fig 1).

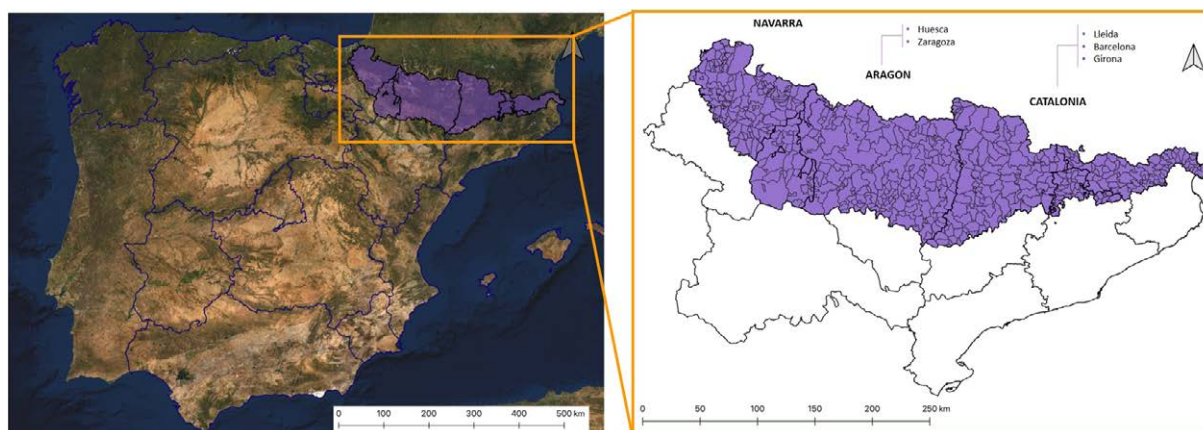


Figure 1. Location of the study area in the Iberian Peninsula (a) and the municipalities included in the study area, showing the autonomous communities and provinces of which they belong (b).

Figura 1. Ubicación del área de estudio en la Península Ibérica (a) y los municipios incluidos (b).

2.2. Sources and materials

This work focuses on three types of written sources: i) two geographical dictionaries, which are printed sources of an encyclopaedic, scientific, and scholarly nature; ii) two official statistical publications of the 19th century; and iii) various official documents (unpublished reports and communications) from the local administrations of the area under study.

For the 19th century, we consulted the *Diccionario geográfico-estadístico-histórico de España y sus posesiones de Ultramar*, which consists of sixteen volumes published between 1846 and 1850 (Madoz, 1846-50) and is the result of work carried out since 1834 and conducted by Pascual Madoz with the help of fifteen hundred collaborators. Geographical, historical, economical, and statistical information of provinces, municipalities, judicial districts, and localities are compiled. Mentions of wildlife are under the heading *Production* for each entry.

For the 20th century, the *Diccionario geográfico de España*, guided by Germán Bleiberg and Francisco Quirós (Bleiberg & Quirós, 1956), consists of seventeen volumes, and was published between 1956 and 1961. It reflects Spain in the fifties, and it was attended by twenty collaborators and two hundred and fifty informants, among professionals of the geography and local administration officials. The species of study is listed under the heading *Fauna*.

Although the dates of both written sources are given as ranges (Bleiberg & Quirós, 1956-61; Madoz, 1846-50), they refer to annual ranges of their corresponding book editions, but the faunal data they provide come from single, one-off surveys.

Two printed documents generated by the official statistics of the 19th century provide precise data on wolves. The first one is the *Memoria elevada al Excmo. Sr. Ministro de Fomento por la Dirección General de Agricultura, Industria y Comercio sobre el estado de los ramos dependientes de la misma en octubre de 1861* (Dirección General de Agricultura, Industria y Comercio, 1861), which is one of the first official statistical publications in Spain. It includes, among many other topics, the answers to a questionnaire circulated to the provinces in 1860 about the wolf's population trend and the number of specimens hunted in the previous five years (1855-1859). The answers are heterogeneous (statistical and opinionated information), but overall, they provide accurate data on the number, location, and trend of Spain's wolf presence during those years (Rico & Torrente, 2000). The second printed document handled is the *Anuario Estadístico de España 1862-1865* (Junta General de Estadística, 1866-67), an official report at the very beginnings of the Statistics in Spain. It publishes a list of *Harmful animals killed in the Peninsula and adjacent islands, for which bounties were paid during 1864* where the bounties distributed for the hunting of the wolf are tabulated at a provincial level by age and sex.

The documentary body of this study concluded with several documentations of the second half of the 90s of the 20th century (1995-1999) and 21st century (2000-2021) to represent the third and current period (beginning of the 21st century), collected from the autonomous communities of Navarre, Aragon and Catalonia in response to queries made by the authors.

Additionally, to create the cartographic data, the layers with the provinces, regions, and municipalities were obtained from the digitized records of each community (Gobierno de Aragón, 2021; Gobierno de Navarra, 2021; Institut Cartogràfic i Geològic de Catalunya, 2021), as well as the UTM grid (10x10 km) from the download centre of the Government of Spain (Ministerio para la Transición Ecológica y el Reto Demográfico, MITECO, 2021).

2.3. Procedures, transformations and criteria

For both historical sources, a common process and criteria were established to avoid erroneous interpretations. First, from the two geographical dictionaries, a database was created, making note of wolf presence or absence of every municipality, judicial district or diocese. Some of these territorial divisions may have undergone variations (i.e., the fusion of several municipal entities), for which the information of each one was united under the name of the current municipality.

For each unit (municipality), we applied the following criteria to assign wolf presence/absence: i) it was considered as “presence” when wolves were explicitly mentioned in the list of wildlife or wolf hunting was mentioned and ii) it was considered as “absence” if the list of species in a municipality listed several species but wolves or if *minor*, *major*, or *harmful animal hunting* was indicated. Also, we omitted any reinterpretation of other faunal indicators such as potential wolf prey. When there was a presence in a locality, it was extrapolated to its municipality, even if it was not mentioned in the description of the municipality.

Furthermore, the 1846-1850 database (from Madoz, 1846-50) was replicated into two different specificities: one of the presences mentioned at a judicial district scale, and another one, more accurate, with the information exclusively from the municipalities. Meaning, that all municipalities included in a judicial district counted as “presence”, were considered as “presence” as well. Furthermore, for Navarre in both periods, there are the *facerías*, pieces of land whose use is shared between two or more municipalities for which the information of the adjacent municipalities was combined. Additionally, each historical source was checked thoroughly a second time to minimize the error rate as much as possible.

Secondly, all municipality data of each period was transferred to a georeferenced vectorial layer through the software QGIS version 2.18© (QGIS Development Team, 2019), associating each unit a binary variable which represented either wolf absence “0” or wolf presence “1”. Moreover, to infer the wolf’s area of influence, considering that the wolf’s home range is about 150 km² (Llaneza, 2016) a 2 km buffer was made all-around each municipal boundary (Fig 2a) since the mean area of all municipalities with presence in this study was less than that ($\bar{x}$ = 75.7 km²; SD = 9.5).

Finally, these outputs were transformed into a 10x10 km UTM grid, and all grids that overlapped with a municipality containing presence were considered (Fig 2a). It should be noted that in this study we assumed that the double increase of areas (buffer + UTM grid) adds an artificial inflation of areas with respect to the source-based data itself, which in itself includes the generalization bias of “pars pro toto”, given the nature and characteristics of the historical sources used.

Regarding the 19th century statistical printed documents (Dirección General de Agricultura, Industria y Comercio, 1861; Junta General de Estadística, 1866-67) data was extracted to represent the period 1855-64. It was considered as “presence” for any hunting mortality record by municipality, and then its pertinent transformation to UTM grid was made. Besides, when data at a locality scale was available, it was also considered, and so, its pertinent point layer was created. Then, the subsequent buffer was created to represent the influence area of the species, in this case, it was greater (9.3 km) since a point had a much more reduced area than a municipality. Finally, for both representations, a transformation to a 10x10 km UTM grid was made (Fig 2b).

Concerning the information of the more recent time period (2000-2021), several different procedures were used depending on the given input data. For Catalonia data, the UTM grids with presence were given within different periods, so the related georeferenced layers were created, keeping the temporal scale for each period, but also generating a new one with all the information combined. From Aragon data, all “sure” and “probable” sightings were selected as presences, as well as the mortality records for the year 1999 and from 2017 to 2021 at a municipality scale. On the contrary, the information referring to livestock attacks and “possible” sightings were rejected. Similarly, from Navarre information, there were selected signs of presence from 1995 and 1996 by municipality. Then, with both information extracted from Aragon and Navarre, a 2 km buffer was created and a transformation into a 10x10 km UTM grid was generated as well.

2.4. Statistical procedures

To verify if there were any differences between the three periods (1850, 1950, and 2000-21), a chi-squared analysis was carried out with the software RStudio© version 1.3.1093 (RStudio Team, 2020). We used the presences and absences in UTM grids with the influence area applied, and two separate analyses were carried out considering different specificity 1850 data input. Altogether, for the interpretation event, distribution maps were generated with the software QGIS© (QGIS Development Team, 2019).

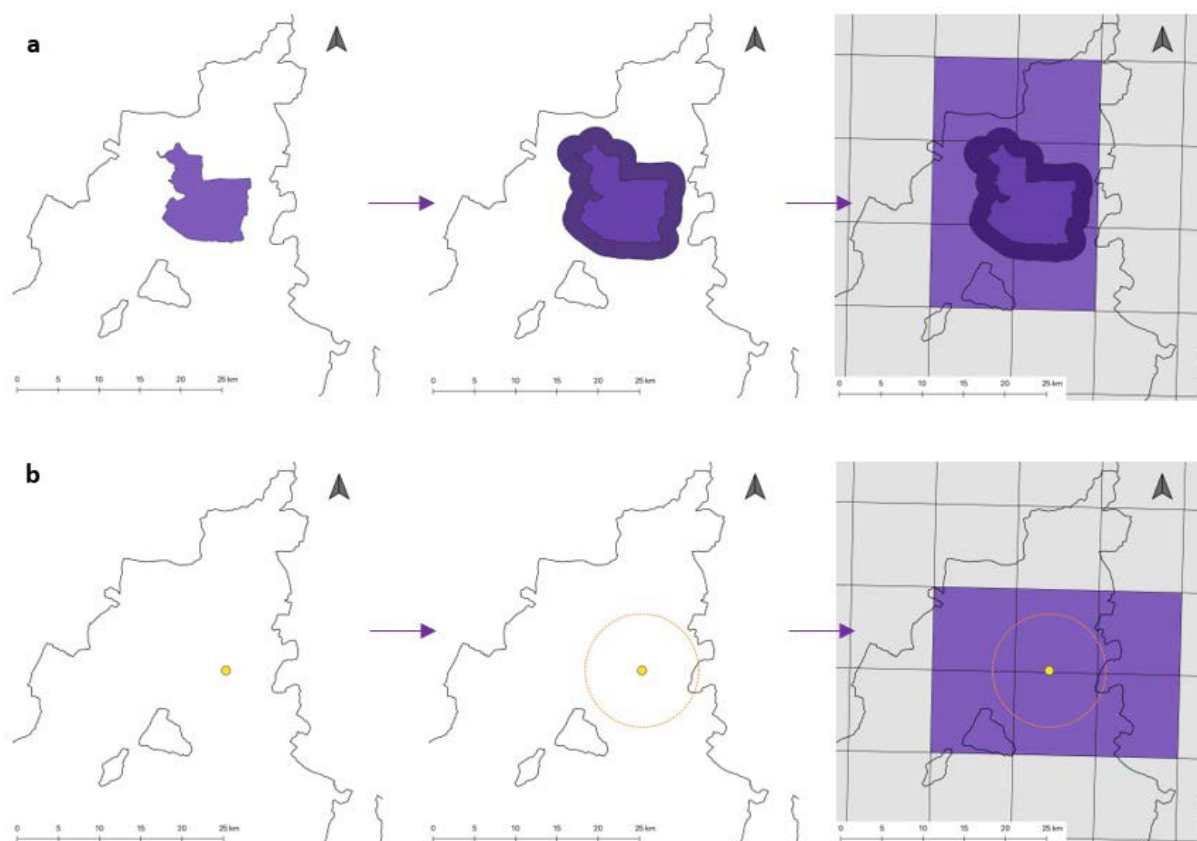


Figure 2. Procedure used in data transformation considering both possible inputs (a) from a municipality and (b) from a locality.

Figura 2. Procedimiento utilizado en la transformación de datos considerando ambas entradas posibles (a) desde una localidad y (b) desde un municipio.

3. RESULTS

For 1850 at a municipal scale **Madoz (1846-50)** shows 152 municipalities with wolf presence in the study area that is 279 UTM grids (**Table 1, Fig 3a**), which represents 68.2% out of the whole area ($n_{UTM} = 409$). If the influence area (buffered) is considered, it makes 309 UTM grids (**Table 1, Fig 3b**) which is 75.5% out of the total UTM grids.

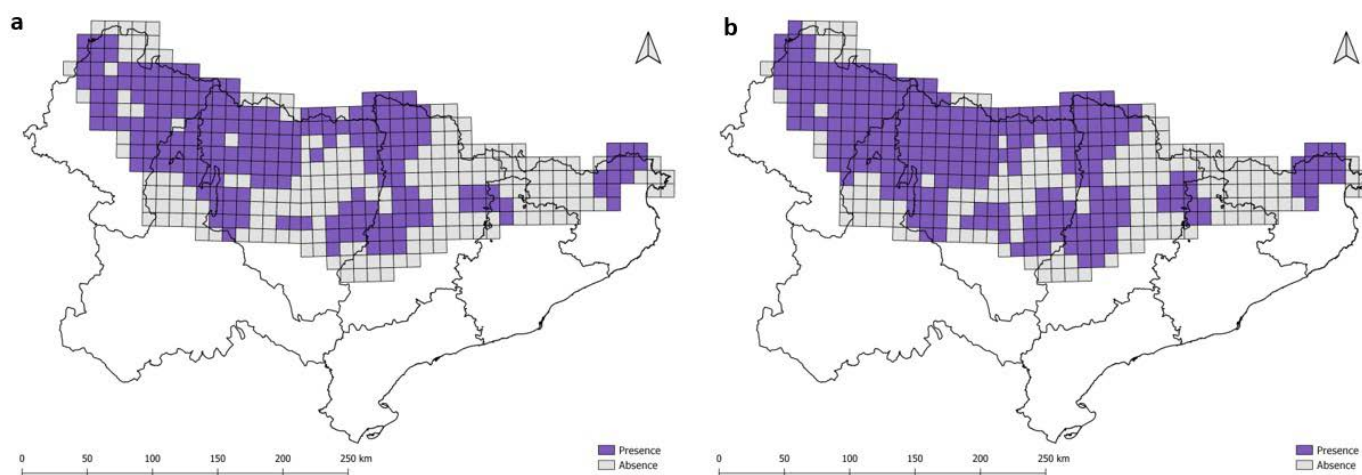


Figure 3. Wolf's distribution in the Pyrenees in 10x10km UTM grid at a municipality scale, original (a) and with the influence area (b) in 1850

Figura 3. Distribución del lobo en los Pirineos en 1850 en una cuadrícula UTM de 10x10 km a escala municipal, original (a) y con el área de influencia (b).

Table 1. Wolf presences and absences count by municipalities (Mun) and UTM grids (UTM) for each period 1850, either at a municipal (MU) or judicial district scale (JD), 1960 and 2000-2021. For UTM representation information with or without buffer is provided as well. All data is represented in absolute numbers (Abs) and its proportion in percentage (%).

	1850 (MU)				1850 (JD)				1960 (MU)				2000-21	
	Mun		UTM		Mun		UTM		Mun		UTM		UTM	
	Abs	%	Abs	%	Abs	%	Abs	%	Abs	%	Abs	%	Abs	%
Original														
Presence	152	27.0	279	68.2	265	47.1	312	76.3	29	5.2	103	25.2	75	18.3
Absence	411	73.0	130	31.8	298	52.9	97	23.7	534	94.8	306	74.8	334	81.7
Buffer														
Presence	-	-	309	75.5	-	-	335	81.9	-	-	136	33.2	82*	20.0*
Absence	-	-	100	24.5	-	-	74	18.1	-	-	273	66.8	327*	80.0*

* Data only available for Navarre and Aragon.

The Madoz numbers at a judicial district scale include 265 municipalities and 312 UTM grids (Table 1, Fig 4a) which stand for 76.3% of the Pyrenees studied. Therefore, after applying the buffer to consider the influence area, the UTM grids increase to 335 (Table 1, Fig 4b), which stands for 81.9%.

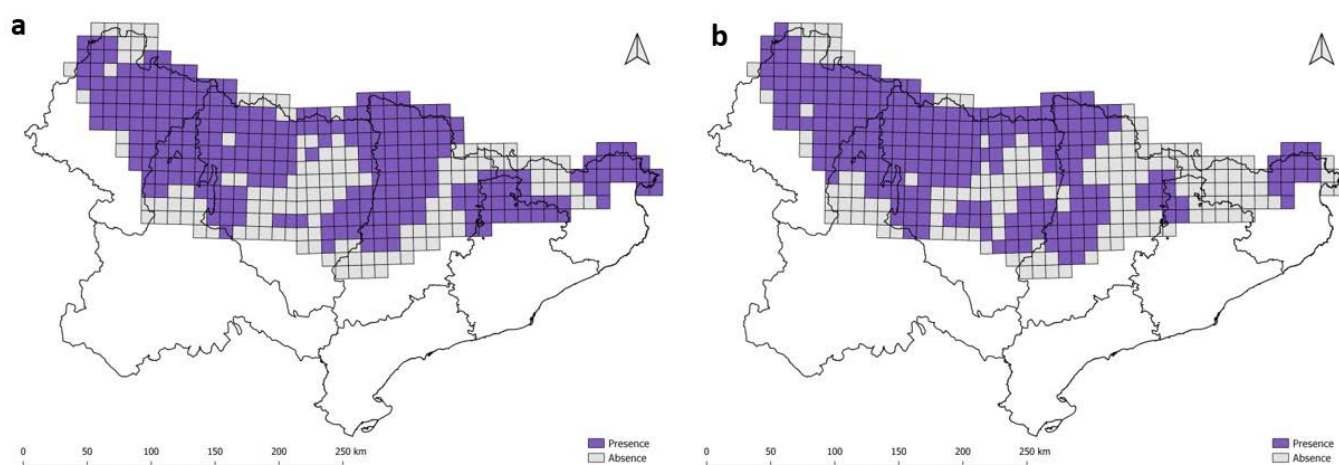


Figure 4. Wolf's distribution in the Pyrenees in 10x10km UTM grid at a *judicial district scale*, original (a) and with the influence area (b) in 1850.

Figura 4. Distribución del lobo en los Pirineos en 1850 en una cuadrícula UTM de 10x10 km a escala de distrito judicial, original (a) y con el área de influencia (b).

Additionally, for the period 1855-64, the information from the *Memoria elevada al Excmo. Sr. Ministro de Fomento* (Dirección General de Agricultura, Industria y Comercio, 1861) and the *Anuario Estadístico de España 1862-1865* (Junta General de Estadística, 1866-67) show 24 municipalities (Table 2, Table 3) and 12 localities (Table 3, Fig 5), that considering the influence area, it represents 66 UTM grids, and therefore a 16.1% with presence (Table 2, Fig 5).

For 1956-61, Bleiberg and Quirós showed 29 municipalities with presence, which represent 103 UTM grids (Table 1, Fig 6a), covering 25.2% of the total area. Considering the influence area, it counts 136 UTM grids (Table 1, Fig 6b), so that's 33.2% of the Pyrenees.

Table 3. Confirmed hunting deaths (highlighted in grey) that had been considered as presences for the period 1855 – 1864.
Rounded cells indicate the considered municipalities with presence (n=24).

AACC	Province	Judicial district	Municipality	Locality	AACC	Province	Judicial district	Municipality	Locality
Navarre	Navarre								Ainet de Besan
		Pamplona					Sort	Alto Aneu	Son
		Aoiz							València d'Àneu
		Tafalla							Isil
Aragon	Zaragoza	Sos	Los Pintanos				Sort	Esterri de Cardós	
	Huesca						Sort	La Guingueta	Unarre
Catalonia	Lleida						Sort	Sort	Altron
		Balaguer	Alfarràs						Enviny
		Balaguer	Alguaire				Tremp	Abella de la Conca	
		Balaguer	Almenar				Tremp	Gavet de la Conca	San Salvador de Toló
		Balaguer	Alòs de Balaguer				Tremp	Isona i Conca Dellà	
		Balaguer	Artesa de Segre	Baldomar			Tremp	Talarn	
		Balaguer	Balaguer				Viella	Arres	
		Balaguer	Camarasa Fontollonga				Viella	Bausen	
		Balaguer	Vilanova de Meià				Viella	Bossòst	
		Balaguer	Vilanova de Segrià	Santa Maria de Meià			Viella	Canejan	
		Lleida	Almacellas			Girona			
		Sort	Alins	Alins			Olot		
				Aréu			Ribas		
						Barcelona			

Table 2. Wolf presences and absences count by municipalities (Mun) and UTM grids (UTM) for the period 1855-64 at a municipal scale (MU) and by localities (LOC).

	1855-64 (MU)				1855-64 (LOC)	
	Mun		UTM		UTM	
	Abs	%	Abs	%	Abs	%
Original						
Presence	24	4.3	56	13.7	22	5.4
Absence	539	95.7	353	86.3	387	94.6
Buffer						
Presence	-	-	66	16.1	61	14.9
Absence	-	-	343	83.9	348	85.1

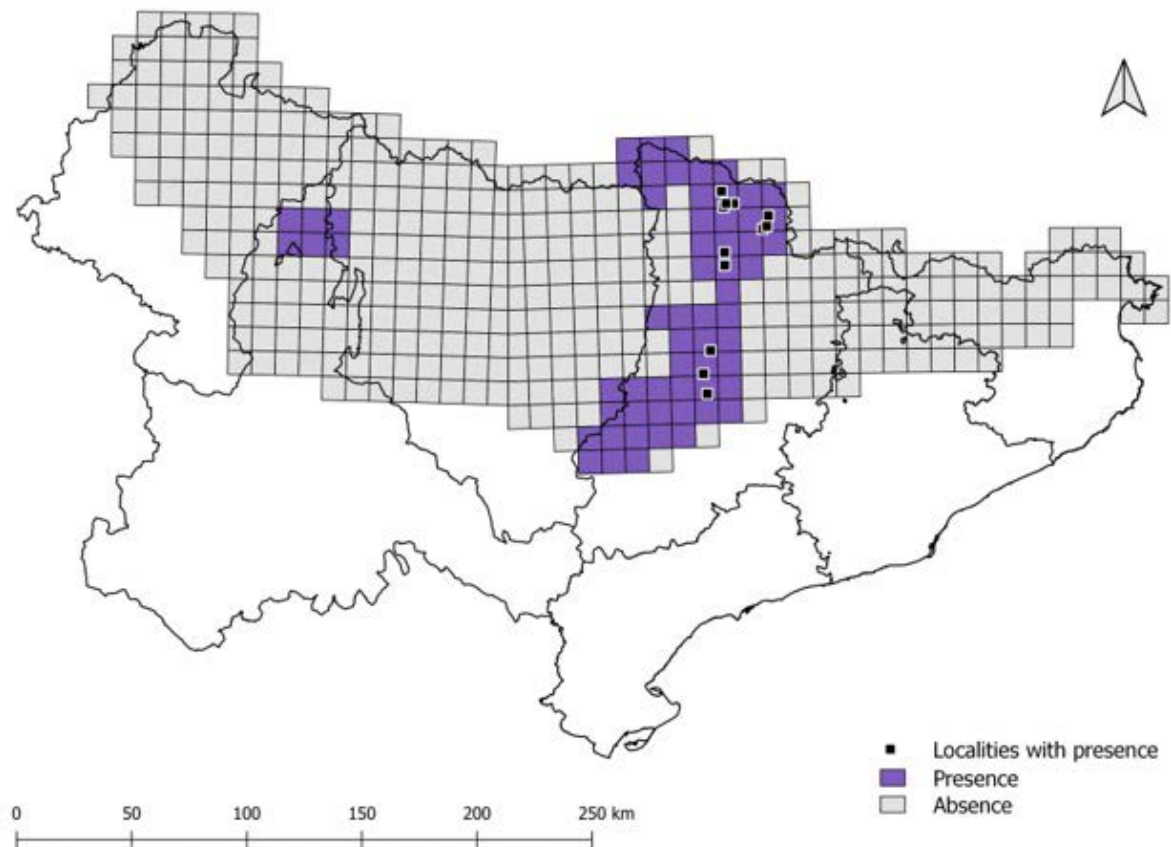


Figure 5. Wolf's distribution in the Pyrenees in 10x10km UTM grid at a *municipality scale* with influence area and *localities* (dots) are shown in 1855-64.

Figura 5. Distribución del lobo en los Pirineos en 1855-64 en una cuadrícula UTM de 10x10 km a escala municipal, con el área de influencia y las localidades (puntos) mostradas.

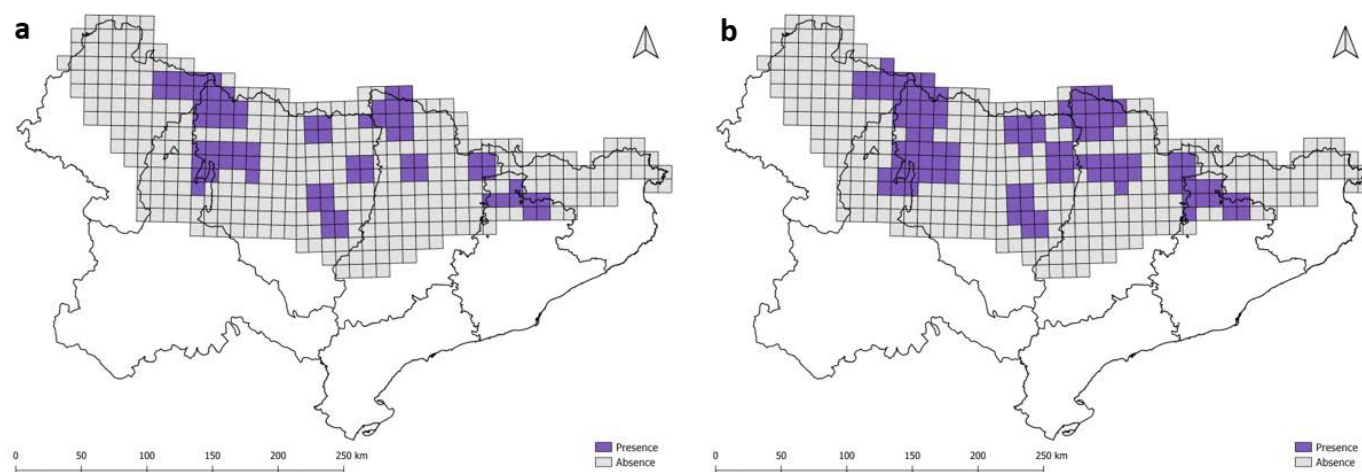


Figure 6. Wolf's distribution in the Pyrenees in 10x10km UTM grid at a *municipality scale*, original (a) and with influence area (b) in 1950.

Figura 6. Distribución del lobo en los Pirineos en 1950 en una cuadrícula UTM de 10x10 km a escala municipal, original (a) y con el área de influencia (b).

Finally, the data for 2000-2021 shows 75 UTM grids (Table 1, Fig 7a), which is 18.3% out of the area. Considering the influence area (only applied to Navarre and Aragon), that makes an outcome of 82 UTM grids, which is 20.0% (Table 1, Fig 7b).

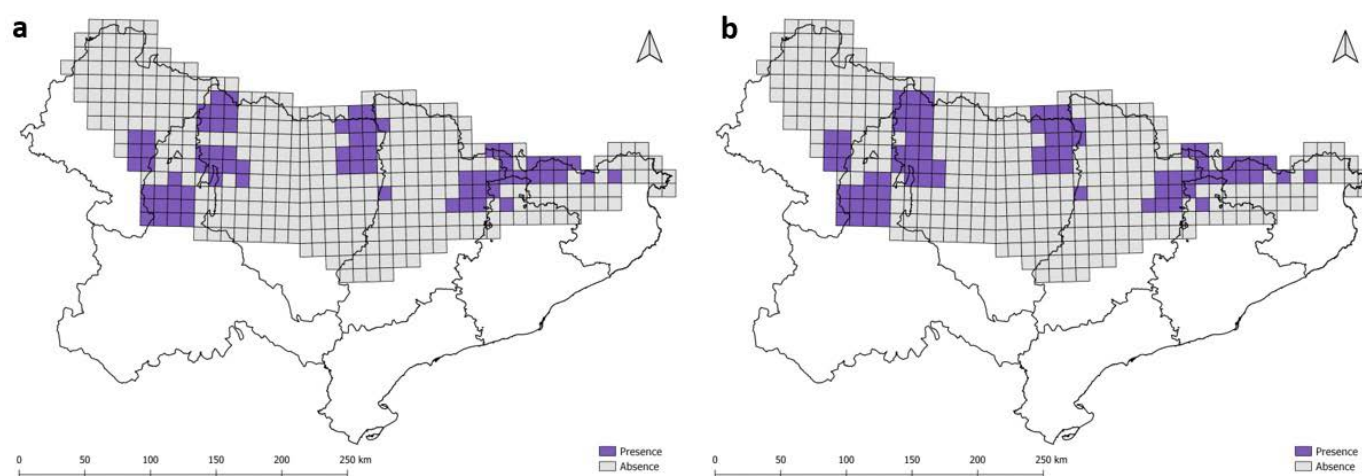


Figure 7. Distribution in the Pyrenees in 10x10km UTM grid at a *municipality scale*, original (a) and with influence area (b) in 2000-21. Buffer only for Aragon and Navarre data.

Figura 7. Distribución del lobo en los Pirineos en 2000-21 en una cuadrícula UTM de 10x10 km a escala municipal, original (a) y con área de influencia (b). Área de influencia solo para los datos de Aragón y Navarra.

Comparing the three periods (UTM grids count), we found significant differences in both cases: using 1846-50 data at a municipal scale (MU) ($\chi^2 = 280.6$ df = 2, $p < 0.001$) and using 1846-50 data at a judicial district scale (JD) ($\chi^2 = 350.7$, df = 2, $p < 0.001$). Moreover, the main period with fewer presences (UTM grids) is the current one (2000-21) followed by 1956-61 and the last is 1846-50 (Table 1). The additional data for the period 1855-64 shows the lowest numbers (Table 1), which is consistent with the amount of data obtained from hunting statistics.

4. DISCUSSION

The wolf, widely distributed in the northern hemisphere, was intensely persecuted during the 19th century for being a highly conflictive species (Chapron *et al.*, 2003; Khalil *et al.*, 2014) and for many years wolves were considered vermin that should be eradicated (Mech, 2012). To achieve its extermination, the administration promoted some legislation that was harmful to the species (Martínez-Abraín *et al.*, 2020; Rico & Torrente, 2000). The implementation of these measures generated, in effect, a considerable reduction in wolf populations throughout their previous distribution range, reducing it to several population cores (Chapron *et al.*, 2014; Llana *et al.*, 2012; Mech, 1995; Wabakken *et al.*, 2001).

As Valverde (1971) extracted from the geographical dictionaries of Madoz (1846-50) and Bleiberg & Quirós (1956-61) the wolf around 1840s was distributed throughout Spain, excluding the coastline of Catalonia; and around the 1950s, “the area of distribution of the wolf has practically been reduced to the western half of the Peninsula [...]. In the eastern half, a residual population remained in the Pyrenees, probably centred in the province of Huesca where “the last wolves must have been killed in 1956” according to official information. The author also includes a basic cartography on wolf distribution in the 1840s, 1950s and 1970s, which has been widely used by subsequent historiography as a graphic reference on the historical distribution of the wolf in Spain. Likewise, Garzón (1974) mentioned that the species was exterminated in the Pyrenees around 1955 and around 1960 in most of the Central System Mountain range of the Iberian Peninsula. He also includes a cartography on the distribution of the wolf in Iberia (Spain and Portugal) in 1973, where the species “is practically reduced to the extreme northwest with small nuclei in some mountain ranges in the centre and south”. Grande del Brío (1983) also explored the distribution of the wolf in the Iberian Peninsula and mentioned the different ecological populations that existed at that time (Zamorano-Portuguese, Burgalesa, Asturleonese, Galaica, Andalusian, Salamantina, and Extremeña) and he points out that the wolf had disappeared from the Central Pyrenees (Huesca) at the end of the 19th century, and that “there were wolves in the Eastern Pyrenees until the beginning of the 20th century”, specifically in the mountain ranges of Port del Comte (Solsonès and Alt Urgell) and Boumort (Pallars Jussà). Also, at the beginning of the 20th century, “the last remaining wolves were concentrated on the southern slopes of the Western Pyrenees” (north of the province of Zaragoza and the valleys of Roncal, Aezcoa, Elizondo and Salazar, plus the Urbasa mountain range in Navarre).

For the regional case of Catalonia, the works of Ruiz-Olmo (1990), Grau i Pujol *et al.* (1990), Manent (2004) and Massip (2011) offer some data on the extinction of the wolf in the different Catalan regions. From the synthesis proposed by the latter author (Massip 2011, p. 234), we know that wolf extinction in the Pyrenean regions followed the following chronology: Alta Ribagorça (1890-1900), Alt Urgell (1890-1930), Pallars Jussà (1890-1930), Cerdanya (1915-1930), Ripollès (1920-1950), Pallars Sobirà (1920-1954) and Val d’Aran (1930-1952).

Besides, it is worth mentioning that the Mapa cinegético nacional, Avance informativo (Servicio de Pesca Continental, Caza y Parques Nacionales, 1968), which illustrates the distribution of the wolf in 1968, does not place the species in the Pyrenees in that period.

The approach used in the descriptions made by Garzón (1974), Grande del Brío (1983) and Valverde (1971) cannot be replicated as a detailed description of the methodology used is missing. The historical distribution of the wolf proposed by Valverde for the 19th century responds to a very personal and debatable interpretation of the data obtained from Madoz. In fact, recent work by Nores and López-Bao (2022) uses the same historical sources used in this analysis to extract the distribution of the wolf in Spain over the last two centuries and, similarly, they note that there is some inconsistency between the interpretation of the status of the wolf in the 19th century made by Valverde (1971) and the results obtained in the study. They conclude that “Whereas it is true that wolves were present in all Spanish provinces at that time, wolf presence was very small, scattered, or even marginal in several provinces [...]. In fact, our estimates of the wolf range for 1846–1850 extensively overlap with the most remote and inaccessible mountainous areas of Spain, [...]”.

The data obtained in our study show that, in 1846-50s, in accordance with [Madoz \(1846-50\)](#) (Fig 3 and Fig 4), some continuity in the distribution of the wolf is interpreted in the community of Navarre, Aragon (provinces of Huesca and part of Zaragoza) and the western part of Catalonia (province of Lleida), as well as two isolated cores in the centre (part of the province of Barcelona) and east (part of the province of Girona) of that community. Regarding the recent work of [Nores & López-Bao \(2022\)](#) and [Clavero *et al.* \(2023\)](#) referring to peninsular Spain as a whole, our regional study (and our method of interpreting the sources) coincides with the distribution of wolf presence in the 19th century proposed by the first one ([Nores & López-Bao, 2022](#)) and differs, in terms of the result of the predictive distribution model, from that proposed by the second one ([Clavero *et al.*, 2023](#)). Additionally, the data obtained from the *Memoria elevada al Excmo. Sr. Ministro de Fomento* ([Dirección General de Agricultura, Industria y Comercio, 1861](#)) and the *Anuario Estadístico de España 1862-1865* ([Junta General de Estadística, 1866-67](#)) for the years 1855-64, show some continuity in the province of Lleida, in the area closest to the province of Huesca, which is consistent with the information obtained from [Madoz \(1846-50\)](#). In 1950, according to [Bleiberg & Quirós \(1956-61\)](#) (Fig 6), despite a decrease in the distribution area, two continuous units are differentiated; one on the border between the communities of Navarre and Aragon (part of provinces Zaragoza and Huesca that border Navarre) and another on the border between Aragon (province of Huesca) and Catalonia (province of Lleida), extending slightly towards the pre-Pyrenees area of Barcelona's province.

The wolf decline between the 19th and 20th centuries observed in the present study is consistent with the historical context of the species and our analysis does not agree with Valverde's first interpretation of the Pyrenean wolf range in the 19th century. Our results show some differences and, additionally, our study provides greater accuracy and detail at a local scale (Pyrenees) than the one made by ([Valverde, 1971](#)). Despite both (Valverde's approach and this analysis) having been extracted from the same geographical dictionaries, Valverde likely made an overestimation with the information extracted from ([Madoz \(1846-50\)](#)) and it is likely that the methodology used was different too. In addition, Valverde's interpretation perpetuated the notion that wolves occupied almost all of peninsular Spain in the mid-19th century, which led to a biased perception of wolf distribution that has persisted over time ([Nores & López-Bao, 2022](#)). In the present study an exhaustive and detailed systematic review has been carefully carried out twice, since the study area was much smaller than that of [Valverde \(1971\)](#), so we are confident that this comparison is strong, since the same methodology and common criteria have been used in the three periods studied, thus minimizing possible interpretative biases.

[Valverde \(1971\)](#) made the assumption that the wolves disappeared from the entire Pyrenees with the information provided only from the province of Huesca ([Servicio de Pesca Continental, Caza y Parques Nacionales, 1968](#)), but we believe that this seems a very risky assumption. Likewise, the information about the wolf's extermination of the Pyrenees around 1955 provided by [Garzón \(1974\)](#) is very ambiguous. In our opinion, Valverde and Garzón refer to a she-wolf and three cubs awarded that year in Huesca by the local board for the extinction of harmful animals ([Rico & Torrente, 2000](#)). In both cases, they differ from the data obtained in this analysis. We show that even though a notable reduction of the wolf populations is shown in 1950, there were still presences at both ends of the province of Huesca. In the last two decades of s. XX data are collected on killed wolves (about 6) in Navarra and Aragon (specifically in Canal de Berdún and Cinco Villas) ([Herrero *et al.*, 1997](#)).

Concerning the most recent data, the representation in UTM grids of the wolf's distribution in the current period (2000-2021) is quantitatively similar to that of 1950, but with slight differences in spatial location. Likewise, a core is seen in the community of Aragon that borders Navarre and another in the part that adjoins Catalonia, although in this area it is perceived more compact towards the north of the Pyrenees than in 1950. The third core is once more, located in the central part of the Catalan Pyrenees, yet again, it is more compact to the north than in the previous century. Thus, as stated in the results, it could not be said that the wolf disappeared from the Pyrenees since there is data of "presence" for the three periods, but neither can the increase, and therefore the recovery of its populations in the study area be assured, since the proportion of presences for the current period is similar to that of about a century ago.

Additionally, it is worth mentioning some investigations such as those of [Nores and López-Bao \(2022\)](#) and [Clavero et al. \(2023\)](#) which have addressed the same study subject as presented here, but have used a broader geographic scope, so our work differs in two fundamental aspects: the choice of sources and the geographic emphasis.

When it comes to source selection, our research adopts a diachronic perspective, supported by a more diverse and complete set of documentary sources than prior studies. In contrast, [Nores and López-Bao \(2022\)](#) focus their attention on sources dating from the mid-19th and 20th century sources, with references to [Madoz \(1846-50\)](#), the report published in [Dirección General de Agricultura, Industria y Comercio \(1861\)](#), and [Bleiberg & Quirós \(1956-61\)](#). However, it neglects several sources as those from 1862-64 ([Junta General de Estadística, 1866-67](#)) and the wolf cartography from [SPCCPN \(1968\)](#). Likewise, [Clavero et al. \(2023\)](#) limit their references to [Madoz \(1846-50\)](#) and the wolf cartography from [SPCCPN \(1968\)](#), omitting intermediate sources such as the 1861 and 1862-64 ones, as well as, more recent sources like [Bleiberg & Quirós \(1956-61\)](#). It is noteworthy that our study exclusively incorporates the updated data from 2000-2021 on the presence of the wolf in the Pyrenees, provided by the regional administrations.

Regarding the geographical dimension, our study sets itself apart with its focus on the mountainous massif and the southern valleys and sierras of the Pyrenees. This approach contrasts with the national approaches of the research by [Nores and López-Bao \(2022\)](#) and [Clavero et al. \(2023\)](#). We believe this landscape-level perspective will offer a more granular and accurate understanding of the historical wolf distribution in this specific region area of the Iberian Peninsula.

The situation of the wolf population in the Southern Pyrenees is a particular case since a remarkable large carnivore recovery across huge swathes of Europe has been observed ([Chapron et al., 2014](#)), including the wolf ([Reinhardt et al., 2019](#)). However, in Spain, note that, for example, the last reliable record in the community of Navarre is from 1996 and it is acknowledged that there is an absence of breeding packs in that community since 1930 (Enrique Castien, personal communication July 12, 2021). In Catalonia, wolf individuals are being monitored since 2004 to corroborate possible reproduction, which has not been demonstrated until now. Moreover, the registered individuals come from the Franco-Italian populations which are expanding since the 90s, and not from Iberian origin ([Clavero et al., 2023](#); [Lampreave et al., 2011](#); [Ministerio de Medio Ambiente, 2006](#)). These wolves mostly occupy the mountain ranges in the regions of Alt Urgell, Cerdanya, Solsona, Berga, and Ripoll. All of the distribution area keeps a geographical continuity with the wolf presence in France and generally are natural protected areas where they can find wild prey such as Pyrenean chamois (*Rupicapra p. pyrenaica*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), European mouflon (*Ovis orientalis musimon*) and red deer (*Cervus elaphus*) ([Lampreave et al., 2011](#)). For these reasons, and based on the type of information obtained, it is likely that the quotes recorded in the Pyrenees on the Iberian side belong to dispersing individuals of passage, as, at the moment, the existence of breeding individuals in the Pyrenees is not known ([Clavero et al., 2023](#)).

In general, in the studies of mammal historical distribution that handle written sources of a certain antiquity, three aspects must be subjected to rigorous critique that clarifies the reliability and accuracy of the sources: chronological dating, identification of the species and its location ([Boshoff & Kerley, 2010](#); [Rico & Torrente, 2000](#)).

The two geographical dictionaries that we have handled in this study are two classic written sources with proven validity and fairly valued by Spanish historiography. However, it is accepted that the development of a geographical dictionary, due to the magnitude of such a project, may lead to errors, inaccuracies, imprecisions, concealments or omissions in terms of the data collected and published. In that way, the existing geographical dictionaries before the 20th century used widely and freely the works that preceded them, so that there may be a chronological gap between the date of publication of the work and the register's original dating. Nevertheless, it is commonly accepted that the information published in the *Diccionario geográfico-estadístico-histórico y estadístico de España y sus posesiones de Ultramar* ([Madoz, 1846-50](#)) offers a consistent picture of the Spain of the first half of the 19th century ([Núñez-Quirós et al., 2007](#); [Torrente, 1999](#)) although some studies have noted the unreliability

of the demographic statistics published in Madoz (Martín García, 2020). Meanwhile, the *Diccionario geográfico de España* by Bleiberg & Quirós (1956-61) is considered a reliable source that reflects well the situation of rural Spain in the times known as the Francoist Autarky (1939-1959). Geographical dictionaries provide organized, comprehensive, and truthful information about geographical entities (Capel, 1981), so the question of the geographical location of the corresponding descriptions and references should not be an aspect that questions their validity as a source, provided that historical variations in terms of the aggregation or elimination of municipalities are taken into account (Ministry of Public Administrations, 2008). Besides, the identification of the species, the wolf in our case, does not offer nomenclature problems, saving the generic references to harmful or fierce animals that, in this study, we have ignored. Moreover, both the *Memoria elevada by the Dirección General de Agricultura, Industria y Comercio* (Dirección General de Agricultura, Industria y Comercio, 1861) and the data recorded in the *Anuario Estadístico de España 1862-1865* (Junta General de Estadística, 1866-67) have, for the purpose of our study, sufficient reliability in terms of the dating, identification and location of the animals hunted.

The environmental information contained in the geographical dictionaries of Spain is a fertilized field for the biological interpretation of historical data. Both dictionaries logically publish a wide range of territorial information based on questionnaires (interrogatories), which respond to a national, regional and local sampling strategy. Although these questionnaires were not originally designed to sample species distribution, the presence of animal species in the resulting body is extensive and their taxa are usually explicit: they are therefore identifiable and georeferenced. Statistical inferences that may result from the use of eventual models to infer or predict species distributions from these sources must take into account the existence of a bias in origin, possible but not evident or easy to correct, which should be completed with contemporary data from other statistics or historical variables; a bias that should not be neither underestimated nor overestimated.

Despite the issues related to historical sources, the strength of our analysis is noteworthy since we applied the same criteria and methodology to three different time periods over the last two centuries, and so, minimize potential interpretative biases. Given that this is a subject under continuous discussion, but the historical data available are unrepeatable, this study has been able to strengthen the historical data available for this species, as well as to provide more detail and adjustment in the interpretation of these data on a more regional scale.

To conclude, we can reassert that the wolf populations in the Pyrenees have suffered a considerable decrease between the 19th and 20th centuries, showing a scarce and continuous presence of wolves between the 1960s and 1990s, and then a recovery in the presence of the species from the beginning of the present century. Still, a restoration of its population cannot be assured due to the non-existence, for the time being, of reproduction events.

Supplementary information ↑

Funding sources

This research received no external funding.

Supplementary material

Not applicable.

Data availability

The authors do not agree to share the database for academic reasons. The information provided in the article itself is sufficient for the interpretation task. Any doubts or clarifications can be addressed to the corresponding author directly.

Acknowledgements

We would like to thank the people we contacted from each autonomous community who have provided us information of present-day wolf distribution: Manuel Alcántara (Gobierno de Aragón); Ricardo Canovas, Gabriel Lampreave and Santiago Palazón (Generalitat de Catalunya) and Enrique Castien (Gobierno de Navarra). We also appreciate the help provided by Iris Martínez with the revision of the *Diccionario geográfico, histórico y estadístico de España y sus posesiones de Ultramar* (Madoz, 1846-50) as well as Dafne Soria and Ana Morton for their assistance during the final revision and correction and Emma Denehy for her English revision.

Authorship contribution statement

Conceptualization, L.L.; methodology, A.Q. and L.L.; validation, L.L. and J.P.T.; formal analysis, A.Q.; resources, L.L. and J.P.T.; data curation, A.Q.; writing—original draft preparation, A.Q., L.L. and J.P.T.; writing—review and editing, A.Q., J.P.T. and L.L.; visualization, A.Q.; supervision, L.L. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare no conflict of interest.

Statement on the use of Artificial Intelligence

Not applicable.

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