Review

Lynx and livestock: Measures to prevent damage and mitigate conflict

Robin Rigg

Slovak Wildlife Society, Liptovský Hrádok, Slovakia

Contact: info@slovakwildlife.org

Background: lynx recovery in Europe

The distribution of the Eurasian lynx (*Lynx lynx*) in Europe has been severely curtailed and fragmented by human actions, including direct persecution to reduce predation on livestock [1]. However, since the 1970s, conservation measures and favourable changes in wild prey populations and habitats have enabled the species to return to parts of its former range [2]. Whether by natural population expansion like in Fenno-Scandinavia, or through reintroductions in Central and Western Europe, this partial recovery has led to renewed concerns about depredation of domestic animals, particularly sheep and, in the Nordic region, semi-domestic reindeer (*Rangifer tarandus*) [3–6]. If such controversies are not adequately addressed, they can lead to retaliatory killing of lynx, socio-political conflict and decline in public support for lynx presence and conservation [7].

Potential impacts on sheep farming are often cited in opposition to lynx reintroduction in, for example, the UK [8,9]. Considerable experience and expertise in managing lynx have been acquired over the last half century in diverse regions of Europe [3–7,10,11]. While local context is an important factor that should be taken into account, lessons learned elsewhere can help guide policies and actions in regions where lynx recovery is proposed or anticipated.

In this article, I examine evidence for the effectiveness of various livestock damage mitigation measures. To do so, I conducted a targeted literature review using web-based search engines (Google and Google Scholar) and snowballing[1] to find relevant information in scientific journals, books, agricultural extension service publications, conference proceedings, theses, reports and other 'grey literature'. Online machine translation tools (DeepL, Google Translate) were used for non-English texts. I checked the digital libraries of the IUCN Large Carnivore Initiative for Europe[2] (LCIE) and Human–Wildlife Conflict

[1] https://www.sciencedirect.com/science/article/pii/S0950584922000659
[2] https://www.lcie.org/Publications

& Coexistence[3] specialist groups, Conservation Evidence[4], ResearchGate[5] and past issues of Carnivore Damage Prevention News[6] (*CDPnews*). I also consulted members of the LCIE, the Eurolynx[7] and People & Wildlife[8] networks and the *CDPnews* editorial team. Potential sources were screened for relevance, reliability and quality. Here, I summarise the findings and recommendations for minimising losses of livestock (especially sheep) and associated conflicts. I begin with an overview of the characteristics of depredation by lynx.

Lynx predation on livestock

Character and extent

The Eurasian lynx is a solitary obligate carnivore that hunts mainly at twilight or night, utilising cover such as vegetation to ambush or stalk potential prey [12]. Its diet varies according to availability but often includes a high proportion of small or medium-sized ungulates, particularly roe deer (*Capreolus capreolus*) [13]. Sheep (mainly lambs) and semi-domestic reindeer are the most frequently predated livestock [14,15]. Damage by lynx seems to vary less among seasons than that by other sympatric predatory species [16,17]. In general, losses are highest when livestock is most available, i.e. abundant and accessible [14].

In Europe, the overall impact on sheep production and the proportion of farmers directly affected are both very small [15,18,19]. Considering only regions with lynx, the proportion of sheep reportedly killed is in the range from zero to 0.03 % for all countries except Norway, where it is 0.70 % (Table 1). The average reported loss per lynx usually varies from zero to one sheep per year, with the extreme outlier again being Norway, where each lynx kills around 16 sheep per year. Within the EU, ~7,000 lynx kill ~0.003 % of ~13 million sheep per year. Fewer domestic animals are predated by lynx than by wolves (*Canis lupus*) or brown bears (*Ursus arctos*). For example, in Slovakia, reported losses of sheep to lynx were about 0.2 % and 1 % of those to wolves and bears, respectively [10]. In Latvia, the lynx is rarely implicated and total economic losses to all large carnivores are negligible [20]. The problem of lynx depredation in the Swiss Alps was described as more emotional than economic [3]. The exception to these general patterns is Norway, where > 90 % of reported livestock losses to lynx are reported to occur.

(Photo: Slovak Wildlife Society)

[3] https://www.hwctf.org/document-library
[4] https://www.conservationevidence.com/
[5] https://www.researchgate.net/
[6] https://cdpnews.net/main-search/
[7] https://euromammals.org/eurolynx/
[8] https://www.wildcru.org/research/people-and-wildlife-initiative/

Table 1. *Average annual reported (compensated) losses of sheep to lynx in 2012–2016 by country, expressed as the number of sheep killed per lynx individual, the total loss and proportion of sheep depredated. Estimates of sheep numbers refer to regions with lynx and are mainly those of adult sheep, not consistently counting lambs. NA = not available (Sources: based on data in Linnell & Cretois [15] and LCIE unpublished data).*

Country	Approximate number present		Sheep depredated by lynx per annum		
	Lynx	Sheep	Per lynx	Total	Proportion
Croatia	40	620,000	0	0	0
Czechia	40	97,000	0.40	16	0.02 %
Estonia	390	100,000	0.08	30	0.03 %
Finland	2,630	149,000	0.01	32	0.02 %
France	95	497,000	1.07	102	0.02 %
Germany	60	NA	0.08	5	NA
Latvia	750	110,000	<0.01	2	<0.01 %
Lithuania	80	160,000	0	0	0
Norway	330	759,000	16	5,296	0.70 %
Poland	350	151,000	NA	NA	NA
Romania	1,300	9,900,000	NA	NA	NA
Slovakia	200	370,000	0.01	1	<0.01 %
Slovenia	15	100,000	0.07	1	<0.01 %
Sweden	1,080	580,000	0.13	145	0.03 %
Switzerland	175	247,000	0.11	19	0.01 %

Variation at different spatial scales

When comparing between countries, there is no obvious correlation between lynx abundance and predation on livestock [21]. Several European countries with hundreds or even thousands of lynx have very few losses (Table 1). Instead, variation is explained by a combination of factors. Overall, sheep kills tend to occur in or near forest habitats rather than open pastures; in areas where protection measures are weak or absent; where densities of sheep are high; and/or where wild prey is scarce [14]. The extraordinarily high losses in Norway are largely due to the practice of leaving sheep to graze freely and unprotected in forest habitats where many are killed not only by lynx but also by several other predators (wolves, bears, wolverines, golden eagles) while more die of other causes or are never found (Box 1). This contrasts with the situation in Switzerland, where lynx depredation peaked at a much lower level then declined despite rising lynx numbers (Box 2).

Within a particular country or region, depredation rates vary temporally and/or spatially in connection with abundance of both predators and prey [22]. In the Swiss Alps, lynx tend to kill more sheep in years when there are more lynx and fewer roe deer [3]. In Norway, the rate of sheep killing by lynx was lowest in areas with high roe deer densities, irrespective of sheep density [23]. In Sweden, where sheep density was also not a significant factor driving depredation, a 1 % increase in lynx density led to a 0.3 % increase in compensation costs [24].

The same or a closely related factor may have diverse effects at different spatial scales. For example, although rates of sheep killing by lynx in Norway are negatively related to roe deer density on a regional level, i.e. fewer sheep are killed in regions with more wild prey [23], on a local level they are positively linked to roe deer habitat suitability, i.e. sheep kills tend to occur in places where lynx are most likely to frequent [25].

Vegetation cover, particularly forest, in the vicinity of grazing areas plays an especially prominent role as it enables lynx to approach undetected. In Switzerland, over 70 % of sheep kills attributed to lynx were found within 100 metres of forest [26]. In the French Jura, 39 % of pastures adjacent or connected to forests had attacks [27]. In Norway, depredation of sheep was linked to the percentage of forest cover in pastures, average lamb slaughter weight (an indicator of summer forage conditions) and spring vegetation characteristics [16]. Various other environmental factors have been reported to influence depredation rates at the local level, such as distance to human settlement, artificial night-time brightness, ruggedness of terrain and proximity to water [6].

(Photo: Slovak Wildlife Society)

Box 1. Norway

Compensation payments for losses of sheep to lynx (and other predators) in Norway far exceed those of any other country in Europe. This results from husbandry practices that leave sheep particularly vulnerable [32]. Total claimed losses to all causes in 2006–2023 were between 28,761 and 66,633 ewes and lambs per year. Of these, 10,422–18,145 were considered “normal loss” (disease, accidents, plant poisoning, etc.) and 14,614–39,833 were compensated as due to predation (Fig. 1). Lynx accounted for 17–31 % of sheep (mainly lambs) for which compensation was paid and 8–17 % of total claimed losses. Only about 4–6 % of sheep losses attributed to lynx were actually verified and documented by examining carcasses. The remainder were set by management agencies based on predator distribution and estimated impact. Research on lynx kill rates [32] contributed to halving the average annual sheep loss attributed to lynx from 8,623 in 2006–2013 (6,239–10,116 per year) to 3,901 (2,838–4,871) subsequently.

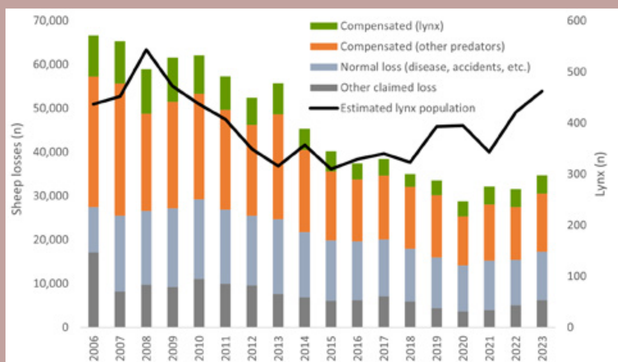

Fig. 1. Total claimed losses of sheep, subdivided by cause/category, and estimated numbers of lynx in Norway in 2006–2023 (Sources: based on data compiled by John Linnell from the Norwegian Environment Agency (www.rovbase.no) and the Norwegian National Predator Monitoring Programme (www.rovdata.no).

Box 2. Switzerland

Predation by lynx on livestock in Switzerland is relatively infrequent and confirmed losses (i.e. examined and verified by game wardens) are financially compensated by authorities. In general, additional measures are only considered necessary if attacks occur repeatedly in the same flock or in the same region (which might indicate the presence of a site effect or a problem individual). Most lynx attacks on livestock target sheep (71 %), goats (22 %) or farmed deer. Cases were sporadic during the first few years following lynx reintroduction in the 1970s [4]. Losses became more frequent a decade later, peaked at a total of 221 animals killed in 2000 following which they declined and stabilised at a level of 20–40 per year until increasing slightly in recent years (Fig. 2).

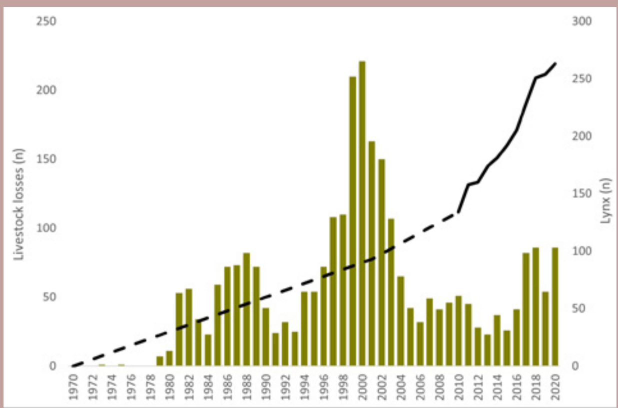

Fig. 2. Verified, compensated losses of livestock to lynx (columns) and estimated numbers of lynx (line) in Switzerland in 1970–2020. For the year 2020, only losses up to 31st October are included (Source: based on data in Breitenmoser et al. [4] and KORA https://www.kora.ch/en/species/lynx/abundance).

Predation 'hot spots' versus problem animals

Experience of depredation sometimes varies considerably among livestock operations within a region. While most are not impacted, a few may suffer high and/or repeated losses [10]. In the Alps and Jura of Switzerland and France, sheep flocks have been repeatedly attacked by lynx in certain localities, typically in scrubby pastures near forests. Such 'hot spots' of livestock depredation persist over several years and/or reappear after the targeted removal of sheep-killing lynx, with other individuals responsible for subsequent attacks. Neighbouring pastures within the hunting territory of the same lynx are largely unaffected, indicating a site effect [3,26,27]. Nevertheless, where sheep are concentrated in a few places that have a lot of vegetation cover, persistent livestock killers occasionally arise [28]. In some cases, such individuals were found to be injured or ill, which was probably a factor in their focus on livestock (Manuela von Arx pers. comm.).

In Norway, where free-ranging sheep are widely dispersed and lynx cause substantial losses, roe deer are nevertheless the preferred prey [29,30]. There is a positive relationship between the suitability for roe deer of a sheep grazing area and the total loss of lambs. This suggests that lynx kill sheep mainly if they encounter them by chance while searching for wild prey, rather than actively searching for them [25]. Moreover, male lynx kill sheep more frequently than females which might be due to differences in habitat use between the sexes, with females showing more selection for roe deer areas and avoidance of pastures than males [25,31]. Therefore, sheep killing behaviour by lynx in Norway is apparently mainly a result of high lynx–sheep encounter rates [25,30–32].

Damage prevention

A review of approaches to protect various human assets from large mammalian predators in 23 countries found that among the most effective were those used to prevent damage to livestock by lynx [33]. A subsequent review focusing specifically on evidence for the effectiveness of individual interventions to protect livestock from felids worldwide found that the Eurasian lynx was among those species for which non-lethal measures were most effective [34]. Details of relevant interventions and evidence for their effectiveness, from these reviews and elsewhere[9], are presented in the following sections and summarised in Table 2.

Barriers

Electric fencing

To protect livestock from lynx, electric fencing is among the most effective measures, achieving damage reduction of up to 100 % [34]. Fifty years of experience

[9] Most of the evidence is from multi-predator systems rather than lynx-only trials and outcomes are likely to be influenced by context including variation in husbandry practices, livestock, landscape and wild prey.

with lynx presence in Switzerland has shown that electric fences are the best tool to prevent depredation [4,35,36]. However, electric fences can be constructed in many different ways, not all of which are equally effective [*Editor's note: see CDPnews issue 5 for guidelines and recommendations on constructing electric fences*]. Simple fencing designed to contain livestock has limited protective value in terms of excluding predators [10] although may be beneficial if it keeps sheep in open areas outside forest, thereby reducing encounter rates. Good-quality anti-predator fencing requires substantial investments of money, time and labour. While adequate maintenance is important to ensure continued functionality, a study in Sweden found that poor initial construction, rather than wear and tear over time, explained most failures [37].

Testing of different fence designs by the Swedish Wildlife Damage Centre[10] found that the best was a 90-cm tall sheep net with two electric wires, one 10–15 cm above the net and the other attached to the outside of the fence, 20 cm above the ground. During trails in captivity, no lynx crossed such fences [38]. Electric fencing with five wires spaced 20–25 cm apart, or six wires 15 cm apart, with the bottom wire 15–20 cm above the ground, was also effective. Of five variants tested, a three-wire electric fence was most often passed by lynx to reach bait. Although the various fences in these trials were only 70–110 cm high, no lynx jumped over any of them. It seems that lynx and other predators are far more likely to step or jump through fencing, or crawl under it, rather than jump over. If fencing is constructed on a slope or where there are nearby objects such as trees or poles that predators could use to climb over, the height of the fence can be increased by adding an extra wire. In Norway, electric fences with wires at 20, 40, 60, 80, 100–105 and 125–130 cm above the ground were approved for protection from lynx [39].

Higher fences have been used in some countries. To protect lambs from Iberian lynx (*L. pardinus*), they were placed inside enclosures constructed using portable electric fences (netting topped with two conductor strips) with a total height of 160 cm [40]. Slightly higher (170 cm) electric nets were recommended in Slovenia, where they proved highly effective against lynx (no damage) as well as bears and wolves [11]. However, 145-cm netting produced equally good results (Tomaž Berce pers. comm.). While lower fences (90–120 cm) seemed to be less effective in Slovenia, the main problem was that farmers left them switched off in pastures outside the grazing season, giving predators the opportunity to learn to cross them. The introduction of regular checks of functionality, in addition to the use of higher netting, improved fence effectiveness to 90–95 %.

Non-electric fencing

Simple non-electric fencing, while not lynx-proof, may have some benefit in keeping livestock away from high-risk areas such as forest and presents a psychological barrier that might act as a deterrent to predators [41]. Even in Norway, no sheep kills by lynx were documented in fenced pastures [32]. Existing wire-mesh stock fencing can be fortified against large carnivores by adding higher fence posts with electric wires to improve both the physical and psychological barrier effect [42]. Mesh fencing improved with electric wires at 20 and 120–125 cm above the ground was approved against lynx in Norway [39].

Although in general lynx seldom jump over fences, they are adept at climbing, so even high conventional fences may not be a physical barrier to determined individuals without additional protection [38]. Electrified wires can be added to deer fences to deter lynx from climbing over. For example, to prevent lynx preying on farmed fallow deer (*Dama dama*) within enclosures in Switzerland, 50-cm steel girders were fitted to the top of fence posts, facing outwards at an angle of 45° above horizontal. Two electrified wires were attached to the girders, following which no further attacks were recorded [4,35,36]. An electrified 'stop wire' can be placed 20–40 cm above the ground on the outside of the fence as well as along the top[11].

Night-time confinement

As lynx are most active during twilight and hours of darkness [12] and are more likely to hunt in open areas such as meadows at night [43], damage prevention measures are particularly pertinent at these times. In Slovakia, sheep flocks confined in a barn or farmyard at night usually had no losses whereas flocks with high/repeated loss-

[10] https://www.slu.se/en/Collaborative-Centres-and-Projects/wildlife-damage-centre/

[11] https://www.protectiondestroupeaux.ch/fileadmin/doc/Herdenschutzmassnahmen/Z%C3%A4une/2138__2b__F_20_WEB_Feuille_jointe_206x293_01.pdf

es to large carnivores were in most cases left in pastures overnight [10]. Fixed or mobile night pens of an appropriate design can protect livestock in pastures [44]. Portable electrified night-time enclosures successfully protected lambs from Iberian lynx [40].

Guardian animals

Dogs

A recent review found that guarding animals were among the most effective ways to protect livestock from Eurasian lynx, achieving a median damage reduction of 93 % [34]. The use of livestock guarding dogs (LGDs), once in decline in many regions where large carnivores had become scarce or absent, has undergone a revival [45]. In the Carpathian Mountains, where large carnivores and LGDs were never lost, damage to livestock by lynx is rare [10]. Finland has no tradition of LGDs, nevertheless 100 % reduction of damage to livestock by lynx and other predators was achieved at farms where they were introduced, mainly in fenced pastures [46]. In the Jura Massif, where both lynx and LGDs were reintroduced following a period of absence, the presence of dogs reduced depredation [47]. Although one dog was not always enough in brushy pastures or close to forest, damage ceased after the introduction of 2–3 LGDs, even in flocks with repeated lynx kills [48].

Like any other measure, LGDs have limitations and are not suitable for all situations [49]. It typically takes 1–2 years to integrate them into a livestock operation. They may not be able to protect widely scattered sheep. Due to the relatively high associated costs and labour, LGDs might not be worth implementing in areas where lynx attacks are rare and there are no other significant predators. On the other hand, they offer several benefits in addition to mitigating losses, such as reassuring flocks and owners with their presence [47].

Donkeys

Experience indicates that donkeys provide protection from lynx in some circumstances. In five pastures in Switzerland where lynx kills occurred, no more sheep were lost after donkeys were introduced [36]. Although rigorous scientific studies are lacking, many users have attested to the effectiveness of their donkeys against canine predators, particularly coyotes (*Canis latrans*), foxes (*Vulpes vulpes*) and domestic or feral dogs, as well as a variety of felids including bobcats (*Lynx rufus*), caracals (*Caracal caracal*), jaguars (*Panthera onca*), leopards (*P. pardus*), cheetahs (*Acinonyx jubatus*) and even lions (*P. leo*) [50].

Donkeys are generally cheaper and easier to deploy than LGDs and avoid some disadvantages of the latter, but

(Photo: Slovak Wildlife Society)

not all individuals make effective guardians. It is recommended to use single donkeys (although welfare legislation does not permit this in some countries), or jennies with foals, to protect small flocks in pastures that are not very steep [51].

Llamas

Similarly to donkeys, there has been little scientific investigation of the effectiveness of llamas as livestock guardians, but practical experience suggests they can sometimes be a viable alternative to more costly protection measures. During a pilot project in Switzerland in 2012–2022, no damage by lynx was recorded at sheep flocks protected by llamas under recommended conditions even though most of them were in areas with lynx and several had experienced damage before llamas were acquired. Most participating farmers reported positive experiences with their guard llamas, found them easy to integrate and appreciated their novelty value [52,53]. However, llamas may themselves be vulnerable to some predators, particularly wolves [52].

Shepherding and other human presence

A global review found that shepherding was the third most effective intervention for Eurasian lynx after fencing and guarding animals, with reported damage reduction of 65 % [34]. In Switzerland, experience over the last quarter century has shown that shepherding is a key factor (Daniel Mettler pers. comm.), preventing losses even at flocks repeatedly targeted by lynx [36]. In Slovakia, wolves and bears sometimes attacked flocks in the presence of shepherds but lynx never did so, perhaps due to their greater shyness [10]. Furthermore, the presence of shepherds facilitates implementation of other protection measures such as LGDs and night pens [44,48], the combination of which is highly effective.

Employing shepherds is a relatively expensive measure likely necessitating financial support for livestock owners to reintroduce them where they are no longer common, but there are precedents such as in the Alps [54]. Alternatively, trained volunteers can help with some tasks [*Editor's note: CDPnews issue 29 focuses on such initiatives*].

Husbandry

Depredation can be minimised by keeping livestock away from preferred lynx habitats. In Switzerland, no sheep kills were observed more than 850 metres from the forest edge. At higher elevations, no kills occurred further than 50 metres from forest [26]. In the French Jura, only 5 % of pastures > 250 m from a forest had attacks by lynx on sheep [27]. Grazing sheep in open areas such as fenced pastures and avoiding forest edges results in substantially lower lynx depredation rates [27,55]. An informative comparison can be made between Norway, with high losses to free-ranging sheep in forest, neighbouring Sweden, where sheep are kept in fenced pastures and losses are substantially lower, and Slovakia, where there is a prohibition on grazing livestock in forests and damage by lynx is negligible [10,15].

Keeping livestock clumped together, rather than widely scattered, reduces predator encounter rates and facilitates use of protection measures such as guardian animals [41]. Confining flocks in barns during winter and lambing indoors or in other well-secured areas (both of which are ubiquitous practices in Slovakia) are also likely to be beneficial in reducing depredation [10]. As small stock is most vulnerable to predators, losses could also be avoided by switching from sheep to cattle where this is appropriate, feasible and socially acceptable [14,15].

Protective collars

Initial trials of collars designed to offer protection from bites to the throat, which are typical for lynx [56], seemed to reduce depredation on free-ranging lambs [41]. However, it was later reported from Switzerland that many sheep wearing protective collars were killed by lynx biting behind or in front of them [36]. Light-weight metal or plastic (HDPE) collars were found to be effective and efficient against felids including caracals and leopards as well as black-backed jackals (*Canis mesomelas*) in South Africa [57,58]. Recently, metal-studded leather collars decreased losses of cattle to leopards in Iran by 100 % and might protect livestock from other felids [59].

Deterrent devices

Flashing lights have been used as a temporary measure to scare off lynx after attacks but, because regular use would likely lead to habituation, they are not recommended as a general preventive measure [4,36]. Foxlights and similar devices are often used in Switzerland[12], where they deter lynx for up to four weeks or more (Daniel Mettler pers. comm.). There are commercially available collars for sheep, goats, cattle and horses designed to deter predators by activating LEDs and ultrasound. To avoid predators habituating to them, they emit lights and sounds in random combinations when the collar wearer runs. The manufacturers claim such devices have been effective in South Africa against jackals, leopards and lynx (sic; presumably referring to caracals) and in Europe against wolves[13]. Swiss researchers plan to test them systematically in summer 2024, mainly against wolves (Daniel Mettler pers. comm.).

Aversion / hazing

It has been reported from Switzerland that lynx avoid places where they were live-captured and released. This might help deter persistent livestock killers, although high costs make the approach unsuitable for widespread application [36]. The use of 'less-lethal' ammunition[14] such as rubber bullets can also be useful to increase the shyness of bold or habituated individuals by negative conditioning but not as a general preventive method.

Predator removal

Historically, declines in carnivore populations were partly driven by eradication programmes aimed at curbing predation on livestock. These efforts undoubtedly succeeded: the lynx was exterminated from much of Europe and, without lynx, there is no lynx-caused damage [2]. Today, such drastic, indiscriminate approaches are rejected by society as reflected in domestic and international law [60]. However, lethal wildlife management takes many forms and still tends to be favoured by farmers and hunters [5,20,61]. The question therefore arises: can predator control reduce livestock depredation without jeopardising other goals such as achieving and maintaining favourable conservation status?

Culling aimed at reducing predator population size is controversial [5]. Whereas it might be the only viable option to lower lynx kill rates on semi-domestic reindeer where alternative prey is scarce and changes in husbandry impractical [62–64], evidence for its effectiveness in limiting depredation on sheep is questionable [34]. Practicalities and other factors may result in public hunts being misdirected. In Norway, recreational hunters tended to kill lynx near roads, where depredation rates on livestock were low, rather than in remote areas, where losses were higher [65]. Nevertheless, there was evidence that fewer lambs were lost when hunting reduced lynx population size on a county scale [66]. Interestingly, the level of livestock depredation by lynx in Slovakia is extremely low despite a ban on lynx hunting since 1999, probably due to the widespread use of non-lethal prevention measures and abundant wild prey [10].

Advocates of lethal control claim that it maintains wariness among hunted populations, helping to reduce the likelihood of attacks on livestock. Theoretically, this might happen through 'hunting for fear' and/or social transmission of risk from parents to offspring. In light of the long history of predator persecution, there seems to be surprisingly little evidence either to support or refute these hypotheses for lynx or other species [67]. Local lynx population density could also be reduced by translocations [3]. However, translocating problem animals such as persistent livestock killers risks moving the problem elsewhere so is not recommended.

Targeted removal of 'problem individuals', defined as being responsible for a disproportionate amount of damage, is often posited as a more acceptable alternative to culling [60]. The paradigm is predicated on the suppositions that: i) such animals exist; ii) they can be reliably identified; iii) are successfully targeted; and iv) are not soon replaced by other individuals with similar behaviour [31]. A study using survival analysis to estimate the effect of lethal control on repeated attacks by lynx on sheep in Sweden found that hunting of lynx decreased the probability of a repeat attack within one year by 60 %, although the long-term effectiveness was unknown [6]. In Norway,

[12] https://www.protectiondestroupeaux.ch/fileadmin/doc/Herdenschutzmassnahmen/Vergr%C3%A4mungsmassnahmen/3090___1___D_22_WEB_Info_Flatterband-Blinklampe.pdf
[13] https://collier-anti-loup.com/
[14] https://www.integrityballistics.com/predator-non-lethal-round/

a significant local effect of lynx removal by recreational hunting was found although it was deemed too small to have much practical benefit [66]. In nearly half the cases in Switzerland when lynx removal was authorised, the individuals could not be shot before the permits expired [4]. However, when habitual 'sheep specialists' were removed from the Alps or Jura Mountains of Switzerland and France, in most cases this led to improvement except in hot spots, where livestock in the same pastures was subsequently attacked by other lynx, indicating a site effect [3,27,68].

Table 2. *Summary of available evidence for the effectiveness of various measures to prevent or reduce damage to livestock by Eurasian lynx.*

Measures	Observed effectiveness in trials and/or usage	References
Barriers		
– *Electric fencing*	Very effective when appropriately designed, correctly installed and adequately maintained.	4, 11, 34–39
– *Non-electric fencing*	May help if keeps livestock away from high-risk areas and presents a partial (psychological) barrier.	35, 36, 38, 40–42
– *Night confinement*	Can eliminate or minimise losses.	9, 44
Guardian animals		
– *Dogs*	Very effective at protecting flocks in defined areas.	9, 34, 45–49
– *Donkeys*	Seem to provide protection under some conditions.	36, 50, 51
– *Llamas*	Anecdotal evidence of effectiveness.	52, 53
Shepherding and other human presence	Continuous human presence helps deter predators and facilitates use of other measures such as LGDs, night-time penning and avoiding high-risk areas.	34, 36, 44, 48, 54
Husbandry	Adaptations such as keeping livestock away from forest cover and lambing indoors are beneficial.	16, 25–27, 30, 41, 55
Protective collars	Lack of consensus on efficacy.	36, 41, 57–59
Deterrent devices	May provide a short-term benefit, e.g. as a temporary measure in response to an attack. Long-term effect typically limited by habituation.	4, 36
Aversion / hazing	Useful against problematic individuals.	36
Predator removal	Can provide relief if persistent livestock killers are targeted, but not in damage 'hot spots.' In some circumstances, population-level management by hunting may limit damage but is controversial.	3–6, 20, 26, 27, 34, 36, 55, 60, 61, 65–68

Conflict mitigation

Impacts versus conflicts

Although the two are often conflated, damage prevention and conflict mitigation are not synonymous. The interventions described above are intended to reduce the impacts of wildlife (predators) on human assets (livestock), generally referred to as human–wildlife conflicts (HWC). They do not necessarily resolve disputes between people holding different attitudes and interests, such as advocates of hunting versus protectionists, which are human–human conflicts (HHC) [69]. The latter range from relatively superficial disagreements to deeply entrenched grievances. Attempting to implement technical fixes to surface-level HWC where the major problem is in fact underlying HHC is unlikely to produce satisfactory outcomes and may even be counter-productive [70].

Attitudes to wildlife are influenced not only by measurable levels of damage but also by a complex array of other factors [71]. To properly understand and address HHC therefore requires social sciences rather than biology or engineering and, above all, necessitates working with people.

Engaging with people

Whereas coercive policies may erode perceived legitimacy and potentially lead to non-compliance issues such as poaching, participatory processes aim to build trust and empathy, psychological ownership, collaborative learning and better social outcomes [72]. There are many different formats for engaging with stakeholders in constructive dialogue, decision-making and collaboration; the choice of which to use should suit the situation at hand [73].

If HHC is already entrenched, professionally mediated reconciliation and transformation approaches might be needed before progress can be made towards compromise, consensus and cooperation. The EU large carnivore platforms provide examples[15]. Conversely, reintroductions represent opportunities to start on the right foot, proactively involving local people and key interest groups from the outset. Indeed, failure to do so risks alienating stakeholders, hindering or even preventing such actions from proceeding [74]. Key measures such as damage prevention, financial support and predator control must be agreed prior to releasing lynx (Urs Breitenmoser pers. comm.). Discussions should aim for co-ownership, co-design, co-production of knowledge and shared responsibilities. For interventions including damage prevention tools and techniques to be widely adopted, they must be regarded as not only effective but also socially acceptable, feasible and cost-effective [61,75]. If, instead, measures are imposed that affected people consider irrelevant, impractical or unacceptable, there is a risk of aggravating their grievances, thus worsening HHC rather than alleviating it [61,76].

Providing support

When society makes a collective decision to restore or protect species that have disproportionate impacts on a minority of citizens, it is appropriate to adopt financial mechanisms that aim to share the burden more equitably. This is often done through *ex post facto* compensation schemes, but these tend to have several drawbacks: bureaucracy and inefficiency [19], difficulties in verifying losses [32,77] and the inherent tendency of such schemes to highlight and even perpetuate negative aspects of wildlife [19,78]. A more positive approach to build tolerance could be through conservation performance payments [79]. Other options, which should be tailored to the local situation, include insurance programmes and *ex ante* systems to incentivise adaptation of husbandry and/or pay for risk [80].

One way to support the coexistence of predators and livestock farming is to subsidise or otherwise help cover the costs of implementing non-lethal damage prevention measures [*Editor's note: see Marsden (2022) in CDPnews issue 24 for details of applicable EU funding streams*]. To encourage uptake, some countries make their use a prerequisite for paying compensation. This might not be justifiable or cost-effective where attacks are rare and most flocks are unaffected [28]. In persistent depredation hot spots, however, permanent implementation of protection measures should be promoted.

Sharing knowledge

Besides financial support, farmers often require information about possible strategies to adapt to lynx pres-

[15] https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive/large-carnivores/eu-large-carnivore-platform/eu-regional-large-carnivore-platforms_en

ence and practical help to implement them. Agricultural extension services and publications such as *CDPnews* exist to help spread scientific knowledge to practitioners. It should be borne in mind that there are different forms of knowledge as well as diverse sources of information and ways of learning [81]. Farmers are more likely to adopt innovations when they are mentored and trained by their peers[16,17] [*Editor's note: see pages 4 to 13 in this issue of CDPnews*]. Communication should be honest where there are gaps in available evidence, for example the lack of rigorous testing of some interventions mentioned above. There is also a need to manage expectations. Protection measures rarely work perfectly in every situation and every time but, when well-designed, they can reduce losses substantially.

Traditional media (newspapers, television, radio, etc.) and new media (social networking tools, blogs, wikis, etc.) both disseminate factual content and informed opinion but also misinformation and 'fake news'. They are prone to sensationalise, over-emphasise negative aspects and amplify fears [82]. Rather than being a simple conduit for reliable information, the media can be viewed as a stakeholder with a strong influence on other groups and the wider public [7,83]. To achieve a balanced and accurate representation of human–carnivore coexistence and its challenges calls for experts to engage with social media and for collaboration between scientists, journalists and policy makers [82].

Hunting for tolerance

To reduce their impact on livestock is not the only reason that carnivores are hunted. In many rural communities hunting is part of the culture, providing intangible benefits such as enjoyment and social prestige, sometimes also income [58,84]. Moreover, when based on a need to limit depredation, it allows stakeholders to engage actively and directly in tackling problematic situations. It is argued that this contributes to normalising the status of predatory species, increasing local people's tolerance of their presence [5,85]. Depending on the broader socio-cultural context, outlawing such activities, if perceived as an unfair imposition, could lead to heightened HHC and potentially non-compliance. On the other hand, although hunting might help raise acceptance of lynx by some stakeholders, it may itself be rejected by others, thereby increasing HHC [5]. Finding an acceptable balance between diverse interests is integral to wildlife conservation and management as well as to addressing HHC but is neither a simple task nor one likely to have a single, permanent solution [15,69].

Synthesis and recommendations

Concerns about damage to livestock are a major part of discourse on large carnivores and so it is logical to seek solutions in preventive measures [15,41,64]. However, there is an important distinction to be made between impacts of wildlife, such as depredation, and socio-political conflicts between people [69,71]. They may be related but are not the same thing. Understanding the nature and drivers of a particular conflict is key to selecting suitable interventions to address it [70], i.e. choosing the right tools for the job.

Notwithstanding the above, the only European country in which lynx kill substantial numbers of sheep is Norway, where the problem is primarily due to a husbandry system that routinely places unattended, unprotected ewes with their attendant lambs in high-risk areas. Evidence from elsewhere demonstrates that the proper use of fencing, particularly electric fences, and/or guarding dogs, shepherding and night-time confinement keeps losses low. Experience where multiple predators are present, in places like the Carpathians, has shown that methods to protect livestock from wolves and bears work equally well or even better against lynx [10]. The choice of which measure(s) to use in any given situation depends on the local context. In addition to their proven or expected efficacy, social acceptability and cost effectiveness should also be considered [61,75,76].

When considering management options, cost–benefit analyses are apposite. As lynx return or are reintroduced to areas lacking experience of coexistence and protection measures, it might not be reasonable or acceptable to expect all livestock producers to proactively implement costly interventions, especially where the risk of lynx depredation is low. Instead, emphasis could be placed on relatively simple husbandry adaptations, such as keeping livestock behind fences and away from forest, where pos-

[16] https://www.eitfood.eu/projects/focus-on-farmers
[17] https://www.trustinfood.com/2021/02/22/building-farmer-peer-learning-networks/

(Photo: Slovak Wildlife Society)

sible. This runs counter to the doctrine of applying prevention measures across a region in order to avoid displacing depredation to neighbouring farms, but ample evidence indicates that lynx rarely target livestock, especially in areas with abundant wild prey.

Livestock farmers are more likely to adopt preventive methods reactively after they have been personally affected by depredation [20]. Furthermore, the predictability of repeat attacks favours reactive use of mitigation measures [86]. Therefore, more expensive, labour-intensive approaches can be focused on high-risk pastures (e.g. those in proximity to forest, far from human settlements and in rugged terrain) and/or depredation hot spots [4]. Various financial mechanisms have been developed to help share costs and encourage uptake [19,80].

To be effective, measures must be well designed, correctly installed and adequately maintained. Regular field checks to ensure functionality can help reduce damage considerably [11,37]. The effectiveness of measures should be assessed systematically. The body of evidence and experience is growing, but more robust testing is still needed for some measures, notably guard donkeys and llamas, protective collars and deterrent devices. In consideration of cost and labour, fences may need to be built according to the actual propensity, rather than theoretical ability, of predators to get past them, accepting that on rare occasions a lynx may jump or climb over[18].

Evidence for the effect of lethal control on damage is equivocal [34,58,65–68]. If a particular lynx is causing a disproportionate level of loss, its removal could alleviate the situation. However, where a depredation hot spot results from a site effect, removing individuals is unlikely to solve the problem, which can probably only be ameliorated through protection measures or relocating livestock [3]. In the absence of either problem individuals or damage hot spots, predator control by hunting or other means may only succeed in limiting depredation if it reduces overall lynx population density across a wide area, which is a controversial strategy rejected by some sectors of society [5].

Coexistence with large carnivores such as lynx is a long-term endeavour, calling for pragmatic approaches that respect the interests and concerns of impacted communities [3]. It may not always be possible to eliminate controversy entirely but, where there is willingness to compromise and collaborate, it can be limited through participatory processes and adaptive management [20,72,73].

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