Early stages in the expansion process of brown bears: A socio-ecological perspective

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Resumo

Nas últimas décadas, a população de ursos pardos Cantábricos (*Ursus arctos*) mostrou uma tendência positiva em toda a Espanha. Dentro do cenário de recolonização do urso pardo, que inclui um aumento no seu tamanho e distribuição, os principais desafios da conservação passam por facilitar a coexistência de humanos e ursos. Os ursos pardos podem persistir em paisagens altamente dominadas pelo homem, como agroecossistemas ou florestas, onde os recursos alimentares humanos estão disponíveis. Quando se trata de áreas de recolonização, onde a população rural perdeu o conhecimento sobre medidas de adaptação à coexistência, a presença do urso pode causar danos, gerando conflitos. Estes danos podem muitas vezes ser causados por um número reduzido de indivíduos. Compreender como os ursos pardos estão a ocupar áreas onde já haviam desaparecido, bem como suas interações com humanos nessas áreas pode ajudar a delinear estratégias de conservação efetivas antecipando conflitos futuros.

Neste estudo, centramo-nos na área de expansão ocidental da população de ursos pardos cantábricos (zonas montanhosas da Galiza), com o objetivo de compreender as fases iniciais da recolonização desta espécie numa perspetiva socio-ecológica, combinando ferramentas genéticas e sociais. Especificamente, pretende-se descobrir o número, o sexo, a origem e o parentesco dos ursos que se encontram atualmente na Galiza, e compreender o regresso do urso pardo a esta região conforme relatado no número de danos registados nesta área e nas notícias do principal jornal regional.

A partir dos resultados obtidos através da genotipagem de microssatélites, conseguimos identificar 12 machos e 1 fêmea no leste da Galiza, o que como esperado, suporta um processo de recuperação mediado por machos. Estes indivíduos têm origem na subpopulação ocidental. A estimativa das relações genealógicas mãe-filho permitiram inferir uma dispersão para a Galiza a partir das três áreas de reprodução de ursos da subpopulação ocidental, nomeadamente de Narcea-Alto Sil, Somiedo e Proaza. De 2010 a 2021, foi registado um número altamente variável de participações de danos por ano, sendo estas principalmente referentes a ataques a apiários. Nos últimos quatro anos, o número de participações de danos de ursos num município não se correlacionou com o número de ursos identificados a partir da amostragem genética não invasiva. Também foi registada uma maior taxa de danos por urso na Galiza quando comparada à subpopulação ocidental, o que pode ser explicado pelas diferenças na história de convivência entre ursos e humanos nessas áreas. A conservação da espécie foi o tema que mais predominou nas notícias. O número de notícias sobre danos no município correlacionou-se positivamente com o número de ursos e com o número de participação de danos nesse município. A monitorização contínua da expansão dos ursos cantábricos, combinando dados genéticos e sociais, é essencial para uma gestão voltada para a mitigação do conflito homem-vida selvagem.

Palavras-chave: *Ursus arctos*, Recolonização, Coexistência, Genética não-invasiva, Relação genealógicas, Comportamento de dispersão, Danos de ursos, Apiários, Noticias, População rural, Galiza

Abstract

In recent decades, the Cantabrian brown bear (*Ursus arctos*) population have been showing a positive trend across Spain. Under the scenario of brown bear recovery, which includes an increment in population size and species range, main conservation efforts often consist in facilitating human and brown bear coexistence. Brown bears can persist in highly human-dominated landscapes, like forest-farmland or agroecosystems, where human food resources are available. In recovery areas, where rural population lost the knowledge to coexist with the species, the presence of bears may cause damages, generating conflict. Interestingly, such damages may be often caused by a few number of individuals. Understanding how brown bears are occupying areas where they had already disappeared, as well as their interactions with humans in these areas may help to delineate effective conservation strategies anticipating future conflicts.

In this study, we focused on the western expansion border of the endangered Cantabrian brown bear population (mountains areas of Galicia), aiming to understand the early stages of the recolonization of Cantabrian bears from a socio-ecological perspective, by combining genetic and social tools. Specifically, we aim to unravel the number, sex, origin and relationships of bears that are currently in Galicia, and to understand the return of brown bear in Galicia as reported in the number of damage claims recorded in this area and in the news of the main regional newspaper

From results obtained through microsatellite genotyping, we were able to identify 12 males and 1 female in eastern Galicia, supporting a male mediated recovery process. Furthermore, the individuals present in eastern Galicia have their origin clearly assigned to the western subpopulation. Mother-offspring relationships support the dispersal into Galicia of individuals from three main bear breeding areas from this subpopulation, namely from Narcea-Alto Sil, Somiedo and Proaza. A highly variable number of damage claims per year, mostly referring to apiaries, was recorded from 2010 to 2021. For the last four years, the number of bear damage claims in a municipality was not correlated with the number of bears identified with non-invasive genetic sampling. We also recorded a higher damage ratio per bear in the Galicia when compared to the western subpopulation, which can be explained by the differences in the history of coexistence between bears and humans in these areas. The conservation of the species was the most predominant theme in the news. The number of news about bear damages in a municipality was positively correlated with the number of bears and the number of damage claims in that municipality. Continuous monitoring of the Cantabrian bears expansion, combining genetic and social data, is essential to a management targeting mitigation of human-wildlife conflict.

Keywords: *Ursus arctos*, Recolonization, Coexistence, Non-invasive genetics, Genealogical relationships, Dispersal behaviour, Conflicts, Bear damages, Apiaries, Media, Rural population, Galicia

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List of Abbreviations

DNA - Deoxyribonucleic acid

PCR - Polymerase Chain Reaction

PID - The Probability of Identity

PID_{sibs} - Probability of Identity for siblings

ADO - Allelic Dropout

FA - False Allele

Q/q - proportion membership

1. Introduction

1.1. Challenges on large carnivores' recovery

Large carnivores are one of the most challenging group of species to conserve in modern times (Chapron et al., 2014; Lute et al., 2018). This challenge is particularly relevant in areas where large carnivores were once present but have been absent for decades, and humans have lost the familiarity of sharing the landscape with them (López-Bao et al., 2017). Both the predatory behaviour of these species and their large home ranges are factors of direct competition with human interests and are often behind the intense conflict that may occur, not facilitating the persistence of large carnivores in human-dominated landscapes (Chapron et al., 2016). Currently, in Europe, most populations of brown bear (*Ursus arctos*), grey wolf (*Canis lupus*) and Eurasian lynx (*Lynx lynx*) are increasing and returning to areas where they were previously locally extinct (Cimatti et al., 2021). This return has been favoured by the widespread rural land abandonment and subsequent increase of forest cover (Cimatti et al., 2021). However, where human populations have lost their memory of coexistence with these animals, the return may be convoluted (López-Bao et al., 2017). There are different factors that challenge the recovery and conservation of these large carnivores (Dressel et al., 2015; López-Bao et al., 2017), among them the illegal killing (Gangaas et al., 2013; Kaczensky et al., 2011; Liberg et al., 2012), public resistance to wolf or bear recovery plans (Bruskotter & Fulton, 2012; Houston et al., 2010; Sjölander-Lindqvist et al., 2015), which is a consequence of fear and resentment (López-Bao et al., 2017), and the lack of knowledge (Dressel et al., 2015).

1.2. Cantabrian bear population and their recovery

The European brown bear populations has been showing positive trends across Europe in recent decades, both in population size and range (Chapron et al., 2014; Gonzalez et al., 2016). Currently, the species is classified as Least Concern by the IUCN Red List (McLellan et al., 2017). Like other brown bear populations in Europe, the endangered brown bear population from the Cantabrian Mountains has been showing the same positive trend in the recent decades (López-Bao et al., 2021a; Gonzalez et al., 2016), particularly since 2004 following the implementation of conservation measures (López-Bao et al., 2021b). The Cantabrian brown bear population has received considerable attention in the recent years, being the focus of different monitoring programs, scientific studies and public efforts, as it is the last remaining of a past distribution that covered the whole Iberian Peninsula (Wiegand et al., 1998). Historical records suggest that the brown bear was widely distributed across the Iberian Peninsula during the 14th and 15th centuries (Alphonso et al. 1582, in López-Bao et al., 2021c). However, due to anthropogenic factors, like hunting and habitat degradation this population declined (Gonzalez et al., 2016). At least 400 years ago, the Cantabrian population became isolated from the Pyrenean population, which is nearest geographical brown bear population (Nores & Naves, 1993). More recently, during the first decades of the 20th century, the Cantabrian population became fragmented into two subpopulations in the Cantabrian Mountains, the eastern and the western subpopulations, which have been separated by 50–100 km of poor habitat quality (García et al., 2007; Nores & Naves, 1993). These two subpopulations continued declining in number until the mid-1990s (Gonzalez et al., 2016), when they reached their minimum of 50–60 individuals in the western subpopulation (Wiegand et al., 1998), and 20–25 in the eastern subpopulation (Palomero et al., 1993).

The Cantabrian population is genetically divided into two genetic clusters supported by nuclear markers and mitochondrial lineages that strongly match the western and eastern Cantabrian subpopulations (Gonzalez et al., 2016; Gregório et al., 2020; Pérez et al., 2009). Due to the strong bottleneck and isolation suffered by these subpopulations, the genetic diversity was reduced, particularly in the eastern subpopulation, which has one of the lowest genetic diversity recorded for bears in Europe (Gonzalez et al., 2016; Kopatz et al., 2014; Valdiosera et al., 2008).

Notably in the last 25 years, the Cantabrian population has been increasing, reaching ~280 individuals in the western subpopulation and ~50 individuals in the eastern subpopulation (Figure 1). Additionally, this population recovery has favoured the movement of males across the subpopulations, mediating admixture and the reestablishment of gene flow between them (Blanco et al., 2020). In 2008 two admixed individuals were identified at the western limits of the eastern subpopulation range (Pérez et al., 2010). Since then, gene flow has been reported in both directions, but mostly from the western towards eastern subpopulation (Blanco et al., 2020; Gonzalez et al., 2016; Gregório et al., 2020). Migrants have restored gene flow and there was an increase in the genetic diversity of subpopulations in recent times (Blanco et al., 2020; Gonzalez et al., 2016). Furthermore, the increase in population size is also favouring a range expansion, and the species is recolonizing areas in eastern Galicia, where it has been recorded with a regular presence since 2009 (Naves & Fernández-Gil, 2017). Currently, there is only a small area in Os Ancares (north of the O Courel mountains) with a stable presence of bears (Figure 1). The species has also been detected in Parque Natural de Montesinho, Portugal, in 2019 (Gregório et al., 2020).

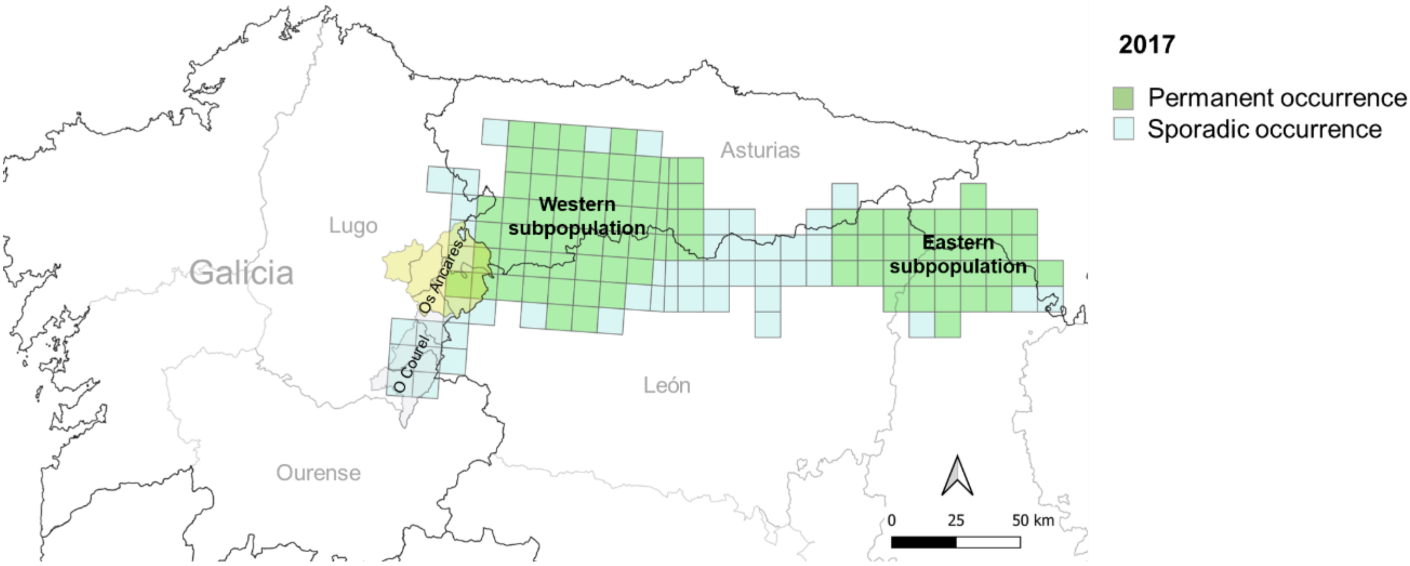

Figure 1 – Map of the distribution range of the Cantabrian brown bear. Distribution actualized in 2017.

The recolonization and permanent presence of brown bear in Galicia is a relatively recent event, starting around 2009, and its presence is mostly limited to the eastern area of the Lugo province (Figure 1; Naves & Fernández-Gil, 2017). Thought the origin of the individuals recolonizing Galicia is unknown, it is expected that dispersing bears in this area were arriving from the breeding areas closest to Galicia in the western subpopulation, namely Narcea-Alto Sil, Somiedo and Proaza (Figure 2; López-Bao et al., 2021b). Females with cubs have been annually detected in the Narcea-Alto Sil breeding area since 1989 (López-Bao et al., 2021b). This is the breeding nucleus that supported the highest density of females with cubs of the entire Cantabrian range and the number of breeding females has risen substantially over time, with a current average of 12.4 females with cubs per year (Figure 2; López-Bao et al., 2021b). Additionally, since 1989 (except for 1994) breeding has been continuous in the Somiedo breeding area (López-Bao et al., 2021b). This nucleus also presents an increase in the presence of breeding females over time, with an annual average of 5.4 females with cubs of the year for the last decade (1999-2018) (Figure 2; López-Bao et al., 2021b). Breeding has also been observed in the Proaza breeding nucleus since 2005, with a current annual average of 3 females with cubs of the year for the last decade (Figure 2; López-Bao et al., 2021b).

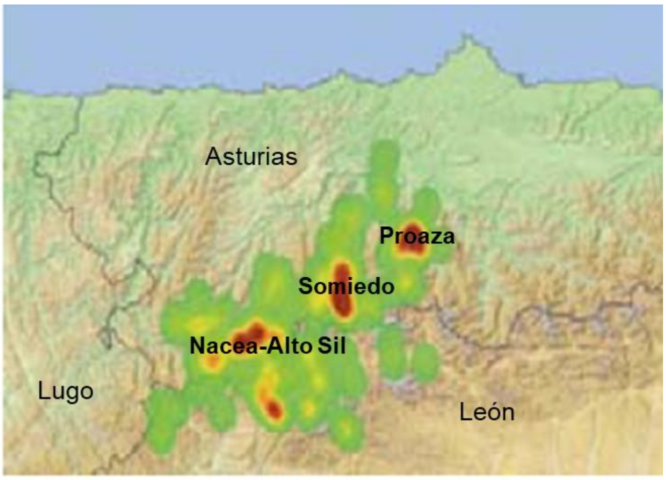

Figure 2 – Density map of the three breeding areas of the western subpopulation between 2009 and 2018. Map obtained from López-Bao et al., 2021b.

From a socio-economic perspective, the expansion and population recovery process of bears may intensify potential negative interactions with humans. Bears have large spatial requirements (Gittleman, 2001), and their regular presence in human-dominated landscapes increases the risk of potential conflicts related to exploitation of human food resources, e.g., livestock predation, or crop and apiaries damages, which may trigger social reactions and even persecution (Can et al., 2014; Dorresteijn et al., 2014). In recolonized areas, where the human memory of coexistence has been lost and damage prevention measures may not be generally implemented, even the presence of a few individuals is expected to increase the number of human-bear conflicts per capita, compared with other areas (Bautista et al., 2017). The knowledge on socio-ecological perspective associated with the recolonization of brown bear in Europe is limited (Glikman et al., 2019).

Thus, understanding the early stages of the Galicia's recolonization of brown bears and consequent interactions between bears and humans is of paramount importance to facilitate coexistence and to maintain the observed expansion trend. Different methods have been used to monitor the expansion of the brown bear populations, both invasive and non-invasive methods, including genetic (e.g., genetic tools), ecological (e.g., spatial capture–recapture, photographic mark-resight, counting of females with cubs) and social approaches (e.g., damage claims, media coverage). In this study we will focus on genetic and social approaches.

1.3. Molecular tools for monitoring brown bear

Brown bears have been a model species to develop and test non-invasive molecular tools that are now routinely used for individual identification, and subsequently in population census, tracking dispersal movements, monitoring gene flow, among many others (Swenson et al., 2011). Furthermore, non-invasive genetic samples (scats and hairs) allow individual monitoring without the need to see or disturb individuals, which makes it a good approach from an ethical point of view (Solberg et al., 2006; Taberlet & Luikart, 1999).

Microsatellites and single nucleotide polymorphisms (SNPs) are the two types of markers generally used in individual identification of non-invasive samples. Microsatellites are characterized by their high mutation rates, which generally make them highly polymorphic and thus remarkably valuable to study small and endangered populations, which are often depauperated in genetic diversity (Larsen et al., 1983; Lorenzini et al., 2004). Their high polymorphism greatly increases the ability to differentiate individuals with high accuracy, and their Mendelian inheritance make them very useful for assigning individuals to original populations and to reconstruct genealogical relationships (Paetkau & Strobeck, 1998; Puckett & Eggert, 2016). On the other hand, SNPs are biallelic markers and thus larger panels are needed to achieve the same accuracy as that presented by a small panel of microsatellites (López-Bao et al., 2020). However, SNPs assure better than microsatellites the reproducibility and allele binning across different laboratories, which is very relevant to joint databases that were built by different teams. When comparing both types of markers for error rates departing from the same initial template, the two markers seem to perform very similarly in non-invasive samples of the brown bear (López-Bao et al., 2020).

Both types of molecular markers have been used in the Cantabrian brown bear population. For instance, microsatellites and SNPs genotyped from non-invasive samples have been used in population census (Taberlet et al., 1997), estimates of population densities (Carroll et al., 2018), assignment of individuals to subpopulations (De Barba et al., 2010; Taberlet et al., 1997), estimates of genetic diversity and gene flow (De Barba et al., 2010; Gregório et al., 2020; Pérez et al., 2010), among others.

1.4. Media and brown bear recolonization

Coexistence and conflict are two very interlinked terms, due to the negative interactions between bears and humans or the existence of different opinions on how bears should be conserved and how humans should share the territory with them (Chapron & López-Bao, 2016; López-Bao et al., 2017). Therefore, the existence of confronting perceptions about bears, e.g. groups opposing bear recovery vs. bear supporters, is one of the major obstacles for the conservation and recovery of the species (Fernández-Gil et al., 2016; Woodroffe et al., 2005).

The occurrence of bears is often perceived as problematic by local communities, because of potential attacks on livestock or beehives, damages to crops or fruiting trees, or the very rare attacks to humans (Ballesteros et al., 2021; Penteriani et al., 2016; Røskaft et al., 2003). In Europe, predation on livestock is the most frequent reported brown bear damage (Bautista et al., 2017), and attacks on beehives are more frequent here than in any other continent (Bautista et al., 2017). In Spain, damages to apiaries are the main type of damage caused by bears (Figure 3), constituting over 60% of all the damage claims filed and compensated between 2009 and 2018 in the Cantabrian Mountains (Ballesteros et al., 2021).

Figure 3 – Image of a brown bear knocking a beehive to the ground to eat the honey and bee larvae in an apiary in the western Cantabrian Mountains. Photo from Ballesteros et al., 2021 .

In areas of the Cantabrian Mountains where bears have been absent until recent times, knowledge of the species is more limited, compared to neighbour areas where the species has been permanently present (López-Bao et al., 2021c). Consistently, the use of damage preventive measures to apiaries or livestock is expected to be lower in areas where brown bear has been absent (López-Bao et al., 2021c). Remarkably, there is no direct correlation between the number of attacks on beehives and the Cantabrian brown bear population increase in areas where there has been a continuous presence of the species over time (Ballesteros et al., 2021). This was explained by the application of mitigating strategies in these areas of continuous occurrence (Figure 4), which reduce the probability of bear damages occurring, as well as their intensity (Ballesteros et al., 2021; Naves et al., 2018).

B.

A.

Figure 4 - A) Image of an ancient beehive enclosure (alvar) in the mountains of Lugo, built to protect the hives from bear attacks. Photo from Ballesteros et al., 2021 B) Image of an electric fence protecting an apiary in the Cantabrian Mountains. Photo taken by J. Naves.

Studying human-bear conflicts from a social perspective is very relevant because conflicts associated with damages caused by bears not only have an economic component derived from direct and indirect losses from the damage, but also have a highly significant emotional component (Ballesteros et al., 2021; Fernández-Gil et al., 2016). A direct relationship between the scale of the conflicts and the quantity or importance of the damage does not always exist (Ballesteros et al., 2021). Therefore, it is not only necessary to have information about how much damage is caused and what is its temporal and spatial distribution, but also about the perception and people's opinions about the species, its damages and conservation, because this perception will influence the management and conservation of the species (Ballesteros et al., 2021)

In a recovery scenario, where the number of interactions between bears and humans is predicted to increase, and people are not used to share the landscape with the species, it might be expected more public awareness of these issues resulting in an increment of news in the media. There are several factors that could influence the perception that society holds on a particular species, like social norms, legislation, knowledge, experiences and information (Stamm et al., 2000). However, the mass media stands out because news can directly influence public´s perception towards the species as the mass media determines the frequency and content of information that reaches the public (Siemer et al., 2007; Stamm et al., 2000). Consequently, they can affect the understanding and interpretation of brown bear presence in areas recently recolonized (López-Bao et al., 2021c). However, media coverage is often biased towards conflict (Jacobson et al., 2012), reflecting the opinion of certain social groups with particular interests (Price et al., 1997). Attending the recolonization of brown bear in Galicia, it would be expected that the social perception towards the presence of bears, and associated potential conflicts, will be reported in the media, which is an important source of information about the general public's opinion (Dressel et al., 2015). On the other hand, social media may have also important impacts on the conservation of species given its prior activity of informing and clarifying, as well as its ability to demystify wrong perceptions and concepts (Chandelier et al., 2018). Knowing how the media portrays the brown bear in Galicia may be very useful to drive approaches to its conservation.

1.5. Objectives

The recolonization of Galicia with a permanent bear population is a recent event and provides an opportunity to contribute for the understanding of the early stages of brown bear recolonization processes from a socio-ecological perspective.

From the ecological perspective of a recent recolonization event, we aim to unravel the number, sex, origin, and relationships of bears that are currently in Galicia. For that, we first genotyped a set of available non-invasive samples collected between 2018 and 2021 using microsatellite and sex-linked markers. Then, we used these results to unveil the origin of these individuals and understanding whether they are mostly originating from a specific region or have scattered origins in one or both Cantabrian subpopulations. Lastly, we used results to search for familial relationships among Galician individuals and between Galician and other bears from the source population. Attending the information from previous studies (López-Bao et al., 2021a; López-Bao et al., 2021b), we anticipate that bears present in Galicia are males that dispersed from the western subpopulation.

From a social perspective, we aim to understand the return of the brown bear in Galicia as reported in the number of damage claims recorded in this area and in the news of the main regional newspaper, *La Voz de Galicia*. We also aim to understand whether the bear recovery in Galicia is being accompanied by a disproportionate level of damage claims compared to other areas with stable bear presence. Furthermore, we are interested in analysing how the media cover conflicts and concerns, but also opportunities in relation to brown bear conservation in an area of recovery. We pretend to disclose if there is a positive correlation between the number of bears identified per municipality and the number of damage claims, as well as news, in those municipalities. We anticipate a significantly higher damage claim ratio for Galicia than for areas with a stable bear occurrence over time (Bautista et al., 2017; Molinari et al., 2016).

Jointly, we hope to bring useful information for the brown bear conservation in a recovery area, helping on promoting peaceful coexistence of bears and humans in an area where people have lost the memory of sharing the landscape with the brown bear.

2. Material and Methods

2.1. Collection of non-invasive samples

This study was focused on the mountainous area of eastern Galicia, where 109 non-invasive samples (both scat and hair samples) of brown bear were collected between April 2018 and November 2021 by personal from the *Fundación Oso Pardo*, and collaborators (Figure 5). All non-invasive samples were collected in the province of Lugo, including areas with and without damages claims (Figure 5). Hairs were collected from damages, barbed wire, trees, and vegetation. Scat and hair samples were stored in 96% ethanol at room temperature until DNA extraction.

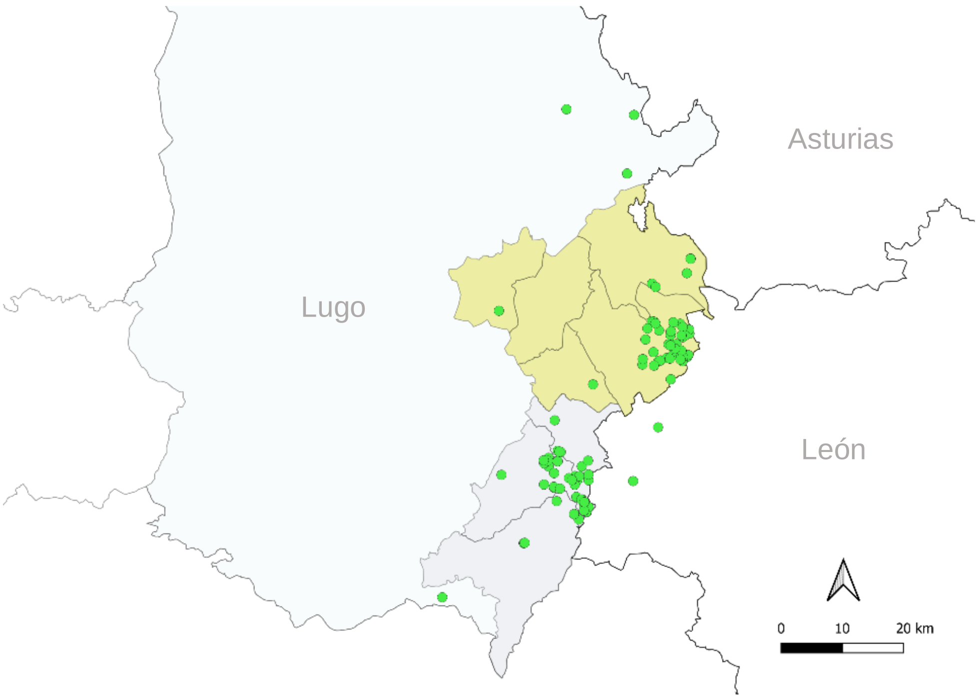

Figure 5 - Geographical distribution of the 109 samples (green dots) collected. The brown area represents Os Ancares. The grey area represents O Courel.

The collection of bear scat and hair samples in eastern Galicia has been carried out under the LIFE project Oso Courel (LIFE16/NAT/ES/000573), awarded to *Fundación Oso Pardo*. This research does not involve animal experimentation and comply with international guidelines on ethical behaviour.

2.2. DNA extraction and genotyping

Non-invasive samples were treated in a dedicated laboratory with sterile conditions and positive air pressure, exclusively for low-quality DNA, in order to reduce possible contaminations. Furthermore, possible DNA cross-contamination was monitored using negative controls throughout the procedures. DNA was extracted from faeces and hairs using the GuSCN/silica protocol following Frantz et al. (2003).

We genotyped a set of 18 microsatellite loci specific for brown bear (Bellemain & Taberlet, 2004; Taberlet et al., 1997). The loci were amplified using a two-steps method of polymerase chain reaction (PCR) (Andreassen et al., 2012). PCR amplifications were conducted using Qiagen Master Mix (Qiagen) in four PCR multiplexes with three to six markers (Table 1). PCR thermocycling conditions for amplifications are described in Table 2. Samples were amplified four times for each PCR multiplex. A negative control was included in all amplifications to monitor possible DNA cross-contaminations. Fluorescent labelling of PCR fragments was accomplished following Blacket et al. (2012). The success of the amplification was assessed through electrophoresis using 2% agarose gels and visualized in a UV transilluminator (BIO-RAD). Successful PCR products were separated by size on an ABI3130xl genetic analyzer. Allele scoring was performed using GENEMAPPER 4.1 (Applied Biosystems) and GeneScan500LIZ size standard as ladder.

The sex of the individuals was determined by amplifying a short fragment of the ZF and SRY gene on the X and Y sexual chromosomes respectively in Ursids (Pages et al., 2009). Each sample was amplified four times. Males and females were identified when two or one bands, respectively, were amplified. PCRs were accomplished with a negative control to monitor possible contaminations.

Table 1 - Content of the four multiplex reactions (microsatellites and sex-linked markers) used for the Cantabrian brown bear, including information of each microsatellite such as locus marker name (locus), repeat motif, allelic size range, fluorescent dye (dye), concentration of primers used in each reaction, and original reference.

Multiplex	Locus	Repeat Motif	Allelic Size Range	Dye	Concentration of primers (μM)	Reference
MS1	UA06	Tetra	63-79	NED	0,4	De Barba et al., 2017
	UA14	Penta	83-128	VIC	0,4	De Barba et al. 2017
	UA68	Penta	66-113	FAM	0,4	De Barba et al. 2017
MS2	UA03	Tetra	55-75	FAM	0,4	De Barba et al. 2017
	UA51	Tetra	68-80	VIC	0,5	De Barba et al. 2017
	UA57	Tetra	70-78	PET	0,5	De Barba et al. 2017
	UA64	Tetra	63-71	NED	0,4	De Barba et al. 2017
	UA67	Tetra	85-101	FAM	1,2	De Barba et al. 2017
MS3	UA16	Tetra	59-87	NED	0,4	De Barba et al. 2017
	UA25	Tetra	61-78	PET	0,5	De Barba et al. 2017
	UA63	Tetra	69-88	VIC	0,4	De Barba et al. 2017
	UA65	Tetra	85-112	FAM	0,4	De Barba et al. 2017
	SRY			FAM	0,4	Pagès et al. 2009
	ZFX/Y			FAM	1,2	Pagès et al. 2009
MS4	MU05	Di	178	NED	1,2	Taberlet et al. 1997
	MU09	Di	196	FAM	1	Taberlet et al. 1997
	MU10	Di	142	FAM	0,8	Taberlet et al. 1997
	MU23	Di	159	PET	1,8	Taberlet et al. 1997
	MU50	Di	215	VIC	0,8	Taberlet et al. 1997
	MU51	Di	145	VIC	0,8	Taberlet et al. 1997

Table 2 - PCR thermocycling conditions for amplification of the four multiplex reactions used in this study, including temperature, time and number of cycles for each PCR step.

	PCR profile for MS1, MS2 and MS3			PCR profile for MS4		
	Temperature	**Time**	**N cycles**	**Temperature**	**Time**	**N cycles**
Step 1	95ºC	15'	1	95ºC	15'	1
	95ºC 57ºC (- 0.5ºC/cycle) 72ºC	30'' 90'' 30''	5	95ºC 58ºC (-0.5ºC/cycle) 72ºC	30'' 90'' 30''	7
	95ºC 55ºC 72ºC	30'' 90'' 30''	15	95 ºC 55ºC 72ºC	30'' 90'' 30''	13
	60ºC	15'	1	60ºC	15'	1
Step 2	95ºC	15'	1	95ºC	15'	1
	95ºC 57ºC (-0.5ºC/cycle) 72ºC	30'' 60'' 30''	5	95ºC 58ºC (-0.5ºC/cycle) 72ºC	30'' 60'' 30''	7
	95ºC 55ºC 72ºC	30'' 45'' 30''	40	95ºC 55ºC 72ºC	30'' 45'' 30''	33
	60ºC	30'	1	60ºC	30'	1

A consensus genotype was constructed by manually analysing the four replicates per locus, following Godinho et al. (2015): i) heterozygous genotypes were accepted if the same genotype was observed in two independent PCRs and ii) homozygous genotypes were accepted if the genotypes was observed in three independent PCRs. Individual genotypes were grouped using the software GIMLET v. 1.3.3. (Valière, 2002). This software was also used to calculated the Probability of Identity (PID) (Paetkau & Strobeck, 1994), which consist in the probability of having two randomly selected individuals from the population with the same genotype, as well as the rates of allelic dropout (ADO) and false alleles (FA). Individual genotypes were used in subsequent analysis.

An additional dataset generated in CIBIO laboratories including 202 individual genotypes, 153 from the western subpopulation and 49 from the eastern subpopulation, was also used in this study, produced under several research projects aimed at estimating the bear population in both subpopulation since 2017 (see López-Bao et al., 2020 and 2021a for more details). This database was constructed using the same set of microsatellites, which were genotyped in CIBIO labs under the same conditions.

2.3. Assessing of the number of bears in Galicia and their spatial origin

To investigate the approximate spatial origin of each individual observed in Galicia, we joined genotypes of these individuals to the available database of genotypes from both Cantabrian subpopulations (López-Bao et al., 2021a). We used the Bayesian inference implemented in STRUCTURE (Pritchard et al., 2000) to assign the Galician individuals to the Cantabrian subpopulations, considering two population clusters (K=2; Gonzalez et al., 2016). We used the admixture model with correlated allele frequencies and no prior information of the population. We performed 10 independent runs for K=2, and $25x10^4$ burn-in iterations followed by $1x10^6$ MCMC iterations.

Attending to the STRUCTURE results, pairwise relatedness (r) between individuals in Galicia, as well as between these individuals and the estimated population of origin was calculated using the COANCESTRY software (Wang, 2011). The pairwise relatedness (r) was estimated using the allele frequencies observed in the data, with 1000 bootstrap permutations, and two estimators, namely Triodic Likelihood and Dyadic Likelihood.

The genealogical relationships among individuals were inferred using the likelihood method implemented in the COLONY software (Jones & Wang, 2010). We considered both bear sexes as polygamous (Wiegand et al., 1998) and used the full-likelihood (FL) method. Update allele frequencies and sibship scaling options were not considered, and the sibship prior was set to weak. Individuals identified as males or females were considered as possible fathers or mothers, respectively. All individuals were considered as possible offspring. An exploratory run was performed with very high likelihood precision and very long run, where one family with 9 individuals from western subpopulation was found. This family was further considered in the final run using medium likelihood precision during a long run. In the end, we calculated the Euclidean distances between Galician individuals and individuals that had genealogical relationships with them, we based on the closest recaptures of each individual.

2.4. Assessing bear damages to apiaries in Galicia

We used a database compiled between 2010 and 2021 under the LIFE Bear Courel Project on bear damages in the study area to assess conflict levels in the first phases of the expansion process. The database contained information on date, localization, municipality and characteristics of each damage.

We evaluated whether the level of damages in a given year was correlated with the number of bears detected in Galicia the same year. We also estimated a damage ratio for Galicia, defined by Bautista et al. (2017), as the average number of damage claims over a six-year period, divided by the number of bears estimated for the area covered. We used the last six years (2016-2021) of the study period and the number of bears identified between 2018 and 2021. For comparison, we also calculated the damage ratio of the western and eastern subpopulations. To do this, we used the recorded damage for both subpopulations between 2014 to 2019, and 280 and 50 individuals to the western and eastern subpopulations, respectively (Ballesteros et al., 2021). We compared the estimated damage ratio obtained in Galicia with damage ratios from other populations (Molinari et al., 2016).

2.5. Assessing the bear expansion process in the media

We performed a search in the newspaper *La Voz de Galicia*, the main regional newspaper from Galicia, between 2010 and 2021 using the key word “oso” (brown bear in Spanish). All news retrieved from this search were open, but only news referring to brown bears were considered for further analysis. When the word “oso” was mentioned with no relation to the brown bear (e.g., as the name of a locality, as the name of a film, as referring only to *Fundación Oso* with no relation to brown bear issues) the news were excluded from our database.

We recorded two general descriptive characteristics for each news: year/date and place (Province and Municipalities). Then, we split the news into two groups: 1) news that had the brown bear as its main topic, and 2) news that had a reference to the brown bear, but the main subject was another (i.e., “mentioned topic”). The main and mentioned topics were classified in 14 categories (Table S1), as follows: 1) Conservation; 2) Research; 3) Observation; 4) Population; 5) Attacks; 6) Education; 7) Damage management/Compensation; 8) Bear in captivity; 9) Tourism/Public use; 10) Public participatory process; 11) Characteristics; 12) Trust; 13) Bear poaching; 14) Hunting. Furthermore, we also identified the main actors who were more mentioned or have an important role in each news. The actors were classified in 13 categories, as follows: 1) Conservationists; 2) Politicians; 3) Beekeepers; 4) Scientists; 5) Inhabitants; 6) Paleontologists; 7) Sindicates (e.g., associations of hunters, farmers); 8) Managers; 9) Teachers and students; 10) Vets; 11) Hunters; 12) Others; 13) Indeterminate. We finally coded (binary factor) whether the news mentioned bear damages on beehives, livestock or crops.

We estimated the Pearson correlation between the number of news that mentioned bear damages (focused on attacks to apiaries/beehives), the number of bear damage claims and the number of bears identified using R software (Mac Nally & Horrocks, 2002). We performed two analyses using different temporal and spatial scales. First, we estimated a correlation between the annual number of bear damage claims, the annual number of all news about brown bears and the annual number of news that mentioned bear damages between 2010 and 2021. Second, we estimated a correlation between the number of news that mentioned bear damages, the number of bear damage claims and the number of bears identified in our genetic monitoring per municipality, using data between 2018 and 2021.

3. Results

3.1 The number and origin of the Galician bears

A total of 56 non-invasive samples were successfully genotyped for microsatellites (51.4%; n=109), of which 46 were faeces (48.4% success rate; n=95) and 10 were hairs (71.4% success rate; n=14) (Figure 6). Genotyping success rate per year was high and consistent for 2018, 2020 and 2021 samples (60.7%, 64.3% and 50.0%, respectively), whereas for 2019 samples it decreased dramatically (9.5%; n=21), likely due to low quality preservation of samples after collection.

Overall, we were able to identify 13 bears in Galicia since 2018, 12 males and 1 female (Figure 6; Figure 7; Table 3). Of these individuals, 7 bears were sampled once, 2 bears were sampled twice, and 4 bears were sample 5 or more times up to 18 (Table 3). This includes 5 individuals identified in 2018, 2 individuals identified in 2019, 8 individuals identified in 2020 and 4 individuals identified in 2021 (Table 3). Four bears were sampled in two different years whereas one bear was samples in three different years (Table 3).

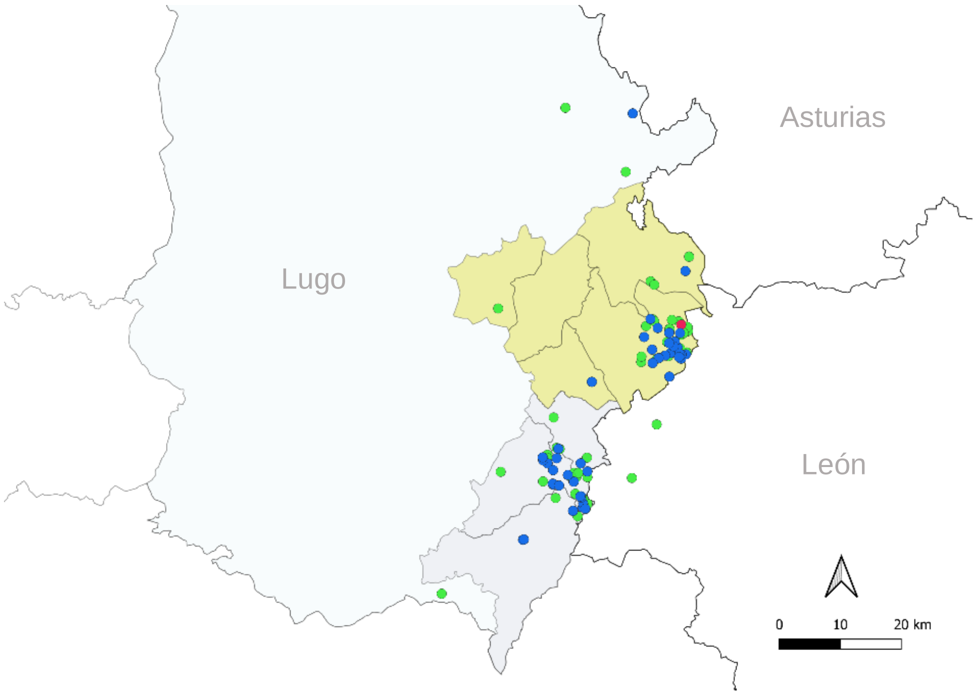

Figure 6 – Geographical distribution of all samples collected but not genotype (green dots), as well as all samples successfully genotype as males (blue dots) and as females (pink dot). The brown area represents Os Ancares. The grey area represents O Courel.

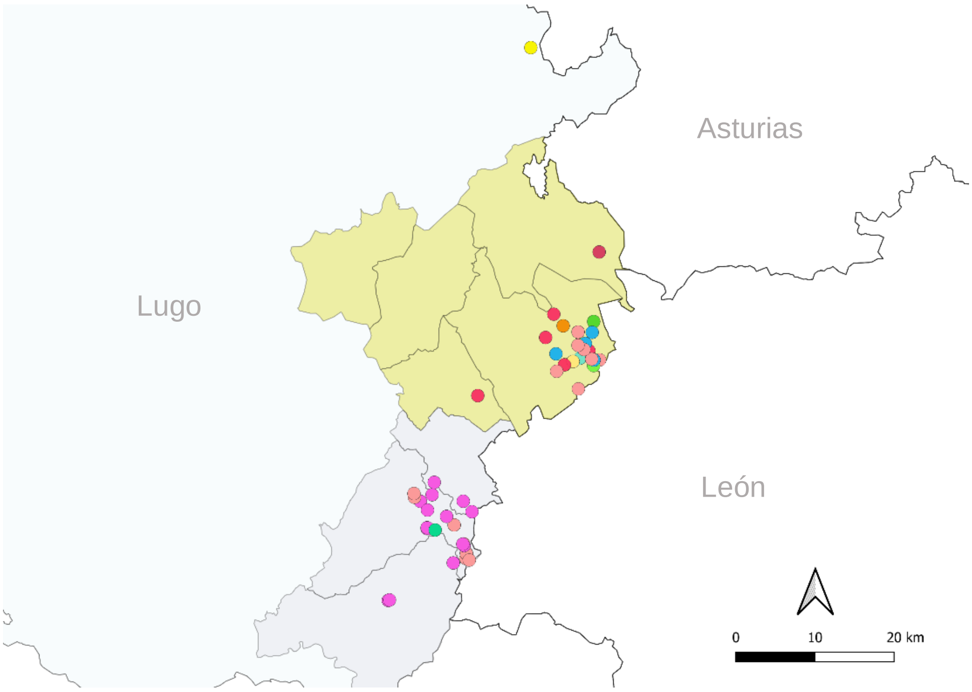

Figure 7 – Geographic distribution of all individuals identified in Galicia. The brown area represents Os Ancares. The grey area represents O Courel.

Table 3 - Detailed information of the individuals identified in Galicia, including sex, year of first detection, years detected and number of samples.

Individuals	Sex	Year of first detection	Years detected	Number of samples
UA204	M	2018	2018	2
UA205	M	2018	2018 2020 2021	18
UA206	M	2018	2018 2020	16
UA207	M	2018	2018	1
UA208	M	2018	2018	1
UA209	M	2019	2019 2020	5
UA210	M	2019	2019 2020	2
UA211	M	2020	2020	1
UA212	M	2020	2020 2021	5
UA213	M	2020	2020	1
UA220	F	2021	2021	1
UA221	M	2021	2021	1
UA222	M	2020	2020	1

The four replicates per sample for the 18 microsatellites genotyped allowed to calculate a *dropout allele* rate of 15.6% on average among loci, and a false alleles rate of 0.1% on average among loci. Our set of markers achieved an unbiased Probability of Identity (PID) for the Galician bears of 5.25×10^{-9}, and the Probability of Identity for siblings (PID_{sibs}) of 1.54×10^{-4}.

Almost all individuals identified in Galicia were assigned to the western subpopulation with a membership proportion of q>94%, whereas one individual (UA213) has an admixed origin, with membership proportions of 63% and 37% to the western and the eastern subpopulations, respectively (Figure 8).

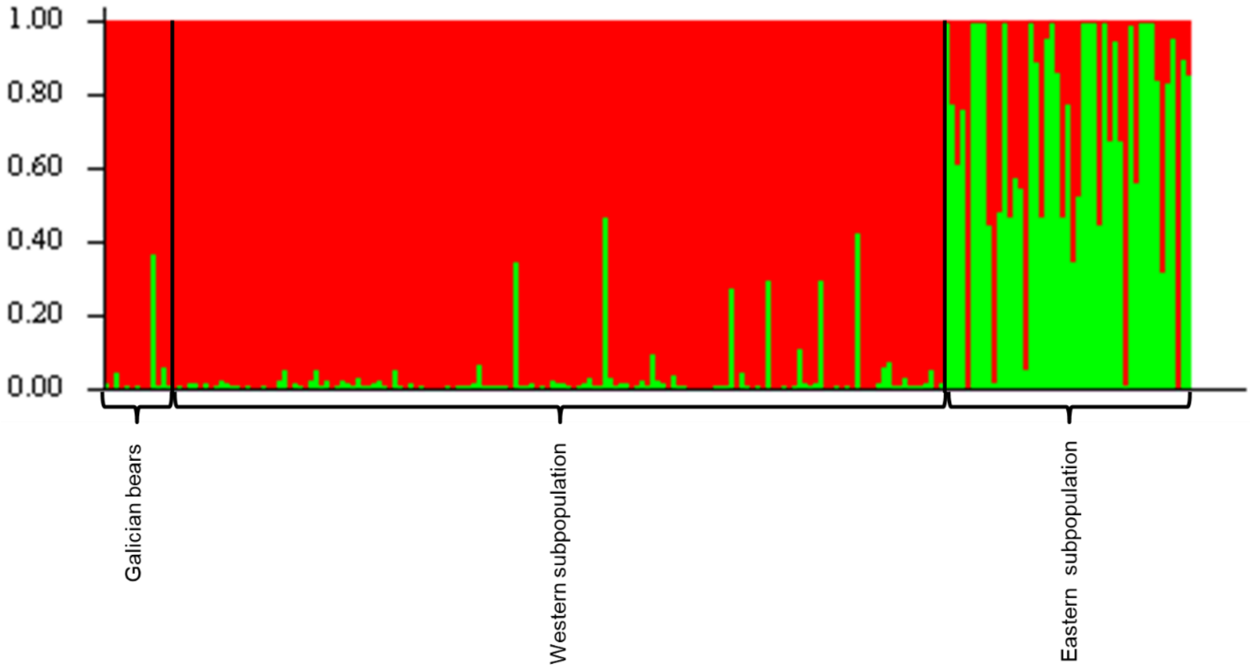

Figure 8 - Bayesian clustering analysis implemented in STRUCTURE based on 18 markers, using the 13 bears from Galicia together with 153 bears from the western subpopulations and 49 bears from the eastern subpopulation. Each bar represents one individual. Bars are coloured according to the proportion of individual assignment to two populations (red for the western subpopulation, green for the eastern subpopulation).

3.2. Genealogical relationships

Overall, we were able to identify 7 bear families with high probabilities ($P \geq 0.80$), involving Galician individuals. One family of two siblings comprised only Galician individuals, and the other 6 families comprised also individuals from the western subpopulation (Figures 9-11). Families are geographically distributed between the provinces of Lugo and León, and in Asturias (Figures 9-11). We named the families 1 to 7, which were as follows:

- Family 1 included the Galician male UA209 and its parents, the male UA149 and the female UA201, both from Asturias, but sampled in different breeding areas. Paternity and maternity relationships presented high probabilities (0.89 and 0.94, respectively) (Table S2). The observed relatedness values between offspring and parents (0.46 and 0.49, respectively) were consistent to the inferred relationship (Table 4). The Euclidean distances between the location of the UA209 sample and the locations of its father and mother were 63 and 30 km, respectively (Figure 9).

- Family 2 included the Galician male UA210 and its father, the male UA175 from Asturias, sampled in Narcea-Alto Sil breeding area. Paternity relationship presented a high probability (0.97) (Table S2). Relatedness values between UA210 and UA175 (0.49) were consistent to the inferred relationship (Table 4). The Euclidean distance between the location of the UA210 sample and the locations of its father was about 33 km (Figure 9).

- Family 3 included the Galician male UA204 and its mother, the female UA094 from Asturias, sampled in Somiedo breeding area. The inferred maternity relationship had a high probability (0.91) (Table S2). The observed relatedness values between offspring and mother (0.50) were expected for the inferred relationship (Table 4). The Euclidean distance between the location of the UA204 sample and the locations of its mother was 60 km (Figure 9).

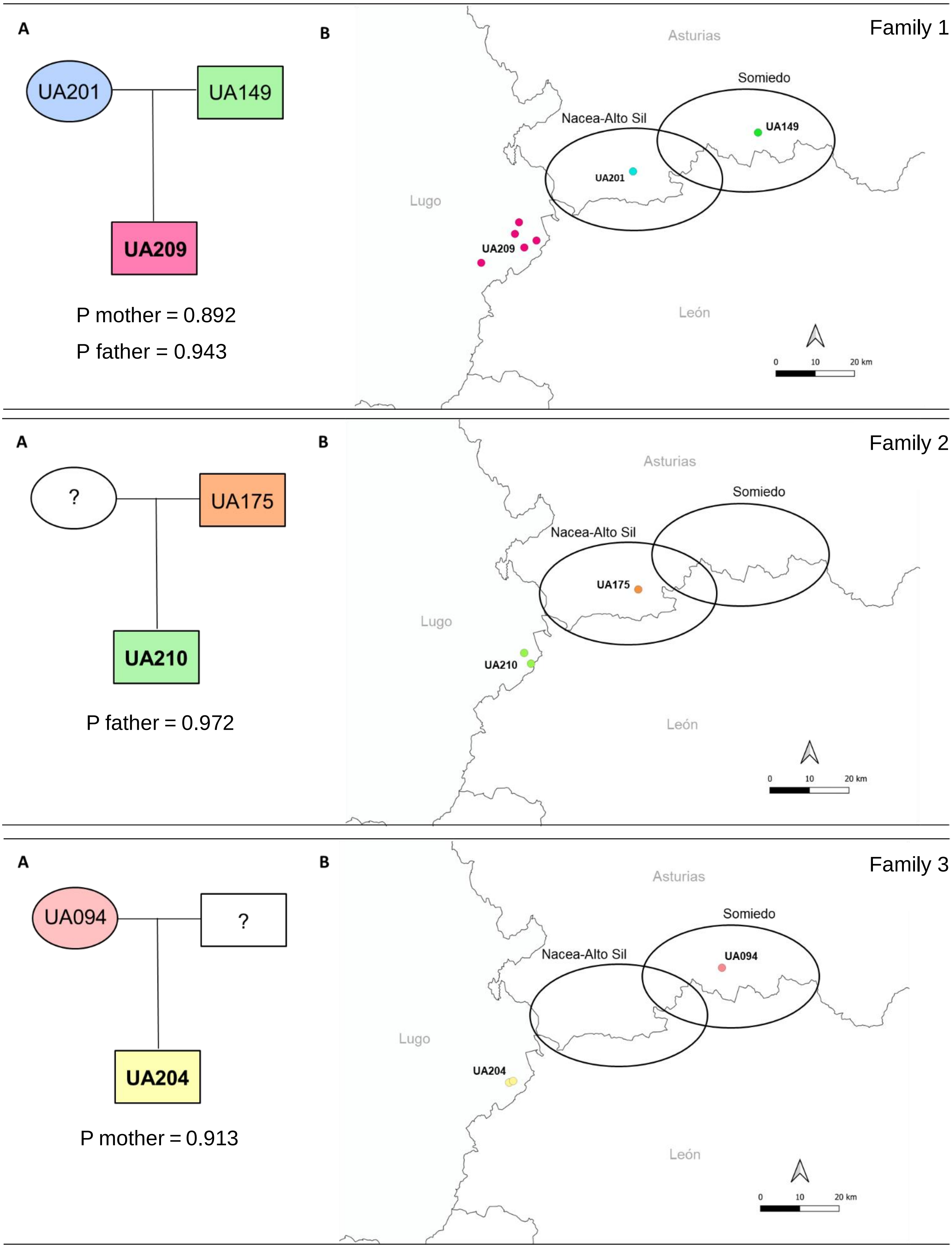

Figure 9 - Representation of families 1, 2 and 3 and their geographic distribution. A) Genealogies constructed with COLONY software. Galician individuals are highlighted in bold. Squares denote males and circles denote females. P mother/father is the probability for the relationship. B) Geographic distribution of each member of the families. Circles sign breeding areas.

- Family 4 included two full sibling males, UA206 and UA221, both sampled in Lugo, with a high probability for the relationship (0.98) (Table S2). The observed relatedness values between full siblings (0.75) were consistent to the inferred relationship (Table 4). The full siblings were found in the same geographic area, however the individual UA206 was sampled in 2018 and 2020, while the individual UA221 was sampled in 2021 (Figure 10).

- Family 5 included the Galician male UA208 and its full sibling, the male UA167 from Asturias, sampled in Narcea-Alto Sil breeding area, with a high probability (0.91) inferred for this relationship (Table S2). The observed relatedness value between full siblings (0.58) was consistent to the inferred relationship (Table 4). The Euclidean distance between the location of the UA208 sample and the locations of its full sibling was 8 km (Figure 10).

- Family 6 included the Galician male UA211 and its full sibling, the male UA107 from León. Full sibling relationship presented high probability (0.80) (Table S2). The observed relatedness value between full siblings (0.53) was consistent to the inferred relationship (Table 4). The Euclidean distance between the location of the UA211 sample and the locations of its full sibling was 72 km (Figure 10).

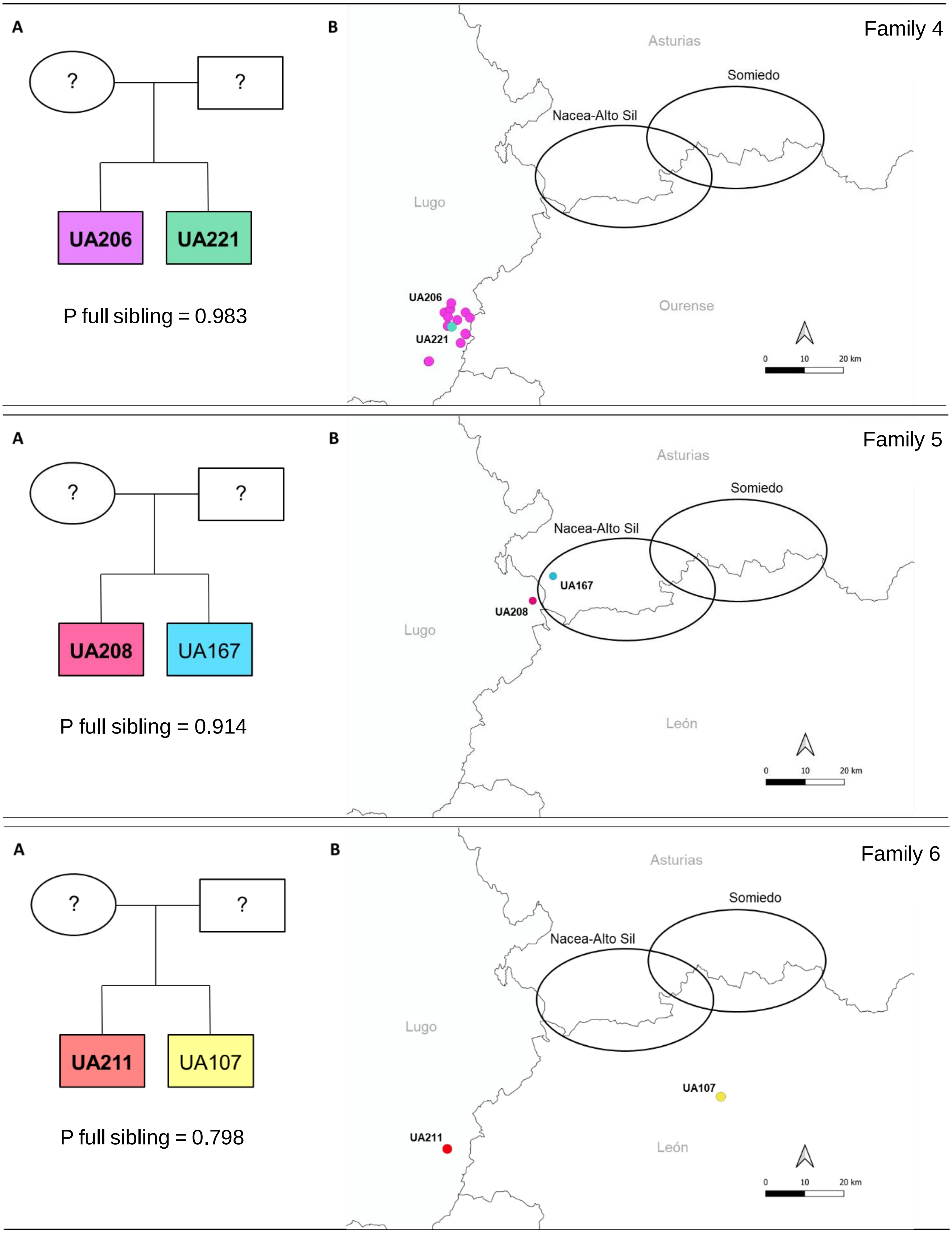

Figure 10 - Representation of families 4, 5 and 6 and their geographic distribution. A) Genealogies constructed with COLONY software. Galician individuals are highlighted in bold. Squares denote males and circles denote females. P full sibling is the probability for the relationship. B) Geographic distribution of each member of the families. Circles sign breeding areas.

- Family 7 included two Galician males UA205 and UA222, and its mother and a sibling, the female UA126 and the male UA136 from Asturias, but sampled in different breeding areas. Maternity relationship presented high probability (0.93), as well as the half and full sibling relationships (1, 1) (Table S2). The observed relatedness values between these individuals (0.50, 0.68 and 0.56, respectively) were consistent to the inferred relationship (Table 4). The two Galician half siblings were found in the same geographic area, both were sampled in 2020 (Figure 11). The Euclidean distances between the location of the UA205 and UA222 samples, and the locations of its mother and its sibling were 82 km and 35 km respectively (Figure 11).

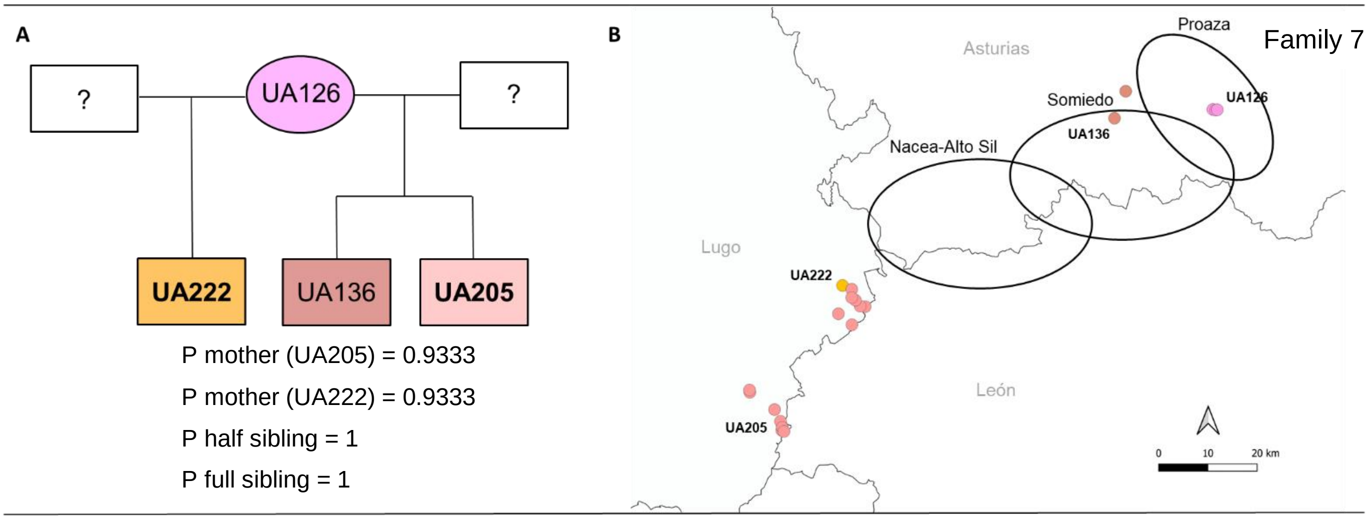

Figure 11 - Representation of family 7 and its geographic distribution. A) Genealogy constructed with COLONY software. Galician individuals are highlighted in bold. Squares denote males and circles denote females. P mother/half sibling/full sibling is the probability for the relationship. B) Geographic distribution of each member of the family. Circles sign breeding areas.

Table 4 - Relatedness between individuals identified in Galicia and western individuals as estimated through the TrioML and DyadML estimators implemented in the COANCESTRY program. Relatedness is only showed between Galician and western individuals that have genealogical relationships (see Table S2).

Family	Genealogical relationship	Individuals		TrioML	DyadML
1	Offspring-parent	UA209	UA149	0.4595	0.5292
1	Offspring-parent	UA209	UA201	0.4938	0.5669
2	Offspring-parent	UA210	UA175	0.4934	0.5417
3	Offspring-parent	UA204	UA094	0.5000	0.5000
4	Full-siblings	UA206	UA221	0.7574	0.8181
5	Full-siblings	UA208	UA167	0.5878	0.6707
6	Full-siblings	UA211	UA107	0.5305	0.7188
7	Offspring-parent	UA205	UA126	0.5000	0.5000
7	Offspring-parent	UA222	UA126	0.5017	0.5017
7	Half-siblings	UA205	UA136	0.5605	0.6341
7	Half-siblings	UA205	UA222	0.6805	0.7982

3.3. Bear damages in Galicia

Between 2010 and 2021 there were 325 bear damage claims in Galicia (Figure 12), mostly on apiaries, and only 14 on crops. The number of claims was very variable over the study period, with years 2014 and 2016 showing the higher number of damages, and years 2012 and 2021 the lower number of damages (Figure 12). The number of bears identified between 2018 and 2021 was not correlated with the number of bear damages in a municipality (focused on damage claims in apiaries, as it represents 95,7% of all damage claims) (r^2=0.371, P= 0.108), although a positive trend was observed (Table 7).

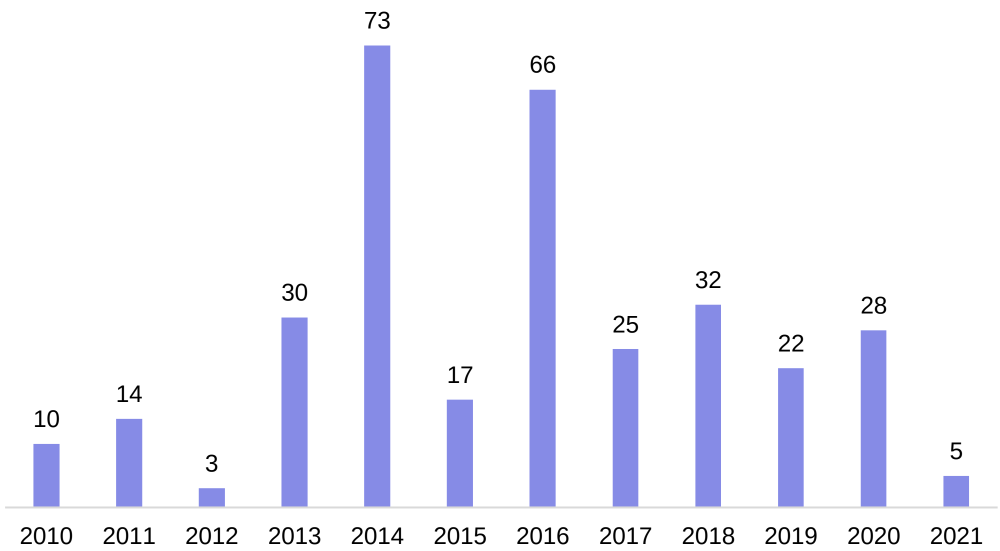

Figure 12 – Number of bear damages in Galicia over time from 2010 to 2021.

The distribution of damage claims recorded between 2018 and 2021 corresponded to the expansion area where bears were identified. In 2018, the distribution of damage claims indicates a damage hot spot where the individuals UA205 and UA206 were identified (Figure 13; Table 5). In the next year, the distribution of part of the damages matches the area where the individuals UA209 and UA210 were identified (Figure 14; Table 5). In 2020, the same damage hot spot was identified, but this time it matches the area where the individuals UA206, UA211 and UA209 were identified, moreover it´s possible to see that the individual UA205 moved 29 km to the north and remained in this area in 2021 (Figure 15; Table 5). Finally, in 2021 there were less damage claims, but the individual UA205 is once again identified in an area where damage claims were recorded (Figure 16; Table 5).

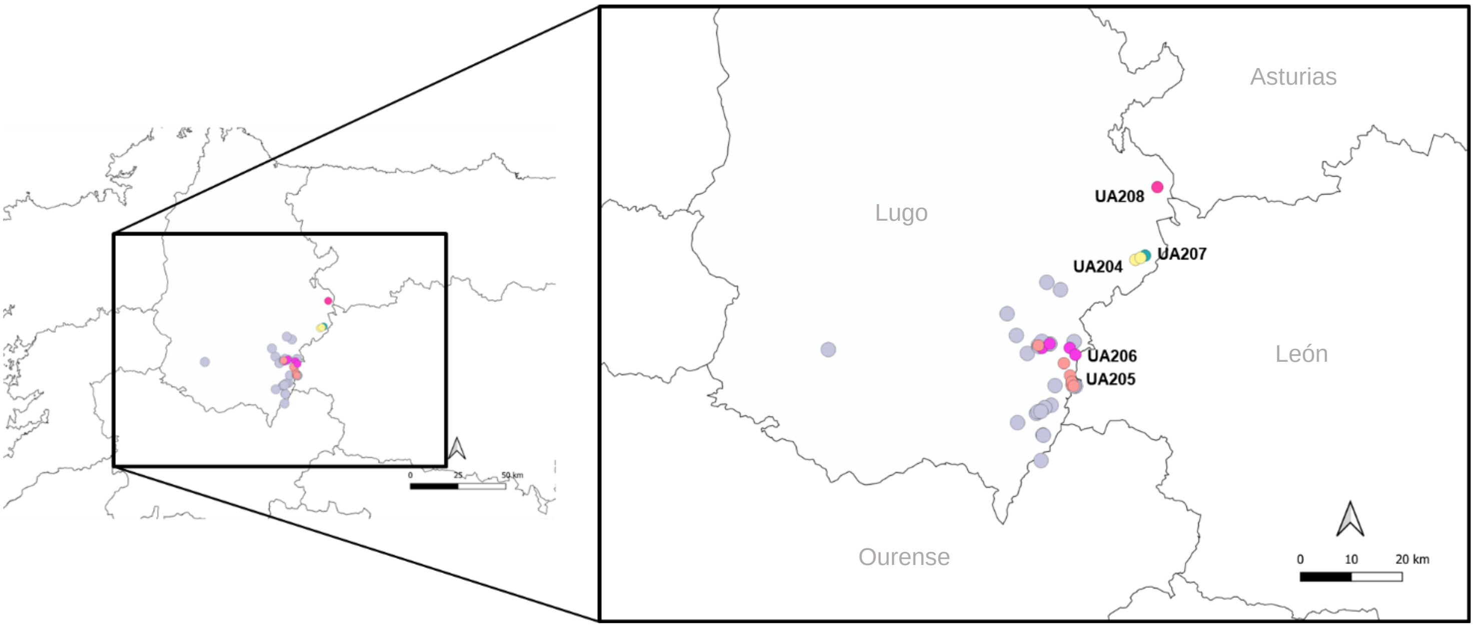

Figure 13 - Geographical distribution of all bears and bear damage claims identified in Galicia during the year 2018. Grey circles represent bear damage claims, and the other colors represent the different bears identified (Light yellow – 204; Light pink – UA205; Lilac – UA206; Water blue – UA207; Dark pink – UA208).

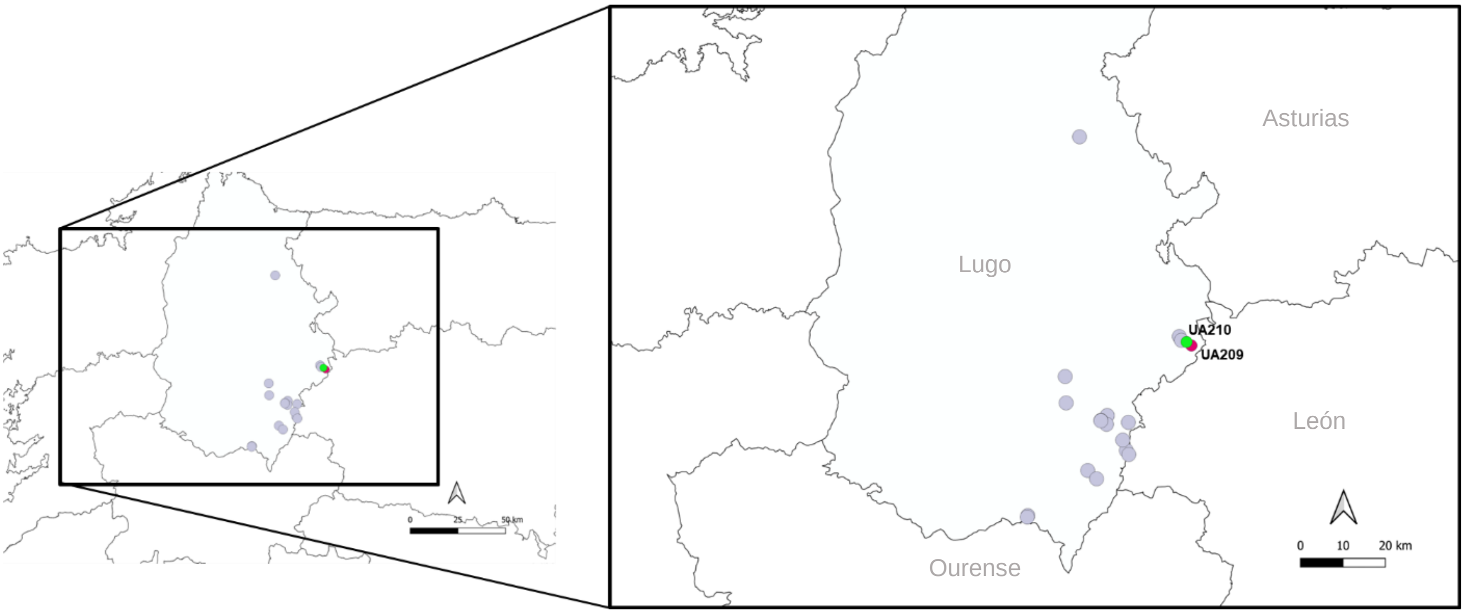

Figure 14 - Geographical distribution of all bears and bear damage claims identified in Galicia during the year 2019. Grey circles represent bear damage claims, and the other colors represent the different bears identified (Pink – UA209; Green – UA210).

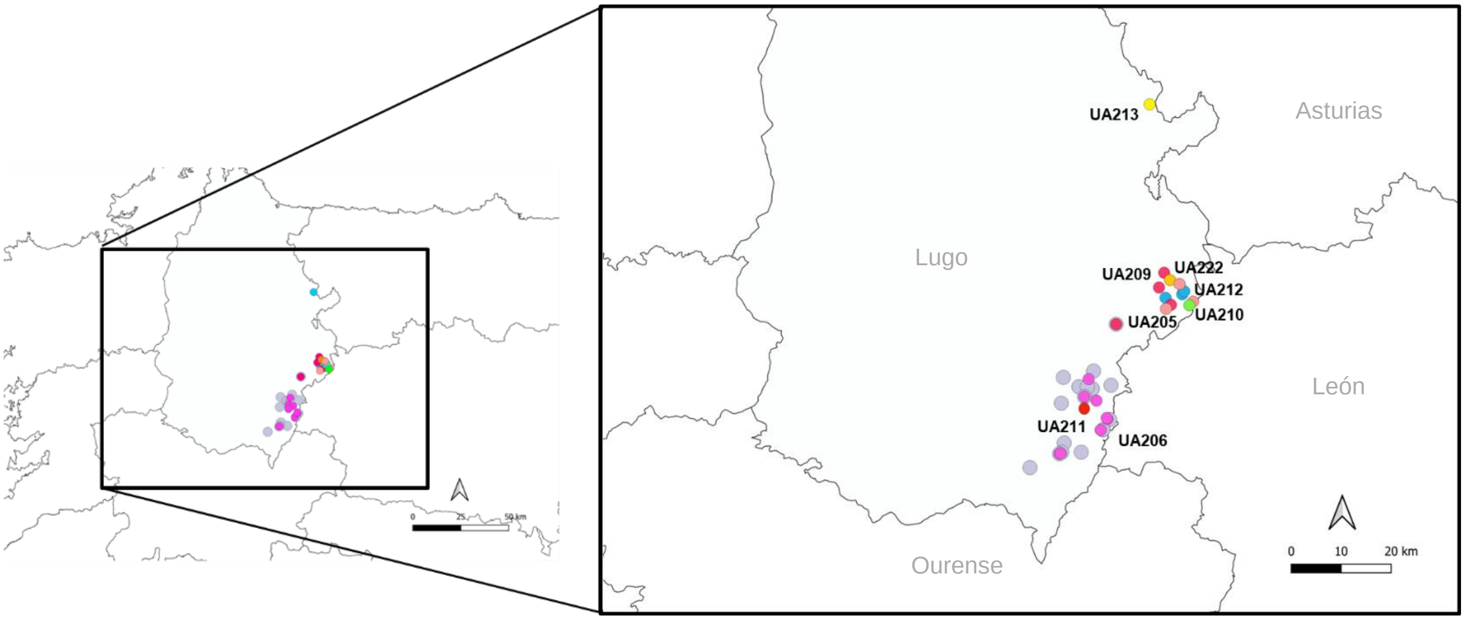

Figure 15 - Geographical distribution of all bears and bear damage claims identified in Galicia during the year 2020. Grey circles represent bear damage claims, and the other colors represent the different bears identified (Light pink – UA205; Lilac – UA 206; Pink – UA209; Green – UA210; Red – UA211; Blue – UA212; Yellow – UA213; Light orange – UA222).

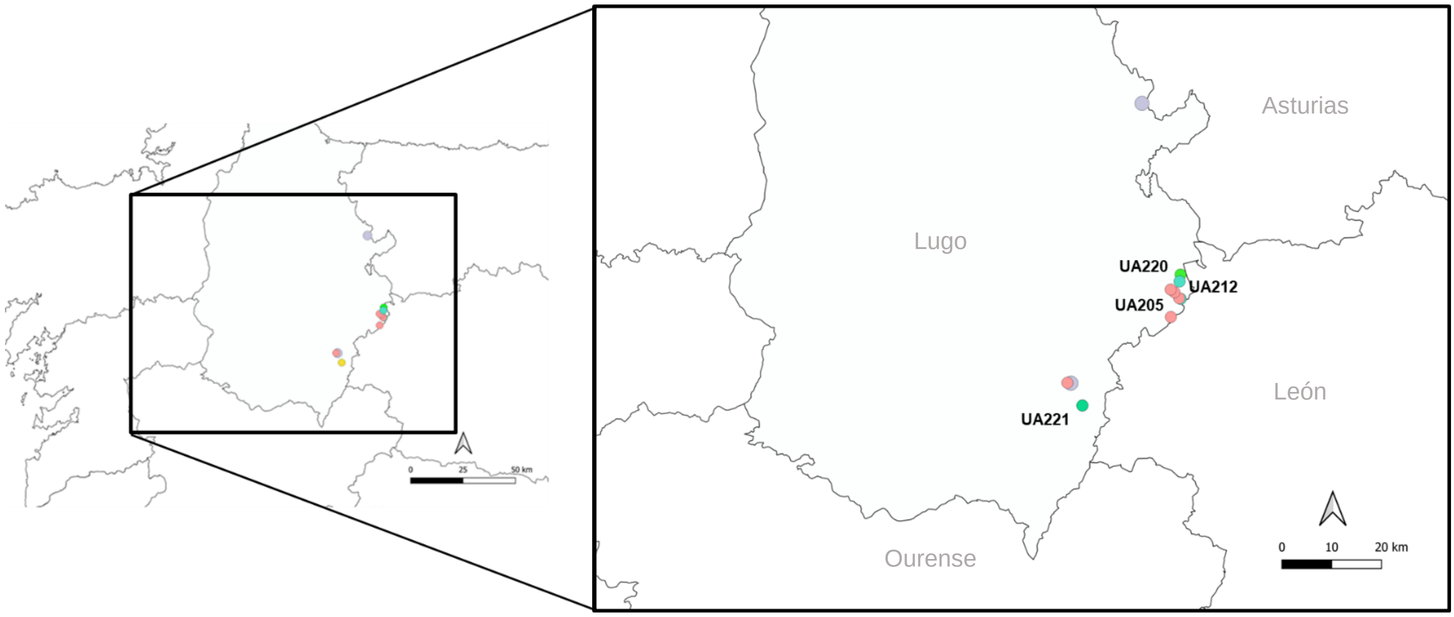

Figure 16 - Geographical distribution of all bears and bear damage claims identified in Galicia during the year 2021. Grey circles represent bear damage claims, and the other colors represent the different bears identified (Light pink – UA205; Blue – UA212; Dark green- 2020; Water green – UA221).

Table 5 – Annual number of bears identified, and number of damage claims between 2018 and 2021.

	Number of bears identified	Number of damage claims
2018	5	32
2019	2	22
2020	8	28
2021	4	5

The distribution of bear damage claims consistently overlaps the bear expansion area in Galicia, whereas the small area of Galicia harboring a stable population has much less damage claims (Figure 17).

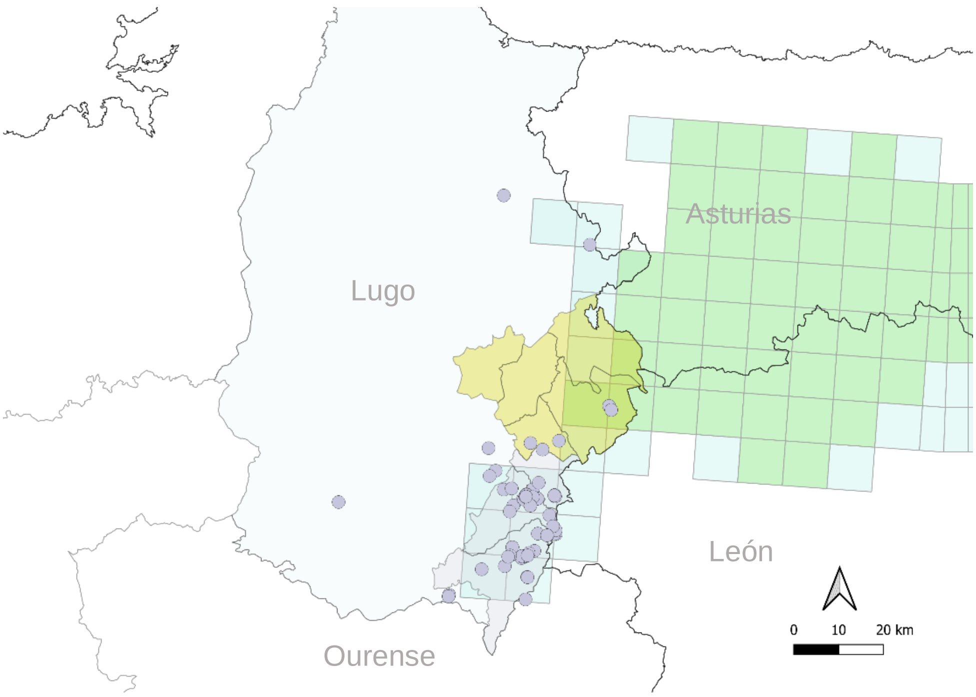

Figure 17 – Geographical distribution of all bear damage claims recorded in Galicia between 2018 and 2021. Grey circles represent bear damage claims. The blue squares represent areas of expansion, whereas the green squares represent areas with stable population. The brown area represents Os Ancares. The grey area represents O Courel.

The damage ratio in Galicia averaged 2.28 damage events in apiaries per bear per year between 2016 and 2021. The damage ratio in the western and eastern subpopulations between 2014 and 2019 averaged 0.72 and 2.23 damage events in apiaries per bear per year, respectively.

3.4. Galician bears in the media

We analysed a total of 323 news from *La Voz de Galicia* between 2010 and 2021 (an average of 27 bear-related news a year). The media interest in the species was variable over the years, with years 2011, 2013 and 2020 showing the higher number of news, and years 2012 and 2016 with lower number of news (Figure 18).

The annual number of bear news was not correlated with the annual number of bear damages between 2010 and 2021 (r^2=-0.239, P=0.454) (Table 6). The total number of bear news between 2018 and 2021 was not correlated with the number of bears identified in a municipality (r^2=0.410, P=0.070) (Table 7).

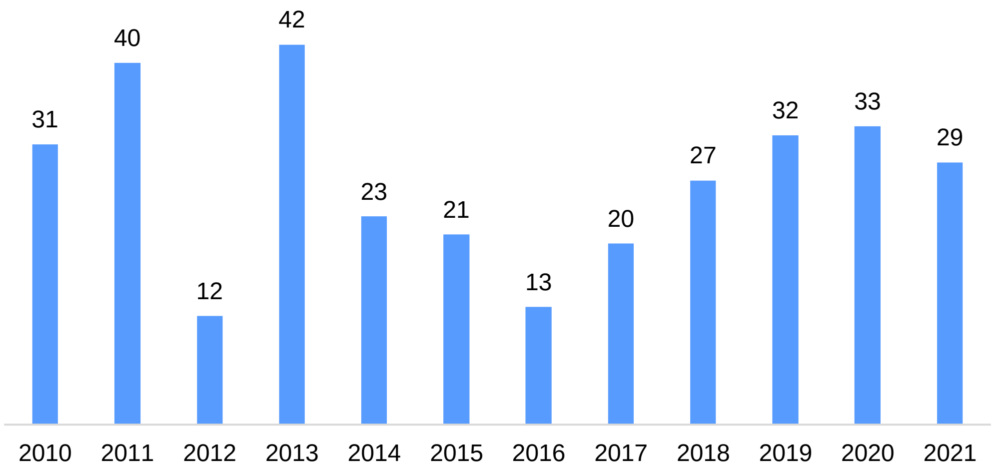

Figure 18 - Number of news from the newspaper *La Voz de Galicia* analyzed per year, between 2010 and 2021.

The brown bear was the main topic in 65% of the news and “Conservation” was the most featured topic in the news, followed by research and observations of the species (Figure 19) (see Table S1).

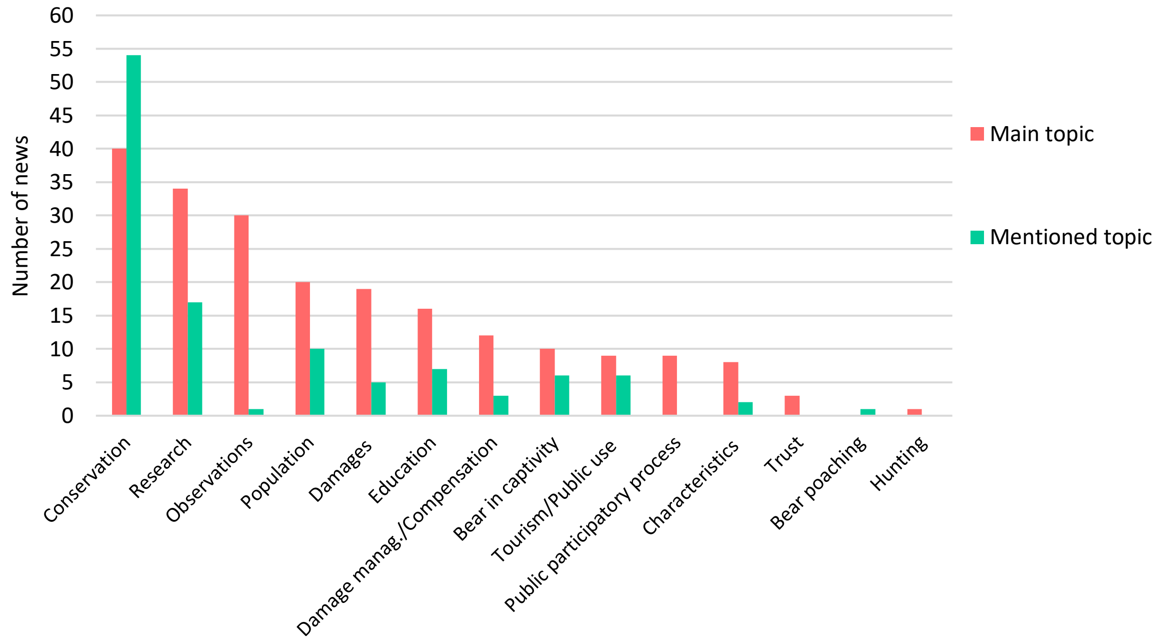

Figure 19 - Number of news from the newspaper *La Voz de Galicia* with the 14 different main or mentioned topics on brown bear between 2010 and 2021 (see Table S1).

We observed that conservationists were the main actors in the news, followed by politicians, beekeepers and scientists (Figure 20).

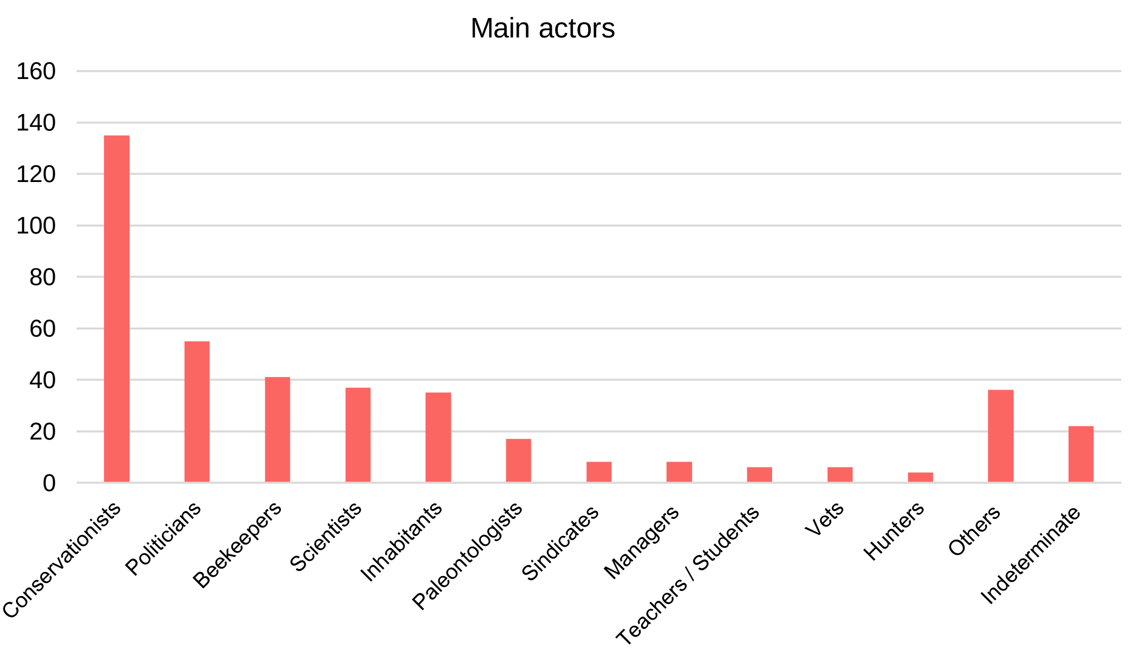

Figure 20 - Number of news in La Voz de Galicia in which each interest group is a principal actors in Galicia between 2020 and 2021.

The interest of media on brown bear conservation and bear damages was not the same across Galicia, in both topics the news on brown bear predominating in Lugo in relation to Ourense (Figure 21). In the province of Lugo 19 municipalities were refenced in the analysed news on conservation and/or in news that mentioned bear damages. One the other hand, in the province of Ourense only one municipality were referenced in news on conservation and 10 municipalities were refenced in the news that mentioned bear damages (Figure 21).

Figure 21 - Number of news analyzed in each municipality of Galicia between 2010 and 2021. A) Number of news with main or mentioned topic on bear conservation. B) Number of news that mentioned bear damages.

During the sampling period between 2018 and 2021 the media interests on bear damages and the number of bear damages were variable over the time (Figure 22). In 2018, more damage claims were recorded, but it was in 2020 that more bears were identified, and there was more news that mentioned bear damages (Figure 22).

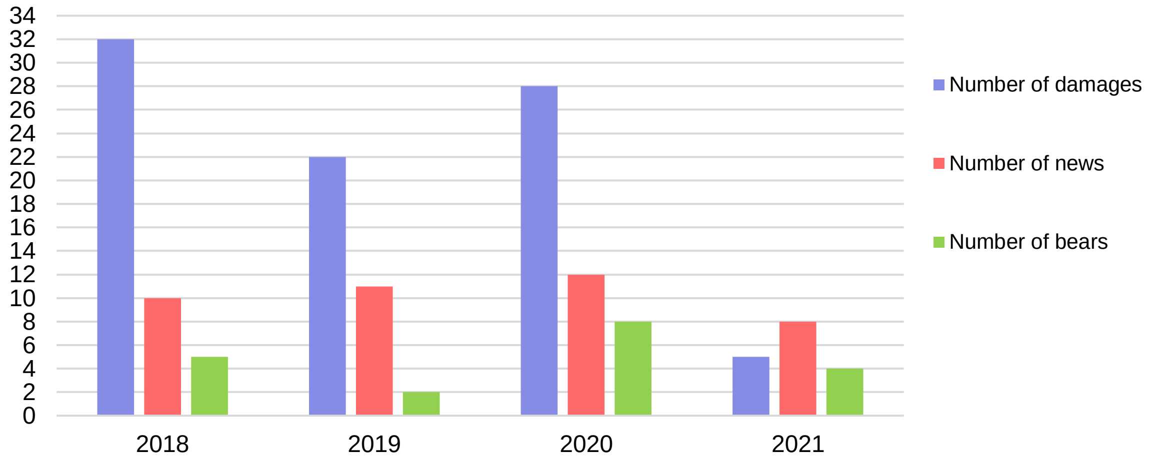

Figure 22 – Number of bear damage claims, number of news that mentioned bear damages, number of bears identified in the years of 2018, 2019 and 2021.

The annual number of news that mentioned bear damages was not correlated with the annual number of bear damages (r^2=0.486, P=0.110) (Table 6). Between 2018 and 2021, the number of news that mentioned bear damages in a municipality was positively correlated with the number of bears identified (r^2=0.486, p=0.030) and the number of bear damage claims (r^2=0.754, p=0.0001) in the same municipality (Table 7).

Table 6 – Correlation between the annual number of bear damages claims, annual number of news on bears and annual number of news that mentioned bear damages between 2010 and 2021. We used a statistical significance of P< 0.05

2010 - 2021 (overall Galicia)		r	P
Annual N bear damage claims	Annual N news on bears	-0.239	0.454
	Annual N news that mentioned bear damages	0.486	0.110

Table 7 - Correlation between the number of bears identified, number of bear damages claims, number of news on bears and number of news that mentioned bear damages at a municipality scale, between 2010 and 2021. We used a statistical significance of P< 0.05

2018 - 2021 (over municipalities)		r	P
N bears identified	N bear damage claims	0.371	0.108
	N of news on bears	0.410	0.070
	N of news that mentioned bear damages	0.486	0.030
N bear damage claims	N of news that mentioned bear damages	0.754	0.0001

4. Discussion

4.1. The ecological perspective

Natal dispersal in brown bears is known to be sex biased, with males dispersing more frequently and over long distances from their natal areas, and females showing a philopatric behaviour, i.e., establishing their home ranges in or near their mother's home range (Alt, 1978; Blanchard & Knight, 1991; Glenn & Miller, 1980; Olejarz et al., 2022; Rogers, 1987; Schwartz & Franzmann, 1992; Zedrosser et al., 2007). This dispersing behaviour results in expansion processes mainly driven by males (Swenson et al., 1998). Between 2018 and 2021, using molecular approaches we identified 12 males and 1 female in eastern Galicia, confirming our prediction of a male mediated recovery process (Zedrosser et al., 2007). Even though the Cantabrian bear population has a substantially positive demographic trend (López-Bao et al. 2021a), females take much longer to reach the new areas. The single female that we observed was only found in 2021 and may represent one of the first females reaching Galicia from the expansion front. This female was found in eastern Galicia very close to the border with León and Asturias, in the single area where a more stable bear population has been considered for Galicia in recent years.

Five bears were observed in Galicia for more than one year, four of which were consistently found in the same geographical area through their sampling period. For one bear (individual UA205), however, we observed its movements from the far south-eastern Lugo close to the border with León and Ourense, where it was first observed in 2018, to the stable presence area in eastern Lugo where it was detected in 2020 and 2021.This continuous occurrence of the same individuals in the same areas is indicative of stability in the bear occurrence area for Galicia, the potential of eastern Galicia for bear habitat, and of a resident population, which is both present in eastern and south-eastern Galicia.

As expected, our results show that the individuals present in eastern Galicia have their origin clearly assigned to the western subpopulation, except for UA213 that showed a genetic background of a recent ancestry in both western and eastern subpopulations. The same genetic signature was observed for a few bears from the western subpopulation, which may likely be offspring of interbreeding between individuals originally from the two subpopulations. Gene flow between western and eastern subpopulations has been consistently described for the Cantabrian brown bear (e.g., Gonzalez et al., 2016; Gregório et al., 2020; Pérez et al., 2010). Although we are not sure about the origin of this individual, we believe that it likely is from the western subpopulation, which is geographically much closer. Notwithstanding, the presence of this admix individual shows that part of the genetic diversity comprised in the eastern subpopulation in the Cantabrian Mountains is also reaching the expansion border in eastern Galicia.

The western subpopulation comprises three main bear breeding areas (López-Bao et al., 2021b). Notably, our genealogical results support the dispersal into Galicia of individuals from all of these breeding areas, namely from Narcea-Alto Sil, Somiedo and Proaza. This is supported by three cases of mother-offspring relationships in three different families. Dispersal into Galicia from León is also plausible because we observed a full sibling relationship between bears from these two regions. However, our reference dataset has a limiting number of samples from León, which possibly hampers the identification of further relationships with brown bears from this region. Additionally, no parent-offspring relationships were observed within Galician individuals, although two cases of full- and half-siblings Galician individuals were observed. Using familial relationships to identify the likely origin of the Galician bears revealed to be a successful approach in studying bears in expansion areas. This was previously used, albeit in a simpler approach using only pairwise relatedness, to identify the likely pack of wolf-dog hybrid individuals (Pacheco et al., 2017), and may be worth applying it in similar situations when a powerful database with reference individuals is available.

4.2. The social perspective

Brown bear colonization processes may generate an excessive amount of damage claims and intense conflicts with local people (Kaczensky et al., 2011). The early stage of the expansion process of bears in Galicia, evaluated from 2010 to 2021, has been characterized by a highly variable number of damage claims per year, mostly referring to apiaries, as we could observe from available raw data from the Galician authorities. Although the number of damages claims per year has been very variable, two picks stand out in the years of 2014 and 2016. The first pick in 2014 is likely related to the higher number of bear observations registered in the area this year (Naves & Fernández-Gil, 2017). The other pick in 2016 likely represents a higher human effort of collecting information on the species, concordant with the implementation of the first LIFE project in Galicia in this year.

For the last four years, overlapping with our non-invasive genetic sampling, we observed that the number of bear damage claims in a municipality was not correlated with the number of bears identified in the same municipality, although a positive but not significant trend was observed. Notably, the variation in the amount and intensity of bear damages has been shown not to be directly related to the number of bears present in an area because several others factors may affect this relationship (Ballesteros et al., 2021; Bautista et al., 2017). For instances, the use of preventive measures like electric fences (Naves et al., 2018), the variation in the availability of natural foods (Naves et al., 2006), compensation schemes, management practices, human land use (Bautista et al., 2017), or even the predisposition to claim a bear damage (Bautista et al., 2017; Bautista et al., 2019; Zarzo-Arias et al., 2021), are among the factors that most have been shown to influence the relationship between the number of bears and the number of bear damage claims.

In bear expansion areas, the yearly volume of damages can be related to the presence of a single individual (Molinari et al., 2016; Naves et al., 2018), particularly in areas where damage preventive measures are absent. In this regard, in 2018, the spatial distribution of damages suggests a concentration of damages where the individuals UA206 and UA205 were detected. In 2020, the same damage hot spot was observed, and the individual UA206 was identified again in the area. Finally, in 2021, the individual UA205 was identified again near of the concentration of damages. Therefore, individuals UA205 and UA206 seem to be associated with most damages in the area. It is strongly recommended the implementation of damage preventions measures in expansion areas (Palomero et al. 2021).

Along these lines, and focusing on an expansion area, we observed a higher damage ratio per bear and year, compared to the western subpopulation. The differences in the damage ratios of these two regions could be at least partly explained by the differences in the history of coexistence between bears and humans, with bears in the western subpopulation being permanently present in the last decades. Hence, local people in the permanent presence area, are generally used to living with bears, and the use of measures to prevent human-bear conflicts has not likely been lost in a large extent (Molinari et al., 2016). In eastern Galicia, however, bears were mostly absent for decades. Therefore, a large part of the memory and knowledge of coexistence with bears was likely lost (Molinari et al., 2016). Higher damage ratios in areas where there is a lack of preventive measures supports the lack of use of damage prevention measures in this expansion area. The observed similar damage claims per bear and year between Galicia and the eastern subpopulation. We also observed higher damages per bear and year in the eastern subpopulation, compared to the studied expansion area. The habitat characteristics are similar in the two Cantabrian subpopulations, both regions have similar forested landscapes, where brown bears can shelter and feed (Lamamy et al., 2019). There is only a difference, the western subpopulation has a more heterogenous and fragmented habitat, consequently the use of forested landscapes in the eastern sector is higher than in the west (Lamamy et al., 2019). Attending the habitat similarities between the two Cantabrian regions, the observed similar damage claims per bear and year between Galicia and the eastern subpopulation may suggest that the very low number of bears that have persisted in the eastern subpopulation may have not been enough to preserve the knowledge of coexistence. A similar result can be seen in a comparison of human-bear conflicts between Veneto (Italy) or Carinthia (Switzerland), regions with very few number of bears and a recent presence, had bear damage ratios of 4.2 and 6.4 respectively, while in neighboring regions with stable populations, such as Trentino region of the Italian Alps or the Dinaric Alps of Slovenia had damage ratios reach values of 2.7 and 1.2, respectively (Molinari et al., 2016).

Human-bear conflicts have been identified as the single most important threat to long-term conservation of brown bear in Europe, and conflict types can differ in respect to how seriously they are perceived by the public (Molinari et al., 2016). The media interest on the brown bear is thus of pivotal importance for the conservation of the species. Although the number of bear news per year has been very variable, it is possible to associate some events to a higher number of news in three different years. The first pick in 2010/2011 represents the novelty of observing bears in Galicia together with a high impact study on bear fossils found in Galicia. The pick in 2013 is associated with news about public participatory process in the debate of the brown bear action plan in Galicia. One the other hand, since 2016 the number of news on bears has been increasing likely due to the implementation of the LIFE project.

We observed a variable trend on the media interest over time, the annual number of bear news not correlated with the annual number of bear damage claims. Similarly, the number of bear news in a municipality was not correlated with the total number of bears identified on our genetic monitoring, suggesting that in the early stages of the expansion process, social interest in the brown bear is possibly related to its presence, including a great diversity of themes, like conservation or observations, regardless the number of animals and/or damage claims.

The main subjects in our target newspaper *La Voz de Galicia* about the brown bear were conservation, research, observations, population, damages and education, covering 72% of all news analyzed. Interestingly, a similar news analysis carried out between 2007 and 2016 in Asturias, where the brown bear has a historical presence, showed different results (López-Bao et al., 2021c). Although conservation stands out as the most predominant theme in the news both in Galicia and Asturias, the other subjects varied substantially between the two areas. For example, observations of brown bear appeared as a prominent subject in Galicia, the third most frequently mentioned in the news, whereas in Asturias it ranked only 12 among the most frequent news (López-Bao et al., 2021c). Notably, damages on apiaries, crop or livestock do not appear as a main subject among the twelve main topics on news in Asturias. The fact that conservation lead the rank of news about brown bear in both areas can be explained by the fact that the species is allover charismatic and its threatened conservation status in Spain, requiring specific management and conservation activities, effectively calls media attention. On the contrary, in Romania which hosts the highest brown bear density in Europe (Popescu et al., 2016; Rozylowicz et al., 2019), the same kind of media news analysis had different results (Neagu et al., 2022). In this case, the main topic addressed by the Romanian media was the interaction between humans and brown bears, comprising all subjects related to bears near areas with human activity, and bear attacks either resulting in human injuries or in damage to gardens, beehives, barns and livestock (Neagu et al., 2022). Recovering bear populations may be portrayed in the media in a more positive way, with media interest being more focused on its conservation than on its damages.

Consistently with the top ranked news' subjects, conservationists and politicians, who have an important role in the development of conservation projects, are the agents who appear most frequently in the news. The high media interest on brown bear conservation in Galicia could be at least partly explained by the development of a well-known LIFE conservation project in Galicia. Many news were actually generated either by actions or by results from the LIFE project, informing about presence or conservation of the species, coexistence with human activities, or their role as a touristic resource (López-Bao et al., 2021c). The six municipalities where we found a higher number of news on conservation are those that are directly involved in the LIFE project and where bears were identified in our genetic monitoring, namely Navia de Suarna, Cervantes, As Nogais, Pedrafita do Cebreiro, Folgoso do Courel and Quiroga. Additionally, beekeepers also have a high emphasis in the news, raking third among all actors considered. Lugo province is an area with a strong beekeeping tradition, and thus the potential conflict and damage caused to beekeeping interest and towards the protection of apiaries may justify the highlight these actors have in the Galician news (López-Bao et al., 2021c).

Interestingly, the annual number of news that mentioned bear damages was found to not be correlated with the annual number of bear damage claims, with the latter being much higher than the former. Similar results were found in the media for the Cantabria Mountains bear range (Fernández-Gil et al. 2016). In fact, the same author observed that bear damages seem to be less conflictive concerning media coverage when compared to wolf damages (Fernández-Gil et al., 2016).

However, at municipality scale overlapping with our non-invasive genetic sampling the number of news that mentioned bear damages seem to be positively influenced by the number of bears and the number of bear damages. The municipalities that showed a higher number of news that mentioned damages are the same municipalities (Folgoso do Courel e Quiroga) where more bear damages were recorded.

5. Conclusion and future perspectives

In recent decades, the Cantabrian brown bear population is showing a consistent growth. Therefore, bears are now re-colonizing areas where the species was absent for decades, such as the mountainous areas of eastern Galicia. We used this re-colonization process as a study model for understanding the early stages of the expansion process of a brown bear population from a socio-ecological perspective. Increasing our knowledge on the expansion of large predators is essential to a management targeting mitigation of human-wildlife conflict.

Our results showed that the first stages of such recovery process are driven by a few number of individuals, the majority of which being males (according with male-biased dispersal patterns in brown bears). Importantly, we have detected bears in this recovery area from all the bear breeding areas in the Western Cantabrian subpopulation. Furthermore, our research shows the potential of genealogical analysis to identify the most probable areas of origin for dispersal bears. We also showed that an expansion area is characterized by higher bear damages ratios, compared to areas where bears have always been present and were numerous, which may be related with a lower use of damage prevention methods in recolonizing areas where people are not used to share the landscape with bears for a long time. Accordingly, a few number of bears seem to be responsible for the damages in the expansion area. Furthermore, in this bear expansion area, the media not only covered conflicts and concerns related to the shared landscape with the species, but mainly conservation issues, in contrast with other areas of permanent bear presence. However, at local scale the number of news that mentioned bear damages seems to be positively influenced by the number of bears and the number of damages.

For the future of bears in Galicia, we expect that the next coming years will be characterized by more males dispersing into this area. Since we have only detected one female since 2018, we expect on the short term a low number of females dispersing to Galicia. On the long term with a continuous population growth, bears may recolonize further areas, including northern areas in Portugal. However, bear conservation is highly dependent of the mitigation of human-bear conflicts, which should be a pivotal concern among all partners involved in bear conservation. Media coverage seems to be a collaborative component, as conservation is on average the most highlighted target of news regarding the endangered Cantabrian brown bear.

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7. Supplementary Material

Table S1 – Description of the main and mentioned topics used in the news analysis.

Main and Mentioned topics	Description
1. Conservation	Any topic about brown bear conservation in Galicia
2. Research	Research about brown bear or something related in Galicia
3. Observation	Observations of brown bears or signs of presence (e.g., footprints, hairs…) in Galicia
4. Population	Brown bear population size or tendency (e.g., increase/recovery bear population)
5. Damages	Bear damages on beehives, crop, or livestock
6. Education	Any action to raise awareness, information, or education about brown bears
7. Damage management/Compensation	Damage management, use of preventive measures (e.g., electric fences, tree planting…) and compensation for bear damages
8. Bear in captivity	e.g., brown bear in a zoo
9. Tourism/Public use	Any action about tourism related to brown bear
10. Public participatory process	e.g., signature collection
11. Characteristics	Ecological characteristics of brown bears
12. Trust	Confidence of the population in the authorities
13. Bear poaching	e.g., road kills of brown bears
14. Hunting	Any action of hunting that can be related or influence the brown bear conservation

Table S2 - Genealogical relationships between Galician individuals and western individuals (in bold) obtained in the COLONY program. A- Probabilities of paternity and maternity. B- Probabilities of half and full sibling.

A

Individuals			Results
Offspring	**Father**	**Mothers**	**Probability**
UA209	UA149	-	0.9425
UA209	-	UA201	0.8915
UA210	UA175	-	0.9717
UA204	-	UA094	0.9130
UA205	-	UA126	0.9333
UA222	-	UA126	0.9333

B

Individuals				Results
Full siblings		**Half siblings**		**Probability**
UA206	**UA221**	-	-	0.983
UA208	UA167	-	-	0.914
UA211	UA107	-	-	0.798
UA205	UA136	-	-	1
-	-	**UA205**	**UA222**	1