AECOM

COST-BENEFIT ANALYSIS FOR THE REINTRODUCTION OF LYNX TO THE UK:

MAIN REPORT

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PREPARED FOR: LYNX UK TRUST

CONTENTS

Prepared by: Chris White, Senior Environmental Economist, AECOM
chris.x.white@aecom.com

Checked by: Adam Eagle (Clifford Chance), Darrell Smith (University of Cumbria), Erwin van Maanen (Rewilding Foundation), Ian Convery (University of Cumbria), Paul O'Donoghue (Lynx UK Trust), Petrina Rowcroft (AECOM), and Steve Piper (Lynx UK Trust).

Approved by: Petrina Rowcroft, Associate Director, AECOM

Photography by: Erin van Maanen (Rewilding Foundation)

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INTRODUCTION

01

INTRODUCTION

Context

The EU Habitats Directive requires Member States to assess the potential and desirability of reintroducing species which have been lost, and to look at other Member States' experiences to support such assessments. In light of these requirements, the Lynx UK Trust is proposing to undertake a trial reintroduction programme of Eurasian lynx (*Lynx lynx*) at several potential sites in the UK.

As part of the preparation for any translocation or reintroduction programme, guidelines prepared by the International Union for Conservation of Nature (IUCN) state that an assessment of the anticipated costs and benefits of a reintroduction should be incorporated into planning for such programmes.[1]

On the basis of these guidelines, AECOM have been asked by the Lynx UK Trust to undertake an impartial and independent analysis of the potential economic costs and benefits to the proposed lynx reintroduction scheme in the UK based on a combination of modelling and data collected from European lynx studies.

The analysis draws on the guidance for undertaking cost-benefit analysis set out by the UK government. In particular, it follows the framework set out in The Green Book which states that a cost-benefit analysis should quantify as many of the costs and benefits of a proposal in monetary terms as is feasible, including impacts for which the market does not provide a satisfactory measure of economic value.

The Green Book further states that in the early stages of identifying and appraising a proposal only summary data is normally required, while at the later stages of an assessment data should be refined to become more specific and accurate.[2]

The analysis in this report is therefore proportionate to the resources involved, outcomes at stake, and the time available. As such, the results should be taken as an initial indicative estimate of the potential costs and benefits of the lynx reintroduction scheme. This approach should provide a proportionate study for the purposes of licensing a trial of the effects of the reintroduction of lynx to the UK, with further studies of the economic impact being undertaken if the trial is adopted.

Report structure

The report is divided into three sections:

- **Section 2** describes the geographical and temporal scope of the analysis, as well as the potential costs and benefits included in the assessment.
- **Section 3** describes the methods used and the results of the analysis for each of the potential costs and benefits.
- **Section 4** provides an overview of the findings and makes recommendations on the potential net impacts of the proposed scheme.

[1] IUCN (2013), 'Guidelines for Reintroductions and Other Conservation Translocations'.
[2] HM Treasury (2013), 'The Green Book: appraisal and evaluation in central government'.

SCOPE

02

SCOPE

Overview

This report looks at the potential costs and benefits of a lynx reintroduction scheme in the UK. As the reintroduction sites have not yet been finalised, the analysis focuses on two potential case study sites for lynx reintroduction for which good data is available: (1) Kielder Forest, Northumberland; and (2) Thetford Forest, on the Norfolk/Suffolk border.

Site 1: Kielder Forest

Kielder Forest is located on the border of Scotland and England and is the largest plantation forest in England covering an area of around 650 km^2. This area is estimated to be able to support a population of around 51 lynx (see Appendix A). The forest is owned by the Forestry Commission, the majority of which lies within the Border Forest Park. The southern section lies within Northumberland National Park.

Site 2: Thetford Forest

Thetford Forest is the largest lowland pine forest in the UK covering an area of 190 km^2. This area is estimated to be able to support around 10 lynx (see Appendix A). The forest is also owned by the Forestry Commission and lies across the northern section of Suffolk and the southern section of Norfolk.

The potential costs and benefits of a lynx reintroduction scheme are estimated for each of the two sites separately, and across the UK as a whole if both sites are selected.

A literature review identified six potentially significant impacts of a lynx reintroduction scheme in the UK that were included into the analysis. These are set out in Table 1 below.

Table 1. Scope of the cost-benefit analysis

Costs	Benefits
Predation on livestock and other species	Recreation / tourism benefits
Costs of monitoring / maintaining the population	Reductions in deer populations
Risks to human health / disease	Existence value of lynx

To ensure that the results of the analysis are presented in a comparable format, all costs and benefits are given in 2014 prices and are converted to present values over a common time horizon of 25 years using a discount rate of 3.5% as recommended in The Green Book.[3]

[3] HM Treasury (2014), 'The Green Book', [online] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

ANALYSIS

03

ANALYSIS

Overview

The analysis in this section provides an estimate of the costs and benefits for each of the six potential impacts listed in Table 1. For each impact a definition is provided and the methodology described. The results are then presented for the central scenario and sensitivity testing is undertaken to identify the potential costs and benefits under a 'best' and 'worst' case scenario.

Impact 1. Predation on livestock and other species

Definition

The most widespread concern around the reintroduction of the lynx to UK is typically related to fears of predation on livestock (particularly sheep), game species such as grouse and pheasant, and wild species of conservation importance such as brown hare and capercaillie.

Methodology

A literature review was undertaken to identify the potential rates of lynx predation on sheep in the UK and the levels of compensation that would be required per kill. The review then looked at potential predation rates on game and other species. The results are set out below.

A) Quantifying predation on livestock (sheep)

Breitenmoser et al. (2000) undertook an assessment of the predation rates of lynx on livestock (principally sheep and reindeer) across Europe. The results for sheep are shown in Table 2.

Table 2. Overview of lynx predation rates on sheep in Europe[4]

Country*	Period	Years	Sheep loss	Lynx pop. (1995)**	Kills per lynx p.a.
Norway	1992-95	3	18,924	600	10.51
Sweden	1990-94	4	234	1,000	0.06
Estonia	1990-95	5	0	500	0.00
Latvia	1990-95	5	0	703	0.00
Lithuania	1990-95	5	0	100	0.00
Ukraine	1990-95	5	0	323	0.00
Poland	1990-95	5	0	185	0.00
Czech Rep.	1990-95	5	44	91	0.10
Germany	1990-95	5	1	18	0.01
Hungary	1990-95	5	0	10	0.00
FR Yugoslavia	1990-95	5	0	70	0.00
Albania	1991	1	17	15	1.13
Greece	1990-95	5	0	-	0.00
FYR Macedonia	1990-95	5	0	-	0.00

[4] Breitenmoser, U. et al. (2000), 'Action Plan for the conservation of the Eurasian Lynx (Lynx lynx) in Europe', Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) Nature and environment, No. 112

Country*	Period	Years	Sheep loss	Lynx pop. (1995)**	Kills per lynx p.a.
Croatia	1996	1	22	60	0.37
Slovenia	1990-95	5	75	75	0.20
Austria	1990-95	5	36	3	2.40
Italy	1991	1	2	12	0.17
Switzerland	1990-95	5	196	130	0.30
France	1990-95	5	852	60	2.84
Average					**0.90**
Average excluding Norway					**0.40**

** Excluding countries where there was no data on sheep kills*
*** Adopting a conservative approach by using lowest estimates of lynx populations*

As shown in Table 2, the recorded number of sheep killed by lynx is zero in most countries in Europe. This is due to the fact that lynx live and hunt in forested habitats which they prefer to open grazing lands. This statistic is supported by other studies which have found that livestock damage is almost unknown in natural lynx populations in central and eastern Europe.[5]

In countries where predation does occur, the rates are typically low. The one outlier is the case of Norway, where an estimated population of 600 lynx killed 18,924 sheep over a 3 year period. According to Wilson (2004),[6] the high number of livestock taken in Norway is due to the particular sheep farming practices adopted in this area. Unlike in most European countries, sheep in Norway are grazed free range and unshepherded in forest areas which leads to higher predation rates by lynx. In the rest of Europe (and in the UK), sheep are typically grazed in open pasture and predation is either non-existent or small-scale and localised.[7]

The second highest rate of predation was observed in the reintroduced population in the Jura mountains (France), where the number of sheep attacks per year increased from 3 in 1984 to 188 in 1989 as lynx colonised the main sheep range. Subsequently, attacks stabilised at around 70 to 100 per year. In most cases only one sheep was killed per incident and few additional animals were wounded. Despite a lack of stock protection measures, Stahl et al. (2001) did not find lynx predation to be a widespread problem in the Jura and estimated that less than 0.5% of the regional sheep stock was taken.[8]

It has been suggested that reintroduced lynx can go through a phase of increased predation on livestock following a reduction in native natural prey.[9] However, 50% of livestock attacks in the Jura from 1984 to 1996 occurred in only 3% of the lynx range and appeared to occur as a result of predation hot spots rather than differential prey availability.[10,11] Close proximity of sheep farming to forest cover seemed to increase the risk of predation and there was some evidence that individual lynx could become problem animals.[12]

[5] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', *Mammal Rev.* 2004, Volume 34, No. 3, 211–232.
[6] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.
[7] Hetherington D. (2013), 'Assessing the potential for the restoration of vertebrate species in the Cairngorms National Park: a background review', Cairngorms National Park Authority.
[8] Stahl et al. (2001), 'Predation on livestock by an expanding reintroduced lynx population: long-term trend and spatial variability', *Journal of Applied Ecology* 2001, 38, 674–687.
[9] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.
[10] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.
[11] Stahl et al. (2001), 'Predation on livestock by an expanding reintroduced lynx population: long-term trend and spatial variability', Journal of Applied Ecology 2001, 38, 674–687.
[12] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.

Evidence also suggests that lynx take wild prey in preference to livestock and in the UK context, where deer are abundant, livestock predation is likely to be less of a problem than in parts of Europe where wild ungulates are scarcer.[13]

Based on this analysis it is expected that lynx predation on sheep in the UK context is likely to be negligible. However, it is possible that predation could occur, particularly in areas where grazing occurs near to the forest edge. Assuming that the Norway case is not applicable in the UK context due to the fundamental difference in sheep farming practices, the average predation rate across European countries is estimated to be 0.40 sheep per lynx per year (see Table 2).

It is also assumed that this rate is constant over a period of 25 years. This is a conservative assumption as it is unlikely that this rate of predation would be sustained over a long period as sheep and sheep owners are likely to adjust their behaviour. Elsewhere in Europe, for example, responses have included: the deployment of preventative measures such as fencing or livestock guarding animals; the translocation of individual lynx; and the licensed shooting of problem individuals.[14]

With regards to the potential level of compensation for sheep that have been killed, UK legislation on compensation for Transmissible Spongiform Encephalopathies (TSE) susceptible animals slaughtered under Regulation 81 or 82 stipulates compensation of £30 for sheep at the end of their productive life if they are found to have TSE after they are slaughtered, and £90 for younger animals.[15]

Looking at liveweight sheep prices across Great Britain over the period 2000 to 2013, the market value per ewe ranged from £19 to £70, while the store lamb price ranged from £47 to £68.[16] A compensation level of £90 per animal therefore appears to be a reasonable level of compensation for sheep lost. However, there could be additional levels of distress to sheep owners resulting from the nature of sheep lost to predators such as lynx, and to account for this a compensation of double the maximum market price is assumed i.e. £140 per sheep lost.

B) Quantifying predation on game and other species

In certain areas lynx have been found to predate upon game species such as grouse, as well as wild species of importance to the UK such as brown hare.[17] Jobin et al. (2000), for example, examined the remains of over 600 lynx kills in the Jura mountains (Switzerland) between 1988 and 1998 and found roe deer made up 69% of prey, chamois 22%, red fox 6%, and brown hare 2%.[18] Predation on game and other species is therefore likely to be minimal, with roe and other deer species likely to make up the majority of the diet of a population reintroduced to the UK.

It is also appears likely that lynx will predate upon foxes, which are abundant in the UK, and could have a significant impact on fox populations. Research on the frequency and pattern of lynx predation on red foxes in Sweden, for example, found that red fox populations could be significantly limited by allowing lynx populations to recover. The study monitored fox populations after lynx were re-established in the area; finding an annual lynx predation rate of 14% on radio-

[13] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.
[14] Hetherington D. (2013), 'Assessing the potential for the restoration of vertebrate species in the Cairngorms National Park: a background review', Cairngorms National Park Authority.
[15] UK Government (2002), 'The TSE (England) Regulations 2002'
[16] Eblex (2014), 'UK Yearbook 2014: Sheep'
[17] Nilsen E.B. et al. (2012), 'Patterns of variation in reproductive parameters in Eurasian lynx (Lynx lynx)', *Acta Theriol* (2012).
[18] Jobin et al. (2000), 'Prey spectrum, prey preference and consumption rates of Eurasian lynx in the Swiss Jura Mountains', *Acta Theriologica* 45 (2): 243-252, 2000.

tracked foxes and a decrease of fox populations of 10% each year following reintroduction.[19]

The reintroduction of lynx may therefore have a beneficial effect on species such as brown hare and capercaillie by helping to control fox populations. This was observed to be the case in Finland where the recent recovery and enhanced protection of lynx was accompanied by a decline in red fox abundance and a commensurate recovery in the abundance of black grouse, capercaillie, and mountain hare.[20]

Regular predation on foxes may also contribute to the conservation of small game and ground-nesting birds such as pheasant, as fox predation on such species is considered to be more significant than lynx predation.[21,22,23,24] Predation of lynx on deer could also have significant positive impacts on bird and other species due to the damage done by deer in terms of browsing young saplings, reducing low lying vegetation, trampling damage to nests, and in the case of muntjac, eating birds eggs.[25]

In the UK context, where deer and fox are abundant, the impact on species such as brown hare, capercaillie, grouse, and pheasant is therefore likely be beneficial due to the low predation rates on such species from lynx and the potential decrease in fox predation rates and deer damage.

This assumption is supported by the fact that both conservation groups and the hunting and shooting industry appear to be largely in support of lynx reintroduction in the UK. Results of a survey of public opinion towards the lynx reintroduction scheme, for example, found that 94% of respondents who were RSPB members supported the scheme, 94% who were Wildlife Trust members, 93% who were BTO members, 67% who were members of the Country Land & Business Association, and 66% who were members of the British Association for Shooting and Conservation.

Results

Given the low risk to game and other species, and the potential benefits in terms of reduced fox populations, it is assumed that the monetary cost of lynx predation on game and other species is likely to be negligible.

With regards to sheep predation, the potential costs were estimated by combining the estimated lynx populations at the two sites each year over a 25 year period (see Appendix A) with an average predation rate of 0.40 sheep per lynx per year and compensation of £140 per kill. The present value was estimated assuming a time period of 25 years and a discount rate of 3.5% according to the guidance set out in The Green Book.

The results are set out in Table 3 below.

[19] Helldin et al. (2006), 'Lynx (Lynx lynx) killing red foxes (Vulpes vulpes) in boreal Sweden – frequency and population effects', Journal of Zoology Volume 270, Issue 4, pages 657–663, December 2006
[20] Ripple et al. (2014), Status and Ecological Effects of the World's Largest Carnivores, *Science,* 343 (2014).
[21] Hetherington D. (2013), 'Assessing the potential for the restoration of vertebrate species in the Cairngorms National Park: a background review', Cairngorms National Park Authority.
[22] Elmhagen & Rushton (2007), 'Trophic control of mesopredators in terrestrial ecosystems: top-down or bottom-up?', *Ecol Lett.* 2007 Mar;10(3):197-206.
[23] Helldin et al. (2006), 'Lynx (Lynx lynx) killing red foxes (Vulpes vulpes) in boreal Sweden – frequency and population effects', *Journal of Zoology* Volume 270, Issue 4, pages 657–663, December 2006
[24] Elmhagen et al. (2010) Top predators, mesopredators and their prey: interference ecosystems along bioclimatic productivity gradients. *Journal of Animal Ecology* 79: 785–794.
[25] Piran et al. 'Economic impacts of wild deer in the east of England'.

Table 3. Estimated cost of predation by lynx

Area	No. lynx after 25 years	Total sheep kills over 25 years	PV of compensation
Site 1: Kielder Forest	28	135	-£11,016
Site 2: Thetford Forest	10	86	-£7,920
UK Total	**38**	**225**	**-£18,936**

In terms of the number of potential sheep kills resulting from lynx predation, the total across the UK over the 25 year period, assuming that reintroductions go ahead at both sites, is estimated to be 225 sheep or an average of 9 sheep per year. Numbers are expected to be higher at Kielder Forest due to the larger potential lynx population. This level of predation compares to:

- The number of lambs lost to white-tailed eagles on Mull which was estimated to be around 35 lambs per year over the period 1999-2002.[26]
- The number of dog attacks on sheep which was reported to be 691 in 2011 and 739 in 2012.[27]
- The number of lambs lost to foxes in mid-Wales which was reported to be 3,134 from 1995 to 1997, or around 1,567 each year.[28]
- The number of lambs lost in a year due to factors such as infectious diseases, malnutrition, exposure, and natural mortality, which is estimated to range from 2 to 6 million.[29]

The relatively low levels of compensation costs incurred as a result of lynx predation are reflected by the findings of a recent lynx reintroduction project in Germany. In this scheme compensation for lost livestock is paid at the market price i.e. around €100-150 per animal (£81 to £121 in 2014 prices). The total annual compensation for loss of livestock (including both sheep and other livestock) was recorded as:

- €1,016 (£819) in 2011
- €938 (£756) in 2012
- €796 (£642) in 2013
- €670 (£540) in 2014

The total compensation over the lifetime of the scheme from 2000 to 2014 amounted to €15,452 (£12,454) or a yearly average of €1,104 (£890).[30] This compares to an estimated £631 per site per year in the UK context.

It is interesting to note that the rate of fox predation on lambs is like to be higher than that of lynx, and that lynx are expected to have a significant impact on fox populations. If, for example, lynx lead to a reduction of fox populations of up to 10% (as was the case in Switzerland), the subsequent reduction in fox predation on lambs may exceed the levels of lynx predation. As such,

[26] Marquiss et al., 'The Impact of White-tailed Eagles on Sheep Farming on Mull'
[27] National Sheep Association (2013), 'Dog attacks on livestock rise across the UK', [online] http://www.nationalsheep.org.uk/news-detail.php?NewsID=141
[28] Burns et al. (2000), The Burns Report on Fox Hunting, http://webarchive.nationalarchives.gov.uk/20100512151544/http:/www.huntinginquiry.gov.uk/mainsections/huntingreport.htm
[29] National Animal Disease Information Service (2015), 'Lambing' [online] http://www.nadis.org.uk/2986
[30] Pers. Comm. with Ole Anders (Koordinator Luchsprojekt Harz) on 21st May 2015.

it may be expected that there could be a **net positive impact on livestock numbers due to lynx reintroduction**.

This impact has not been studied in the literature and so has not been included in the cost-benefit analysis, although it is an area where further research could be undertaken during the scientific studies conducted as a part of a trial reintroduction.

Sensitivity testing

In order to test the sensitivity of the estimates provided in the previous section, a comparison of potential 'best' and 'worst' case scenarios is presented below.

In the best case scenario it is assumed that the rate of predation is equal to the most common outcome across Europe i.e. zero. In the worst case scenario it is assumed the rate is equal to the worst case in Europe (excluding Norway) where the predation rate is 2.84 sheep kills per lynx per year.

The results are set out in Table 4 below.

Table 4. Estimated cost of predation across potential scenarios

Area	Worst case scenario	Central scenario	Best case scenario
Site 1: Kielder Forest	-£78,214	-£11,016	£0
Site 2: Thetford Forest	-£56,234	-£7,920	£0
UK total	**-£134,449**	**-£18,936**	**£0**

Impact 2. Costs of monitoring / maintaining the population

Definition

The trial reintroduction scheme is likely to involve costs in terms of administering and managing the scheme, both in terms of the initial five year trial period and the longer term period if there are additional management requirements such as trapping lynx for testing or relocation, and monitoring the impacts over the longer term.

While these costs will not be borne by the UK government or therefore the taxpayer, it is important to identify them in a cost-benefit analysis to avoid any overestimation of the potential net benefits of the scheme. It should also be noted that discussion with the Lynx UK Trust suggested that a large proportion of the estimated costs have already been covered through voluntary donations (PhD funding is already available from several universities, vet time has been agreed on a voluntary basis etc.).

Methodology

The estimated costs of the initial five year trial period were developed as part of the licence application procedure and are set out for each site below:

- Infrastructure e.g. holding enclosures = £75,000
- Capture costs = £40,000
- Monitoring ecologist = £30,000 per year
- Monitoring PhD/research assistant = £20,000 per year
- Local education/consultation = £185,000
- Travel/subsistence = £16,000

- Vet costs = £21,000
- Project management = £15,000 per year
- Exit fund = £60,000

With regards to the longer term costs it is estimated that ongoing costs could be around £5,000 per year in terms of covering tracking, capture of lynx, veterinary fees etc. The compensation fund is not included in this section as it is already covered in the section on livestock compensation.

Results

The total costs of the scheme were estimated using the figures above and assuming the introduction of five lynx per site. The present value was estimated assuming a time period of 25 years and a discount rate of 3.5% according to the guidance set out in The Green Book. The results are set out in Table 5 below.

Table 5. Estimated costs of project administration

Factor	Site 1: Kielder	Site 2: Thetford	UK Total
Infrastructure e.g. holding enclosures	-£75,000	-£75,000	-£150,000
Capture costs	-£40,000	-£40,000	-£80,000
Monitoring ecologist	-£150,000	-£150,000	-£300,000
Monitoring PHD/research assistant	-£100,000	-£100,000	-£200,000
Local education/consultation	-£185,000	-£185,000	-£370,000
Travel/subsistence	-£16,000	-£16,000	-£32,000
Vet costs	-£21,000	-£21,000	-£42,000
Project management	-£75,000	-£75,000	-£150,000
Exit fund	-£60,000	-£60,000	-£120,000
Longer term monitoring costs	-£100,000	-£100,000	-£200,000
Present Value	**-£723,504**	**-£723,504**	**-£1,447,008**

The total potential costs over the 25 year period are therefore estimated to be in the region of £724,000 per site with a UK total of £1.4 million. This compares to recorded expenditure on the Scottish Beaver trial of £2 million over the 7 years between 2007 and 2015.

Sensitivity testing

In order to account for uncertainty in the cost estimates, a best and worst case scenario was estimated assuming a potential over/under spend of 20%. The results are set out in Table 6 below.

Table 6. Estimated cost of administration across potential scenarios

Area	Worst case scenario	Central scenario	Best case scenario
Site 1: Kielder Forest	-£868,205	-£723,504	-£578,803
Site 2: Thetford Forest	-£868,205	-£723,504	-£578,803
UK total	**-£1,736,410**	**-£1,447,008**	**-£1,157,606**

Impact 3. Risks to human health / disease

Definition

There is a potential concern that the reintroduction of a large carnivore to the UK could lead to direct risk to human populations due to death or injury, or through the spread of harmful diseases such as rabies.

Methodology

A review of the literature was undertaken to quantify the direct risk of lynx populations to human health and the potential risk of the spread of disease.

According to the literature, lynx pose no predatory threat to people. There are no records of lynx purposefully attacking humans and even females pushed away from their litters are reluctant to defend their cubs. Negative views of lynx appear to be restricted to concerns about predation on game or livestock.[31,32]

With regards to potential impacts on pets, lynx avoid human habitation and so are highly unlikely to pose any threat to household pets. Incidental conflict may occur with dogs which have been allowed off their leads in lynx habitat. However, the evidence from other European countries suggests that this is likely to be a rare event. Information from the Harz Mountain lynx project in Germany – where hikers with dogs are common – suggests that lynx typically avoid conflict with dogs and there has only been one unconfirmed case of a lynx attacking a dog in the 15 years of this project.[33]

With regards to disease, rabies is occasionally reported in the lynx although they are not considered to be an effective vector for the disease[34] and low population densities make transmission to humans unlikely.[35] The regions where lynx will potentially be sourced from have all undergone an active anti-rabies campaign. Further, studies suggest that red fox are a more important vector of the disease[36] and populations of red fox are likely to decrease following a reintroduction of lynx due to predation.

Other diseases are sporadically reported in the lynx although only sarcoptic mange, in an outbreak in Scandinavia, has been recorded as serious enough to cause losses in the lynx population.[37] Secondary infection of this disease can occur in domestic dogs and even people, but again the red fox is likely to be the most important wildlife vector.[38]

Moreover, all lynx introduced to the UK as part of the proposed trial would be fully vaccinated before being released and will have gone through all legal requirements and best practice for quarantine and selection in order to avoid disease issues. As such, the risk of any spread of disease is likely to be negligible.

It is also possible that reintroduction of lynx may reduce incidence of certain diseases due to reductions in deer populations (and selective targeting of weak and diseased animals) which can

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[31] Breitenmoser, U. et al. (2000), 'Action Plan for the conservation of the Eurasian Lynx (Lynx lynx) in Europe', Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) Nature and environment, No. 112
[32] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', *Mammal Rev.* 2004, Volume 34, No. 3, 211–232.
[33] Pers. Comm. with Anders Ole, coordinator of the Harz Lynx project.
[34] Breitenmoser, U. et al. (2000), 'Action Plan for the conservation of the Eurasian Lynx (Lynx lynx) in Europe', Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) Nature and environment, No. 112
[35] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', *Mammal Rev.* 2004, Volume 34, No. 3, 211–232.
[36] Zimen, E. (1981) The Wolf: His Place in the Natural World. (English edition). Souvenir Press, London.
[37] Breitenmoser, U. et al. (2000), 'Action Plan for the conservation of the Eurasian Lynx (Lynx lynx) in Europe', Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) Nature and environment, No. 112
[38] Simpson, V.R. (2002) Wild animals as reservoirs of infectious disease in the UK. Veterinary Journal, 163, 128–146.

act as hosts for diseases of significance to livestock, including bovine tuberculosis, paratuberculosis, foot and mouth disease, bovine diarrhoea virus, and tick-borne fever.

Further, there is at least some correlative evidence that deer play a role in increasing the risk of transmission of Lyme disease to humans, although other mammals and birds are also involved in the epidemiology of the disease.[39] A study of reductions of deer populations in the United States found that reducing deer density to 5.1 deer per km^2 resulted in a 76% reduction in tick abundance, 70% reduction in the entomological risk index, and 80% reduction in resident-reported cases of Lyme disease in the community.[40] Predation of deer by reintroduced lynx populations could therefore lead to potential reductions in the risk of Lyme disease in the UK.

Results

Given the extremely low risk of direct harm to human populations or the spread of harmful disease arising from the reintroduction of lynx to the UK, and the potential benefits in terms of reducing the potential for disease spread through other species, the monetary cost is expected to be negligible.

Sensitivity testing

Due to the low likelihood of any impact in terms of risks to humans it is assumed that the cost is negligible under all scenarios.

Impact 4. Recreation / tourism benefits

Definition

One of the key potential benefits of a lynx reintroduction project is the potential to increase the number of recreational visits to the reintroduction sites. Recreational visits generate benefits to the user, as well as generating direct and indirect monetary expenditure, and supporting jobs within local economies.

This section estimates the potential monetary benefits of lynx-based recreational visits in the UK, focusing on the direct expenditure of visitors and the jobs supported by this expenditure. It does not attempt to quantify the consumer surplus (benefit to the user) of each visit, or the indirect expenditure associated with recreational visits.

The approach in this report therefore adopts a narrow definition of the potential economic benefits from increasing recreational visits, focusing on clearly evidenced expenditure decisions such as food, accommodation, entrance fees etc. In addition to this direct recreational expenditure, the reintroduction of lynx could support a range of benefits to local economies through branding, merchandising, and specialist safari tour operations, as well as providing opportunities for volunteering, apprenticeships, and education.

While a literature review and discussion with other lynx reintroduction projects in Europe suggested that these opportunities are potentially significant (see Appendix B), they could not be quantified robustly at this stage of the assessment and so the scope was restricted to direct expenditure. As such, the estimates provided in this section are likely to be a lower bound.

With this in mind, the potential number of visits at each site were estimated for two periods:

- **Initial trial period:** the initial five years of the trial where visits are likely to focus on a visitor

[39] Piran et al. (2002) 'Economic impacts of wild deer in the east of England'.
[40] Kilpatrick et al. (2014), The Relationship Between Deer Density, Tick Abundance, and Human Cases of Lyme Disease in a Residential Community, Journal of Medical Entomology

centre and lynx enclosure offering direct interactions with the lynx such as through guided walks and feeding events organised through the centre.

- **Longer term period:** a twenty year period following the end of the trial where the site becomes known as a lynx tourism destination and is supported with associated facilities, visits are likely to focus on less direct interactions with wild populations of lynx in the area through guided or self-guided walks along 'lynx trails' (as is the case in Germany).

Methodology

A) Estimating recreational visits during the initial trial period

In order to estimate the potential number of people who are likely to visit the lynx sites, a survey of public support for reintroduction of lynx was undertaken by the Lynx UK Trust.

The survey described opinions expressed from two targeted groups. Over 9,600 people responded to an elective survey, collecting responses from members of the general public who would actively seek to express their opinion given the means to do so. Over 1,000 responses were also collected from a representative UK sample using an independent national omnibus polling company.

In both surveys the participants were asked to respond to the statement, "If lynx were returned to the UK landscape and viewing facilities were available, I would visit the facilities to see the lynx". In the first 'active' group 88% of respondents agreed with the statement, of which 73% strongly agreed, compared to 47% of respondents agreeing in the second representative survey and 18% strongly agreeing.

Adopting a conservative approach, the percentage of people strongly agreeing with the statement in the second survey was assumed to provide the basis for estimating the number of potential visitors to the two sites during the trial period.

The visitor survey results could therefore be interpreted as suggesting that 18% of people within the UK are likely to visit the lynx trial sites (or around 1.2 million people per site per year). There is, however, likely to be a constraint on visitor numbers in terms of how far people are willing to travel to see the lynx. It was therefore assumed that the actual number of visitors is likely to be constrained to 18% of people living within a travelable distance of the two sites.

In order to define the travelable distance, a potential visitor catchment area was estimated for each site based on the geographical area where most visitors to that site are from. For Thetford this was based on a Forestry Commission survey of visitors to Thetford Forest which found that the majority of visitors, around 72%, were from the East of England.[41] For Kielder Forest, the location of visitors was much more spread out, with the greatest concentration estimated to be from the North East, see Figure 1.[42]

As such, the visitor catchments for the two sites were identified as the East of England for Thetford Forest and the North East for Kielder Forest.[43] The different visitor catchments for the two areas suggest that it is unlikely that the two pilot sites act as a substitute for one another, and as such it appears reasonable to assume that there is unlikely to be any overlap between visitors to the two sites.

[41] BMG Research (2012), 'Quality of visitor experience survey: Kielder Forest', Forestry Commission.
[42] TNS Tourism & Leisure (2005), 'Monitoring the quality of experience in forests: Thetford', Forestry Commission.
[43] Note, the potential catchment area is based on existing visitors to the two pilot sites. Due to the charismatic and unique nature of lynx it is likely that people would be willing to travel further than that for a typical forest based recreation visit. As such, the catchment areas could be significantly larger.

Figure 1. Origin of visitors to Kielder Forest in 2012[44]

With the catchment areas identified, the survey responses on expected visitor numbers were broken down into regionally specific estimates. As set out in Table 7, the results suggest that 21.10% of people in the North East are likely to visit the lynx reintroduction site at Kielder Forest, and 20.90% of people in the East of England are likely to visit the site at Thetford Forest. These figures were then combined with the total population of the visitor catchment areas for the two sites, and divided by the number of years of the trial in order to provide an estimate of the potential visitor numbers for each year of the trial period.

[44] BMG Research (2012), 'Quality of visitor experience survey: Kielder Forest', Forestry Commission.

Table 7. Number of potential visitors to a lynx viewing facility based on response from an independent national survey of a representative UK sample, n(total)=1042

Region	Strongly Agree	Somewhat Agree	Total Agree
North East	21.10%	18.40%	39.50%
North West	24.20%	30.30%	54.50%
Yorkshire & Humberside	22.20%	21.20%	43.40%
East Midlands	18.10%	23.60%	41.70%
West Midlands	14.10%	31.30%	45.50%
East of England	20.90%	31.80%	52.70%
London	19.70%	30.80%	50.40%
South East	16.60%	33.10%	49.70%
South West	14.10%	28.30%	42.40%
Scotland	12.00%	33.00%	45.00%
Wales	22.40%	27.60%	50.00%
UK total	**18.67%**	**28.13%**	**46.80%**

In order to avoid the potential for double counting, it was assumed that people who already visit the two sites for wildlife watching do not count as additional potential visitors as it is likely that they would visit the site even if the lynx were not present. The estimated number of people from each catchment area already visiting the two pilot sites for wildlife watching purposes was therefore subtracted from the estimated visitor numbers. This was done by estimating the total number of visitors currently visiting the sites for wildlife watching (16,148 at Kielder[45] and 63,000 at Thetford[46]) and multiplying this by the percentage of visitors from the two catchment areas, to identify the number of wildlife visitors currently visiting the two sites from the North East and East of England.

The average expenditure per day for recreational visits at both sites was then estimated from visitor surveys undertaken by the Forestry Commission which found values of £36.11 per person per day at Kielder Forest and £25.82 at Thetford Forest (in 2014 prices).[47,48]

It was also assumed that there is likely to be a visitor entrance fee at the trial sites of £7. This compares to existing participation charges of £5 for wildlife experiences at Kielder Forest (recognised as below market value)[49] and €7 for visits to a lynx based visitor centre at the reintroduction programme in Harz National Park in Germany.[50]

B) Estimating recreational visits during the longer term period

With regards to the longer term potential impacts on recreation it was assumed that the visitor numbers are likely to fall following the conclusion of the trial. A literature review was therefore undertaken to identify any case studies quantifying the potential impacts of lynx on recreational visits to particular areas.

[45] Bowles Green Ltd. (2010), 'Kielder Wildlife Tourism Study'.
[46] Christie et al. (2006) 'Valuing Forest Recreation Activities Final Phase 2 report', Forestry Commission.
[47] BMG Research (2012), 'Quality of visitor experience survey: Kielder Forest', Forestry Commission.
[48] TNS Tourism & Leisure (2005), 'Monitoring the quality of experience in forests: Thetford', Forestry Commission.
[49] Bowles Green Ltd. (2010), 'Kielder Wildlife Tourism Study'.
[50] Pers. Comm. with Ole Anders (Koordinator Luchsprojekt Harz) on 21st May 2015.

A number of sites were identified in Europe although limited data was available on the economic benefits of such visits. As such, the review was widened to examine the economic benefits of other species such as whales, osprey, and beaver, focusing on the UK where possible. The findings are summarised in Table 8.

Table 8. Comparison of recreational expenditure and jobs supported by wildlife watching (2014 prices)

Species	Region	Total wildlife visits	Primary reason for visit	Average spend per day*	Total spend per year	Jobs supported
General wildlife	Scotland wide[51]	1,120,000	-	-	£297 million	2,763 FTE
Wolves	Yellowstone, USA[52]	2,233,108	93,343	£281.55	£24 million	-
Whales	West Scotland[53]	241,591	54,439	£80.82	£10.6 million	115 FTE
Dolphins	Moray Firth, Scotland[54]	63,000	17,100	£52.32	£7.0 million	202 FTE
General wildlife	East Yorkshire, England[55]	266,385	45,670	£14.33	£7.0 million	171 FTE
Osprey	UK wide[56]	293,000	-	£8.58	£4.2 million	-
Sea eagles	Mull, Scotland[57]	78,085	4,305	£97.42	£3.6 million	86 FTE
Sea birds	Orkney[55]	81,000	5,850	£306.42	£1.8 million	36 FTE
Peregrine falcon	Forest of Dean, England[55]	42,500	-	£18.31	£778,000	18 FTE
Sea birds	Bempton Cliffs, England[55]	55,000	-	£13.01	£715,000	-
Sea birds	South Stack[55]	36,000	-	£13.83	£497,873	-
Hen harrier	Caithness, Scotland[55]	4,200	-	£63.85	£268,000	-
Red Kite	Black Isle, Scotland[55]	-	-	-	£160,000	3 FTE
Chough	Cornwall, England[55]	18,000	5,400	£17.83	£149,000	3 FTE
Beaver	Knapdale, Scotland[58]	-	6,582**	£71.48	£109,000	-
Capercaillie	Strathsprey, Scotland[55]	1,667	-	£76.25	£90,000	-

** Mean averages used where high and low estimates provided across day trips and holiday trips.*
*** Guided walks only.*

From this review it was decided that the case study most applicable to the potential lynx reintroduction scheme was likely to be the case of sea eagles on Mull; due to the similarities in terms of restoring a charismatic, predatory species into an area where it has previously been extinct.

In the absence of robust data on potential lynx visits, it was assumed that the annual number of visitors to Mull to watch sea eagles is likely to broadly correspond to the annual number of visitors to each of the two pilot sites to watch lynx following their reintroduction (although it should be noted that Mull is a much more remote site than either of the two pilot areas so this approach may underestimate potential visitor numbers).

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[51] Scottish Government (2010), 'The economic impact of wildlife tourism in Scotland'.
[52] Duffield et al. (2008), 'Wolf Recovery in Yellowstone: Park Visitor Attitudes, Expenditures, and Economic Impacts', The George Wright Forum, Volume 25, Number 1 (2008).
[53] Warburton, C.A., Parsons, E.C.M., Woods-Ballard, A., Huges, A. & Johnston, P. (2001) Whale Watching in West Scotland: Report for the Department for Environment, Food and Rural Affairs.
[54] Davies et al. (2010), 'The Value of Tourism Expenditure related to the East of Scotland Bottlenose Dolphin Population'
[55] ICRT Leeds (2010), 'The Economic Potential of Nature Tourism in Eastern Yorkshire'
[56] Dickie et al. (2005), 'Watched Like Never Before… the local economic benefits of spectacular bird species'.
[57] Molloy, D, (2011). Wildlife at work. The economic impact of white-tailed eagles on the Isle of Mull. The RSPB, Sandy.
[58] Moran, D. & Lewis, A.R. 2014. The Scottish Beaver Trial: Socio-economic monitoring, final report. Scottish Natural Heritage Commissioned Report No. 799.

Based on the results of a survey of visitors to Mull it was estimated that around 4,305 people visit the island each year with the primary purposes of viewing sea eagles, and around 73,780 additional visitors identify the presence of eagles as an important reason for their visit.[59]

Using the number of visitors who travel specifically to see sea eagles, or for who the presence of sea eagles provides a strong attraction, it was therefore estimated that there are likely to be 4,305 annual visitors to each of the pilot sites whose primary purpose is to view lynx, and a further 73,780 annual visitors for whom the presence of lynx at the two sites is an important reason for their visit.[60]

Following the approach adopted by the RSPB to attributing expenditure to wildlife watching[61] it was assumed that 75% of the expenditure by those who identify lynx as the primary reason for their visit, and 25% of the expenditure of those who identify lynx as an important reason for their visit, could be attributed to the presence of the lynx. The average expenditure per person per day was based on the estimates provided by the Forestry Commission (excluding any potential visitor fees).

A review was also undertaken to identify if there are likely to be changes in visitor numbers over time (i.e. decreasing numbers visiting the site over the long term as the species spreads and becomes more common). However, evidence from visitor numbers to osprey sites in Scotland suggests that any such effect is only likely to become evident over a period longer than 25 years if there are multiple sites where the animals can be seen.[62] Further, both the UK population and the demand for recreational activities is projected to grow over time which suggests that assuming a static level of demand for lynx visits may underestimate the potential value.

With regards to estimating the potential impact on jobs in the local economy, the approach in Molly et al. (2011) was adopted which developed tourism multipliers for recreational visits to RSPB reserves. Using this approach, it is assumed that £48,772 (2014 prices) of local visitor spend supports 1 full time equivalent (FTE) job.

Results

The potential monetary benefits were estimated by combining the estimated visitor numbers with the average visitor expenditure during both periods. The present value was estimated assuming a time period of 25 years and a discount rate of 3.5% according to the guidance set out in The Green Book. The results are set out in Table 9 below.

Table 9. Estimated benefits from lynx based recreational expenditure

Factor	Kielder Forest	Thetford Forest	UK Total
Trial period			
Catchment area	North East	East England	-
Population in catchment areas	2,597,000	5,847,000	-
Potential visits from catchments each year	109,593	244,405	-
Existing wildlife visits from catchments	5,888	45,360	-
Net increase in visits due to lynx	103,706	199,045	302,751
Expenditure per person per trip	£43.11	£32.82	-

[59] Molloy, D, (2011). Wildlife at work. The economic impact of white-tailed eagles on the Isle of Mull. The RSPB, Sandy.
[60] Note, as discussed earlier it is considered unlikely that the two sites act as substitutes for one another and so there is no overlap between visitors.
[61] Molloy, D. et al. (2011), 'RSPB reserves and local economies', RSPB.
[62] Dickie et al. (2005), 'Watched Like Never Before… the local economic benefits of spectacular bird species'.

Factor	Kielder Forest	Thetford Forest	UK Total
Total expenditure per year	£4,470,276	£6,531,778	£11,002,054
Jobs supported	92 FTE	134 FTE	226 FTE
Longer term period			
Visits primarily to see lynx	4,305	4,305	8,610
Attributable expenditure	£116,576	£83,352	£116,576
Visits for which lynx are important	73,780	73,780	147,560
Attributable expenditure	£665,966	£476,170	£1,142,136
Total spend per year	£782,541	£559,522	£1,342,063
Jobs supported	16 FTE	11 FTE	27 FTE
Total Present Value	**£29,547,783**	**£36,186,820**	**£65,734,603**

The results suggest that over the 25 year period the potential recreational benefits could amount to around £29.5 million at Kielder, £36.2 million at Thetford, and £65.7 million across the UK as a whole. This is expected to support around 92 FTE jobs each year at Kielder during the trial period and 16 FTE jobs each year over the longer term; with 134 and 11 FTE jobs at Thetford respectively over these two periods.

This amounts to a 44% increase in visitor numbers to Kielder during the trial period and a longer term increase of 33% following the trial, compared to a 13% increase in Thetford during the trial and a 5% increase over the longer period.

The difference between the two sites is due to a range of factors, in particular, the greater population density surrounding Thetford Forest which leads to a greater expected number of visitors and a corresponding higher level of benefits. The more remote nature of Kielder, on the other hand, suggests there will be fewer visitors than at Thetford although they are likely to travel further and to spend more. The relative increase in benefits is therefore greater at Kielder where there is likely to be a proportionately larger increase in visitor numbers to the area due to the reintroduction of lynx.

Comparing the estimated values to other recreational wildlife sites in the UK suggests that the estimates are conservative given the charismatic and unique nature of the lynx; in Macdonald et al. (2015) the Iberian lynx was ranked as the third most charismatic mammal species by UK respondents after the tiger and the African elephant.[63] During the trial period, for example, the annual expenditure on lynx tourism assuming both sites are selected is estimated at £11.0 million per year, falling to £1.3 million per year over the longer term period. This would put the potential revenue from lynx tourism at a similar level to whale watching in Scotland during the trial period and significantly less than osprey and sea eagles over the longer period.

While this estimate is conservative compared to many of the wildlife watching opportunities in the UK, it is significantly higher than the estimated benefits from recreational visits to the beaver reintroduction in Scotland. This is likely due to a combination of factors, including the atypical approach used in the estimation of visitor numbers, the remoteness of the trial site from centres of population, and the nocturnal nature of beavers.

A number of lynx reintroduction trials have been undertaken in Europe although there is limited

[63] Macdonald et al. (2015), ‘Conservation inequality and the charismatic cat: Felis felicis’, Global Ecology and Conservation 3 (2015) 851–866

data available on the actual numbers of visitors there to see lynx which makes robust comparisons and estimates of total expenditure difficult.

In terms of broad comparisons, a lynx reintroduction project in the Bavarian Forest National Park, Germany set up a lynx enclosure for visitors. The enclosure's car park receives an estimated 500,000 visits each year although there are two other attractions in the vicinity. As such, a significant yet unknown proportion may be expected to visit the lynx enclosure. Representatives of the National Park also mentioned that a significant number of nature photographers enquire about permission to take pictures at the lynx enclosure although no hard estimates were available.[64]

Sensitivity testing

The figures provided in the previous section rely on two key assumptions for estimating visitor numbers during the trial period and the longer term period:

- The number of visitors who would visit the trial sites can be approximated by those who **strongly agreed** that they would visit the site during the trial.
- The number of visitors during the longer term can be approximated by the number of people who visit the **sea eagles** on Mull.

In order to test the sensitivity of these estimates, a potential 'best' and 'worst' case scenario was developed.

With regards to visitor numbers during the trial period it was assumed that in the best case scenario the number of visitors equals those who **strongly agreed** and **agreed** that they would be likely to visit the trial site (i.e. 39.50% in the North East and 52.70% in the East of England). For the worst case scenario, the numbers were assumed to be the same as in the central scenario which was based on the most conservative possible interpretation of the survey results.

With regards to the number of visitors over the longer term, in the best case scenario it was assumed that potential visitor numbers are broadly similar to the number of dolphin watching visits in Moray Firth (i.e. 17,000 visitors primarily there to see lynx and 63,000 for which it is an important reason). While in the worst case scenario it was assumed that the longer term number of visitors are similar to the number of visitors to see chough in Cornwall (i.e. 5,400 primary lynx visitors and 18,000 for which it is an important reason).

The results are set out in Table 10 below.

Table 10. Estimated tourism benefits across potential scenarios

Area	Worst case scenario	Central scenario	Best case scenario
Site 1: Kielder Forest			
Annual value trial period	£4,470,276 92 FTE	£4,470,276 92 FTE	£8,589,851 176 FTE
Annual value longer term period	£308,702 6 FTE	£782,541 16 FTE	£1,029,006 21 FTE
Net Present Value	**£23,877,603**	**£29,547,783**	**£51,097,192**

[64] Pers. Comm. with Melina Oldorf on 8th June 2015.

Area	Worst case scenario	Central scenario	Best case scenario
Site 2: Thetford Forest			
Annual value trial period	£6,531,778 134 FTE	£6,531,778 134 FTE	£18,734,908 384 FTE
Annual value longer term period	£220,724 5 FTE	£559,522 11 FTE	£735,746 15 FTE
Net Present Value	**£32,132,604**	**£36,186,820**	**£93,393,370**
UK total	**£56,010,207**	**£65,734,603**	**£144,490,562**

Due to the limiting assumptions made, the central scenario may be a significant underestimate of the total potential value. As such it is thought that the actual value of lynx reintroduction is likely to lie towards the best case scenario value and the reintroduction project could potentially create a significant tourist draw for people within the UK and other countries.

Impact 5. Reductions in deer populations

Definition

Deer populations are increasing across the UK and in many areas are generating significant and rising economic costs due to their impacts on forestry, tree growth, crop production, traffic accidents, and wild species diversity. The reintroduction of lynx to the UK may lead to cost savings due to reductions in deer populations and subsequent reductions in the negative impacts associated with deer abundance.

A study of the economic costs of deer damage in the East of England[65] (based principally on research undertaken in Thetford Forest) identified a number of important impacts caused by deer in the UK. Of these impacts, the following were scoped into the analysis due to the availability of robust monetary estimates:

- Costs of road traffic accidents (RTAs) due to collision with all deer species.
- Crop damage by fallow, roe, muntjac, and red deer.
- Damage to forestry operations due to:
  - Browsing of conifers by fallow, red, roe, and sika deer.
  - Bark stripping of conifers by red deer.
  - Culling costs for all deer species.

The report also identified a number of other impacts of deer populations which were not scoped into the analysis. It was assumed, for example, that there are no costs to conservation activities from deer populations at the two sites due to the assumption in Piran et al. (2002) that plantation forests are managed for forestry and have zero conservation value.

In reality, coniferous forests can provide important habitat for a range of important species, with the

[65] Piran et al. (2002) 'Economic impacts of wild deer in the east of England'.

pilot sites supporting species such as red squirrel and osprey, and there are likely to be potentially significant benefits to wild species populations due to reductions in deer populations.

It was also assumed that there is not likely to be any impact on beneficial services provided by deer such as venison production and deer stalking revenues. This is due to the fact that deer culling is still likely to be required following the reintroduction of lynx. As a result, it is unlikely that either the harvesting of venison or stalking will be impacted.[66]

A further assumption is that the impacts of lynx on deer populations are strictly limited to the numbers of deer killed by lynx. A number of studies, however, have suggested that there may be more significant impacts on deer populations than predation due to the 'landscapes of fear' created by the reintroduction of predators. This can lead to greater expenditure of energy on predator avoidance (and thereby less expenditure on feeding), higher levels of stress, and lower rates of reproduction.[67,68,69,70]

Due to a lack of quantifiable evidence on the potential impacts this has not been included in the analysis but it should be noted that such impacts may be more significant than actual predation rates and, as a result, the estimates of the benefits to lynx reintroductions in this section are likely to be an underestimate of the actual values.

Methodology

A) Estimating impacts of lynx on deer populations

The first step was to develop an estimate of the impacts of reintroducing lynx on deer populations at the two pilot sites.

For Thetford Forest, where deer populations are a significant problem, detailed information on deer abundance was available from a number of studies. Piran et al. (2002), for example, found that muntjac and roe deer make up the majority of deer in Thetford Forest; estimating the (pre-cull) population of deer species to be 335 fallow, 4,748 muntjac, 679 red, and 3,276 roe deer.

Over a 25 year time period, the lynx population is estimated to grow from 0 to 10 individuals in Thetford Forest. Each lynx is assumed to consume an average of 2 kg of meat per day.[71] This amounts to a requirement of 730 kg of meat per lynx per year.

Assuming that this meat is sourced entirely from wild deer populations and the consumption of deer reflects the abundance of each species, the total number of deer consumed per lynx is estimated to be 43.3 each year.

Details of this estimate are set out in Table 11.

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[66] Impacts on disease, recreation, and existence values are discussed in the relevant sections of the analysis.

[67] Creel & Christianson (2008), 'Relationships between direct predation and risk effects', *Trends in Ecology & Evolution*, Volume 23, Issue 4, April 2008, Pages 194–201.

[68] J. Ward Testa 2004. POPULATION DYNAMICS AND LIFE HISTORY TRADE-OFFS OF MOOSE (ALCES ALCES) IN SOUTH-CENTRAL ALASKA. Ecology 85:1439–1452. http://dx.doi.org/10.1890/02-0671

[69] Manning et al. (2009), 'Restoring landscapes of fear with wolves in the Scottish Highlands', *Biological Conservation,* Vol. 142, No. 10, pp. 2314-2321.

[70] Creel et al. (2007), 'Predation Risk Affects Reproductive Physiology and Demography of Elk', *Science* 16 February 2007: Vol. 315 no. 5814 p. 960

[71] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.

Table 11. Potential consumption of deer species by lynx in Thetford Forest

Deer species	Relative abundance (%)*	Average weight (kg)	Consumption (kg/yr/lynx)	Consumption (deer/yr/lynx)
Roe deer	36%	20 kg	263 kg	13.1
Muntjac deer	52%	13 kg	380 kg	29.2
Fallow deer	3%	50 kg	22 kg	0.4
Red deer	9%	130 kg	66 kg	0.5
Total			**730 kg**	**43.3**

** Based on population estimates in Piran et al. (2002)*

Based on this analysis, it is estimated that a population of 10 lynx in Thetford Forest would consume around 445 deer each year or around 4.92% of the pre-cull deer population each year (assuming there is no growth in deer populations over time).

A similar analysis was undertaken for the potential impact of lynx populations at Kielder Forest. While there were no estimates available for the total deer population, Hetherington & Gorman (2007) provide an estimate of biomass density for the area which provides an indication of the relative proportion of species within the forest.

On this basis, it is estimated that a population of 28 lynx in Kielder Forest could consume around 898 deer each year. The results are set out in Table 12.

Table 12. Potential consumption of deer species by lynx in Kielder Forest

Deer species	Relative abundance (%)*	Average weight (kg)	Consumption (kg/yr/lynx)	Consumption (deer/yr/lynx)
Roe deer	85%	20 kg	618 kg	30.9
Fallow deer	2%	50 kg	11 kg	0.2
Red deer	14%	130 kg	101 kg	0.8
Total			**730 kg**	**31.9**

** Based on population estimates in Hertherington & Gorman (2007)*

B) Estimating the monetary impact of changes in deer populations

For each of the impacts discussed above, the average monetary cost per deer was quantified based on the analysis undertaken by Piran et al. (2002). It was then assumed that for each deer killed by the reintroduced lynx populations, the total economic costs attributed to deer populations would be reduced by the corresponding cost per deer.

According to the Piran et al. study, the total number of deer-related road traffic accidents (RTAs) leading to human injuries in the East of England was around 58 in 2002, generating a total cost of £5,489,364 (in 2014 prices). In the same year, the number of deer related RTAs not leading to human injury was around 672, generating a total cost of £532,098.[72] Based on an estimated deer population of 76,237 across the East of England in 2002, the average RTA damage per deer each year is estimated to be £78.98. It was therefore estimated that each deer killed by lynx at the two sites would have a monetary benefit of £78.98 in terms of reduced rates of deer related RTAs.

[72] Note, the central outcome is taken as the mean average of minimum and maximum estimates provided by Piran et al. (2002).

There is, however, a degree of uncertainty surrounding the potential impacts of lynx on deer behaviour and it is possible that, although lynx would reduce the abundance of deer, there may not be a corresponding decrease in the rate of deer related RTA's due to increased levels of movement and skittishness amongst deer populations which may offset the reduction in collisions.

A review of the literature did not identify any studies looking directly at the impact of lynx on deer related RTAs or reveal any evidence to suggest that the introduction of lynx to an area could increase the likelihood of RTAs. Studies have found that deer behave differently in the presence of ambush predators such as lynx which sit and wait for prey, from when they are in the presence of coursing predators such as wolves which chase prey over long distances. According to Wikenros et al. (2015), the presence of lynx leads to reduced deer visitation to particular areas where predation is likely, whereas the presence of wolves does not lead to a change in visitation rates, but instead leads to greater vigilance amongst deer.[73] The impacts of an ambush predator are therefore most likely to lead to a change in the distribution of deer, rather than an increase in their vigilance and rate of fleeing from predators.

Studies also show that Eurasian lynx are crepuscular,[74] moderating their behaviour in response to the activity of their main prey (roe deer)[75] which are also crepuscular.[76] Further research has shown that in areas where lynx are present, roe deer have a higher level of diurnal (daytime) activity than expected, in order to avoid predation from lynx. As such, the reintroduction of lynx to the pilot sites may be expected to lead to an increase in diurnal activity amongst deer populations in order to reduce predation risk.

A study of deer related RTAs across the UK undertaken by the Highways Agency found that the level of risk for deer related RTAs is highest at night (particularly during the period 18:00 – 21:00 and 21:00 – 24:00), followed by the morning (06:00 – 09:00).[77] The potential increase in diurnal activity, together with an overall reduction in deer numbers, suggests that there is likely to be a reduction in deer movement during the evening and night when the majority of crashes happen; thereby suggesting that lynx would be expected to lead to a reduction of deer related RTAs.

With regards to damage from deer to agricultural crops, the total damage in 2002 across the East of England from fallow, roe, muntjac, and red deer was estimated to be £4,267,651 (in 2014 prices). Based on an estimated population of the four species of 73,457, the average crop damage per deer each year is estimated to be £58.10.

With regards to the impacts on forestry operations, fallow, red, roe, and sika deer in the East of England were estimated to cause a total of £9,107 (in 2014 prices) of damage due to browsing of conifer species or £0.32 per deer each year. Red deer were estimated to cause a total of £110,517 of damage due to bark stripping of conifer species or £22.33 per deer. While the total culling costs for all deer species was estimated to be £111.29 per deer each year. The total forestry impacts are therefore estimate at £133.94 per deer each year.

A comparison of these estimates is provided in Table 13.

[73] Wilkenros, C. (2015), Behavioural responses of ungulates to indirect cues of an ambush predator, *Behaviour*, 152 (2015) 1019-1040.
[74] Podolski et al. (2013), 'Seasonal and daily activity patterns of free-living Eurasian lynx Lynx lynx in relation to availability of kills', Wildl. Biol. 19: 69-77 (2013).
[75] Pagon et al. (2013), 'Seasonal variation of activity patterns in roe deer in a temperate forested area.', Chronobiol Int. 2013 Jul;30(6):772-85. doi: 10.3109/07420528.2013.765887. Epub 2013 Jun 5.
[76] Heurich et al. (2014), 'Activity Patterns of Eurasian Lynx Are Modulated by Light Regime and Individual Traits over a Wide Latitudinal Range', PLOS One.
[77] Langbein, (2007), National Deer-Vehicle Collisions Project England (2003-2005).

Table 13. Monetary cost of deer populations

Type of impact	Monetary cost (£/deer/year)
RTAs	£78.98
Crops	£58.10
Forestry	£133.94
• *Browsing conifers*	*£0.32*
• *Bark stripping of conifers*	*£22.33*
• *Culling costs*	*£111.29*
Total	**£271.02**

Results

The total potential cost savings due to reductions in deer populations was estimated by combining the expected reduction in deer numbers at each site due to predation by lynx each year, with the total estimated cost per deer in terms of impacts on RTAs, crops, and forestry operations. The present value was estimated assuming a time period of 25 years and a discount rate of 3.5% according to the guidance set out in The Green Book. The results are set out in Table 14 below.

Table 14. Estimated cost savings due to reductions in deer populations

Area	Total no. deer killed	PV avoided damage			Total PV
		RTAs	Crops	Forestry	
Site 1: Kielder	10,786	£495,434	£364,423	£840,161	£1,700,017
Site 2: Thetford	9,731	£483,704	£355,795	£820,270	£1,659,769
UK total					**£3,359,786**

As set out in Table 14, the total estimated cost savings due to reductions in deer populations are estimated to be around £3.4 million over a 25 year period, or an average of £134,000 per year. The estimated size of the impacts is similar at the two sites due to the fact that, while there is a larger population of lynx at Kielder Forest, there is expected to be a greater focus of predation on roe deer (rather than muntjac). The larger size of roe deer relative to muntjacs results in lower estimates of the numbers of deer consumed per lynx.

In terms of the impacts on deer populations from lynx predation, the analysis in this study predicts a loss of around 4.92% of the deer population in Thetford Forest.[78] This compares to estimates of the impact of lynx predation on deer species of 4% on roe deer in high density populations reported by Wilson (2004) and around 6 to 9% of roe deer in the Swiss Alps.[79]

In terms of the total cost savings, the study of the economic costs of deer populations in the East of England estimated the total cost to range from £9.3 to 13.6 million each year (in 2014 prices), rising to £11.7 to £15.2 million in 5 years, and £13.4 to £16.5 million in 10 years.

It is interesting to note that the potential cost savings to agriculture due to reductions in deer damage to crops (£365,000 at Kielder and £356,000 at Thetford) far exceed the potential costs of sheep predation by lynx (£7,920 at Kielder and £11,016 at Thetford), suggesting that lynx

[78] There is insufficient data available to do a similar estimate for Kielder Forest
[79] Wilson, C.J. (2004), 'Could we live with reintroduced large carnivores in the UK?', Mammal Rev. 2004, Volume 34, No. 3, 211–232.

reintroduction could potentially result in significant economic benefits for agriculture within the vicinity of the two trial sites.

This is supported by the findings of the survey of public opinion towards lynx reintroduction which found that 58% of respondents who were members of the National Farmers Union support the lynx reintroduction scheme (47% strongly agree with the scheme and 11% agree).

3.5.4 Sensitivity testing

In order to test the sensitivity of the estimates provided in the previous section, a comparison of potential 'best' and 'worst' case scenarios is presented below.

In the 'best' case scenario it is assumed that the potential cost savings in terms of RTAs, crops, and forestry are equal to the maximum estimates in Piran et al. (2002), while the 'worst' case scenario cost savings are assumed to be equal to the minimum estimates. Due to the levels of uncertainty over the potential impacts of lynx populations on deer related RTAs, it was further assumed in the 'worst' case scenario that any potential reductions in RTAs due to lower deer populations would be fully offset by potential increases due to deer activity and therefore the economic benefits are equal to zero.

The results are set out in Table 15 below.

Table 15. Estimated cost savings due to reductions in deer populations across potential scenarios

Area	Worst case scenario	Central scenario	Best case scenario
Site 1: Kielder Forest	£760,908	£1,700,017	£2,187,134
Site 2: Thetford Forest	£742,893	£1,659,769	£2,135,353
UK total	**£1,503,801**	**£3,359,786**	**£4,322,487**

Impact 6. Existence value of lynx

Definition

Existence value is the amount that people are willing to pay towards preserving the existence of a particular type of habitat or species even if they are not directly encountered or used. Examples could include the donations made by people living in the UK to protect areas of the Amazon rainforest which they may never experience themselves, or legacy donations left to charities such as the RSPB in a person's will. These values can be motivated by an ecological ethic, altruism toward others, or bequests to future generations.

The existence values associated with reintroducing a charismatic species are often high and can make up the largest share of the values associated with such schemes. However, they are also difficult to quantify due to the lack of market prices.

In the Scottish Beaver Trial, for example, the existence value associated with the reintroduction of beavers to Knapdale was estimated to range from £560,000 to £6,000,000 over the five year trial period, compared to a recreational value of the scheme estimated to range between £355,000 and £520,000.

As such, despite the methodological challenges, it is important that such values are considered within a cost-benefit analysis.

Methodology

The ideal approach to estimating the existence value of lynx in the UK would be to undertake primary research in the form of a survey asking members of the public how much they would be willing to pay to reintroduce lynx to the UK. However, such an approach is beyond the scope of this analysis.

An alternative approach to undertaking primary data collection is to use benefits transfer to generate willingness-to-pay (WTP) estimates for lynx reintroduction based on the findings of similar studies.

A number of stated preference studies have been undertaken to ascertain the public's WTP for the preservation or reintroduction of lynx species in Sweden[80], Spain[81], and Poland[82]. However, none of these studies provide clear WTP estimates that could be transferred to this project.

An alternative approach was used in Canada, where Kroeger & Casey (2006) used a benefits transfer function for threatened and endangered species to construct value estimates for expanding lynx populations. The authors used a study looking at the existence value of the otter as a basis for the valuation exercise, as an example of a similarly charismatic predatory species which poses no threat to human life.[83]

While this approach cannot provide an accurate estimate of the existence value of lynx within the UK, it can provide an initial estimate of the potential scale of this value which can then be further refined based on primary research.

A review of the literature on WTP for mammal species in the UK identified a number of studies which could potentially be used as a basis for estimating the existence value of lynx reintroduction. The results of this review are set out in Table 16 below. All values have been converted to 2014 prices and, following the approach used by White et al. (2001), have been presented as both a one-off and an annual payment assuming a discount rate of 8% and a time period of 10 years.

Table 16. WTP per respondent for mammal species in the UK

Species	One-off WTP £2014	Annual WTP £2014	Scenario valued
Brown hare	£0.00	£0.00	Maintain brown hare populations and, where possible, restore them to all areas inhabited 25 years ago by the year 2010[84]
Red squirrel	£3.90	£0.58	Maintain red squirrel populations and, where possible, restore them to all areas inhabited 25 years ago by the year 2010[6]
Otter	£17.26	£2.57	Maintain otter populations and, where possible, restore them to all areas inhabited 25 years ago by the year 2010[6]

[80] Bostedt et al. (2007), 'Contingent values as implicit contracts: estimating minimum legal willingness to pay for conservation of large carnivores in Sweden', *Environmental and Resource Economics* February 2008, Volume 39, Issue 2, pp 189-198
[81] Martin-Lopez et al. (2007), 'The non-economic motives behind the willingness to pay for biodiversity conservation', *Biological Conservation* Volume 139, Issues 1–2, September 2007, Pages 67–82.
[82] Bartczak & Meyerhoff (2013), 'Valuing the chances of survival of two distinct Eurasian lynx populations in Poland – Do people want to keep the doors open?', *Journal of Environmental Management* Volume 129, 15 November 2013, Pages 73–80
[83] Kroeger & Casey (2006), 'Economic Impacts of Designating Critical Habitat Under the U.S. Endangered Species Act: Case Study of the Canada Lynx (Lynx Canadensis)', Human Dimensions of Wildlife, 11:437–453, 2006
[84] White et al. (2001), 'The use of willingness-to-pay approaches in mammal conservation', *Mammal Rev.* 2001, Volume 31, No. 2, 151–167.

Water vole	£10.78	£1.61	Maintain water vole populations and, where possible, restore them to all areas inhabited 25 years ago by the year 2010[6]
Pine marten	£13.61	£2.03	Restocking of pine martens across former ranges[85]
Beaver*	£522.76	£77.91	Re-introduce the beaver to a large (80,000 ha) native forest[86]
Wolf*	£18.50	£2.76	Re-introduce the wolf to a large (80,000 ha) native forest[8]

** WTP estimates are based on results from Model I for greater consistency with the other approaches.*

Of the value estimates set out in Table 16, there are two outliers: **brown hare** and **beaver**. According to White et al. (2001), the lack of willingness-to-pay for the brown hare may be due to the fact that, although they are in decline across the UK, there are substantial regional differences in brown hare abundance and in some areas they are considered an agricultural pest. Further complicating factors include the fact that the brown hare has only relatively recently emerged as a species of conservation concern and is also perceived as a game species. As such, it is unlikely that this species provides a useful comparison to lynx.

With regards to beaver, while they are likely to be more comparable to lynx in terms of being a charismatic mammal species previously native to the UK, the estimated WTP per respondent in MacMillan et al. (2001) is much higher than for other species. For comparison, an assessment of the impacts of the Scottish Beaver Trial reports that an unpublished study has been undertaken which estimates a WTP of £56 per household per year in a scenario of a reintroduction of beavers to over 50% of the national territory. In order to estimate the WTP value for the trial itself the authors use a range of values from £5.60 to £56 with a mid-range of estimate of £30 per household per year (due to the smaller scale of the scheme). Converting these values to a one-off lump sum using the method in White et al. (1997) provides WTP estimates of £37.58, £201.30, and £375.76. These are significantly lower than the MacMillan et al. (2001) study although still higher than the other studies.

With this in mind, it is considered that the proposed wolf reintroduction scenario is likely to bear the closest resemblance to a lynx reintroduction and as such it is assumed that the reintroduction of lynx in the UK could generate a one-off existence value of £18.50 per household or £2.76 per household per year.[87]

Without primary research on the issue, the next challenge is to define the boundary in terms of how many households would be likely to pay this value. The assessment of the Scottish Beaver Trial looks at a range of possible scenarios in terms of the number of households who are likely to be willing to pay for the reintroduction scheme, including a subset of households in the local area, all households in the local area, and all households in the UK.

While it could be argued that the boundary should be the entire UK population given the widespread public support for the reintroduction project, for the purposes of this analysis a conservative approach is adopted, assuming that existence value for lynx is only likely to extend to people living within the local area. For the site at Kielder Forest, the local area is assumed to be the county of Northumberland while at Thetford forest, the local area is assumed to be the county

[85] MacPherson (2014), 'Feasibility Assessment for Reinforcing Pine Marten Numbers in England and Wales', The Vincent Wildlife Trust.
[86] MacMillan et al. (2001), 'Modelling the Non-market Environmental Costs and Benefits of Biodiversity Projects Using Contingent Valuation Data', *Environmental and Resource Economics* 18: 391–410, 2001.
[87] Note, the outputs from Model I were used which focuses on mean WTP. The other estimates in the study included negative WTP bids. These are not likely to be capturing pure existence value, rather they are likely to include concerns over wolf attacks on livestock/human safety, which are addressed in other sections of the report and are likely to be non-existent for lynx populations.

of Norfolk. This is a more conservative assumption than the estimate for the potential visitor catchment area due to the greater levels of uncertainty associated with estimating existence values.

With regards to the number of people in the local area likely to contribute, two surveys of public support for reintroduction of lynx were undertaken by the Lynx UK Trust (see Section 3.4). Each of these surveys asked respondents the extent to which they agreed with the following statement, *"As part of a controlled and monitored scientific trial lynx should be reintroduced to the UK"*.

The first of these surveys found 91% of respondents strongly supported a trial reintroduction and 84% strongly agreed it should begin within the next 12 months. While the second more representative survey found strong support of 70% for the principle of lynx reintroduction, with 60% strongly supporting it within a 12 month period. Based on this level of support, it is assumed that 60% of all households in the local areas would be willing to pay in order to support the reintroduction scheme.

Results

The public's WTP for a lynx reintroduction programme in the UK was estimated by combining the total number of households in each local area who are in favour of the scheme with the estimated WTP value of £2.76 per household per year.[88] The present value was estimated assuming a time period of 25 years and a discount rate of 3.5% according to the guidance set out in The Green Book. The results are set out in Table 17 below.

Table 17. Estimated existence value of lynx populations

Area	No. households*	No. households willing to pay**	WTP per year (2014£)***	Present value (2014£)
Site 1: Kielder	138,500	83,100	£229,356	£3,780,134
Site 2: Thetford	223,260	223,260	£616,198	£10,155,870
UK total				**£13,936,004**

** Based on 2011 census data*
*** Assuming 60% of households are in favour of the scheme*
**** Assuming annual household WTP of £2.76*

As set out in Table 17, the estimated existence value of reintroducing lynx at both trial sites is around £14 million over a 25 year period. The estimate for Thetford is significantly higher than for Kielder due to the greater population density, and thereby greater numbers of potential beneficiaries, in the Thetford area.

This compares to estimates of the existence value of beaver reintroduction in the UK ranging from £0.56 million to £6.0 million over a five year period when restricting the sample of households who are willing to pay to half of the households in the area of Argyll & Bute. Using the annual WTP figures estimated in the Scottish Beaver Trial and comparing them over a 25 year period using a discount rate of 3.5% produces an estimated value between £1.9 million to £18.6 million.

For further comparison, White et al. (2001) found that the total value households in North Yorkshire were willing to pay for brown hare, red squirrel, otter, and water vole was estimated to be £0, £2.0 million, £9.3 million, and £5.8 million respectively.

[88] Note, the MacMillan (2001) study estimates annual WTP rather than a one-off payment so it is more appropriate to use this value rather than the PV estimated using the method set out in White et al. (1997). This also allows consistency in terms of assumptions over the discount rate and time period of assessment.

Sensitivity testing

In order to test the sensitivity of the estimates provided in the previous section, a comparison of potential 'best' and 'worst' case scenarios is presented below.

In the 'best' case scenario it is assumed that the WTP per household is equivalent to the amount estimated for the beaver reintroduction scheme of £56.00 per household per year. While in the 'worst' case scenario, household WTP is assumed to be equivalent to the amount estimated for red squirrel i.e. a one-off payment of £3.90 per household. The results are set out in Table 18 below.

Table 18. Estimated existence values across potential scenarios

Area	Worst case scenario	Central scenario	Best case scenario
Site 1: Kielder Forest	£870,714	£10,155,870	£206,061,125
Site 2: Thetford Forest	£324,090	£3,780,134	£76,698,376
UK total	**£1,194,804**	**£13,936,004**	**£282,759,501**

As expected when estimating existence values, the total potential value appears to be significant and there is a considerable range of uncertainty in the estimates of the range of values. Based on a comparison of similar studies it appears that the mid-range estimate is a reasonable one, however, due to the significant levels of uncertainty, further work would be required before this value could be included in a cost-benefit analysis with the requisite level of robustness. As such, this value is not included in the final analysis, and serves only to provide an indication of the potential magnitude of the value.

CONCLUSIONS

04

CONCLUSIONS

Based on the analysis set out in the sections above, the estimated net present value of lynx reintroduction over a 25 year period is £30.5 million at Kielder Forest, £37.1 million at Thetford Forest, and £67.6 million across the UK if both sites are selected. The results are set out in Table 19 below.

Table 19. Results of the cost-benefit analysis for lynx reintroduction

Potential impact	Site 1: Kielder Forest	Site 2: Thetford Forest	UK Total
Predation on livestock	-£11,016	-£7,920	-£18,936
Costs of monitoring	-£723,504	-£723,504	-£1,447,008
Risks to human health	£0	£0	£0
Recreation and tourism	£29,547,783	£36,186,820	£65,734,603
Reductions in deer	£1,700,017	£1,659,769	£3,359,786
Existence value of lynx	*Not included*	*Not included*	*Not included*
Net Present Value	**£30,513,280**	**£37,115,165**	**£67,628,445**
Benefit:cost ratio	**43:1**	**52:1**	**47:1**

Existence values of lynx were excluded from the results in Table 19 due to uncertainties over the estimates, if these are included the net present value increases to £34.3 million at Kielder, £47.3 million at Thetford, and £81.6 million across the UK.

According to the findings of this analysis the economic case for reintroduction appears to be strong for both sites individually and together. The net present value is higher for Thetford Forest, principally due to the greater population density and therefore greater potential for recreational benefits.

In order to account for some of the uncertainties in the estimates, a 'best' and 'worst' case was developed for each site. The results of this exercise (excluding existence values) found that all scenarios are expected to deliver positive and significant economic returns ranging from £55.6 million across the UK under the worst case to £147.7 million under the best case (see Table 20).

Table 20. Results of the cost-benefit analysis across potential scenarios

Area	Worst case scenario	Central scenario	Best case scenario
Site 1: Kielder Forest	£23,692,092	£30,513,280	£52,705,523
Site 2: Thetford Forest	£31,951,058	£37,115,165	£94,949,920
UK total	**£55,643,150**	**£67,628,445**	**£147,655,443**

The results of the analysis therefore suggest there is a strong economic case for reintroducing lynx at the two sites even under a worst case scenario. While there are a number of assumptions made in this analysis and the results should be interpreted as an initial 'high level' estimate, the findings suggest that the potential benefits are significant and robust across a range of scenarios. As such, it is considered unlikely that any additional evidence would be required to inform the analysis at this stage.

It should also be pointed out that the estimates in this report erred on the side of caution and several potentially significant positive impacts were excluded from the assessment due to a lack of robust monetary estimates. These include estimates of:

- Potentially positive benefits that lynx could have in terms of restoring ecosystem functioning and supporting wild species diversity.
- Potentially net beneficial impacts on sheep due to a reduction in fox predation rates.
- Consumer surplus from recreational visits, indirect expenditure, potential for business opportunities (branding, merchandising, safari tours), or volunteer and educational opportunities.
- Impacts of lynx on deer populations due to the landscapes of fear effect (which could potentially be of greater significance than direct predation).
- Existence value of a lynx reintroduction scheme (while they were quantified and found to be significant they were not included due to uncertainty).

The results of this analysis are therefore likely to provide a lower bound estimate of the net benefits of this scheme. Further, undertaking a controlled scientific trial would provide a significant opportunity to develop a greater understanding of the potential impacts of lynx in the UK, and to develop a better understanding of some of the potential benefits through monitoring of impacts on the wider ecosystem processes, impacts on fox populations, recording actual visitor expenditure, estimating existence values through a stated preference survey, and recording the impacts on deer populations beyond direct predation.

A final consideration is the potential for distributional impacts. While the lynx reintroduction scheme is expected to have significant net economic benefits to agriculture at the two trial sites, the scheme does have the potential to impose costs on particular groups (i.e. sheep farmers in the areas around the two sites, particularly those with sheep close to the edge of the forest). While the potential economic benefits are likely to significantly outweigh these costs, a compensation/adaption scheme (such as the one developed for sea eagles on Mull) may need to be developed to ensure that these groups are fully compensated for any economic or general welfare losses.

APPENDIX A

Modelling lynx populations at the case study sites

In an analysis of the potential habitat network available for lynx in Scotland, Hetherington et al. (2008)[89] identify potential habitat patches for lynx populations as follows:

- **Small:** an area of 45 – 73 km^2 could support one adult female home range.
- **Medium:** an area of 74 – 549 km^2 could support at least one female and one male but fewer than 20 (this is based on the minimum combined home range sizes for seven males and 13 females from a study in the Swiss Alps)
- **Large:** an area greater than 550 km^2 could support at least 20 adult lynx home ranges.

Based on this analysis the extent of habitat in the two case study sites suggests that Thetford Forest could support a population of up to 20 lynx while Kielder could support at least 20.

In addition to habitat, the availability of prey is also likely to act as a key constraint on population size. A study undertaken by Hetherington & Gorman (2007),[90] looked at the available biomass in the southern uplands of Scotland (including Kielder Forest), estimating population densities of 5.5 roe deer, 0.9 red deer, and 0.1 fallow deer der per km^2.

Based on an analysis of the size of lynx populations relative to prey biomass in a number of studies across Europe, they estimate a population density function for the number of lynx per 100 km^2 using the formula:

$$Lynx\ density = 4.58\ log_{10}\ (x) - 9.53$$

Where x is equal to ungulate biomass density in kg per km^2. Using this approach, Hetherington & Gorman (2007) estimate that a southern uplands network including Kielder Forest could support a population of around 51 lynx.

Assuming a reintroduction of five lynx to the Kielder Forest site, and assuming that the lynx populations are able to spread across the southern uplands habitat network, it is therefore estimated that the population will reach a maximum of 51 individuals.

With regards to the site at Thetford Forest, the approach developed by Hetherington & Gorman (2007) was used to estimate potential lynx density. Within Thetford Forest, the population density of ungulates is recorded as 3.2 fallow, 32.9 muntjac, 6.6 red, and 13.6 roe deer per km^2.[91]

Assuming average weights for each of these species of 50, 13, 130, and 20 kg provides an estimated ungulate biomass density of 1,718 kg km^2. Using the formula developed by Hetherington & Gorman (2007) suggests an estimated lynx density of 5.3 per 100 km^2 or a total population estimate of 10 individuals.

Due to the isolated nature of the forest within a predominantly agricultural and urban area it is assumed that lynx populations will not expand beyond the boundaries of the forest. As such, given

[89] Hetherington et al. (2008), 'A potential habitat network for the Eurasian lynx Lynx lynx in Scotland', Mammal Rev. 2008, Volume 38, No. 4, 285–303.
[90] Hetherington & Gorman (2007), 'Using prey densities to estimate the potential size of reintroduced populations of Eurasian lynx', Biological Conservation 137 (2007) 37–44.
[91] Piran et al. (2002), 'Economic impacts of wild deer in the east of England'.

the size of the habitat and the abundance of prey in the forest it is therefore assumed that the population in Thetford Forest could reach a maximum of 10 individuals.

With regards to the potential growth rate of lynx populations, a study undertaken on the dynamics of lynx in the Jura Mountains found:

A. An adult mortality rate of 24%.
B. A sex ratio not significantly different from the expected 50% female ratio.
C. An average of 81% of females reproducing each year.
D. An average of 1.67 kittens per female per year.
E. A survival rate for kittens of 46%.

Assuming that this provides a reasonable model for the UK (which appears to be a reasonable assumption given the similarities in habitat types), the population growth rate was estimated using the formula:

$$Pop_t = Pop_{t-1} + (Pop_{t-1} * A * B * C * D * E)$$

By combining this estimate of population growth with the maximum population size estimates provided above, an outline model of lynx populations at the two sites was estimated over a 25 year period. A summary of this model is set out in Table 21.

Table 21. Population model for reintroduced lynx in the UK

Area	Year 1	Year 5	Year 10	Year 15	Year 20	Year 25
Site 1: Kielder Forest	5	7	10	14	20	28
Site 2: Thetford Forest	5	7	10	10	10	10
UK total*	10	13	19	26	32	40

** Figures may not add up due to rounding*

APPENDIX B

The lynx as a flagship species for nature conservation, ecotourism, culture, science, and education in Germany

Lynx have been or are being restored in a number of areas in Germany, including the Harz, Pfälzerwald (Palatinate Forest), Bavaria (Black Forest), and Saxion Switzerland. These areas hold sizeable national parks which are promoted by the government as rewilding areas or biosphere reserves. The regions attract significant cultural, recreational, and eco-tourism from within Germany and internationally.

While detailed quantitative data is not available on visitor numbers and expenditure, qualitative evidence suggests that the lynx – as an element of 'wildness' which restores part of the natural balance – is a significant source of eco-tourism and business opportunities. The lynx features in a number of German documentaries, books, websites, stamps, tourist brochures, and information brochures to inform the public about lynx sightings.

The national parks in Germany which are home to lynx all have centres where people can view lynx since they are difficult to see in the wild; although the thought of their presence or the finding of tracks and signs are also important to visitors. The visitor centres have displays on the life of the lynx and the process of reintroduction. A variety of lynx paraphernalia are also sold (toys, books, posters, statues, T-shirts, buttons, etc.), and special 'lynx trails' are support educational and recreational visits for families.

In the absence of quantitative data, this section provides an example of the level of interest in lynx in Germany and the eco-tourism/wider business related opportunities.

Figure 2. A number of TV programmes highlight the German public's pride in the lynx as a charismatic 'wilderness' species returning to the countryside

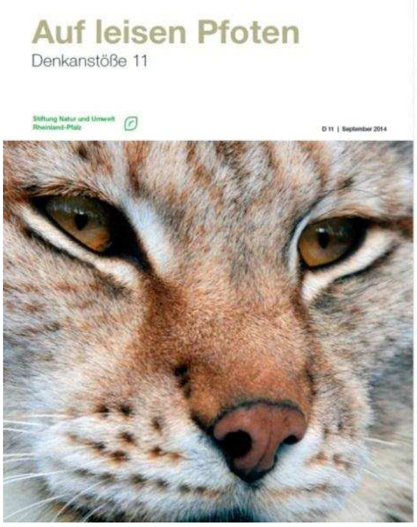
Figure 3. Examples of lynx paraphernalia in Germany

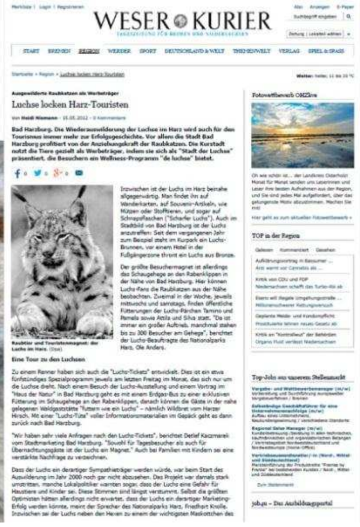
Figure 4. Lynx tourism in Germany with pictures of tourist offices, visitor centres, and lynx viewing areas in the Harz and in Saxion Switzerland

Figure 5. Information graphic from the Bavarian Forest National Park on lynx reintroduction

Figure 6. Cable way to lynx enclosure in Bad Harzburg (left), German district brochure informing the public about the 'return of the lynx' (right)

Figure 7. Information on lynx in a brochure (left), newspaper article on lynx as a tourist attractor in the Harz (centre), poster on lynx habitat restoration (right)





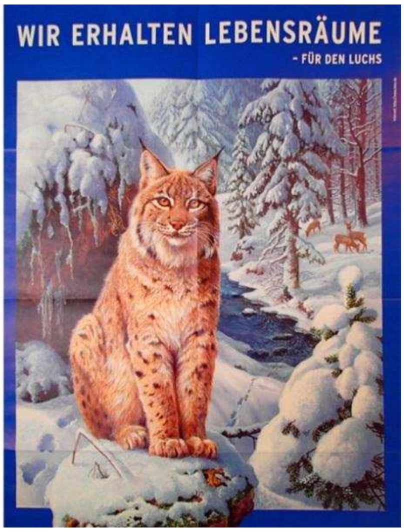


Figure 8. Public lynx brochure (left), monument in the Harz on a spot where the last lynx was killed (centre), a Dutch ecotourist snow tracking lynx (right)

Figure 9. Lynx on a wall painting in Bad Harzburg (left), female lynx Alice an ambassador lynx in the Rabenklippe enclosure in the Harz (right)

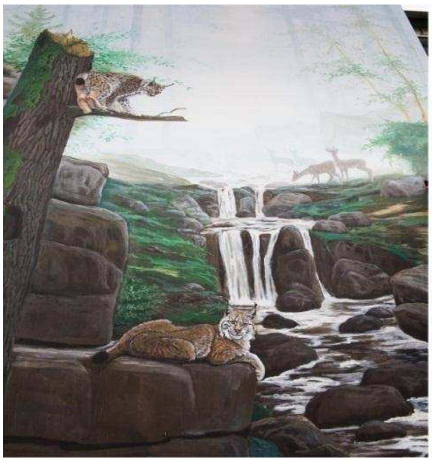


Figure 10. General lynx paraphernalia including town statues, websites, educational brochures, information panels, museums, and branded products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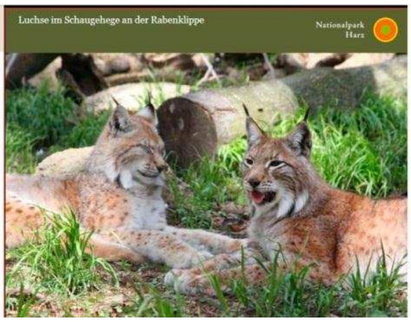
Luchse im Schaugehege an der Rabenklippe
Nationalpark Harz


Tasche
9,90 €


de luchse
BAD HARZBURG
WELLNESS-WANDERLAND


Luchs-Initiative Baden-Württemberg e.V.
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Aktuelle Pressemeldungen zum Luchs
Aktuelle Pressemeldungen zum Luchs im Mai 2015:
Link auf den Artikel "Umweltministerin setzt 10.000 Euro Belohnung aus" (suedkurier.de, 28.05.2015)
Link auf den Artikel "Mehrere Luchse im Bayerischen Wald getötet und zerstückelt" (nordbayern.de, 21.05.2015)
Aktuelle Pressemeldungen zum besenderten Luchs im Schwarzwald
Naturpark Südschwarzwald
AKTUELLES
Aktuelle Pressemeldungen zum Luchs
Hier präsentieren wir Ihnen aktuelle Luchs-Meldungen aus der Presse.
Diese sind mal kurios, mal erfreulich, mal traurig - wir wünschen interessante Lektüre!
--» mehr Informationen
Aktuelle Pressemeldungen zum besenderten Luchs im Schwarzwald
Hier finden Sie die aktuellen Meldungen zum im April 2015 besenderten Luchs im


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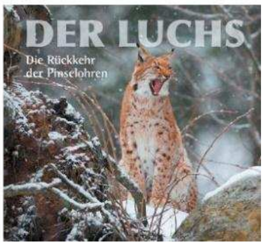

DER LUCHS
Die Rückkehr der Pinselohren

Arbeitskreis Hessenluchs

http://www.luchs-in-hessen.de
Kontakt: Gerd Bauer, Tel. 0611/846543
E-Mail: gerdbauer33@AOL.com

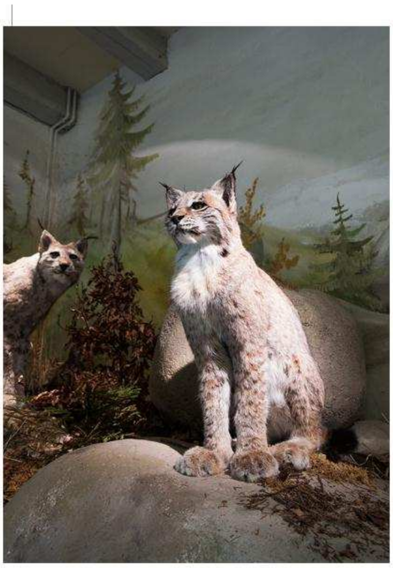
Spendenkonto:
BUND Landesverband Hessen e.V., "Stichwort Luchs"
Frankfurter Sparkasse, Konto 369853, BLZ 500 502 01

Merkblatt Luchsspuren

Die Fährte des Luchses zeigt eine leichte Schränkung - also keine schnurgerade Linie wie beim "schnürenden" Fuchs. Der Schrittabstand erinnert an eine Schwarzwildfährte.
Das Trittsiegel (Pfotenabdruck) ist beim erwachsenen Luchs etwa "handtellergroß" und zeigt in der Regel keine Nägel (Krallenabdrücke). Der wichtigste Unterschied zu den Fährten von Fuchs, Hund oder Wolf, die (fast) immer Krallenabdrücke zeigen.

Typisch für den Luchs: die Zehen sind asymmetrisch gespreizt. Soll heißen: teilt man das Trittsiegel durch eine (gedachte) Mittellinie, entstehen - anders als bei Hunden und Wölfen - keine spiegelgleichen Hälften.

Keine Regel ohne Ausnahme:
Hin und wieder fährt auch der Luchs die Krallen aus und hinterlässt ihre Eindrücke im Schnee. Typisch ist aber, dass die Nägel im flachen Schnee in einem deutlichen Abstand vor den Zehen aufsetzen. Bei Füchsen, Hunden und Wölfen schließen die Krallenabdrücke direkt an die Zehen an.



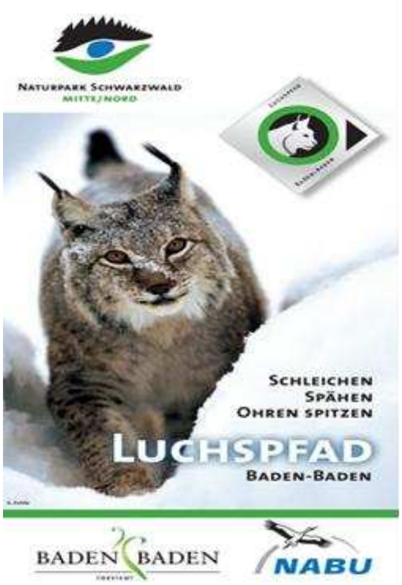


Figure 11. Tufted ears in a display on a lynx trail explain how the brushes improve the directional hearing of the lynx

Figure 12. TV documentary on the lynx featuring Ole Anders from the Harz Lynx Project performing telemetry on lynx number M4

Figure 13. Lynx viewing platform at the enclosure in the Harz, where the lynx was chosen animal of the year in 2011