Project

IMPROVING PROTECTION OF BEEHIVES AND LIVESTOCK FROM BEARS: PIROSLIFE IN CATALONIA, SPAIN

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1. Introduction

The Pyrenees mountain range has historically offered suitable habitat for the brown bear (*Ursus arctos*) thanks to its orographic and biogeographic characteristics. However, bears were almost extirpated there at the end of the 1980s, mainly due to human causes, i.e. poisoning, poaching and trapping for bounties (Casanova, 2005). In 1996, a plan was initiated to recover the species in France and the Catalonia region of northeast Spain. Since then, 11 individuals from Slovenia have been released (Quenette et al., 2001; Sentilles et al., 2020). As a result, there is now a population of more than 50 individuals distributed over the vast majority of the Pyrenees.

With the aim of consolidating the bear population in the Catalan Pyrenees, the PirosLife project, a LIFE+ Nature project, was implemented in 2014–2019. Its main goal was to ensure the long-term conservation of bears in the Pyrenees. The project was coordinated by the Department of Territory and Sustainability of the Generalitat de Catalunya and involved partners such as the General Council of Aran, Lleida University, Forestal Catalana and the Fundación Oso Pardo. One of the project actions was to design and implement a series of protection measures to prevent damage by bears to beehives and livestock, as well as to evaluate their effectiveness. This article summarises and discusses the effectiveness of the prevention measures applied during the PirosLife project.

2. Project area

Most of the bear population is located in the central Pyrenees. This area belongs to three different states (France, Spain and Andorra). The Spanish portion is spread across three autonomous communities (Catalonia, Navarra and Aragon) that are responsible for bear conservation and management. The PirosLife project was implemented only in Catalonia, where there are two administrations: the General Council of Aran in the Val d'Aran region and the Generalitat de Catalunya in the rest of the Catalonian Pyrenees.

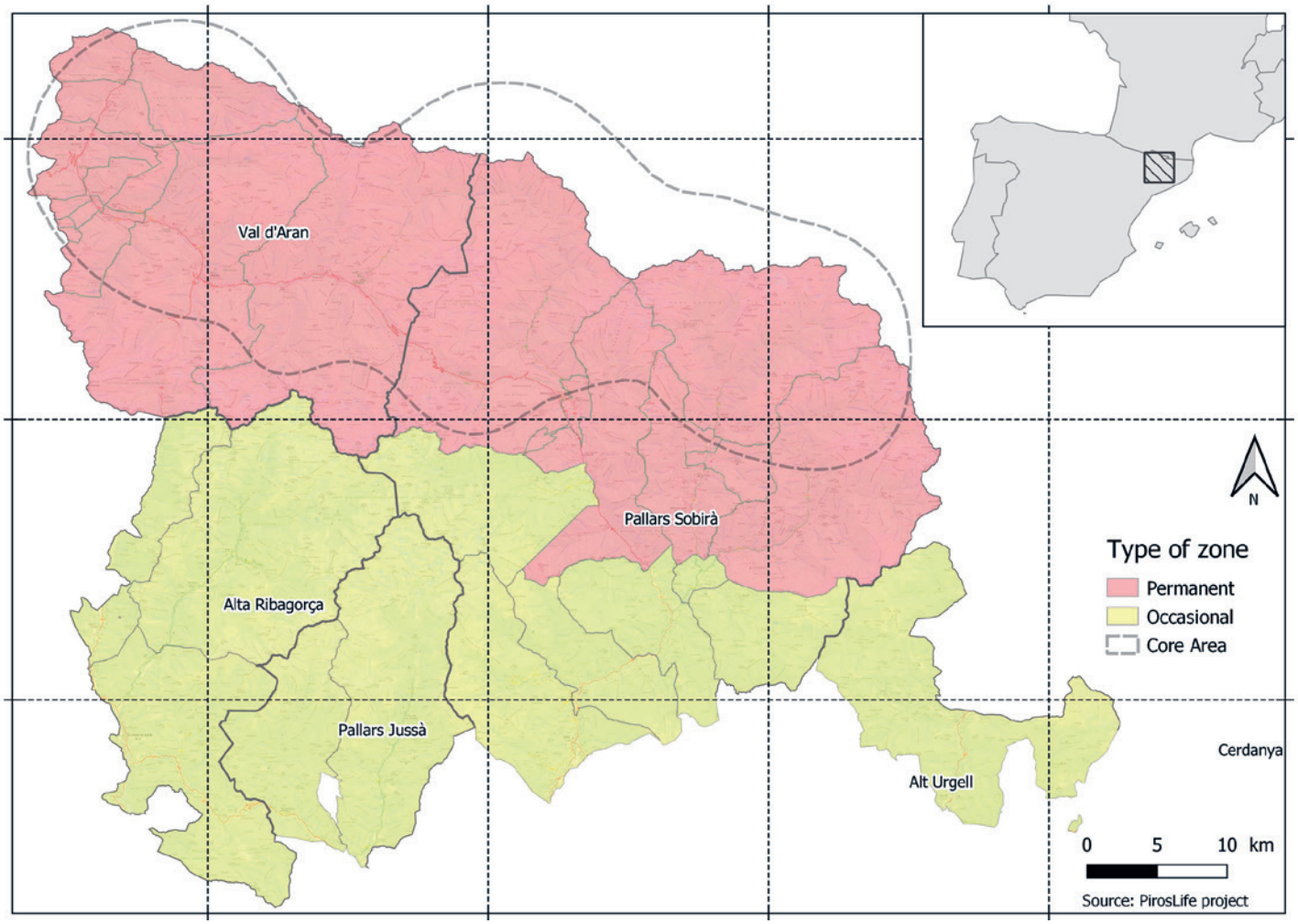

Fig. 1 Location of brown bear permanent presence zone (ZPP), occasional presence zone (ZPO) and Core Area in Catalonia, Spain.

The PirosLife project created two different management areas based on bear occurrence: a zone of permanent presence (ZPP), where prevention measures are implemented at most apiaries and livestock grazing areas, and an occasional presence zone (ZPO) where protection measures are applied only when damage occurs (Fig. 1).

3. Prevention measures: implementation and results

Livestock rearing in the Catalan Pyrenees is mainly dedicated to meat production. It is managed through extensive grazing approximately from April to November and a semi-extensive rearing system during the rest of the year. The main sector is cattle, followed by horses and sheep. The least abundant type of livestock are goats, although recently a few goat farms with semi-extensive rearing systems and dedicated to milk production have arisen. Additionally, at the end of the 20th century, and thanks to the improvement of road networks, transhumant beekeepers began to use the area.

The application of measures to prevent damage by large carnivores is one of the main strategies in any project focused on reintroduction of these species. For this reason, the PirosLife project created a so-called Annual Livestock Plan that includes the bases for the deployment of an integrated system of measures to prevent damage by bears in this economic sector.

3.1 Beekeeping

The presence of sedentary bees in the Pyrenees was not common historically. However, during recent decades, there has been an increasing number of transhumant beekeepers from the south of Catalonia who move from place to place during the summer season in search of high-altitude blossoms.

In the Catalan Pyrenees, until the end of 2017, there was no systematic registration of beehives that were temporarily located in the ZPP. As a result, it was a challenge to trace and check apiaries installed during

the season. Subsequently, the administration made the registration of apiary movements compulsory, thereby motivating and improving communication channels between the administration and beekeepers. In the Val d'Aran, beehives have been registered since 2009.

3.1.2 Implementation of prevention measures

The two administrations in Catalonia have implemented the same protection system: electric fences with three metal wires at heights of 20, 45 and 90 centimetres above the ground, grounding, a battery and 4 Kw solar panel (Fig. 2) (PirosLife Team, 2019). This is similar to fences used elsewhere, but the total height (90cm) is lower and there are fewer wires than fences used, for example, in the Cantabrian Mountains of Spain (Seijas et al., 2016 in *CDPnews* issue 12) and Trentino in Italy (Vittorio et al., 2016 in *CDPnews* issue 12). Maintenance of the fences consists of clearing vegetation around the wires in order to avoid short circuits and checking the continuity and intensity of the power supply. Follow-up maintenance is performed every two weeks during the spring and every 25 to 30 days during the rest of the year.

Protection and maintenance of these electric fences have been slightly different in Val d'Aran than in the rest of the Catalan Pyrenees. In Val d'Aran, apiaries within the ZPP areas were protected with electric fences after damage occurred. Maintenance of these fences was the responsibility of the beekeeper. In the rest of the Catalan Pyrenees, all the apiaries registered or detected within the ZPP areas were protected and the public administration maintained and monitored the fences.

Fig. 2 Electric fence protecting beehives from bears. *(Photos: PirosLife project)*

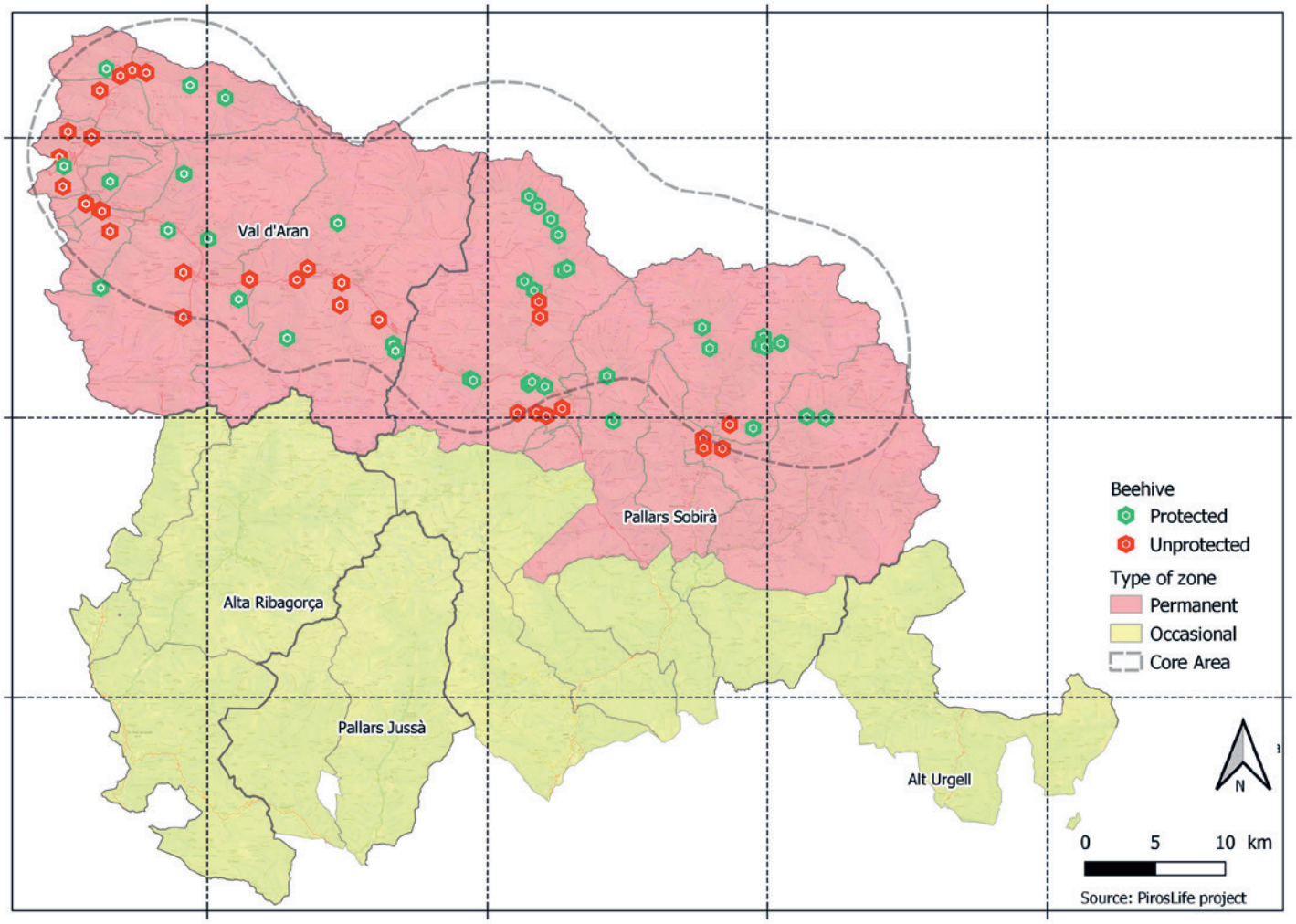

Fig. 3 Protected and unprotected beehives within the zone of permanent presence of bears in 2019.

During the PirosLife project, the proportion of apiaries within the whole project area protected with electric fences peaked in 2019, when 39 of 70 apiaries (56%) located in the ZPP were protected (Fig. 3), including a total of 3,304 hives (63%).

3.1.3 Effectiveness of prevention measures

The outcomes of the applied protection measures differed between areas. Surprisingly, during 2017 and 2018 bears more often damaged protected apiaries than unprotected ones. Most damage to protected beehives occurred in Val d'Aran, due to the presence of individual bears that repeatedly overcame electric fences (Fig. 4). Paradoxically, during 2017 protected beehives suffered 3.75-fold more damage events than unprotected ones (Table 1) and the number of beehives damaged was 10 times higher in protected apiaries. Genetic analysis of biological samples found at damaged beehives revealed that a male bear called Cachou was responsible for these events (see section 3.2.2.2).

In areas without such 'specialised' individuals, properly maintained three-wire electric fences successfully prevented damage by bears. When damage occurred, this was a result of failures in the electrical system due to poor maintenance (vegetation in contact with electric wires or discharged batteries) or defects in fence installation, allowing bears to access beehives easily.

3.1.4 'Specialised' bears

As mentioned above, three-wire electric fences were not enough to stop some individual bears 'specialised' on apiaries. For this reason, electric fences at apiaries that had suffered repeated damage were progressively improved during the PirosLife project. In 2018, double and triple three-wire fences – spaced 50cm apart – were installed, but this change did not increase the protection effectiveness, since 'specialised' bears were still able to pass these fences, either by accumulating soil on the electric wires or digging under them (Fig. 5). Therefore, a new fence design was tested. This consist-

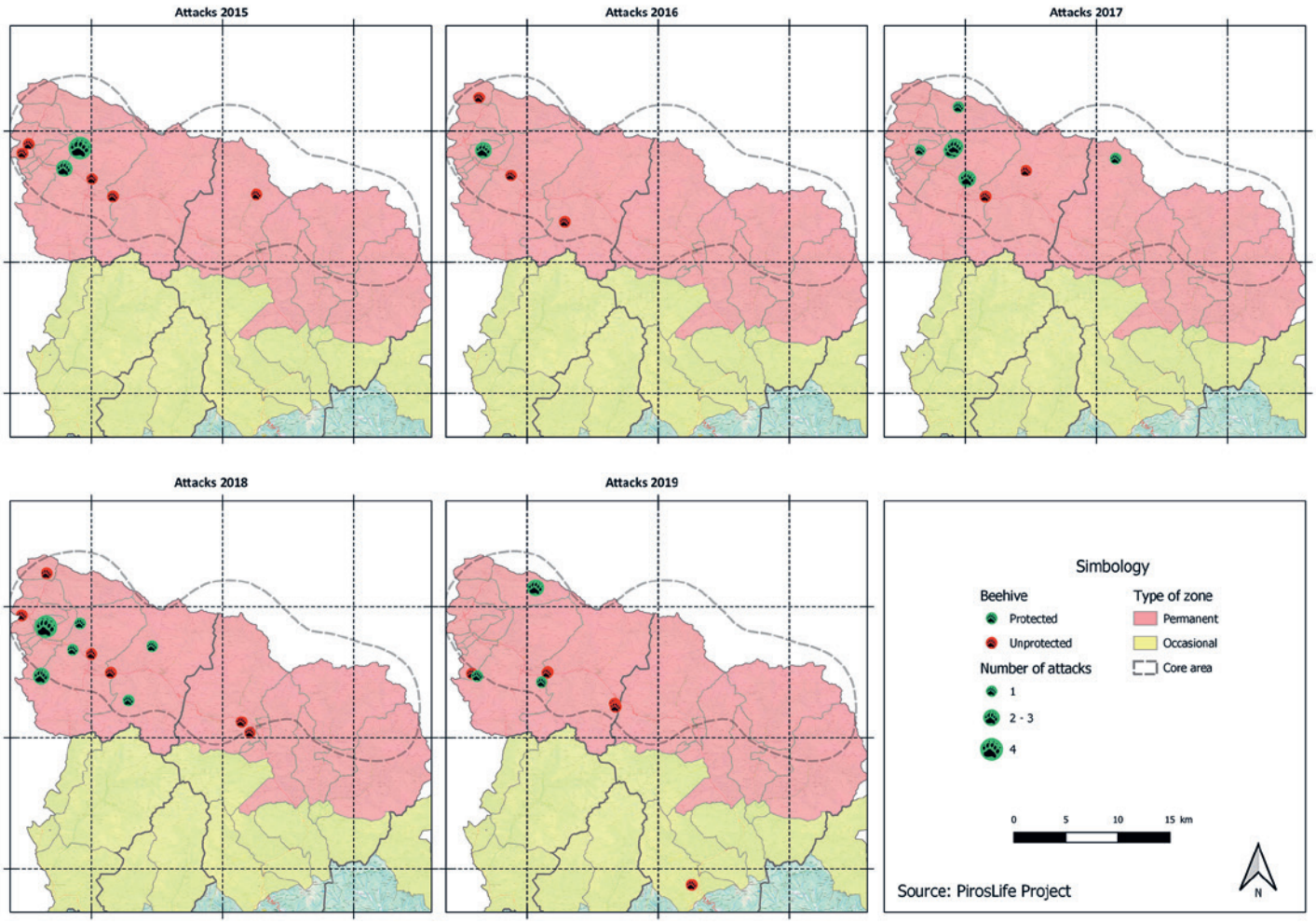

Fig. 4 Incidents of damages by bears to beehives in Catalonia from 2015 to 2019.

Table 1 Number of damage events and hives damaged by bears in protected versus unprotected apiaries in the zone of permanent presence of bears (ZPP) from 2017 to 2019.

Status of apiaries	2017		2018		2019	
	Events	Damage	Events	Damage	Events	Damage
Protected	15	62	10	34	4	14
Unprotected	4	6	6	25	6	28
Total ZPP	**19**	**68**	**16**	**59**	**10**	**42**

Fig. 5 Beehives protected with a double electric fence showing where a bear successfully dug underneath.

ed of wire mesh fencing mounted on wooden poles, with five electrified wires on the outside. In response, 'specialised' bears tried to dig underneath such fences to access beehives (Fig. 6). Therefore, we reinforced these fences with an exterior electric mesh, following which no further damage was recorded.

Two more electric fence designs were developed in 2019 in order to prevent 'specialised' bears from accessing apiaries. The first design, for heavy permanent fencing, was 2.2 m high and built with rigid 15×15 cm iron mesh attached to concrete posts and cemented into the ground, with three electrified wires on the outside. The second design, lighter and mobile, was the same as that tested in 2018 but, to prevent bears digging underneath, 150 cm-wide rigid iron mesh was placed horizontally on the ground, 100 cm outside the fence and 50 on inside (Fig. 7). Since the installation of these reinforced fences, no further events have been detected at apiaries that were previously subject to repeated damage by specialised bears.

3.2 Livestock

3.2.1 Sheep and goats

Sheep and goat farms in the Pyrenees mainly consist of small- and medium-sized farms that use the grass on alpine and subalpine mountains in summer and valleys in winter. The PirosLife project protected approximately 8,000 head of livestock of 40 different owners. In addition, some farmers focused on meat production bring their flocks from other parts of Catalonia to graze on mountain meadows in the ZPP during the summer season, temporarily increasing the number of sheep and goats in the area. During the PirosLife project, four transhumant flocks moved to the project area with a total of 6,000 animals. The owners of these flocks took care of protection measures themselves, using a combination of electric fences, shepherds and livestock guarding dogs (LGDs). The PirosLife project donated equipment (battery, solar panel, mesh) when it was requested by farmers.

Fig. 6 Brown bear digging attempt and detail of fence construction.

Fig. 7 Improved electric fence designs to prevent repeated damage to beehives by 'specialised' bears.

3.2.1.1 Implementation of prevention measures

Shepherds and LGDs almost disappeared in the project area after the eradication of large carnivores. Following the recovery of the bear and the progressive increase of its population, the need to revive these management elements became evident in order to make extensive livestock farming compatible with brown bear conservation. Therefore, the following measures for coexistence were considered:

a. To merge some small flocks into larger flocks, with more than 600 head;
b. To hire herdsmen to watch over flocks during the summer grazing season;
c. To build huts for shepherds to improve their working conditions;
d. To encourage the use of LGDs;
e. To encourage the enclosure of flocks at night in electrified mesh corrals.

The number of protected flocks has varied over the years and according to the needs of the sector. Participation in these groups was a voluntary decision, so that not all livestock farms became beneficiaries. Participating farmers signed a collaboration agreement with the administration, making the following commitments:

- The administration committed itself to pay for shepherds and installing shepherds' huts; to provide and supervise electric fences, batteries and solar panels; to give technical support with LGDs; and to carry out veterinary inspections to check the health status and body condition of livestock.
- The livestock farms had to ensure they had a shepherd working every day, therefore ensuring a replacement during holidays. They were also responsible for verifying the optimal health status and physical condition of animals before including them in the protected flock, to avoid compromising the management of the rest of the group. If optimal health status is not ensured, weaker animals may not be able to follow the rest of the flock, presenting a challenge to protect them within electric fences during the night, increasing the risk of bear attack.

Flocks consisted mainly of sheep for meat. There were not enough goats in the project area to justify the existence of a goat-only flock. In addition, many sheep breeders would not agree to include goats in sheep flocks because of their different behaviour and pasture management. Therefore, goats were not included in combined flocks or even, in most cases, in the project's prevention measures.

Combined flocks were formed for periods of between 3.5 and 5 months from June to October. Each flock included from 600 to 2,000 animals. During the PirosLife project, six to seven flocks were formed each year, each of which had two or three LGDs (Pyrenean Mountain Dog or Spanish Mastiff breeds). In most cases, farmers obtained the LGDs themselves from other farms although, in some cases, the public administration assigned them purebred Pyrenean Mountain Dogs. Additionally, all these flocks were protected with electric fences at night (Fig. 8). The number of protected flocks and farms increased throughout the project. On average, 78% of flocks within the ZPP were protected during the PirosLife project (Fig. 9).

Fig. 8 Sheep flock protected by electric netting and LGDs.

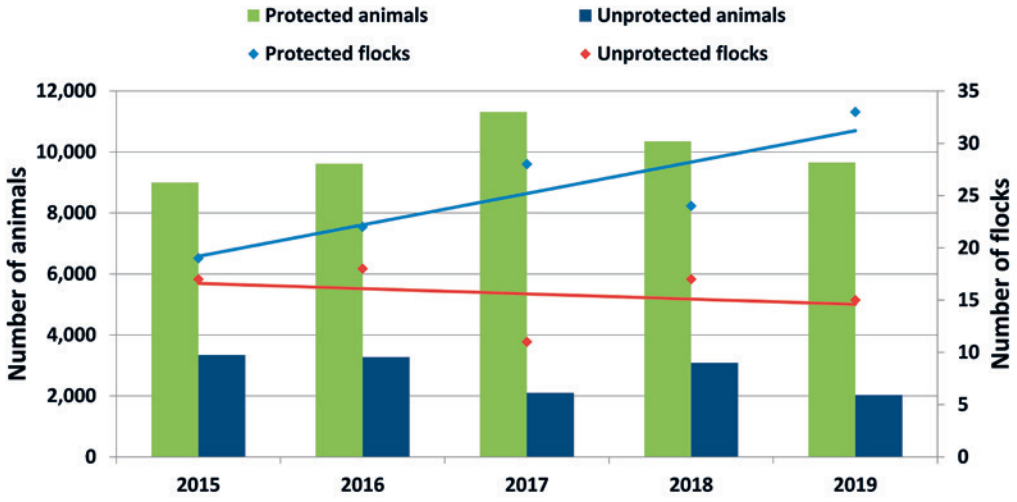

Fig. 9 Numbers of protected and unprotected flocks and animals during the PirosLife project.

3.2.1.2 Effectiveness of prevention measures

Overall, unprotected livestock suffered a higher number of attacks and damage than protected ones, which is evident when we consider the number of animals present in the region in each category (Table 2). On average, 67% of damage was to unprotected livestock and 33% to livestock protected with the measures described above (see section 3.2.1.1). The maximum difference between these two groups was reached in 2018, when 87% of damage was to unprotected livestock. Furthermore, the number of losses per attack was usually lower in protected livestock.

Among the attacks that affected unprotected flocks, three different situations were detected: 74% of attacks affected large farms that grazed extensively during the summer but had not voluntarily adhered to prevention measures and, therefore, did not protect the flocks overnight or use LGDs. Another 16% of attacks occurred on flocks located at the bottom of the valley and outside the summer protection campaign. Finally, 10% of attacks happened on small farms (less than 50 head) that were not included in the prevention system and did not graze on mountain pastures during the summer season.

Among the flocks with preventive measures, 64% of damage occurred while animals were not properly protected. This was mostly due to certain weather conditions (e.g. intense storms or presence of fog) or because some animals were incapable of following the flock due to poor health status or physical condition. The remaining 36% of attacks on protected flocks occurred despite the correct application of protective measures (Fig. 10).

During the PirosLife project, the probability of protected sheep suffering an attack was 0.19% (sd = 0.05), compared to 1.42% (sd=1.04) for unprotected sheep. These figures were obtained by dividing the number of animals killed by bears by the total number of animals included in flocks, considering the number of livestock each year. Unprotected flocks were therefore 7.5-times more likely to suffer an attack than protected ones (Fig. 11).

3.2.1.3. Particular cases

In 2018, an unprotected flock of approximately 2,000 animals that grazed very close to a protected flock suffered several attacks. When this flock moved to another area, the protected flock started suffering bear attacks, probably as a result of the presence of a bear that had become accustomed to attacking the unprotected sheep. In order to improve the protection of the pen, an additional three-wire electrified perimeter fence was installed at a distance of 60 m from the electrified mesh with the aim of preventing the bear from approaching close to the sheep. Based on observations, it seems that this additional fence prevented the sheep from detecting the presence of a bear in close proximity, thereby reducing their stress which had previously resulted in them breaking through the fence. When fences break, protection becomes a challenge, because animals scatter down the mountain. This additional fence also facilitated the work of the LGDs and prevented the animals from passing through the fence if they were frightened.

Some other bear attacks in 2018 happened as a result of a lack of correct implementation of the prevention system. A few participating breeders did not

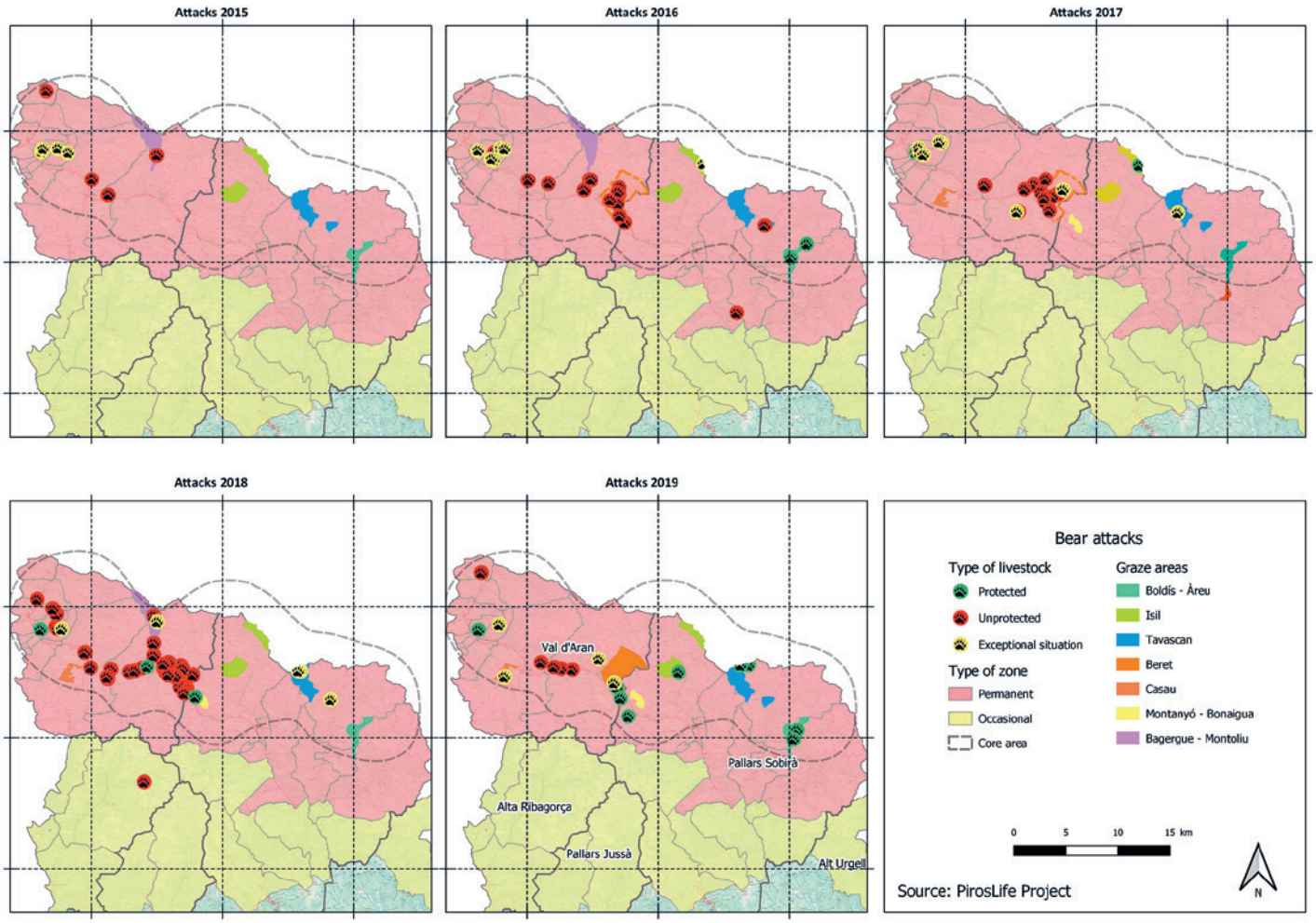

Fig. 10 Distribution of damage to livestock by bears in Catalonia in 2015–2019.

Table 2 Damage by bears to protected and unprotected livestock within the Catalonia zone of permanent presence of bears during the PirosLife project.

Year	Status of flock	No. animals	No. attacks	Attacks/ Animals (%)	No. lost	Losses/ Animals (%)	Lost/ Attack
2015	Protected	8,997	5	0.06	8	0.09	1.60
	Unprotected	3,342	6	0.18	7	0.21	1.17
	Total	**12,339**	**11**	**0.09**	**15**	**0.12**	**1.36**
2016	Protected	9,615	9	0.09	16	0.17	1.78
	Unprotected	3,272	16	0.49	30	0.92	1.88
	Total	**12,887**	**25**	**0.19**	**46**	**0.36**	**1.84**
2017	Protected	11,310	9	0.08	17	0.15	1.89
	Unprotected	2,099	13	0.62	28	1.33	2.15
	Total	**13,409**	**22**	**0.16**	**45**	**0.34**	**2.05**
2018	Protected	10,353	9	0.09	13	0.13	1.44
	Unprotected	3,082	52	1.69	87	2.82	1.67
	Total	**13,435**	**61**	**0.45**	**100**	**0.74**	**1.64**
2019	Protected	9,652	14	0.15	17	0.18	1.21
	Unprotected	2,031	7	0.34	10	0.49	1.43
	Total	**11,683**	**21**	**0.18**	**27**	**0.23**	**1.29**
Average/ Year	Protected	9,985	9	0.09	14	0.14	1.56
	Unprotected	2,765	19	0.68	32	1.17	1.68

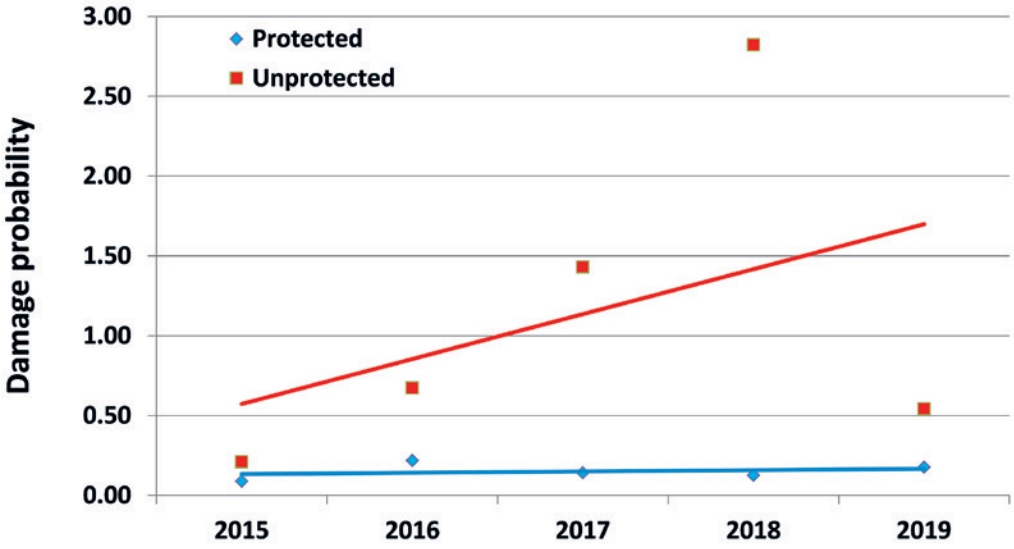

Fig. 11 Probability of suffering damage in protected and unprotected livestock from 2015 to 2019.

apply the measures agreed with the public administration; prevention material and support were therefore removed. There was thus a substantial increase in the number of unprotected flocks in 2018 and, as a consequence, attacks and damage to the resulting unprotected animals also increased. During 2019 the farmers implemented the protection measures correctly and the situation reversed: total damage was reduced from 100 animals killed in 2018 to 27 in 2019.

3.2.2 Cattle and horses

Management of cattle and horses within the project area is characterised by extensive grazing in alpine meadows during the summer season without surveillance or protective measures. Most animals belong to local farmers; transhumant cattle are not very common in the area.

3.2.2.1 Implementation of prevention measures

It is not currently possible to use prevention measures for cattle and horses homologous to those implemented for sheep. One reason is that their cost is not likely to be offset by the benefits of their use. Some pastures are more than three hours away from farms and using electric fences to protect animals overnight would be costly. In addition, farmers are not with their cattle on a daily basis but, more often, only once a week. LGDs have not yet been used in the Pyrenees for large stock, which presents many challenges due to the local context. The free-grazing system makes it harder for dogs to properly bond with cattle which are never in stables, being kept year-round in the mountains or in lower pastures in the valleys, usually confined with a single electric wire. The system also makes it difficult for farmers to regularly monitor dogs' development. Furthermore, the high presence of tourists may easily disturb LGDs and compromise their development and future performance. Therefore, no prevention measures were applied to large stock within the PirosLife project. Instead, a support action to bovine and equine herds was carried out: a person was hired to provide an additional weekly monitoring service in the mountains with the aim of detecting incidents and potential interactions of cattle with bears.

3.2.2.2 'Specialised' bears

Attacks on large livestock were less common than on sheep and goats. When attacks occurred, they were mostly caused by specific bears that had 'specialised' on this kind of livestock. In particular, two male bears named Goiat and Cachou repeatedly caused damage, especially to horses. Goiat was captured in Slovenia and released in Catalonia in 2016, when he was nine years old. He was the main cause of damage to the equine sector in 2017–2018 (Fig. 12), with a total of 11 animals killed in 2018, and an additional case in 2019. Cachou was a local male, captured with a culvert trap and fitted with a GPS collar in May 2019, when he was four years old. He was responsible for seven attacks on mares and foals during summer 2019. Five of these attacks took place within a 15-day period.

All damage caused by these two male bears occurred within ZPP areas, especially that belonging to the Val d'Aran, and affected both young and adult animals, apparently in good health. Within the PirosLife project area, these two bears spent most of their time in Val d'Aran (Goiat in 2017–2018 and Cachou in 2019).

Fig. 12 A mare killed by a brown bear in Catalonia.

Goiat's attacks on horses during 2017 and 2018 caused alarm in the community, leading to the approval of a *Protocol for intervention with bears in the Pyrenees*, prepared by the Pyrenean Brown Bear Working Group (Anon., 2018). This protocol defines the characteristics of a "repeatedly predatory brown bear" as "an animal that repeatedly attacks livestock over an extended period of time (at least two months), with four or more attacks per week on protected sheep or goat flocks, or one or more attacks per week on (unprotected) cattle or horses" (Anon., 2018) and allows the application of aversive conditioning measures and even the removal of such individuals from the natural environment in exceptional cases.

In Val d'Aran, several aversive conditioning techniques were attempted in order to prevent attacks by Goiat and Cachou but in this case proved to be unsuitable. These two bears avoided people and, as a result, aversion techniques were impractical as they could not be performed during an attack. For example, after Goiat had attacked large livestock, acoustic aversive techniques, electric fences or pyrotechnics were applied close to the carcass(es) or large livestock herds, but the next night he attacked horses again. Nevertheless, Goiat's predation on horses decreased and he did not cause any damage to horses in the Pyrenees after July 2019.

Supplementary feeding was conducted in autumn 2019 in an attempt to stop Cachou attacking livestock. Deer carcasses were provided close to horses on which he had previously predated, following which Cachou started predating on wild deer, with only one subsequent attack on horses. Later, Thiram, a fungicide that has been used on wildlife as a chemical repellent (Tobajas et al., 2020), was applied to horse carrion. After his exposure to this chemical, Cachou did not commit additional attacks on livestock. Unfortunately, his death in spring 2020 prevented verification of the long-term effectiveness of these methods.

3.3 Conclusions and recommendations

3.3.1 Beekeeping

Protection of apiaries within the ZPP during the PirosLife project period (2015–2019), as described in section 3.1.2, reduced damage by bears to only one case where the public administration maintained the prevention measures and up to 15 cases where beekeepers were responsible for maintenance, excluding damage related to areas with 'specialised' bears**.** As previously described by other authors (Seijas et al., 2016; Vittorio et al., 2016), the experience of using electric fences to protect beehives during the PirosLife project shows that their effectiveness is dependent not only on proper set-up but also on regular maintenance, such as vegetation clearance around the wires, and a minimum intensity of 4 kilovolts.

In relation to 'specialised' bears that bypass simple electrified fences, the project demonstrated the effectiveness of reinforced barriers: a combination of mesh fencing, electrified wires and anti-digging systems. The additional costs of such measures are amortised within a few years after installation.

3.3.2 Sheep and goats

The probability of bear damage occurring to sheep was 7.5-fold greater for unprotected flocks than for protected ones. The most effective approach is a combination of protection measures: presence of herdsmen, use of LGDs and/or night-time confinement in corrals. Preventive measures have not yet been applied to extensive goat grazing, since this is less common in the project area and husbandry practices hinder the application of such measures. Farmers and shepherds do not support mixing of goats and sheep in a single flock due to their behavioural differences, which

could lead to serious challenges for shepherds to manage the flock and keep track of all individuals while grazing in high mountain pastures.

3.3.3 Cattle and horses

No efficient method of preventing damage to large livestock is widely considered applicable to the region. This affects the level of acceptance of bears by local farmers. Male bears predating on adult mares hampers the establishment of coexistence between the livestock farming sector and the brown bear in the Pyrenees, causing a deep social conflict. To address this, the use of LGDs and technological tools for monitoring are being evaluated, but it is still too early for their implementation.

Aversive measures applied to an adult male bear 'specialised' on horses did not entirely result in the desired outcome, although he progressively changed his behaviour and attacked horses less often. Chemical aversion and supplementary feeding applied to a sub-adult male showed some initial promise, but their long-term effectiveness could not be evaluated. These two bears were not habituated to people and so, when approached by technicians seeking to apply aversive measures, they fled the area. Our experience suggests that classical aversive techniques are not suitable for elusive bears. Nevertheless, further attempts should be made before drawing stronger conclusions regarding their application and effectiveness.

Acknowledgements

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