NATIONAL CONSULTATION BRIEFING PACK

LYNX TO SCOTLAND

The Lynx to Scotland project is a partnership between Trees for Life, SCOTLAND: The Big Picture and The Lifescape Project. The project is seeking to explore the feasibility of reintroducing the Eurasian lynx (*Lynx lynx*) to Scotland, including all the ecological, social and practical considerations. This pack has been designed to support the national stakeholder consultation that forms a key part of this process and provides basic information on lynx ecology, the reasons for the consultation and details of the planned workshops.

Lynx ecology

The Eurasian lynx is one of four species of lynxes found around the world, with the others being the Iberian lynx (found in Spain and Portugal), the Canada lynx (native to Canada and the Northern United States) and the bobcat (ranging from Northern Mexico to southern Canada). The Eurasian lynx is the species that once lived in Scotland and is still found across much of Europe and Asia, being henceforth referred to here as the lynx.

The lynx is a woodland animal, requiring some availability of forest cover throughout its range. Males are slightly larger than females, with adult lynx weighing in the range of 18-25 kg (i.e. a bit smaller than your average Labrador). Both sexes defend territories against same-sex competitors, but a male's territory is larger and typically overlaps those of several females.

Being apex predators, lynx occur at much lower densities than mid-ranking predators like foxes or badgers. Where abundant potential prey and sufficient suitable habitat is available, lynx densities can exceptionally exceed 3 per 100 km^2, but where prey is scarce a single lynx territory can extend over more than 2,000 km^2.

Lynx are generally shy animals, avoiding human activity. They do not attack people but may kill livestock under certain circumstances, especially where sheep are allowed to wander woodlands unsupervised. However, their preferred prey are wild ungulates – primarily roe deer – and where these are abundant, sheep attacks are rare.

Lynx are solitary ambush predators, with a single deer carcass enough to sustain an adult lynx for 3-5 days. Each lynx is thus potentially responsible for killing 50-70 deer in a year, and although roe deer are their preferred prey, red deer, sika deer and fallow deer are all potential prey in Scotland, especially where roe deer are unavailable.

A maximum of 15% of the lynx's diet is made up of carrion. Smaller species – including hares, woodland grouse, wild boar, badgers and wildcats – have also been recorded as occasional items in the lynx's diet. However, aside from ungulates, foxes tend to be killed with the most regularity.

Lynx reach sexual maturity between the ages of 2 and 3, and rarely live longer than 10-12 years in the wild. Females produce litters of 1-5 kittens (average 2), with juveniles independent after ten months. Juvenile mortality can be 50% during the first year and 50% in the second year, but adults have few natural predators, with the most common causes of adult mortality in Europe today being human-related (e.g. vehicle collisions or targeted killings).

Lynx are still legally hunted in Norway and can be shot by rangers in Switzerland if they are identified as a persistent threat to livestock.

The comeback cat

Being a cryptic animal, it's not known exactly when the last Scottish lynx died – only that its presence across Britain declined to eventual extinction at some point during the last 1500 years. At least one naturalist describes what might have been a lynx population surviving in Dumfries and Galloway as late as 1760, but the record is unclear. The lynx's eventual disappearance was likely caused by a combination of deforestation, loss of prey (following overexploitation by people) and direct persecution.

The lynx had also disappeared from much of Europe by the middle of the 20th century. However, since the 1970s, a series of lynx reintroductions have taken place across Europe, including in Germany, Switzerland, Slovenia, Italy, Austria, the Czech Republic, France and Poland, while endangered populations, such as the one in Croatia, have been reinforced with additional releases.

Lynx have been successfully reintroduced in a variety of countries around Europe.

Not all these reintroductions have been a success. Early attempts in Germany and Austria failed after hunters killed the reintroduced lynx, while other attempts were hampered by inbreeding. However, with improved knowledge and increasing public support, the success rate has improved, and lynx have now been successfully reintroduced in the Swiss Jura, the French Vosges, Slovenia and Croatia's Dinaric Alps and the Czech Republic's Bohemian Forest, as well as in Poland and Germany's Palatinate Forest.

By contrast, Scotland still lacks any of its native apex predators. No other country supports such abundant numbers of natural prey (up to one million deer) alongside so few people (the Scottish Highlands has some of the lowest human population densities in Europe) while continuing to exclude apex predators – a situation at odds with our country's stated commitment to biodiversity restoration.

Why reintroduce lynx?

Reintroducing a charismatic apex predator like the lynx offers Scotland a variety of ecological and socioeconomic benefits. The lynx's predatory influence would revitalise many missing or subdued natural processes and boost biodiversity. Notably, lynx predation could complement deer control efforts, which would help facilitate woodland regeneration, while lynx kills would return a regular supply of large carcasses to the woodland environment, supporting a wealth of other life.

The concentrated activity of scavengers around carcasses can generate gaps in understorey vegetation, encouraging sapling emergence. Additionally, large carcasses could serve to increase the proportion of carrion in the diet of smaller predators, reducing predation pressure on ground nesting species, while the lynx's suppression of smaller predators like foxes could help regulate the wider food web, easing pressure on threatened species and even leading to population increases for species like capercaillie, black grouse and mountain hares – as has been documented in Scandinavia.

Lynx are also likely to attract visitor numbers at least equal to those drawn to see white-tailed eagles, which on Mull alone add a minimum of £4.9 million per year to the economy, supporting between 98 and 160 full-time equivalent jobs. Lynx might be harder to see than eagles, but the mere presence of wild lynx in Germany's Harz Mountains has been estimated to generate £7-11

million each year. Additional revenue could also be generated from spin-off products, like lynx-friendly wool or lamb.

Lynx-mediated reductions in deer numbers could further help lower the costs associated with deer damage. Such damage costs Forestry and Land Scotland alone an estimated £3 million every year, while costs linked to habitat damage (e.g. peatlands), loss of agricultural crops, vehicle collisions and Lyme disease add up to further tens of millions.

Finally, reintroducing lynx would clearly signal our collective willingness to reverse Scotland's long history of environmental degradation, providing a totemic symbol of ecosystem recovery around which we can rally hopes for a greener future and helping Scotland to meet its goal of having "restored and regenerated" our impoverished biodiversity by 2045.

Lynx may be hard to see, but even so, their mere presence can create a popular tourist attraction.

Could Scotland support lynx?

Modelling suggests that Scotland has enough suitable habitat and sufficient prey to support 250-400 lynx. However, reintroductions – especially of large carnivores – also require assessments of social acceptance to establish their overall socio-ecological feasibility. Accordingly, in 2019, Lynx to Scotland commissioned the Vincent Wildlife Trust (VWT) to carry out a study to examine the social feasibility of reintroducing lynx in Scotland.

116 interviews with stakeholders were carried out over the duration of the study, while in addition, online webinar sessions were conducted with eight stakeholder organisations and facilitated community consultation events were undertaken with a further five community groups — three in the Cairngorms National Park and two in Argyll. The results were subsequently published in a peer-reviewed journal.

Several themes emerged from this work, including the availability of suitable habitat, the relationships between lynx, gamebirds, deer and other native biodiversity, potential impacts on livestock and the rural economy, as well as issues of trust surrounding the way reintroductions have been managed in Scotland to date.

Not all perceptions were negative, with many enthused by the benefits they anticipated a lynx reintroduction might offer, but equally, many of those consulted had genuine concerns. Nonetheless, there was widespread appetite amongst all stakeholders to continue to identify and address knowledge gaps, and to develop a more comprehensive understanding of the potential for lynx reintroduction in Scotland. Most encouragingly, an empathetic understanding was reported to have emerged between event attendees, despite some fundamentally adversarial positions.

National consultation process: overview and objectives

Following publication of the VWT study in 2022, the Lynx to Scotland project has carried out further research exploring the key themes identified within VWT's report, assembling an extensive body of information on each. The project is now beginning a national consultation process intended to share this assembled information, to further explore stakeholder attitudes towards a trial reintroduction, and to examine if and how it might be possible to mitigate key concerns, drawing on experience from lynx management elsewhere in Europe.

The workshop process will investigate each of the concerns in turn and consider the recommended mitigation measures that would be required if a trial reintroduction was to take place. The process begins with an in-person meeting, followed by a series of online meetings which are designed to result in the development of recommendations regarding each topic under discussion (**Table 1.**).

The consultation will culminate with a second in-person meeting in the Autumn, where the final recommendations developed by stakeholders will be summarised. These recommendations, along with a report on the process itself, will be circulated for comments to all workshop participants, before being made publicly available. Lynx to Scotland will then use the report to help assess the degree of consensus that exists at a national level in support of a trial reintroduction of lynx.

The Lynx to Scotland project is seeking to establish both the ecological and the social feasibility of a lynx reintroduction in Scotland.

Table 1. Meeting dates

EVENT	DATE	LOCATION
Introduction to the process and recommendation statement development (see also Table 2)	9th May	Joan Knight Studio, Perth Theatre
Online workshop 1: Habitat and prey: Could Scotland sustain a population of lynx?	16th May	Online
Online workshop 2: Lynx impacts on deer and implications for Scotland (Part 1)	3rd June	Online
Online workshop 3: Lynx impacts on deer and implications for Scotland (Part 2)	13th June	Online
Online workshop 4: To what extent are lynx likely to impact game bird populations?	20th June	Online
Online workshop 5: Lynx impacts on other species of concern (Part 1)	27th June	Online
Online workshop 6: Lynx impacts on other species of concern (Part 2)	4th July	Online
Online workshop 7: Impacts on livestock and potential responses (Part 1)	18th July	Online
Online workshop 8: Impacts on livestock and potential responses (Part 2)	24th July	Online
Online workshop 9: Impacts on livestock and potential responses (Part 3)	1st August	Online
Online workshop 10: Opportunities and criteria for a trial lynx reintroduction	15th August	Online
Review, final words and next steps	29th August	Norie-Miller Studio, Perth Concert Hall

Workshop process facilitators

The workshop process is being facilitated by the Conservation Planning Specialist Group (CPSG) of the International Union for Conservation of Nature (IUCN). CPSG has been working to support governments, non-governmental and civil society organisations in making collaborative decisions concerning the conservation of threatened species for more than 40 years. The organisation centres its work on good collaborative process design, neutral facilitation and consensus-building. CPSG bases its process design on some core Planning Principles and Steps. Jamie Copsey, who will be the lead facilitator for this process, has supported other planning efforts in Scotland, most recently with the facilitation of the process to design a National Beaver Strategy.

Workshop participants

You have been selected to be included within this participatory process due to the perspective and knowledge that you will bring to discussions. Collectively, you represent a diversity of views that reflect the differences that exist at a national level over the question of lynx reintroduction to Scotland. Ideally, you will be able to attend all meetings as your input would be desired throughout. If for some reason you are unable to attend one or more of the meetings, then please do let the organisers know and work with us to decide if there is someone else you could identify who could reflect a similar perspective to your own. We would ask that you inform this person of the stage that the process is at before they attend as this will ensure that we do not retrace our steps unnecessarily during the process.

Aims and agenda in-person meeting (9th May)

The 9th of May represents the first opportunity for all stakeholders to meet, in-person, and to build a shared understanding of how we will work through the process together (Table 2.). The meeting will provide an opportunity for information exchange and the identification of stakeholder needs. Importantly, the meeting will also enable us to reach agreement on the level of consensus that will be acceptable to all when developing recommendations emerging from the process.

BRIEFING NOTES

LYNX TO SCOTLAND

QUERY: is there enough suitable HABITAT in Scotland to support a lynx reintroduction?

Summary

In central Europe, lynx habitat selection is primarily thought to be driven by avoidance of human activity during the day and prey availability during the night, with connectivity between habitat patches important for sustaining viable populations. However, lynx are highly adaptable and perfectly capable of existing in human-dominated, multi-use landscapes, as indeed they do across their European range – often alongside higher human densities than occur across most of Scotland. Repeated analyses have demonstrated that Scotland contains sufficient habitat to meet the ecological requirements of a reintroduced lynx population, with an existing woodland network that is both adequately stocked with suitable wild prey and is also sufficiently extensive to sustain a healthy population of lynx in Scotland. Furthermore, the extent and connectivity of suitable habitat is only likely to increase as reforestation efforts continue.

The fuller picture

The Eurasian lynx (*Lynx lynx*) – henceforth referred to simply as the lynx – is predominantly a woodland species[1], requiring habitat that includes a significant proportion of woodland and provides access to suitable prey, such as roe deer.[2] In line with this, lynx habitat selection in central Europe has been observed to be driven by avoidance of human activity during the day and prey availability during the night.[3]

Woodlands are thus important because they offer cover for lynx to stalk their prey, but also because they represent critical refuge habitats, allowing lynx to avoid, or at least minimise, human encounters. However, woodlands are not the only landscape feature that can offer such refuges, with sparsely populated, mountainous landscapes also offering scope for human avoidance.[4]

Lynx may rely on woodlands more heavily in human-dominated landscapes, increasing their use of refuge habitats during periods of higher exposure to human activity or increased vulnerability (e.g. during the postnatal denning period).[4] However, while woodlands are important, it is the *interaction* between human pressures (e.g. disturbance or anthropogenic mortality) and refuge habitat availability that ultimately determines whether lynx can persist in human-dominated landscapes. As such, an exclusive focus on woodland availability threatens to overlook the equal or greater importance of critical human pressures.[4]

In a striking demonstration of their adaptability, a female lynx (equipped with a tracking collar, fixes shown in pink) established a territory and had kittens near Switzerland's Bern airport. This is a human-dominated landscape but one which nonetheless contains enough woodland to provide secure daytime refuges. Image from KORA.ch

Human influences on habitat availability

In 2019, a study by the Vincent Wildlife Trust found that some Scottish stakeholders believe Scotland is not yet ready for a lynx reintroduction, either because of a perceived lack of habitat (or habitat of sufficient quality), or because there is thought to be either too much potential disturbance or insufficient connectivity between suitable habitat patches.[5] Others expressed concerns that the Highland areas being considered for lynx reintroduction have too few roe deer, and that the most optimal lynx habitats, in terms of woodland and deer densities, may be in the middle ground and lowlands, where there are also higher densities of sheep, creating more potential for conflict.[5]

However, much of the Scottish Highlands currently sustains human population densities of just 8-12 people per square kilometre, whereas lynx commonly persist in European landscapes supporting 22-74 people per square kilometre.[6] And while lynx are sensitive to human disturbance, they readily adjust their ranging behaviour to avoid humans, making lynx more resilient to such pressures than species like capercaillie.

Does Scotland have enough woodland?

Contrary to claims that Scotland lacks enough woodland to support lynx, repeated analyses have assessed Scotland to contain sufficient suitable habitat to sustain a viable lynx population. Early work identified ±15,000 km^2 of potential lynx habitat in Highland Scotland and ±6,000 km^2 in Scotland's Southern Uplands,[7] with the two habitat networks separated by Scotland's highly developed (and thus effectively impenetrable) Central Belt.

Applying hypothetical lynx densities of 2.63 lynx per 100 km^2 across the Highlands and 0.83 lynx per 100 km^2 in the Southern Uplands (as predicted by available prey biomass[8]) suggested that the Highlands habitat network could support up to 400 lynx while the Southern Uplands habitat network could support around 50 cats.[7]

More recently, modelling techniques have been developed to better account for lynx ecology, demography and the influence of random events on dispersal behaviour when assessing the likely viability of a reintroduction to Scotland,[1] with this more advanced modelling again strongly supporting the likely viability of a lynx reintroduction to Scotland within the current network of available woodland habitat.[1]

This conclusion was reached despite factoring in the fact that lynx are generally considered to be relatively poor dispersers, with large roads representing potential barriers to their movement.[9] However, Scotland is relatively thinly covered by roads outside of the Central Belt, comparing favourably with some other parts of Europe where lynx occur.

In purely ecological terms, Scotland already contains enough woodland habitat to support lynx.

The Lifescape Project has also examined whether Scotland could sustain a viable lynx population, with their modelling suggesting that Northern Scotland might support 200-250 lynx, while Southern Scotland could support around 50 lynx.[10] All these models are subject to assumptions, but the key one is that Scottish woodlands support sufficient densities of potential prey.

Prey availability

Roe deer are likely to be the lynx's preferred prey in Scotland, as they are across most of Europe,[11,12] where they form up to 91% of their diet.[13] However, lynx may be more likely to tackle red deer in the absence of competition from other large carnivores, or where red deer are much

more common than roe deer.[11] Indeed, red deer can form up to 72% of a lynx's diet in some parts of Europe and the smaller size of red deer in Britain may encourage lynx to target red deer more regularly, when and where they share the lynx's preferred woodland habitats.[11]

Red deer densities have been estimated to range from 0.3-35 per km^2 in conifer plantations in central and northern Scotland, while roe deer densities ranged from 0.5-25 per km^2 in the same habitats.[14] More widely, average roe deer densities have been estimated to be 7.4 per km^2 across the Scottish Highlands and 5.5 per km^2 in the Southern Uplands.[7] However, such large-scale population estimates can mask considerable local variation. For example, in Glen Affric, roe deer density estimates ranged from 1.4 to just 2.0 per km^2, while in Glen Tanar, estimates ranged from 4.7 up to 21 per km^2.[15] Thus, not every woodland can be assumed to support the same densities of deer or, potentially, of lynx.

The Eurasian lynx specialises in hunting roe deer - a medium-sized ungulate abundant in Scotland.

Despite such local variability, at a landscape scale, there is no shortage of deer in Scotland. NatureScot estimate there may be around 300,000 roe deer in Scotland, with between 40,000 and 100,000 roe deer shot each year.[16] More precise data remain unavailable, but reported cull figures have been steadily increasing and the total population appears to be growing. This suggests the population could easily absorb an annual offtake of 15,000 to 21,000 animals (assuming a population of 300 lynx and that each lynx kills 50-70 deer per year). The roe deer predated by lynx could supplement human efforts to control the deer population, working synergistically to benefit woodland regeneration, or they could partly replace human hunting, reducing the cost of deer management.

Scotland also supports abundant red deer (±400,000), sika deer (±25,000) and fallow deer (±8,000) populations, all of which could be suitable prey for lynx. Deer densities vary around Scotland, as does the relative abundance of the different species, but lynx are efficient predators of roe deer even at low densities.[17] Shortage of prey is thus unlikely to ever be a problem, especially as reforestation efforts progress.

Is Scottish woodland suitable?

Some stakeholders have further queried the impact that modern forestry practice might have on the suitability of woodlands for lynx, where a large proportion of the total woodland cover is managed on a short rotation clearfell system. However, lynx readily use a variety of woodland types and successional stages.[18] Notably, felled coupes within conifer plantations often attract deer, while denser coupes provide cover and shelter. So, while the impact that such landscape dynamism might have on a reintroduced population is uncertain, there is little reason to suspect lynx will not be able to adapt, much as pine martens already do.[5]

Overall, in terms of habitat availability, the weight of evidence suggests Scotland is suitable for a lynx reintroduction. Across the whole of Scotland, woodland cover now stands at around 19%, but this figure varies across different regions. Both Perth and Kinross and Aberdeenshire support marginally less than the national average, but in Dumfries and Galloway, woodland cover is about 28%, while in both Moray and in Argyll and Bute, woodland cover is about 30%. Certainly, lynx have affected successful recoveries in regions with little more woodland cover than already exists in Scotland. For example, much of the Swiss Alps has reduced and fragmented forest cover, with lynx populations now established in the North-western Swiss Alps where forest cover is only 26-27%.[19]

References

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Table 2. In-person meeting agenda, 9th May

TIME	TITLE	FORMAT	LEAD
09:30-09:50	Introduction	Presentation	Jamie Copsey
09:50-10:15	Working agreement - How will we interact with each other during the process?	Discussion	Jamie Copsey
10:15-10:35	Overview of lynx ecology, history in UK and reintroductions in Europe	Presentation	David Hetherington
10:35-10:45	Clarifying questions		Jamie Copsey
10:45-11:05	Lynx to Scotland: rationale for the project and work to date	Presentation	Peter Cairns
11:05-11:30	Questions and open discussion	Discussion	Jamie Copsey
11:30-12:00	**BREAK**		
12:00-12:20	Vincent Wildlife Trust workshop outputs	Presentation	David Bavin
12:20-12:45	Questions and open discussion	Discussion	Jamie Copsey
12:45-13:45	**LUNCH**		
13:45- 14:05	The recommendation development process - How will we work together to develop recommendations regarding the concerns raised?	Presentation	Jamie Copsey
14:05-14:45	Finalising the scale of agreement - What is the desired level of agreement for the recommendations that will be developed?	Discussion	Jamie Copsey

Table 2. In-person meeting agenda, 9th May (cont'd)

TIME	TITLE	FORMAT	LEAD
14:45-15:05	**BREAK**		
15:05-15:20	Clarifying needs	Presentation	Jamie Copsey
15:20-16:00	Needs statement generation (including needs to be addressed at the local level)	Individual to group activity	Jamie Copsey
16:00- 16:45	Theming needs	Group activity/ discussion	Jamie Copsey
16:45-17:00	Wrap-up and next steps	Discussion	Jamie Copsey
17:00	**END**		

We look forward to you joining us and helping us to further explore the feasibility and desirability of a trial reintroduction of lynx in Scotland.

If you have any questions concerning the agenda or your participation in the workshop, please contact Jamie Copsey at jamie@cpsg.org.

BRIEFING NOTES

LYNX TO SCOTLAND

QUERY: what impact are lynx likely to have on DEER in Scotland?

Summary

Lynx preferentially target roe deer when they are available, but will hunt other deer species, especially if roe deer are scarce. Fallow deer thus also represent potential prey, while sika deer may be especially vulnerable to lynx and Scotland's relatively small red deer may also be more readily targeted than larger European specimens. Lynx predation can reduce deer numbers – particularly of roe deer – but it is less clear how lynx predation might change deer behaviour or to what extent impacts on deer numbers or behaviour might encourage woodland regeneration, with all such effects likely to be highly context specific. Lynx can feed on a deer for several days but rarely consume the entire carcass, and any increase in the year-round availability of large carcasses within the woodland environment would be likely to boost natural nutrient cycling processes and enrich biodiversity. Lynx are generally disinclined to target red deer stags or hunt far from woodland refugia, so their impact on open hill stalking should be limited. However, they could reduce the local availability of trophy roebucks. This conflict could potentially be offset for some estates by marketing lynx as a tourist draw.

The fuller picture

Across most of its European range, the Eurasian lynx (*Lynx lynx*) – henceforth referred to simply as the lynx – is a specialist ambush hunter of roe deer (e.g. roe deer made up 82% of prey remains identified in Germay[1] and 91% in Poland[2]). Where roe deer are less common, lynx may target other deer species, with fallow and sika deer likely to be opportunistically targeted where they are locally common. Red deer may also be taken, especially young animals, forming up to 72% of the lynx's diet in some parts of Europe, but are rarely targeted by the smaller female lynx and even males show some reluctance to tackle mature stags.[3] On the other hand, the smaller size of red deer in Britain may encourage lynx to target them more often and could also reduce their reluctance to tackle stags.[3]

Sika deer pose a threat to the genetic integrity of native red deer and can be challenging to control. However, having evolved in the absence of a large felid throughout much of their native range, sika may be more vulnerable to lynx predation.

Impacts on deer numbers

On average, a lynx kills between 50 and 70 deer per year. In one Swedish study, male lynx killed an average of 4.9 roe deer every 30 days, while females with kittens killed 6.2 deer every 30 days and lone females killed just 2.7 deer in the same period.[4] Notably, kill rates do not decline significantly until roe deer densities drop below 1 deer per km^2 (i.e. 1 deer per 100 ha). A population of 300 lynx (roughly the number that are estimated to be possible within Scotland's existing woodland habitats[5]) might thus be expected to be responsible for killing 15,000 to 21,000 deer every year.

Deer are notoriously difficult to count but NatureScot estimate there are around 300,000 roe deer in Scotland. There are also believed to be more than 100,000 red deer living in Scottish woodlands (with more on open ground), plus around 25,000 sika deer (which may be especially vulnerable to lynx, due to having evolved in the absence of any large feline predator[6]) and at

least 8,000 fallow deer, all of which lynx could target, subject to their relative availabilities.[3] Human hunters also shoot all these species, including at least 40,000 roe deer every year, suggesting that Scotland's deer population is more than large enough to sustain the 15,000 to 21,000 deer that might be killed by a healthy lynx population.

Ambush predators (like lynx) can exert stronger effects on prey populations than more selective coursing-style predators (like wolves), but their impact varies and there is no clear-cut correlation between lynx density, roe deer density, and the amount of roe deer mortality due to predation. Indeed, roe deer mortality due to lynx depredation ranges from 9% to 65% in different parts of their range.[7,8]

Where roe deer are common, lynx reintroduction may have little initial impact on deer numbers,[7] as has been reported from Germany's Palatinate Forest. Elsewhere, however, lynx predation has been linked to a reduction in roe deer population growth rates and the size of some populations.[4] One consistent factor seems to be that lynx predation is especially impactful in habitats subject to harsher climatic conditions[9] and/or where the roe deer population is either small or unnaturally clustered, as in some European hunting reserves.[10]

The proportion of predation that is additive versus compensatory (i.e. deer deaths that would have happened anyway) is also key to determining the impact of predation on deer populations.[4] Thus, if lynx predation occurs in addition to human hunting or other sources of mortality (road accidents etc.), it can be enough to precipitate localised population declines.

Crucially, local context is key. Average roe deer densities have been estimated to be 7.4 per km^2 across the Scottish Highlands and 5.5 per km^2 in the Southern uplands.[11] However, such large-scale population estimates can mask considerable local variation, with roe deer density estimates in conifer plantations across Scotland ranging from 0.6 to 24.8 per km^2.[12]

Notably, lynx predation is likely to be more impactful in areas supporting smaller initial populations. For example, lynx could have a big impact in Glen Affric, where roe deer density estimates range from 1.4 to just 2.0 per km^2, but might be less impactful in Glen Tanar, where roe deer estimates range from 4.7 up to 21 per km^2.[13]

Consequences of predation

At high densities, deer can reduce crop yields, harm commercial forestry interests, impair natural woodland regeneration, reduce biodiversity of woodland ground flora and impact other woodland animals, while also acting as reservoirs of disease and causing vehicle collisions, at a collective cost of many millions.[14]

The extent of these various impacts – and the costs linked to them – are often related to deer density, and so it might be thought that any reduction in deer density manifested by lynx predation would achieve a proportional reduction in these damages. In practice, however, the relationship between the extent of these harms and deer density is nonlinear, meaning that above a certain threshold, reductions in deer density may affect little reduction in deer impacts.[14]

Much interest surrounds the potential for lynx to reduce deer numbers - or just change deer behaviour - with some Swiss foresters convinced that lynx predation has led to a reduction in browsing pressure and an increase in woodland regeneration following lynx reintroduction to Switzerland in the 1970s.

The threshold for harmful impacts also varies according to what impacts are considered harms. For example, roe deer may nip off the leading shoot of a sapling, encouraging multi-stemmed growth. This may be tolerable or even beneficial (up to a point) for natural woodland regeneration but is unwelcome in commercial forestry.

In degraded habitats, the threshold below which deer densities must be lowered before regeneration can begin is also lower than the threshold at which impacts are first felt in healthy habitats. In general, though, the threshold at which the impacts of different species of deer become problematic depends on their relative biomass, feeding strategy and social organization.

Accordingly, larger, more social deer species, like red deer and fallow deer, tend to have greater impacts than smaller species like roe deer.[14] It follows that if lynx predation is focused on roe deer – as expected – we should anticipate it to have less impact than predation on larger species might, but equally, where lynx do target these other species, they might have greater impacts than elsewhere.

Landscape of fear?

Much interest has focused on the potential for lynx to initiate a trophic cascade, whereby a reduction in deer numbers, or a change in deer behaviour (reflecting a so-called 'landscape of fear'), might lead to an increase in woodland regeneration. Anecdotally, Scottish forest managers have described how deer learn which areas to avoid in relation to risk from human hunters.[15] However, human proximity, hunting and recreation may have a bigger impact in shaping deer browsing patterns than do lynx.[16]

Furthermore, in Norway, roe deer show no avoidance of habitats associated with high lynx predation risk and recolonization by lynx has had little impact on roe deer habitat selection.[8] One explanation for this may be the remarkable efficiency of this stalking predator, with prey species offered few opportunities to learn to avoid lynx. By contrast, when coursing predators like wolves take one or two individuals from a herd, survivors can adapt by changing their behaviour.

Roe deer may become more nocturnal when human disturbance levels are high, but then in the presence of lynx, become relatively more diurnal again.[17] Roe deer also appear to respond to the olfactory cues present in Eurasian lynx urine by increasing their vigilance levels, but only in the immediate wake of scent detection, exhibiting similar levels of overall vigilance in areas with and without lynx.[18]

It is also difficult to definitively link vegetation changes to lynx. Following lynx reintroduction in Switzerland, deer density decreased, followed by a reduction in reported browsing impacts and an increase in natural regeneration.[19] However, it is difficult to decouple the influence of lynx in this case from other factors like fluctuating human hunting pressure and varying climatic conditions.

In some cases, reductions in roe deer density may have little effect on vegetation, at least in productive European woodland habitats. Notably, in one study that looked specifically at roe deer, oak regeneration in France was little affected by roe deer densities as high as 25 per km^2. In such productive woodlands, unless roe deer densities are above this threshold before lynx arrive, any reduction in density mediated by lynx predation will have little effect on vegetation, simply because underlying productivity is so high.[14]

Whether this would be equally true in Scotland's climate is unclear, since harsher environmental conditions are likely to make Scottish woodland regeneration more sensitive to browsing effects. Indeed, there can be few unfenced Scottish woodlands where deer are having no impact because the underlying productivity is so great.

Furthermore, if lynx also serve to reduce red deer densities in Scottish woodlands, their influence might be even more impactful, since the threshold density at which red deer begin to inhibit woodland regeneration is known to be much lower (around 4 to 5 deer per km^2 in upland sites[14]).

In general, at the very least, lynx are likely to usefully complement human deer management.[20] Indeed, the potential for lynx to help control deer in areas that cannot easily be managed by humans[21] was identified by forestry professionals in the Vincent Wildlife Trust study as a significant likely benefit of lynx reintroduction.[15] Lynx also select deer differently to human hunters, showing little selectivity for either the age class or sex of hunted roe deer,[4] and thus have a different influence on which deer are killed and when, with correspondingly different ecological impacts.[20]

Large carcass impacts

Beyond any impact on deer numbers or behaviour, lynx predation has another potentially significant ecological benefit, which is that the renewed year-round supply of large carcasses generated by reintroduced lynx would revitalise missing natural processes, including nutrient cycling mediated by scavengers and decomposers.

Large carcasses have become a scarce resource in Scotland, with farmers obliged to remove dead livestock and human hunters typically carrying away everything except the gralloch. By contrast, lynx observe no off season and may leave significant amounts of a carcass uneaten. This is especially true of male lynx, which can kill larger animals and tend to kill more often, perhaps because the need to patrol their larger territories prohibits them from feeding for as many days on any single carcass.

In Norway, male lynx may eat as little as 16% of the edible parts of a carcass[22] and lynx leftovers have the potential to support a wealth of biodiversity, from specialist invertebrates to opportunistic avian and mammalian scavengers. Large carcasses can even promote localised woodland regeneration, with saplings benefiting from both the heavy trampling of understory vegetation around a carcass and the pulse of nutrients released following carcass decomposition.[23]

Left undisturbed, lynx will consume a deer carcass over several days, typically starting at the rump and often consuming almost all the edible parts of smaller ungulates like roe deer.

Lynx impacts on deer stalking

Reductions in deer numbers caused by lynx may be welcomed where deer damage threatens either forestry interests or woodland regeneration schemes but might be less welcome on sporting estates where trophy hunting generates valued revenue. The threat to red deer stags on the open hill is likely to be minimal, but a medal head roebuck can be worth as much as £1,500 and some stakeholders feel that lynx reintroduction could jeopardise this trophy hunting industry.[15] Indeed, in Europe, the major conflicts surrounding lynx are often not around livestock but are instead around wild ungulate hunting.[24]

However, in many European countries, local communities are more heavily involved in deer control and community models of hunting are widespread. Consequently, hunting provides a source of sustainable food to which local people have priority access, with game meat an important part of food culture – rather than an undervalued by-product of trophy hunting or deer control efforts, as can be the case in Scotland.[25]

All this means that, where lynx are perceived to reduce the availability of shootable animals and threaten the supply of local game meat, lynx may be viewed as unwelcome competition.[26] Certainly, conflict with hunters continues to motivate lynx persecution,[27,28] with illegal killing the primary threat to lynx across much of Europe, accounting for up to 50% of all adult mortality.[3]

A complex relationship

Many studies have identified a link between hunting and negative attitudes towards large carnivores, often based on the competition described above, yet other research has shown that hunters can sometimes be more supportive of predators than non-hunters.[29] Hunter sentiments towards lynx are further complicated by wider social conflicts around hunting, dominated by conflicting ideas around land use, urban-rural tensions and varying biases towards different forms of knowledge.[29]

In southwest Germany, a vigorous conflict about lynx exists even in areas where no lynx reside, with the hunters' opposition to the lynx here thought to be shaped by negative historical experiences with pro-lynx groups.[29] In this interaction, hunters believe their social identity is being threatened and fear impairment of perceived freedoms, which in turn leads to resistance against the lynx.[29] Elsewhere in Europe, the opposite is true, with hunters from Slovenia, Croatia, Italy, Romania and Slovakia not only supportive of lynx reintroduction to the Dinaric Mountains,

Lynx are unlikely to threaten traditional hill stalking of red deer, but may reduce the local availability of trophy head roebucks.

but integral contributors to the reintroduction process and key partners in ongoing monitoring efforts.[30]

In Scotland, the market for roe deer stalking is growing and for some landowners, renting out stalking to syndicates may constitute a significant amount of their annual income.[15] Any threat to this revenue is thus unwelcome. However, other hunters acknowledge that the presence of lynx could prove an additional attraction for people seeking a "more authentic, wild experience", and so some estates recognise that lynx could offer an attractive marketing opportunity, representing a powerful touristic draw that could help fill bed nights, with such opportunities providing potential scope to offset any lost revenues from trophy hunting.[15]

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BRIEFING NOTES

LYNX TO SCOTLAND

QUERY: what impact are lynx likely to have on GAMEBIRDS in Scotland?

Summary

Eurasian lynx primarily hunt medium-sized ungulates, favouring roe deer where they are available, but gamebirds have been recorded as occasional items in the lynx's diet. Red grouse (a Scottish relative of the willow grouse) are largely restricted to open moorland environments little favoured by woodland-loving lynx, so Scotland's driven grouse shooting industry would be unlikely to be greatly affected by lynx. Ptarmigan are also unlikely to be affected in their high montane environment, but black grouse could prove more vulnerable, given their greater preference for mosaic habitats, and capercaillie have been recorded as occasional prey items. However, neither species is shot as a gamebird in Scotland today, so black grouse and capercaillie are dealt with in a separate briefing note detailing effects on other species. Pheasants and partridges are widely shot and could be potential prey for lynx in Scotland, with fears that they might be especially vulnerable in and around rearing pens. Increased pen security may mitigate this risk, but disturbance post-release could also interfere with shooting drives. However, any occasional predation by lynx could be more than offset by an overall decrease in predation pressure from other smaller predators like foxes, which lynx have been shown to suppress.

The fuller picture

The Eurasian lynx – henceforth referred to simply as the lynx – specialises in hunting roe deer where they are available in most of Europe, but will also take a wide variety of other species, from small rodents to red deer.[1] Some lynx populations in central Asia and north-eastern Europe specialise in hunting hares where deer are scarce or unavailable, but they too switch to targeting larger prey species when they become more abundant.[2]

Gamebirds – loosely defined as a bird that is shot for sport or food – can also occasionally appear in the lynx's diet. Some studies suggest gamebirds appear more often in the diet of female lynx but they remain a small component of the diet of all lynx.[3] For example, out of more than one thousand prey items recorded across two decades in Switzerland, lynx killed 655 roe deer, 295 chamois, 53 foxes, 25 brown hares, 13 white hares and 9 sheep, but just a single capercaillie and a single black grouse.[1]

Woodland grouse occasionally make up a greater proportion of the lynx's diet (e.g. in the Ural Mountains) but are never a substitute for hares or ungulates.[2] Nonetheless, the fact that these birds can appear in the diet of lynx has been cause for concern among some stakeholders.[4]

Impacts on grouse

The Vincent Wildlife Trust's (VWT) study examining stakeholder attitudes to lynx found few concerns about direct impacts on red grouse, with their open moorland habitat thought to be less likely to attract lynx. Even so, some gamekeepers have expressed fears that ground nesting birds would be an easier option for lynx than hunting larger, more challenging prey such as deer.[4] Additionally, the role of sheep as tick mops (often employed as part of grouse moor management) was highlighted by some gamekeepers, who expressed concerns about potential predation on sheep.[4,5] The VWT study noted that this threat to sheep could create a perception that lynx represent an indirect threat to gamebird management, with the feeling that "if sheep are lost, then so are the grouse."[4]

However, it should also be noted that the risk of sheep depredation decreases with increasing distance from woodland, meaning that sheep on grouse moors should be relatively safe.[6] Data on lynx diet across Europe also clearly shows that ground nesting birds form a vanishingly small proportion of lynx kills.[1] Instead, after medium-sized ungulates, the next most targeted prey species for lynx is often the red fox, and multiple studies have found evidence of a net *reduction* in predation levels of various ground nesting species due to the lynx's suppression of foxes.[5]

One ten-year study of lynx in the Swiss Jura Mountains recorded adult male lynx killing an average of 2.3 foxes per year, while subadults killed 6.1 foxes per year (perhaps because younger lynx found it harder to tackle larger ungulate prey) and lynx with kittens killed 13.3 foxes annually (likely in response to a perceived threat to their offspring), giving a weighted average of 4.8 foxes per lynx per year.[6]

After medium-sized ungulates like roe deer, the next most commonly targeted prey species for lynx is often the red fox, with the lynx's suppression of foxes linked to a net reduction in predation levels for ground nesting birds in Scandinavia

Notably, this has not led to any decrease in the abundant Swiss fox population, but where initial fox densities are lower – as they are in Sweden and parts of Highland Scotland – lynx predation may significantly reduce fox numbers,[7] especially where it is added to existing fox control efforts by gamekeepers and land managers. Indeed, where this happens, the lynx's contribution to fox control may more than offset its occasional predation of gamebirds.

Such an effect is thought to have been responsible for the observed *increase* in black grouse, willow grouse, capercaillie and mountain hare numbers noted in parts of Sweden and Finland after the recovery of their local lynx population.[5] Of course, such complex interactions are subject to a variety of contextual caveats, but enough similarities exist between these regions of Scandinavia and large parts of the Scottish Highlands to make a similar effect plausible.

Ptarmigan are rarely shot in Scotland but are still classed as legal quarry. Exceptional records of lynx killing ptarmigan are noted from northern Sweden at times when other prey are scarce, but as they are restricted to montane habitats above the treeline in Scotland (except in very cold weather), predation by lynx remains unlikely here.

Black grouse are not a commonly recorded lynx prey item, but any predation would be unwelcome, given the precarious status of Scotland's black grouse population.[8] They remain legal quarry but are subject to a voluntary shooting moratorium in Scotland and are therefore covered separately in the briefing note on other species.

Woodland-dwelling capercaillie are more widely recorded as an occasional prey item for lynx but are no longer a legal quarry species in Scotland and so are also dealt with in the separate briefing note covering lynx impacts on other native species.

Red grouse are typically found on open heather moorlands which lynx would be unlikely to frequent, preferring to hunt roe deer in or close to woodlands.

Impacts on pheasants and partridges

The gamebird species most often shot as quarry in Scotland today are non-native pheasants and red-legged partridges. Both pheasants and red-legged partridges are extensively bred in captivity and then raised in fenced woodland pens before being released for shooting, although a small number of shoots focus on wild birds. Where gamebirds are confined within woodland pens, often in large numbers, concerns have been expressed that these slow and predator-naïve birds could be both attractive and vulnerable to lynx.[4]

There are few examples in Europe comparable with this model of mass-rearing gamebirds, so the risks to penned birds from reintroduced lynx cannot easily be inferred from continental comparisons. However, it is likely that these birds would be vulnerable to some level of predation. Pheasant and partridge shooting is more widespread in the Scottish Lowlands and is a less common land use in the Highland areas identified with the most potential as lynx reintroduction sites.[9] Nonetheless, significant numbers of pheasants and red-legged partridges are released in Perthshire, Angus, Aberdeenshire and Moray, which could form part of the lynx's range in the long-term.[10]

There are also concerns that fencing largely designed to protect gamebirds from foxes, badgers and raptors might offer less of a barrier to a lynx. Designs could probably be modified to make them more lynx-safe, but a further concern is the potential for lynx to disturb released birds from woodland edge and at roost sites, pushing them off shooting beats and so rendering the birds unavailable to sporting clients.[4]

On the other hand, lynx occur at much lower densities than foxes in the landscape[11,12] (typically 0.3-3 per 100km^2 versus 10-500 per 100km^2) and if lynx predation on foxes leads to a reduction in fox densities,[5] there could be an overall *decrease* in disturbance rates to roosting birds.

Native grey partridges are now relatively rare and so are rarely shot. Furthermore, grey partridges are associated with open, arable landscapes, meaning they would be less likely to encounter woodland-loving lynx. They could still be vulnerable to lynx predation where their habitats abut woodland edges; however, this review could find no examples of grey partridges occurring in the Eurasian lynx's diet, so the risk seems small.

Wider concerns

Raising gamebirds is widely perceived to be increasingly challenging due to the increase in abundance of protected predators like pine martens, as well as the potential threat from novel forms of disease outbreaks.[4] As a result, predator management remains a contentious issue for many in the sector who often feel that society undervalues the contribution that land managers, farmers and gamekeepers believe they make to the rural environment. For some, a large, protected cat like the lynx thus appears as an unwelcome extra burden, regardless of its more nuanced impacts, with estate management already struggling to balance a complex mix of management interventions.[4]

However, despite these concerns, potential impacts on the gamebird shooting industry are not commonly cited as a major barrier to lynx reintroduction. Instead, the VWT study suggested that stakeholders simply feel the potential conflict needs to be considered as a factor when conducting a full risk assessment reviewing the overall costs and benefits that would attend any reintroduction.[4]

Pheasants may be vulnerable to lynx attacks when confined within woodland pens, while some concern surrounds the potential for disturbance to roost sites and the subsequent disruption of shooting opportunities.

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BRIEFING NOTES

LYNX TO SCOTLAND

QUERY: what impact are lynx likely to have on OTHER NATIVE SPECIES in Scotland?

Summary

Eurasian lynx specialise in hunting medium-sized ungulates, with roe deer their preferred prey. They may also take a variety of smaller species, including several that are relatively rare in Scotland, like wildcats, mountain hares, capercaillie and black grouse, but where suitably sized deer are available, these other species are rarely taken. Furthermore, the lynx's ability to suppress fox populations can result in a net reduction in overall predation pressure for these other species. Deer carcasses left by lynx may also provide an alternative food source for smaller predator species, including foxes, pine martens and badgers, with recent experiments suggesting that an increased availability of carrion can serve to reduce predation pressure on species commonly targeted by these smaller predators. Wildcats may also benefit from increased scavenging opportunities, as well as from reduced competition from foxes, if lynx prove able to lower Scottish fox densities. All these effects remain necessarily speculative, with Scottish ecosystems to some extent unique, but comparisons with lynx interactions with the same species across Europe are still informative, and notably only provide evidence for positive or neutral effects on species of conservation concern in Scotland. Thus, while lynx may occasionally predate individuals of different threatened species, their overall influence is more likely to manifest net benefits for populations of vulnerable Scottish species.

The fuller picture

A commonly voiced concern regarding lynx reintroduction to Scotland is the potential impact lynx might have on species of conservation concern such as wildcats, mountain hares, ground nesting birds or red squirrels.[1] In Europe, the Eurasian lynx – henceforth referred to simply as the lynx – specialises in hunting medium-sized ungulates, with its preferred prey being roe deer, but other deer species are also hunted. Accordingly, red deer, fallow deer and sika deer could all form part of the lynx's diet in Scotland, likely being targeted somewhat in proportion to their availability.[2,3]

Some stakeholders have expressed fears that where roe deer are relatively scarce – in places like the uplands of the Cairngorms National Park – lynx might switch to targeting more birds or hares.[1] However, lynx would only be forced to resort to relying on such small prey items in the absence of any suitably sized ungulates, and since British red deer are smaller than European specimens[2], red deer may provide a viable alternative in most areas where roe deer are scarce, while sika and fallow deer could be important prey items elsewhere. Lynx would also be unlikely to stray far into upland areas where there was not at least some woodland cover available as shelter.

Of course, lynx can also hunt smaller species, with this being especially true for female and younger, less experienced lynx.[4] Aside from deer, documented wild prey species known to be taken by lynx and which occur in Scotland include foxes, European brown hares, mountain hares, capercaillie, black grouse, red squirrels, pine martens, wild boar, badgers and wildcats.[3,5,6]

However, among these non-deer wild prey species, only foxes and hares are taken with any regularity in western Europe, with hares taken more often in young plantations, where their densities can be relatively high.[7] Even so, out of more than one thousand prey items documented across two decades in Switzerland, lynx were recorded to have killed 655 roe deer, 295 chamois and 53 foxes, but just 25 brown hares, 13 mountain hares, a single red squirrel, a single capercaillie and a single black grouse.[6]

Interactions with black grouse and capercaillie

Capercaillie and black grouse, alongside hazel grouse, have only been recorded as significant prey items for lynx in boreal and montane forests. In different studies conducted between the 1950s and 1980s, these three species together constituted up to 20% of recorded lynx prey in north-western Russia and the central Urals, and 14-16% of lynx prey in Sweden, the southern Urals and the Carpathian Mountains, while in Siberia, in the 1960s, traces of capercaillie were recorded in up to 50% of lynx scats.[7]

Contemporaneous deer densities are not provided by these studies, so we do not know what their availability was at these times, but it should be noted that ungulate biomass typically declines at higher latitudes[7] and where suitably sized deer are available, they are the preferred prey. Indeed, in Belarus, the proportion of forest grouse found in lynx scat declined as roe deer densities increased.[8]

Capercaillie and black grouse numbers have increased in parts of Scandinavia that have been recolonised by lynx, with this trend understood to be due to the cats' suppression of foxes.

Furthermore, while lynx may kill individual birds, evidence suggests that their net effect on populations of both black grouse and capercaillie is more likely to be positive – manifested through their suppression of mesopredators, especially foxes. When an apex predator suppresses populations of previously abundant mid-ranking predators, the resulting reduction in predation pressure experienced by prey populations of those same mid-ranking predators is known as 'mesopredator release'.

Under these conditions, prey animals which were previously intensively hunted by abundant mid-ranking predators classically enjoy a net reduction in the level of predatory pressure they face due to a decline in the overall number of individual predators of all species (and a concurrent decline in the total number of predation events).

This is exactly what appears to have happened in Scandinavia following regional recolonisation by lynx, with data from Finland and Sweden revealing that mountain hares,[9] capercaillie[10] and black grouse[10] all enjoyed population increases after the lynx returned – thought to be driven by the lynx's suppression of foxes.[11] Indeed, in the case of forest grouse in Finland, it has been suggested that an increase in the lynx population worked better for controlling fox numbers than human hunting.[10]

After medium-sized ungulates, foxes often represent the next most targeted prey species for lynx. However, lynx do not necessarily eat the foxes they kill.[11] Instead, lynx appear motivated to kill foxes out of an instinct to eliminate a potential competitor and threat to their kittens. It may also be that consuming foxes poses a risk of contagion from diseases like mange, creating selective pressure to abstain from eating fox carcasses.

The rate at which lynx kill foxes varies. One ten-year study in the Swiss Jura Mountains recorded adult male lynx killing an average of 2.3 foxes per year, while subadults killed 6.1 foxes per year (perhaps because younger lynx find it harder to tackle larger ungulate prey) and lynx with kittens killed the most, accounting for 13.3 foxes annually (likely in response to a perceived threat to their offspring), giving a weighted average of 4.8 foxes predated per lynx per year.[12]

Notably, this has not caused any decrease in the Swiss fox population, where productive agricultural landscapes support so many foxes that the lynx's depredations have no effect on the overall fox population. However, in less productive landscapes, where fox densities are lower – as they are in Sweden – lynx predation can significantly reduce fox abundance. The same effect might thus be anticipated in the Scottish Highlands, especially where lynx predation is added to existing fox control efforts by gamekeepers and land managers.[9, 11]

Carcass effects

Direct predation on mesopredators is not the only mechanism by which lynx might relieve pressure on vulnerable species like ground-nesting birds. Partially eaten deer carcasses left by lynx[13] could, theoretically, also serve to create an alternative food source for mesopredators (including foxes, badgers and pine martens), in turn acting to reduce the pressure felt by their prey.

Evidence that this can happen again comes from Scandinavia, where the proportion of venison in foxes' diets increased following the return of lynx to southern Sweden, rising to account for half of the food consumed by foxes in winter, even as local roe deer densities fell.[14] Importantly, this provisioning did not subsidise any concurrent increase in fox densities. Instead, fox numbers declined during the same period, seemingly due to predation by lynx.[11]

Thus, even in cases where mesopredator densities are unaffected by the lynx's return, the provision of an alternative food supply, in the form of increased carrion availability, may serve to reduce predation of ground-nesting species. Such an effect was recently illustrated by an

Lynx would increase the availability of large carcasses in the environment, potentially diverting some mesopredators from a focus on predatory behaviour and encouraging a switch to more scavenging.

experiment in Scotland which investigated how so-called 'diversionary feeding' might reduce predation pressure on capercaillie nests.[15]

This experiment showed that maintaining a supply of by-products from deer culling operations led to a substantial reduction in the depredation rate suffered by artificial nests, largely thanks to a reduction in nest predation by pine martens and badgers.[15] This suggests that deer carcasses provided by lynx could potentially improve capercaillie nest survival and so boost breeding success, the current lack of which remains a key impediment to capercaillie recovery in Scotland.

Deer carcasses provided by lynx could offer wider biodiversity benefits too. Unlike human hunters who typically remove everything except the gralloch, lynx generate large carcasses year-round, offering rich pickings for specialist and opportunistic scavengers alike, including small birds – which can gain a vital energy boost in winter – mice and even hedgehogs. Large carcasses also

boost invertebrate biodiversity, attracting a wide variety of beetles, flies, butterflies and ants, and can help promote tree growth since seedlings benefit from vegetational trampling around carcasses, allowing young trees to emerge from the forest understorey, boosted by a pulse of nutrients from the nearby carcass.[16]

Implications for wildcats

We could find no evidence that Eurasian lynx reintroduction has led to a decline in wildcats anywhere in Europe. Evidence from Spain suggests a level of interference competition between Iberian lynx and wildcats.[17] However, this probably reflects the greater niche overlap between the relatively small Iberian lynx (a totally separate species to the Eurasian lynx) and the wildcat. By contrast, data from Anatolia shows a high degree of temporal overlap between Eurasian lynx – the species being considered for reintroduction to Scotland – and wildcats, with wildcats exhibiting no change in their activity patterns in the presence of Eurasian lynx.[18]

Wildcats do not compete directly with lynx and may indeed benefit from their presence, with their distribution and abundance positively correlated with the presence of lynx in countries like Switzerland and Romania.

Data from Romania further found that wildcats were more common in areas where Eurasian lynx were present,[19] with the same pattern reported in the Swiss Jura Mountains (pers. comm. KORA). While there is always a chance that lynx could predate some individual wildcats, the positive association between the distributions of these two species elsewhere in Europe suggests that Scotland's wildcat population is more likely to enjoy a net benefit from a lynx reintroduction, perhaps as a result of gaining access to more scavenging opportunities as well as suffering less competition from foxes.

Effects on hares

The proportion of hares in the lynx's diet increases with latitude and is inversely proportional with the abundance of ungulates; where deer are available, they remain the preferred prey choice.[7] Of the two species of hares found in Scotland, the European brown hare is adapted to open country, where it would be unlikely to be much troubled by the woodland-loving lynx. By contrast, the so-called mountain hare (or white hare) occupies coniferous boreal forest around much of its circumpolar distribution – wherever such woodland incorporates a healthy mix of shrubs, herbs and grasses at ground level.

Mountain hares could thus encounter lynx in places where they came to share the same woodland habitats. However, where roe deer are common – as they often are in these habitats – hares would be likely to remain an infrequent prey item.[3] Mountain hares would also be less at risk on the open moorlands where they reach their highest densities, with lynx disinclined to hunt very far from woodland edges. And again, where lynx are able to suppress fox numbers, mountain hares can experience a net decrease in overall predation pressure.[9]

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BRIEFING NOTES

LYNX TO SCOTLAND

QUERY: what impact might lynx have on SHEEP in Scotland?

Summary

Eurasian lynx are known to kill sheep across much of their European range, but how many sheep they kill varies greatly between countries, influenced by factors including varying styles of livestock husbandry, varying numbers of lynx, the availability of suitable wild prey and the density of sheep in the areas where lynx occur. Sheep are not the lynx's preferred prey and are not sought out like wild ungulates, but instead appear to be taken opportunistically during chance encounters. How often lynx attack sheep also varies between individual lynx and the two sexes; some individuals become habitual livestock killers while others never kill sheep at all. However, males tend to kill sheep more often than females and are more likely to engage in multiple killings. Norway suffers the highest sheep losses, seemingly due to the large number of sheep left unguarded and unconfined within wooded landscapes that often support relatively low densities of wild prey. However, even in Norway, sheep losses are low where they are kept confined within fields. Everywhere else in the lynx's European range, sheep depredation occurs at much lower levels, but even in these countries, conflict hotspots can develop where individual pastures or farms suffer repeated attacks.

The fuller picture

A key concern surrounding the potential reintroduction of lynx to Scotland is that lynx may attack sheep.[1] Lynx certainly can and do kill sheep, but the frequency with which they do so varies greatly around Europe. Annual losses range from zero to fewer than 150 sheep in most countries within the lynx's European range.[2] The significant exception to this is Norway, where farmers were compensated for average losses of more than 5000 sheep a year between 2012 and 2016[2], and annual losses between 2,000 and 10,500 sheep between 1992 and 2013,[3] representing up to ±0.5% of the 2-2.5 million sheep grazed in forest and mountain habitats in Norway during that period.[4]

However, less than 10% of these Norwegian losses have ever been independently verified[3] and recently, the number of claimed losses has fallen. Misuse of the compensation system is also suspected, with a significant discrepancy noted between how many sheep could plausibly be being killed by lynx (as calculated from direct observations of verified kill rates) and the larger number for which compensation has been paid.[3]

This discrepancy is thought to have arisen because mortality from other causes (e.g. a lack of micro-minerals, accidents, disease, or predation by other carnivores) is sometimes wrongly attributed to lynx.[3] There have also been convictions for fraudulent claims relating to alleged attacks by other carnivore species, with recent examples from Norway[5] and Spain.[6] Nonetheless, while the total reported number of losses may be exaggerated, there is no doubt that lynx do kill large numbers of sheep in Norway.[7]

Sheep are kept indoors over winter in much of Europe, only grazing outside through the summer months. By comparison, Scottish sheep are typically grazed outside all year round and in some cases even lamb on the hill.

Table 1. Reported sheep losses attributed to lynx predation around Europe, compared against differences in sheep density, lynx abundance and distribution overlap. Data extracted from EU report.[2]

Country	Lynx population	Compensated attacks (annual average 2012-2016)	National sheep density per km^2	Overlap (%) between sheep and lynx distribution	Annual sheep losses per lynx
Norway	250-350	5296	3.4	69	15-21
Sweden	1050-1450	145	1.3	100	0.1
France	100	102	12.9	7	1
Finland	2500	32	0.5	93	0.01
Estonia	600-800	30	2.2	100	0.04-0.05
Switzerland	200	19*	6.3	95	0.1
Czechia	40-50	16	2.8	44	0.3-0.4
Germany	85	5	4.4	No data	0.06
Slovenia	15	1	4.9	100	0.07
Latvia	45-60	2	1.7	100	0.03-0.04
Slovakia	300-400	1	7.6	100	0.003
Lithuania	160?	0	2.5	100	0
Croatia	40-60	0	11.0	100	0
Scotland	0	NA	51.8	NA	NA

*Notably the period between 2012 and 2016 selected for this EU dataset coincided with an unusually low period of losses in Switzerland, with more recent data between 2017 and 2020 (from KORA) documenting between 54 and 86 attacks per year.

The importance of livestock protection

The varying numbers of sheep lost to lynx predation in different countries reflects a complex mix of risk factors, from how many lynx there are to how many sheep, but also how much wild prey is available, and – crucially – how much protection is provided to livestock. Countries like Slovakia, which have never exterminated their large carnivores and which consequently have an unbroken history of active herd protection, tend to suffer very few losses, even though they support relatively high numbers of both lynx and sheep.[2]

Norway's high losses are exceptional when compared to anywhere else in Europe, and notably, even compared to next-door Sweden, where there are far more lynx, but also far fewer sheep losses.[2] Partly, this may be because Sweden also has fewer sheep, but while Norway has around four times as many sheep as Sweden, the rate at which Swedish sheep are lost to lynx is between one hundred and one thousand times lower than reported Norwegian losses.[2]

In Sweden, sheep are grazed in small, fenced pastures, with a relatively small number of sheep kept on each farm (most Swedish sheep farms have fewer than 50 ewes). By contrast, in Norway, sheep are largely left to roam the forest in large numbers, unfenced and unguarded all summer.[8] The main reason for the enormous variation in sheep losses between Norway and Sweden thus seems to be the style of livestock husbandry employed in the two countries. Indeed, even in Norway, in those places where sheep are kept confined in fields, sheep are reportedly 'almost never killed'.[3]

This phenomenon is not thought to be due to fencing excluding lynx, since few of these fences are truly predator-proof. Instead, fencing appears to reduce predation mainly by preventing sheep entering woodland habitat (i.e. the lynx's preferred habitat), thereby reducing the rate of random encounters between lynx and sheep, with such encounters understood to increase the risk of lynx-sheep predation.[9]

High-risk zones for sheep are thus those habitats which are either shared with or adjacent to areas where lynx spend most time in activities such as resting or hunting, and where the risk of a fatal chance encounter is greatest.[4] Accordingly, the risk of predation by lynx gets lower the further sheep are kept away from woodland habitats[10] and most predation is focused within situational hotspots.[9]

Roe deer are the lynx's preferred prey. However, the relationship between wild prey density and levels of sheep depredation can be complex.

The influence of wild prey availability

Lynx habitat selection – where they choose to spend their time – is governed by the availability of refuges (places to rest and shelter, typically in woodland) and the availability of wild prey (typically roe deer),[11] with wild prey density having an important influence on the likelihood of sheep depredation.

Lynx kill rates on domestic sheep – the rate at which individual lynx kill sheep – are highest in regions where wild prey densities are low and where lynx have few other choices.[7] In Norway, where roe deer occur at densities above four deer per km^2 – a quite modest density by Scottish standards – kill rates are low, even within woodland.[3] Once roe deer densities exceed six or seven deer per km^2, the chance of a lynx killing a sheep becomes extremely low (see Figure 1).[7]

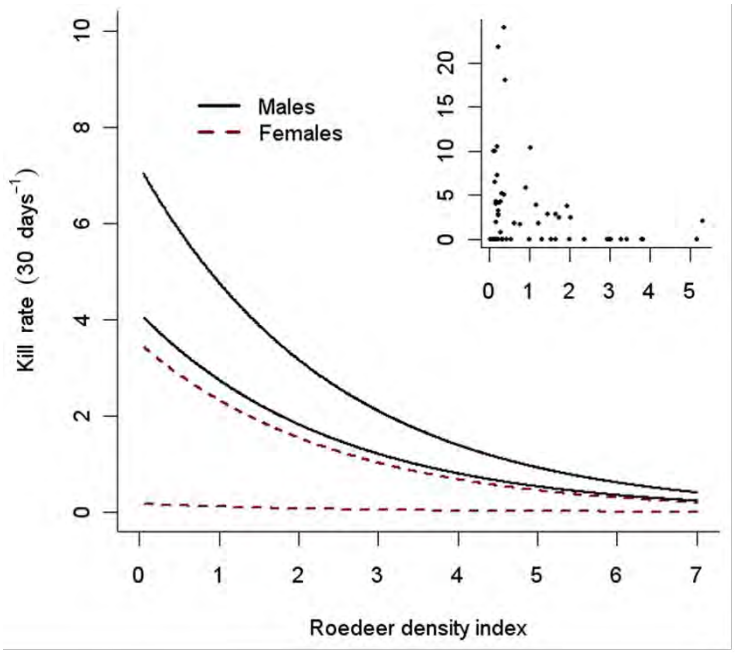

Figure 1. Predicted kill rates (i.e. number of sheep killed within 30 days) in areas supporting different roe deer densities. Solid black lines for males and dashed red lines for female lynx. Upper lines for each sex are predicted kill rates under high sheep density (95% percentile of observed lamb densities: 6.6 lamb km^2) and lower lines are predictions for low sheep density (5% percentile of observed lamb densities: 0.1 lamb km^2). Scatter plot inset in top right corner represents the raw data. Figure extracted from Odden et al. (2013)[7]

However, at a finer scale, the likelihood of a pasture suffering an attack can be positively correlated with roe deer density,[10] and higher losses of lambs may occur in areas with higher roe deer densities.[4] Lynx follow deer and go where they go, but as a result they then inevitably bump into sheep more often in areas with more deer, sometimes responding to these encounters by killing them.

Such depredation appears to be opportunistic, occurring at a rate below that which would be predicted from the fundamental availability of sheep compared to wild ungulates in the landscape.[4,12] Indeed, research from Norway concluded that "in contrast to what we would expect if sheep were a preferred prey, lynx did not show a selection for sheep grazing areas, and females actually avoided sheep grazing areas."[4] This conclusion matches earlier research (also from Norway) which concluded that foraging patch selection in Eurasian lynx is determined by the abundance of natural prey species, rather than the availability of livestock.[12]

The exceptionally high sheep losses reported from Norway may therefore not just be an inevitable result of grazing millions of sheep unsupervised in woodlands, or a possible consequence of their generous, few-questions-asked, compensation scheme, but may also be a consequence of Norway's relatively low densities of wild ungulates – reportedly averaging just 0.3 roe deer per km^2 in some areas.[4]

More sheep, more risk

The risk of sheep predation is not just influenced by the availability of wild prey, but also by sheep density,[3,7] since the abundance of sheep in areas frequented by lynx increases the risk of a chance encounter and an opportunistic attack. When sheep are less common, attacks are rare. Indeed, one study from Norway suggested that when sheep densities are low, females rarely kill sheep irrespective even of roe deer density.[7]

Notably, Scotland supports a lot of sheep – at least twice as many as Norway. Scotland's national flock is estimated at over 6.8 million animals (including lambs) with densities of over 120 sheep per km^2 in many places. Sheep densities are at their lowest in the Highlands, but still reach an average of 30 sheep per km^2 in Argyll, 17 sheep per km^2 in Inverness-shire, 15 sheep per km^2 in Ross and Cromarty, and 12 sheep per km^2 in Sutherland (calculated according to 2021/2022 APHA survey data).

By comparison, in the Swiss Jura, sheep densities are a little under 5 per km^2 and nationwide Switzerland supports just under 10 sheep per km^2, while Norway averages fewer than 4 sheep per km^2, although this average is skewed by the fact that large areas of Norway support no sheep at all. Sheep densities within Norway's summer grazing pastures are reported to be between 10 and 80 animals per km^2.[14]

Some Scottish sheep graze extensively across open moorlands, where they might be expected to be relatively safe, but some do range into woodlands, where they would be more at risk. Most are kept in fields, decreasing the risk of attack, but these fields are often adjacent to or partly surrounded by woodland, which may again increase the risk of an attack (see below). Sheep and livestock are also often kept indoors over winter in much of Europe, only grazing outside through the summer months. By comparison, Scottish sheep are typically grazed outside all year round and in some cases even lamb on the hill, making them potentially more vulnerable.

Other risk factors

There is a clear link between the proximity of grazing pastures to woodland and the frequency of attacks. A study from the French Jura found that 39% of pastures that were either adjacent or connected, via wooded extensions, to large, forested areas (over 2000ha) suffered at least one lynx attack at some point between 1995 and 1999.[10] However, only 5% of pastures that were more than 250 metres from such large forests were attacked in the same period.

This study also identified the absence of human dwellings nearby, a local abundance of roe deer and the proximity of other attacked pastures in the vicinity as further risk factors linked to an increased risk of attack. When too many of these risk factors aligned, the authors concluded that while selective removals of 'problem lynx' could temporarily reduce predation, the combination of risk factors meant that enduring relief might only be achieved through improved protection measures.[10]

A study in Sweden documented a similar trend, finding that farms that have already suffered one attack are, on average, 55 times more likely to suffer a further attack within 12 months compared to any other farm in the same area. Approximately 30% of repeat attacks occurred within one week of the initial attack and 60% occurred within the first five weeks. The authors suggested that this trend was partly explained by carnivores returning to kill sites and then making further opportunistic attacks, but also noted that this trend meant that temporary, proactive deterrents may thus be most efficaciously deployed during these relatively brief high-risk periods.[15]

Sheep in Scotland are often grazed in pastures that are adjacent to woodland, which some studies suggest exposes them to a higher risk of lynx attacks, but other studies suggest that where fencing keeps sheep out of woodland flocks suffer fewer attacks, especially where abundant wild ungulates provide lynx with their preferred choice of prey.

Which sheep, which lynx, and how often?

Lynx are most likely to kill lambs (≤1 year) and juveniles (1–2 years), but will also prey on adults, especially when lambs are absent, with some measure of seasonality in the rate of losses reported from different studies.[9] A study in the French Jura which followed nine lynx between 1995 and 1999 documented how two individuals – one male and one female – became habitual sheep killers.

Other lynx that had access to the same flocks in the same places were only occasional sheep killers, or in some cases, never killed sheep. No obvious causal factor (e.g. sex, reproductive status, physical debilitation) explained this differing individual propensity for killing livestock.[10] Nonetheless, various studies suggest that male lynx kill sheep more frequently than females.[7,16] Indeed, one study which followed 34 radio collared lynx in Norway, across six successive grazing seasons, recorded that all adult and yearling male lynx killed sheep at some point.[16] A separate Norwegian study, which followed 48 lynx between 1995 and 2011, recorded that 18/24 (75%) males and just 8/24 (33%) females killed sheep while being monitored.[7]

This male-bias in sheep predation behaviour may be explained by the possibility that males are willing to take more risks than females,[4] by the fact that they range more widely and so encounter sheep at higher rates,[17] or by a habitual difference in habitat use between male and female lynx, with some evidence that females actively avoid sheep pastures.[4] Males are also much more often responsible for multiple killing events[16], typically involving two to five sheep, with multiple kills featuring in 10% of attacks (15/154) in one study from Norway.[7] Sheep also constitute a larger part of the diet among males compared to females.[18]

The frequency with which lynx kill sheep varies enormously around Europe, with the highest losses reported in Norway followed at a distance by Switzerland[9] or, in some years, Sweden or France (see Table 1).[2] In Norway, an average of eight sheep may be killed per male lynx every 30 days in the worst affected areas at the worst affected times, but much lower rates are reported in parts of the country with fewer sheep and more wild prey.[7] A separate study from the Swiss Jura recorded similar variation, with between 0 and 12·4 attacks per lynx per 100 days, further reflecting the great variation in kill rates between the sexes and between individuals.[10]

A 1999 study suggested Norway might lose an average of 9 sheep per lynx per year[19] but more recent EU figures recorded that between 2012 and 2016 compensation was paid out in Norway for an average of 16 sheep and goats (data combined) per lynx per year.[2] However, as noted earlier, only a small number of these losses are verified, and compensation claims should

be interpreted with caution given the various ways they can either inflate or mask the true level of predation.[19] Average losses across the rest of Europe are still fewer than 2 sheep per lynx per year.[2]

How much sheep depredation might we see if lynx were reintroduced to Scotland?

It is very hard to predict the level of sheep depredation that we might experience from reintroduced lynx in Scotland. Scottish sheep are not frequently grazed within woodlands as they are in Norway and where, as a direct consequence, losses are exceptionally high. Anecdotal evidence suggests that killing fenced-in sheep is not so easy for a lynx, partly because the sudden and rapid movements of the whole flock are thought to deter hunting lynx in a manner that is not possible among sheep dispersed throughout woodland.[10] However, where Scottish sheep are grazed either in woodland or alongside it, especially in systems with little or no fencing, it is likely that lynx would kill some sheep, albeit largely opportunistically.

Scotland also has relatively high densities of natural prey compared to many countries within the Eurasian lynx's range (roe deer estimated to occur at densities of 7.4 per km^2 across the Scottish Highlands[20] compared to as low as 0.3 per km^2 in Norway[4]), which should lower the overall risk, but how this would combine with high sheep densities (which increase the risk of predation), and local or indeed temporal variations in deer density is hard to anticipate. Nonetheless, because sheep predation appears to be mostly opportunistic, at least until it develops as a habit in some individuals, any measures which can be taken to reduce the rate of accidental encounters should help to reduce losses. Indeed, there are a range of mitigation measures which can be effective in reducing sheep depredation and these will be reviewed in the next briefing pack.

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BRIEFING NOTES

LYNX TO SCOTLAND

QUERY: what options are available for managing SHEEP predation by lynx?

There are a number of ways in which conflict with lynx is managed across Europe, and with other large carnivores around the world. These encompass compensation programmes for losses, protective measures to reduce the likelihood of losses, and innovative ways to increase tolerance and promote coexistence.

1. Compensation schemes and insurance

There is no standardised compensation policy for livestock predation across Europe. Some countries, like Albania and Ukraine pay no compensation. Others, like Norway, Switzerland, Sweden and France, pay out millions (albeit, mostly for damages caused by and protection against wolves).[1] Some countries, like Poland, Czechia and Slovakia, used not to pay any compensation but, since 2018, farmers within all EU countries are supposed to be able to claim 100% reimbursement for costs linked to damages caused by protected predators like lynx through the Common Agricultural Policy (CAP). However, this does not always occur.[2]

The average annual compensation across Europe paid per animal for damages attributed to lynx from 2005-2012 was €700 (compared to €1800 for bears, €2400 for wolves and €6300 for wolverines).[1] This reflects the fact that sheep predation by lynx is not an issue in most countries. However, for those countries in which it is an issue, significant amounts are paid out annually.[3]

There are three main ways that compensation payments for damage by large carnivores are managed: ex-post payments (reimbursing losses after they occur), ex-ante payments (up-front payments, based on the assumption that carnivores will impose some level of cost), and insurance schemes.

i) Ex-post (reimbursement) schemes

Ex-post schemes are the most common method of disbursing compensation payments and are used by many countries around Europe to compensate people for damages attributed to lynx.

In most countries, losses must be verified by a game warden or other official before damages are paid (with one notable exception being the approach taken in Norway, where fewer than 10% of claimed losses are independently verified).[4] The amount paid varies between countries, with richer countries typically paying out more,[1] but in all cases tends to reflect the local market value of the animal, sometimes tweaked to reflect breeding potential and other factors relevant to its real value. Some countries also cover indirect costs such as abortion and reduced lactation, vet bills and consequential costs such as the increased labour required to manage and reduce the likelihood of future attacks. However, compensatory payments to cover indirect losses and opportunity costs are generally rare.[5]

Furthermore, while compensation for losses can reduce the financial burden of coexistence with predators, there are a number of disadvantages to ex-post style payments. A common complaint is that the system for claiming payments can be slow and overly bureaucratic. Secondly, whilst verification is commonly required to avoid fraudulent or mistaken claims, this presents challenges; it is not always trivial to definitively confirm the perpetrator of predation events, or even to find a carcass in some cases. Lynx kill with a diagnostic neck bite, and camera traps can confirm their presence if set up at carcasses, but some losses are still difficult to attribute definitively. In some Swiss cantons, losses which are not confirmed to be due to a lynx attack but for which there are reasonable grounds to suspect a lynx's involvement are eligible for 50% of the full compensation rate.

It is also important to note that ex-post compensation payments have often attracted criticism in that they can create what is recognised as a form of perverse incentive, discouraging livestock owners from taking steps to reduce the likelihood of depredation.[5,6] This can ultimately increase losses and exacerbate conflict rather than reduce it. To counteract this risk and encourage diligent livestock husbandry, some countries set compensation at below market rates, but this frequently only serves to increase resentments.

ii) Ex-ante 'conservation (upfront) schemes

An alternative approach to traditional ex-post compensation schemes is to offer payments linked specifically to the production of a desired environmental output (e.g. coexistence with lynx). Such payments have been used to encourage carnivore conservation in Mexico, where ranchers are paid if camera-traps record a jaguar, puma, ocelot, or bobcat on their land, while the Swedish government operates a performance payment scheme to maintain a stable population of lynx in Sami pastoralist rangelands.[5]

This approach works best where there is good congruency between the scale of the target species' range and the scale of the land tenure system and potential number of payment recipients. 15-20,000 Sami pastoralists live in Sweden, and under this scheme, payments are made to their villages according to the number of carnivore reproductions certified on each village's domesticated reindeer grazing land. The amount is calculated to offset all future costs imposed by these carnivores during their lifetimes. The villages manage, allocate and disburse the payments as they see fit, and the scheme appears to have been successful in promoting coexistence with lynx and wolverines, although wolves are still not tolerated.[5]

The advantage of these schemes is that they remove the issue of perverse incentives, rewarding those who take steps to protect their livestock, while avoiding the potentially complex bureaucracy and difficult verification process that ex-post payments demand. However, establishing appropriate payment rates requires an understanding of the local level of risk and so, at least in the early stages of reintroductions, a more basic ex-post compensation scheme may be more practicable.

iii) Insurance schemes

Ex-post and ex-ante compensation payments are typically supported by funding from the state, but an alternative approach that has been employed in some countries is the establishment of predator insurance schemes. Under such schemes, livestock owners typically pool their resources, all paying some small premium towards pay-outs that can be offered to individuals suffering an attack on their livestock. These funds are sometimes supported by eNGOs, ecotourism or other conservation funds, but have nonetheless often suffered from funding shortfalls and many such schemes have failed.[7]

Both compensation and insurance initiatives have achieved some successes, being credited with reducing ranchers' animosity toward wolf recovery in Yellowstone National Park and being linked to fewer lions being killed in Kenya, as well as the success of the Sami pastoralist scheme.[5] However, due to the complexities and difficulties outlined above this has not always been the case and it has also been observed that compensation payments may not actually work to improve tolerance of protected predators. Indeed, a study in Wisconsin found that people who were compensated for losses to wolves were no more tolerant of them than those who were not compensated.[8]

2. Livestock protection measures

Compensation for losses, whether paid upfront or after the event, can help offset the economic costs of coexistence with large carnivores. However, it is important not to focus on such payments as a standalone solution, but to remain focused on reducing the costs of carnivore presence as much as possible via appropriate protective measures,[5] while also periodically evaluating the effectiveness of compensation and prevention programs in an adaptive manner.[1]

A review of protection methods used for various large predators in 23 countries found that those used to prevent damage to livestock by lynx were among the most effective.[9] A separate review also concluded that non-lethal measures can be highly effective in reducing depredation of livestock by both Eurasian and Iberian lynx.[10]

The most common protective measures used against lynx are electric fences, shepherding and livestock guardian dogs, with a range of other methods used as well. Details on each of these

Livestock guardian dogs are an effective deterrent to predators like lynx.

methods are given in the Appendix at the end of this document. It should be noted that most countries in Europe also have wolf and/or bear alongside lynx and protective measures are thus often designed for these higher-conflict species, with the resultant outcome that they can also be effective for lynx.

3. Responding to predation events

i) Rapid Response Teams

Livestock protection measures can be very effective in reducing stock losses to predators but often require an investment of time as well as financial, technical and human resources. A useful measure in the immediate aftermath of predation events can be the use of so-called Rapid Response Teams. These are teams of either paid staff or volunteers that can be called upon to install temporary deterrents such as additional shepherding resources or volunteer patrols, equipped with scaring/hazing devices and mobile electric netting.

Analyses from Sweden[11] and the French Jura[12] suggest that farms that have already suffered one lynx attack are more likely to suffer further attacks, with the Swedish study documenting how 30% of repeat attacks occurred within one week of the initial attack and 60% occurred within the first five weeks. The use of Rapid Response Teams can therefore help to reduce the likelihood of such further attacks. Later, if persistent localised trouble hotspots are identified, it may be cost effective to invest in long term interventions tailored to local conditions.[13]

ii) Removal of problem lynx

When existing protections and any additional preventative measures still fail to prevent repeat attacks, a threshold may be reached at which the decision is made to remove an identified problem animal. In some circumstances, translocation to an area where the lynx is less likely to encounter livestock may be suitable, but difficulties in capturing lynx and the fact that a proven livestock killer will be unwelcome in most locations, mean that removal usually means lethal control – typically by shooting the offending lynx.

However, the removal of animals from conflict hotspots is not guaranteed to offer long term relief from further attacks.[12,14] In Switzerland, renewed attacks by a different individual were reported within a year of 50% of instances of lethal control.[15] This phenomenon is thought to be because repeat attacks tend to occur where certain landscape features – such as proximity to large

A complex suite of factors, including proximity to large forests, remoteness from human habitation and other more subtle, incompletely understood environmental elements, all likely combine to increase predation risk in a few specific locations identified as conflict hotspots.

forested areas – make attacks more likely, although relatively little is still known about what makes some areas so problematic.[14] What is known is that when such areas exist, even if one animal is removed another will soon come in to fill the void, such that the only long term solution becomes an increase in protective measures.[12,14]

The key question with lynx removal is where to set the threshold beyond which further attacks trigger a lethal response, not least because the premature removal of an animal after a small number of opportunistic attacks may exacerbate a local conflict if that individual is quickly replaced by an animal that may then go on to become a habitual stock killer. The removal of individual lynx can also have an impact on the population, especially if that population is small or lacking genetic diversity.

In Switzerland, a lynx can only be removed if at least 15 sheep are confirmed to have been killed by a lynx (albeit potentially in fewer than 15 attacks) in less than 12 months and within a 5km radius. Alternatively, lynx removal may be sanctioned when separate sheep predation events fall outside of that radius, if at least 15 fatal attacks can be linked to the identity of a specific lynx

(normally established by camera trap photographs set up at carcasses). If there have been attacks by lynx the previous year, this threshold is reduced to 12 sheep. Additionally, before a lynx can be removed, three key criteria must be met:

i) Authorities must be satisfied that removal is the only option and no other solution (e.g. implementation of further protective measures) exists.
ii) The lynx's removal must not threaten the health or viability of the national lynx population.
iii) Reasonable attempts must have been made to protect livestock from attack.

This balance between protecting the viability of a newly reintroduced, vulnerable population alongside the threat to the entire reintroduction programme if habitual livestock killers were not removed is something that would need to be given careful consideration in any potential reintroduction of lynx to Scotland.

4. Increasing the value of lynx

One of the best ways to promote coexistence is to shift the cost-benefit equation by increasing access to financial benefits among those suffering the greatest costs from coexistence.[5] Lynx tourism may offer some landowners a way to offset some of the costs incurred, with lynx tourism continuing to generate significant local revenues in Germany's Harz Mountains since the lynx's reintroduction in this area.[16]

Alternatively, for smaller farmers and crofters who are either unable or uninterested in accessing the tourist market directly, predator-friendly certification may allow producers to charge a premium for their product, be it meat or wool. Exciting precedents already exist for such enterprises, from wool shoes made with wool sourced from producers coexisting with Iberian wolves,[17] to the fledgling markets for predator-friendly meat[18] and biodiversity credits, akin to the more established market for carbon credits. More novel approaches to funding coexistence include projects such as Colorado's Wolf Plate (an annual subscription service for a number plate emblazoned with 'Born To Be Wild') which raised over $300,000 within six months of its launch, with the funds exclusively dedicated to supporting conflict reduction.[19]

However, some farming representatives have voiced doubt over consumers' willingness to pay for environmental goods,[18,20] and predator friendly certification schemes can be challenging to implement and sustain.[21] Others have expressed concerns that tourism revenue could be site specific, or that the novelty could wear off (although fifty years of sea eagle tourism on Mull

suggests this is unlikely), or simply that such diversification distracts from farming or involves too much risk for farmers.[2]

Money isn't the only issue

Reintroductions of apex predators are nearly always complex, costly and contested endeavours.[20] Many agricultural stakeholders also remain sceptical about the effectiveness, labour burden and financial cost of potential conflict mitigation and management tools, while additional concerns are sometimes raised about the role and ability of governments to manage reintroductions.[20] Achieving public support for such an endeavour therefore depends most critically on nurturing a sense of fairness for all affected parties and avoiding feelings of disempowerment.

Planning fair and effective measures for co-existence before conflict species are reintroduced rather than reacting after the event is recognised as being critical for the success of any reintroduction programme.[22] While there is no one-size-fits-all solution to all the problems that large predators pose, there are instead a complex mix of protective measures, conflict mitigation strategies, innovative funding streams and various compensation programmes. These tools can and do work but are always best when they are adapted to local circumstances, and when their design and implementation has been informed by consultation with those most affected.

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APPENDIX

Mitigation Methods Factsheet 1 – Herding & Livestock Guardian dogs

Herding, further reinforced by the use of guard dogs, is an age-old method to protect livestock from carnivores, including lynx. It is widely practiced throughout Asia and in Eastern and Southern Europe, but it is also undergoing a revival in Western Europe in response to the recovery of regional carnivore populations, although its economic practicality is debatable in areas where lynx-induced damage is limited. Livestock guardian dogs (LGDs) protect livestock from large carnivores, albeit mostly from larger carnivores than lynx, since lynx are rarely considered enough of a threat to justify the effort and expense of maintaining LGDs.

LGDs can provide protection in remote areas, or in areas with limited shepherding supervision. They can be highly effective and require minimal maintenance once in place but can be costly to train and/or purchase, and to then maintain/feed. There is also some risk of conflict with walkers and their dogs. LGDs live with the livestock they protect. Puppies are often raised with the herd which represent their pack. They deter carnivores by frequently urinating and barking to mark their territory and chase off any animal that approaches. In some areas LGDs remain with a flock that is free roaming. However, optimal protection is achieved when the flock is contained at night (with low electric netting for example, see factsheet 3).

LGDs should not be aggressive towards people if they are properly socialised and trained (Photo: D. Brady)

It is recommended that LGDs do not work alone and should be kept in pairs or larger groups. Like any other dog LGDs need to be fed daily and have regular vet checks. When protecting flocks in remote areas they should be accompanied by a shepherd. When LGDs are left alone and not fed they can become a problem for wildlife and even sometimes prey on sheep.

Conflict is reported in some touristic areas between people and LGDs. For example,

dogs may harass hikers, joggers, and mountain bikers. Attacks from LGDs usually involve biting incidents. However, with formal training and socialising LGDs should not be aggressive towards people. Visits to breeders in Slovenia and France revealed that LGDs can be friendly and easy to handle.

LGDs must be sourced from a responsible breeder to ensure they have been appropriately trained. A responsible breeder will ensure any LGD is able to develop its strong pack instinct whilst being adequately socialised and will consider each dog's individual characteristics when pairing them.

"LGDs are the best protection method and not only protect from large carnivores but also other dogs and foxes. Their primary purpose is to protect the flock overnight when the risk is higher. It is very important to socialise them to prevent issues with walkers as much as possible, but one should also remember that there will always be bad dogs." Sheep farmer and LGD breeder, France

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Mitigation Methods Factsheet 2 – Permanent Fencing

Several types of permanent fencing can be used to protect livestock, keeping lynx out or penning livestock in (e.g. to keep livestock away from high-risk woodland areas), with this approach used in France, Germany and Slovenia. Smaller enclosures can be built to protect animals at night, while larger fenced areas can be designed to contain and/or protect animals at all times. These larger enclosures can also be divided into smaller areas with electric tape or netting to help manage rotational grazing. Covered enclosures such as stalls and sheds are also used to protect animals at sensitive times such as during the lambing season.

Permanent protection enclosures are usually designed with stock fencing and electrified wires. The first electrified wire should be quite close to the ground and the stock fencing should be secured to the ground, or even buried with a small underlap towards the exterior of the fenced area, to keep carnivores from digging under. A second electrified wire may be added at about 1m high. Wires can also be added above the stock fencing to prevent animals from jumping or climbing over the fence, but overhanging vegetation must be removed in these cases. It is recommended that the enclosure fencing should be at least 140-170cm high and dug into or secured to the ground, and with at least 5-7kV.

Existing deer enclosures can be improved with the addition of electrified wires at the top to prevent lynx climbing in. In all cases, permanent fencing is a costly measure, demanding significant time and investment to install, but it can be an effective and long-lasting solution to predator attacks.

A permanent enclosure in France (Photo: C. Munro)

"If it's possible to install a permanent enclosure, it is one of the best protection methods. After predations on our sheep, we decided to build a permanent fence in 2010. It was a big investment, but we haven't had any problems since, and others are coming to us for advice. A fence with an electrified offset at the top is ideal to prevent lynx climbing in." Sheep farmer, France, who built a 12km fence, electrified and 130/140cm high, around their property.

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Mitigation Methods Factsheet 3 – High Electric Netting

High electric netting is useful to create temporary or permanent enclosures. Unlike low electric netting, it is used to both contain livestock and keep carnivores out. It is easy to set up, is mobile and adaptable, and can be especially useful as an emergency solution after a predation event. As the netting is flexible it is useful for areas that are difficult to fence such as hillsides, although installation can still be challenging in certain terrains. It is highly visible to both livestock and wildlife, and is convenient as it can be regularly moved to prevent overgrazing in one area.

The perimeter should not exceed 500m to maintain a sufficient electrical current, so this netting is most useful for enclosing smaller flocks or to create night-time enclosures. It is also recommended that the perimeter should not be less than 300m to allow space for livestock to flee if they become agitated during a predation attempt, to prevent trampling of the netting.

The netting must be properly installed ensuring there are no gaps underneath or where ends meet. It needs to be inspected regularly to insure nothing is touching it, and grass under and around it must be kept short. Batteries or solar panels must be connected and in good working order.

High electric netting (Photo: D. Brady)

High netting is principally used to prevent predation from other large carnivores but it is considered effective against lynx. The recommended height is minimum 170cm as predators can jump over lower fences. Lynx usually climb rather than jump but are unable to pass this type of fence as long as no trees overhang into the pasture.

"I have not suffered any damages since using this type of fence." Cattle farmer, Slovenia, using a 140 cm high electric netting as a night enclosure.

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Mitigation Methods Factsheet 4 – Low Electric Netting

Low electric netting is mostly used to contain livestock and restrict their movements rather than to keep carnivores out. When fences are designed to keep animals inside but do not properly prevent the intrusion of carnivores from the outside, they can be ineffective and may even provoke surplus killing. The aim can be to keep livestock away from high-risk areas such as woodland or to facilitate their protection with other mitigation methods such as livestock guardian dogs (LGDs) or volunteers.

The netting comes in 50m lengths that can be joined together to create larger enclosures. It is light and relatively easy to transport even to remote areas. It can be powered by a 12V battery or solar panel with an energiser to achieve a recommended voltage of 3000-5000V. It is quickly set up by a single person and easily repaired making it ideal for temporary night enclosures.

It is important to ensure that the netting is straight and taut to prevent it from collapsing easily if livestock push against it. It should also be set up on short grass and maintained to ensure the electrical current is sufficient.

This type of netting is widely used to create night enclosures in mountain pastures to prevent large carnivore predation. A shepherd is often responsible for bringing the sheep back in at night and LGDs are usually present with the flock. Audio-visual deterrents can also be placed outside the enclosure. The netting is used to restrict the livestock's movements and prevent them from dispersing if a carnivore approaches, helping the LGDs to protect the flock. Additional human presence in the form of volunteers is sometimes used. They would usually set up camp either inside or next to the enclosure, and are able to easily patrol the fence line or respond in case of an incident.

"Nets are useful to delimit pastures and ensure sheep remain in a chosen area. They can also be unhelpful if some sheep find a way out or get stuck in them therefore they do not replace the work of a shepherd"
Shepherd, Switzerland

Low electric netting creating a small enclosure (Photo: Stiftung Nature und Umwelt)

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Mitigation Methods Factsheet 5 – Shepherding

Human presence is one of the most efficacious methods to protect livestock from carnivores and fully attendant shepherding – whereby a shepherd or herder maintains a constant watch on livestock, at least during the day – is still practised around the world. As well as providing protection simply by being present, shepherds can respond quickly if a problem arises. They can identify an injured sheep in need of attention and provide necessary care.

Around Europe, livestock are commonly grazed in pastures during the day and shepherds are responsible for bringing the sheep back to a protected area for the night, where they can easily set up a temporary night enclosure with low electric netting. Additional protection methods are often used overnight such as audio-visual deterrents and livestock guardian dogs. Shepherds may also sleep nearby and can respond quickly if a predation attempt takes place during the night. A livestock owner may act as the shepherd or, more often in Europe, livestock owners employ a shepherd. In some cases, flocks from several owners are brought together and looked after by one shepherd. In Europe, shepherding is usually a seasonal activity; the livestock remains on the owners' property during the winter months and goes out to mountain pastures with the shepherd from spring to autumn.

Although such shepherding makes a high demand on time and resources, making it less cost effective for smaller flocks, it is highly effective as a carnivore deterrent. Additionally, employing shepherds can have socioeconomic and ecological benefits, improve livestock welfare, and have a positive impact on the pastures and wider biodiversity by managing grazing pressure. When looking after large flocks of sheep, a shepherd's hand, a citizen on national service (e.g. Switzerland) or volunteer can also be employed to assist the shepherd in daily activities and reinforce the human presence.

A shepherd regroups sheep in a night enclosure in the Alps (Photo: B. Morel)

"The enhanced shepherding was very

useful and had wider benefits including helping stimulate discussion about the use of different flock management strategies and consideration of the aims and objectives for the flock going forward. The support helped the Sheep Stock Club employ a part time shepherd and having an experienced, enthusiastic, young person take on this responsibility has made a significant difference." Scottish Crofting Federation Director and Clerk of Kingsburgh Sheep Stock Club commenting on the Enhanced Shepherding Programme for white-tailed eagles on the Isle of Skye

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Mitigation Methods Factsheet 6 – Visual & Acoustic Deterrents

Visual and acoustic deterrents can be used to deter carnivores by mimicking human presence, including items specifically designed for this purpose, but a simple radio or a device playing noise such as podcasts can also be used. The more variety in sound and lighting, the more efficient it will be in deterring predators and preventing habituation.

Foxlights contain 9 LEDs emitting yellow and blue light flashes in random patterns, used around the world to deter a wide range of carnivores. A light sensor automatically turns them on between sunset and sunrise. Light flashes are projected at 360 degrees and are visible from 2km. A range of features make them ready to clip onto a wire fence, hook onto a metal post, or hang from a tree, making them quick and easy to install, and they should be moved regularly to prevent habituation. They are wireless and can be battery (6V) or solar powered.

Critter Gitters are wireless audio-visual repellents used mostly in the USA to deter a wide range of carnivores. They are small battery-powered (9V) devices activated by infrared and motion detectors. When they detect an animal within a 90 degree radius, up to 12m away, they emit a high pitched sound and a series of light flashes. They are available as waterproof units and additional casings can be bought to protect them. Similar devices activated by motion sensors such as Margo Gadfly and Guard Alarms are also available.

More intricate devices are used by researchers and US Wildlife Services. Guard boxes contain a solar powered battery, strobe lights, and can play over 30 different sounds which are triggered randomly. They can be motion or radio activated. Radio-activated guard (RAG) boxes are triggered when a radio-collared animal is detected within a ±300m radius. Some designs also include a text alert function that informs the owner if the system is triggered.

Radio-activated guard box (Photo: USDA-APHIS Wildlife Services)

"Foxlights cause a visual disturbance and are a good add on to other protection methods but should not be used on their own."
Sheep farmer, France

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Mitigation Methods Factsheet 7 – Protective Livestock Collars

Livestock protection collars create a barrier around an animal's neck, protecting them from carnivores that kill their prey by a strong bite to the neck. King collars were developed in the 1990s by South African farmers to protect their sheep from jackals. They have proved effective to reduce predation from carnivores in both South Africa and the USA.

Livestock protection collars are available in two sizes (lambs 1 to 6 weeks and sheep 6 weeks to 18 months) that can be further adjusted to fit individual animals. They need to be adjusted as the animals grow: at least every 3 weeks for lambs and every 3 months for weaned lambs. Collars can be fitted and removed in less than a minute. The collars do not interfere with grazing or suckling as long as the collar fits correctly.

Collars have been used in Norway since 1992 to protect lambs specifically from lynx. Several designs of the collars have been developed over the years. The first collars were made of nylon material with elastic at the back. They were improved to include Velcro to allow for adjustments as the lambs grows. Other versions are made of plastic, metal, or fitted with a bell. There have been issues with some of the collars where lambs got caught on bushes or got their legs stuck in the collars. The metal and bell collars have had the fewest problems and a significant decrease in lynx predation has been observed where they have been used. To reduce the risk of injury to the lamb it is recommended that the lamb should weigh at least 10kg (3-4 weeks old?) when fitting the first collar.

CALs (Collier Anti-Loup) have also recently been developed in France to emit flashes and ultrasonic sounds. They have proven very successful in reducing wolf predation in trials in France and Germany.

Left: King collars on sheep (Photo: L. King)
Below: Nylon collar; Metal collar; Plastic collar; Bell collar (Photo: Bioforsk)

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Mitigation Methods Factsheet 8 – Volunteer Guardians

Volunteer programmes started in the 1990s across Europe, focused on improving coexistence with large carnivores by supporting livestock farmers. Several new programmes have been created in recent years as large carnivores have been recolonising much of Europe. There are 2 main ways in which volunteers can help: work parties and surveillance.

i. Work parties can involve building new permanent enclosures, renovating/improving existing fencing, renovating/building shelters in mountain pastures, or clearing vegetation to ensure electric fencing is working correctly or to improve visibility. It is particularly helpful in areas where protection methods are funded but labour is not.

ii. Livestock surveillance often takes place in mountain pastures where livestock is supervised by a shepherd during the day, but additional surveillance is needed overnight. Depending on the organisation, volunteers set up a tent or shelter in or just outside a night enclosure and are asked to keep watch overnight or to undertake an animal check every few hours and make their presence known to carnivores. Some projects provide volunteers with night vision equipment and scare/hazing devices. In some cases, volunteers can also be more involved in the day-to-day tasks, such as care of the livestock and set up of enclosures.

Many organisations provide training for their volunteers. A range of subjects are covered such as biology and behaviour of the large carnivores, conservation and management context, introduction to a range of protection measures, diagnosing an issue with an electric fence, interacting with livestock guardian dogs, scare techniques in the event of a predation attempt, first aid training and mountain safety. These training events offer the opportunity to meet livestock owners, hear about their experience, and build an understanding of farming practices. OPPAL, a non-profit organisation that focuses on improving coexistence between wildlife

and humans, supported 55 Swiss livestock owners in 2023 with the help of 360 volunteers. No predation took place on these pastures, despite approximately 35 predation attempts by wolves.

"We have too few sheep to justify having a shepherd, and as they are kept in parcs, we only need a surveillance overnight. We had an assessment done for guardian dogs, but it would have been too complicated especially as the area is very busy. So, I contacted OPPAL as soon as I heard about the programme after predations happened in the neighbouring pastures. Volunteers are the most effective method." Sheep farmer, Switzerland

Supporting resources

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Mitigation Methods Factsheet 9 – Other Guardian Animals

Studies have found both alpacas and llamas to be very effective in reducing lamb losses to foxes, coyotes and dogs in Australia and the USA, while a handful of anecdotal reports suggest they have reduced lamb losses to foxes in the UK. Little is known concerning their efficacy against larger carnivores and no scientific study has yet tested their utility with respect to lynx. However, a pilot study in Swiss alpine pastures yielded promising results.

About 35 farms in Switzerland now use llamas to protect sheep or goats against lynx, foxes, single wolves or stray dogs. Since the start of this pilot project in 2012, there has been no reported damage by lynx to flocks protected by llamas under recommended conditions, even though the majority of them are in regions with confirmed lynx presence and, in some cases, there were losses before the arrival of guard llamas. There are also no officially recorded cases of foxes or stray dogs causing damage, suggesting that llamas could be a viable alternative to more costly prevention measures.

Some sheep and goats are frightened by dogs but will accept a llama in their field. Llamas also do not need to be trained to guard sheep. Instead, their protective effect is based on a natural aversion to unknown intruders, especially canines. Llamas form social bonds with other species and, as they stay near them, are able to defend them from predators by biting, kicking, screaming, spitting and/or chasing them away, with this protective behaviour useful against small predators and in situations where predators do not attack in groups.

Although either females or males can make a good guardian, gelded males are most commonly used because they are larger and less expensive than females and safer than intact males. One guard llama may be kept with as few as four sheep or as many as 2,100, although two llamas may be optimal, complementing each other by maintaining more consistent vigilance and better 360-degree awareness. However, with more than two, they may lose interest in the livestock they are meant to be protecting. They do not necessarily need any experience

Llamas have a natural aversion to unknown intruders, and trials in Switzerland suggest they may offer an effective alternative to livestock guardian dogs for protecting sheep against lynx.

with sheep before being introduced into a flock, with an initial adjustment period of as little as a few hours (for 50% of llamas) and nearly 80% being adjusted within a week. Many producers rate their guard llama's ability to reduce predation losses of their sheep as "very effective" or "effective." In a study in the US, however, all producers, however, report continuing to use other preventative and control methods in addition to the llamas.

Alpacas and llamas are very efficient grazers and do well on poor pasture, requiring no supplementary feeding beyond access to hay. They require shearing once a year, toenail clipping three times a year and deworming and vaccinating twice a year. Llamas have a calm temperament and may appear less threatening than a large guardian dog. However, llamas do need to be handled and socialized with people or adult llamas can become dangerous. An experienced guard llama will provide immediate predator control and can have a long working life, since their lifespan is 20 to 25 years. However, not all llamas are peaceful flock companions. Some llamas will injure or harass livestock and they may interfere with the birthing process. Other llamas do not adjust to living without other llamas or will live apart from their stock. They may need shelters in bad weather, and cannot use hard salt or mineral blocks, requiring an appropriate loose salt or mineral mix. They need copper in their mineral mix, which may be toxic to sheep.

Supporting resources

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QUERY: what benefits and opportunities are lynx likely to generate in Scotland?

Summary

Lynx reintroduction offers ecological and socioeconomic benefits, as well as an invaluable contribution to our experience of nature. Lynx could help reduce deer densities, potentially lowering the cost of management efforts and reducing some of the negative impacts associated with high deer densities. Lynx would also help revitalise many natural processes, increasing the availability of large carcasses in the landscape, re-energising nutrient cycles and boosting biodiversity, while the lynx's suppression of fox numbers and/or influence on fox behaviour (e.g. dietary shifts) could ease pressure on species like capercaillie, black grouse and mountain hares. Separately, lynx would create a tourist attraction, creating opportunities for lynx-friendly businesses. The economic boost this generates could be amplified with the development of lynx trails and other lynx-themed attractions, helping to keep Scotland an attractive destination for domestic and international tourists. Reintroducing lynx would also represent a profound statement of Scotland's commitment to biodiversity restoration, encouraging hope that nature loss can be reversed and that we can begin to match the efforts of other European countries in returning a large carnivore to live alongside us, reconnecting more of us with the wonders of wild nature and inspiring renewed pride in Scotland's natural heritage.

Reducing deer numbers

Eurasian lynx, henceforth referred to as lynx, are specialist hunters of roe deer and have sometimes contributed – in combination with other pressures – to local declines in roe deer density.[1,2] Lynx predation has also been linked to reductions in roe deer population growth rates and the size of some populations,[3] offering a potential reduction in the costs associated with high deer densities.

At high densities, deer can reduce crop yields, harm commercial forestry interests, impair natural woodland regeneration and reduce biodiversity, while also acting as a reservoir of disease and causing vehicle collisions.[4] One benefit of lynx predation on deer could therefore be to reduce the extent and cost of these various impacts in Scotland. However, because the relationship between the extent of these harms and deer density is nonlinear, lynx predation may achieve limited reduction in deer impacts unless and until deer numbers are reduced below certain thresholds.[4]

Nonetheless, at the very least, lynx are likely to usefully complement human deer management.[5] Indeed, the potential for lynx to help control deer in areas that cannot easily be managed by humans was identified by forestry professionals in the Vincent Wildlife Trust study as a significant likely benefit of lynx reintroduction.[6,7] Lynx also select deer differently to human hunters, showing little selectivity for either the age class or sex of hunted roe deer,[3] and thus have a different influence on which deer are killed and when, with correspondingly different ecological impacts.[5]

Restoring natural processes

The risk of predation can trigger behavioural changes in prey species like deer with what are often termed 'landscape of fear' effects. A study in the Swiss Bernese Oberland showed that roe deer avoided areas with a particularly high lynx predation risk,[8] while another study in the same area showed that female chamois spent more time closer to rocky areas (which they may traverse better than lynx) and were more alert when lynx were present.[9] However, in Norway, roe deer show no apparent avoidance of habitats associated with high lynx predation risk and recolonization by lynx has had little impact on roe deer habitat selection.[10]

Where temporal or spatial shifts in ungulate distributions are manifested by predation pressure or the threat of it, improved natural regeneration of certain tree species may occur due to reductions in browsing pressure. This was classically reported in Yellowstone,[11] but such an effect has also been linked to lynx recovery in Switzerland,[1] with the potential benefits of lynx-mediated woodland regeneration including mitigating climate change, reducing flood risk from upland catchments and enriching biodiversity.

Lynx would also increase the year-round supply of large carcasses in the environment, with large carcasses having become a scarce resource in most Scottish habitats. Restoring the availability of such carcasses would revitalise missing natural processes including nutrient cycling. Indeed, recent research suggests that the removal of deer carcasses from the Scottish uplands is stripping the environment of vast quantities of key nutrients, with predator reintroduction suggested as one solution to this problem (the others being that more deer are allowed to starve or that more culled carcasses are left on the hill).[12]

The carcasses generated by lynx also have the potential to support a wealth of biodiversity, from specialist invertebrates to opportunistic avian and mammalian scavengers. Large carcasses can even promote localised woodland regeneration, with saplings benefiting from both the heavy trampling of understory vegetation around a carcass and the pulse of nutrients released following carcass decomposition.[13]

A boost for biodiversity

Lynx regularly kill red foxes,[14] with lynx predation linked to a decline in fox abundance in Scandinavia.[15,16] Such top-down regulation of smaller carnivores by lynx is not universally reported, with no equivalent reduction in fox density seen in Switzerland (seemingly because the underlying productivity of the Swiss landscape supports so many foxes that the lynx's impact on their numbers is insignificant). However, in Scandinavia, where lynx have manifested reductions in fox densities in environments very similar to the Scottish Highlands, it has had knock on benefits for a variety of species.

For example, data from Finland and Sweden reveal that mountain hares,[17] capercaillie[18] and black grouse[18] all enjoyed population increases after regional recolonisation by lynx – thought to be driven by the lynx's suppression of foxes.[16] Furthermore, these benefits are not necessarily dependent on lynx reducing the absolute numbers of foxes, with a shift in fox diet following lynx recolonization also linked to reduced predation pressure on these species. Indeed, the proportion of (scavenged) venison in foxes' diets increased following the return of lynx to southern Sweden, rising to account for half of the food consumed by foxes in winter, even as local roe deer densities fell.[14]

Such an effect may help naturally replicate the results of a recent experiment in Scotland which showed that maintaining a supply of by-products from deer culling operations in the woodland environment led to a reduction in the depredation rate suffered by eggs set in artificial nests, largely thanks to a reduction in nest predation by pine martens and badgers.[19] This suggests that deer carcasses provided by lynx could improve capercaillie nest survival and so boost breeding success, the current lack of which remains a key impediment to capercaillie recovery in Scotland.

Lynx with tourism

Lynx are usually difficult to see but that appears to do little to limit their potential as a tourist attraction. After all, 'Nessie' might generously be described as extremely cryptic but attracts huge and sustained interest from tourists. And unlike Nessie, lynx regularly leave real signs of their presence which can generate thrills almost equal to an actual sighting, as evidenced by testimony from a visitor to the Harz Mountains.

"A few years ago, in winter, I found my first lynx tracks. It was so exciting finding the tracks of this animal that lives so hidden in the woods of the Harz. Since then, I have been following the tracks of lynx and once found a kill and scat of the cat. Once you learn to recognize the tracks and signs of the lynx, you gain insight into the life and behaviour of this beautiful animal. The presence of lynx and also the wildcat make the Harz very special to me. Knowing that these animals are there and maybe watching me is a great feeling."[20]

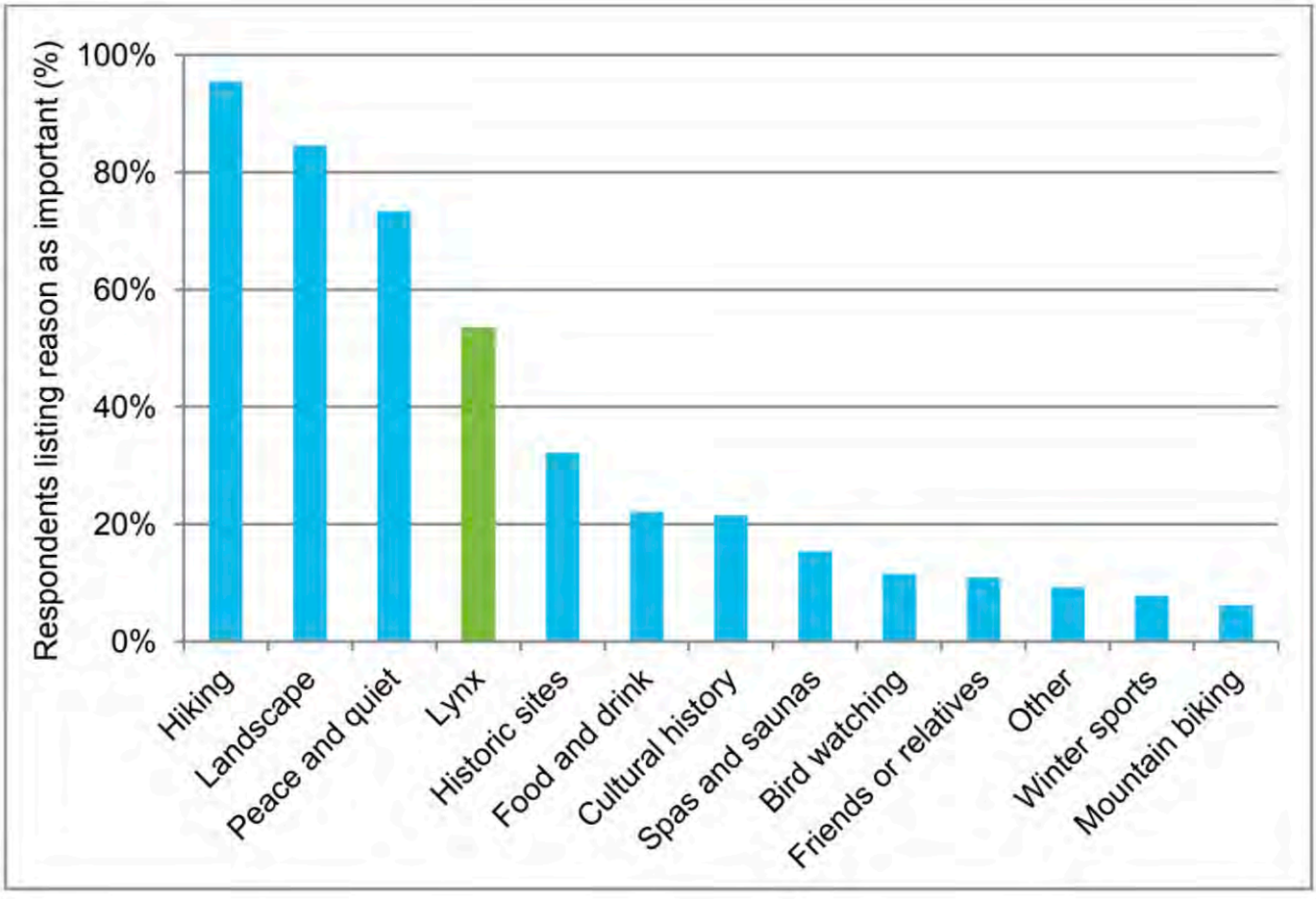
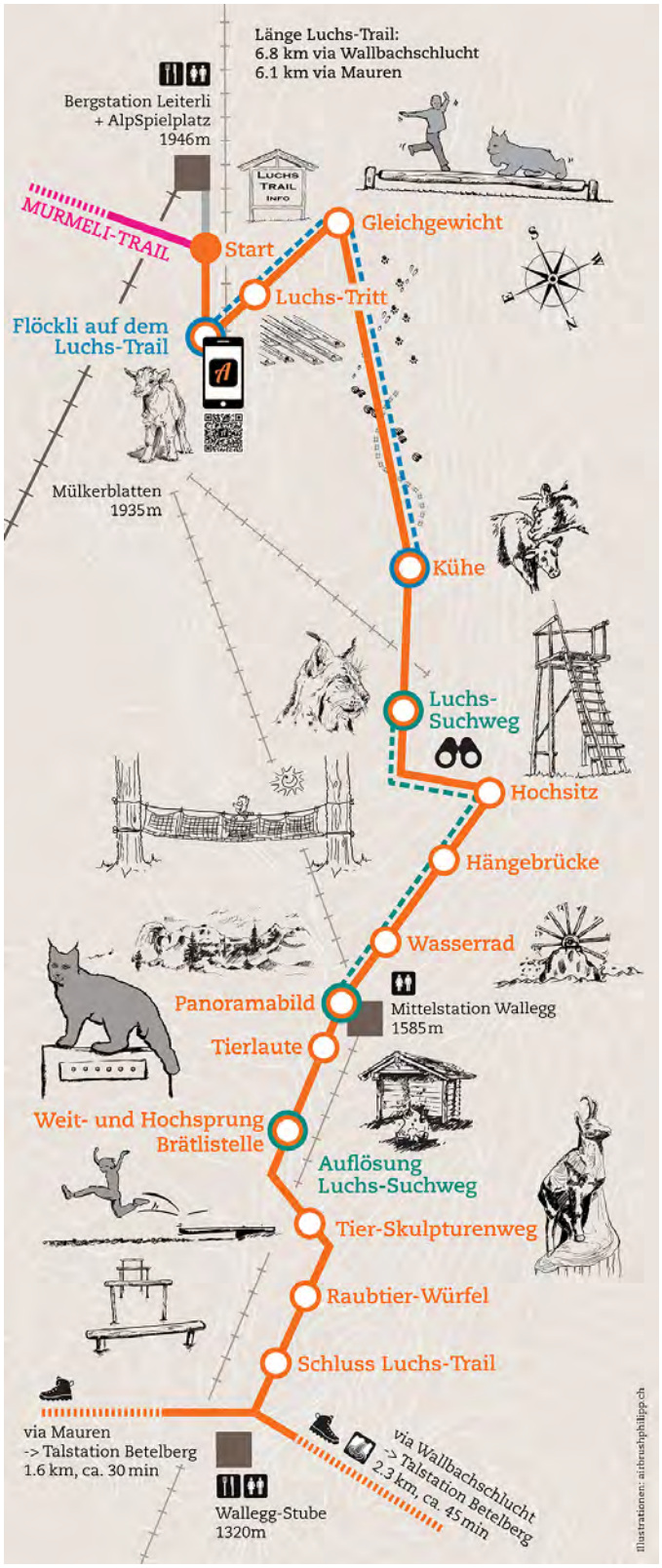


Figure 1: Factors identified by visitors as motivations for their visit to the Harz Mountains.[20]

Lynx were reintroduced to the Harz Mountains in 1999 and were identified as an important factor influencing the decision to visit the area by just over half of surveyed visitors in 2016 (49.3% of visitors listed lynx as one of the main reasons motivating their visit, while 1 in 25 listed lynx as the main reason).[20] Based on these survey results it has been calculated that, in total, lynx generate between £7.5M and £12.5M of tourist spend in the Harz Mountains every year.[20]

Around 12% of the visitors who identified lynx as an important factor in their decision to visit the Harz Mountains said that they would have been less likely to visit the area if they had known they were unlikely to see a wild lynx. To counteract this concern, an enclosure has been constructed which allows visitors to view captive lynx from a platform.[20] A similar experience could easily be imagined at the Highland Wildlife Park at Kingussie, where lynx can already be seen, with interest likely to increase alongside the return of wild lynx nearby.

The village of Bad Harzburg on the southern edge of the Harz National Park has branded itself as a lynx tourist destination with lynx statues, images, memorabilia, and recreational activities widely promoted alongside a number of lynx-themed hiking trails.[20]



The lynx trail at Lenk in Switzerland (featuring lynx-based activities – balance like a lynx etc. – replicas of lynx and their prey, all supported by a guided App).

Lynx-themed trails have been set up in countries around Europe, including in the Harz Mountains and in the Black Forest at Baden-Baden in Germany (the latter featuring an interactive trail with information boards and a visitor centre).[21] There is also a lynx trail at Lenk in Switzerland (featuring lynx-based activities – balance like a lynx etc. – replicas of lynx and their prey together with a guided App)[22], two different lynx trails in Kocevje, Slovenia (featuring information boards, games and an accompanying booklet and online lessons for kids)[23] and a lynx trail at Tarvisio in Italy (featuring life-size cutouts placed along the trail).[24]

A more unconventional form of tourism could also be developed around the business of protecting livestock from predation, with the Organisation Pour la Protection des Alpage (OPPAL) one example of an organisation attracting volunteers for this purpose.[25] OPPAL is funded by donations and the support of various philanthropic organisations, conservation charities and foundations, but the experience of Trees for Life and other UK-based conservation charities shows that volunteers are willing to pay for working holidays in which they feel they can contribute to a conservation cause,[26] creating the conditions under which longer term volunteers and dedicated rangers might be funded sustainably through the less popular times of year.

Wildlife tourism in Scotland

Scotland's landscapes, wildlife and outdoor activities are consistently listed among the top reasons for tourists to visit. The nature-based tourism sector is also one of Scotland's fastest growing sectors, with 'activity and adventure' tourism worth £759M to the Scottish economy, accounting for nearly 40% of tourism spending in Scotland[27] and supporting nearly 40,000 full time equivalent jobs.[28] Wildlife tourists typically spend more per head and contribute to the overall tourist economy by combining wildlife-watching trips with other touristic activities, supporting a wealth of hospitality businesses.[29]

On Mull alone, data from 2019 recorded that a quarter of visitors cited sea eagles as one of the reasons motivating their visit, while an additional 3.5% cited it as the main reason, even half a century after sea eagles were first reintroduced to Scotland, demonstrating the longevity of their appeal. These visitors contribute a conservatively estimated minimum of £4.9M per year to the Mull economy, supporting between 98 and 160 full-time equivalent jobs.[30] Elsewhere, bottlenose dolphin watching in the Moray Firth generates at least £4M for the local economy each year, with dolphin watching identified as a 'significant reason' for 52,200 overnight visitors a year, and with over 17,000 of these visitors identifying dolphin-watching as the 'main reason' for visiting.[29]

However, the sector also faces challenges, including competition from foreign holidays and the enduring seasonality of Scottish tourism. Lynx could help boost interest in Scottish wildlife (around twice as many people cited lynx as an attraction drawing them to the Harz Mountains compared to the proportion who listed white-tailed eagles as an important reason for their visit to Mull)[20,30] and lynx could provide a year-round attraction, with the chance of seeing lynx potentially better in the winter months (without so much leaf cover) and the possibility of tracking lynx also best in muddy or snowy conditions.

Importantly, tourism creates its own challenges and care would need to be taken that lynx tourism did not exacerbate pressure on those communities for whom tourism already generates significant costs as well as benefits. Equally, it is important to remember that the benefits of large carnivore tourism rarely accrue to those suffering the greatest costs of coexistence with such species. Accordingly, means would need to be sought to redirect some of the profits of lynx-related tourism to those bearing these costs, either through support for lynx-friendly farm-based enterprises, or perhaps through some form of targeted tourist levy dedicated to funding coexistence with lynx.

Intrinsic value

Full consideration of the potential benefits of a lynx reintroduction demands consideration of the lynx's intrinsic value and those beneficial effects linked purely to the lynx's existence should it complete its return to Scotland. Such value is largely derived from the pleasure and joy people take in the survival of wild things, rather than any utilitarian function the lynx may serve in terms of ecological or economic terms.

This worth is sometimes framed as an animal's 'existence value' and quantified according to how much people say they would be prepared to pay to support its continued existence, either as a one-off payment or as an annual donation, even if they are unlikely to ever encounter the animal in the wild. Such valuations are subject to significant uncertainties – due to the inherent challenge in placing a monetary value on what is often considered invaluable – but the sums are nonetheless often significant. For example, in the case of the lynx, it has been estimated that a reintroduced lynx population in Northern England would be valued by pro-lynx households at around £14M.[20]

Furthermore, the prospect of reintroducing lynx to Scotland offers many people much more than a crudely monetised existence value. Reintroducing lynx promises an opportunity to encourage more people to rekindle their interest in nearby nature, reconnecting people with the wonder that wildness can inspire. More profoundly, the reintroduction of the lynx would reverse a human-caused extinction, righting a historical wrong and encouraging hope that ecological impoverishment can be reversed.

The return of the lynx would also offer Scotland's citizens an opportunity to experience the awe and excitement that can only be felt when sharing a landscape with such a charismatic predator, to walk in woods that feel perceptibly wilder for the presence of an apex predator. It may be difficult to quantify such intangible experiences, or to directly measure their impact on quality of life and wellbeing, but for many people, they are worth a very great deal, making the benefit of a lynx comeback far greater than the sum of its ecological and economic impacts alone.[31]

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