RESEARCH FAQS:
ECOLOGICAL FEASIBILITY MODELLING

Answers to a range of Frequently Asked Questions about the lynx ecological modelling.

THE MISSING LYNX PROJECT

ECOLOGY AND POPULATION GROWTH

What are the 'ecological requirements' of lynx?

- Lynx need food and shelter, and they need to encounter other lynx to mate and grow the population.
- Food: Lynx mainly eat roe deer, which are abundant across Britain. It will take several days for a lynx to eat a whole deer, so they hide it and return later. They normally need to eat one deer every few days but may need more if they either have kittens to feed or if other species (or other lynx) steal and eat their stashed deer. Lynx hunt by stalking, meaning they need cover to get close enough to their prey to catch it. This means they need habitats that have enough cover to allow this, such as woodland or scrubland, or complex terrain with many features that provide enough cover.
- Shelter: Lynx, like domestic cats, are territorial, but their home ranges (where they hunt, raise kittens, and rest) are huge by comparison (50-250 km^2). This means although they are wide-ranging, they tend to exist at extremely low densities in the landscape (perhaps one or two per 100 km^2). It is mainly when they are resting or raising kittens ('denning') that they need refuges to hide and feel safe from being disturbed – especially during the day when humans are most active. These refuges are normally sheltered spots far away from humans, in hard to access terrain such as rocky outcrops, caves, or among dead wood.
- Mates: Lynx live mostly solitary lives in their own territories, although male territories do overlap with female territories. During the breeding season lynx will meet to mate. Male lynx will usually mate with more than one female; those that have territories within his own. The females will birth and raise the kittens alone.

What will happen if lynx don't just eat roe deer? (will their numbers grow faster/out of control / spread etc)?

- Lynx can eat a range of animals, but where roe deer are available, these are usually preferred.
- Where prey are more numerous and can be caught by lynx, this abundance of food will help the lynx to survive and breed and result in there being more lynx - up to a point. The more lynx there are the better the chance that the lynx population will properly establish itself and persist into the future in Britain.
- Although the number of lynx in an area does depend on the availability of prey (more prey = more lynx) there are other factors that limit how many lynx can exist in an area. For example, competition among lynx for any suitable refuges in the landscape. Lynx are solitary and territorial and do not like to share space with other lynx of the same sex. They will patrol and scent mark their territory to signal to another lynx that it is theirs. This is one of the ways that the numbers of lynx are naturally regulated.
- This competition for space, shelter, and resources means some lynx remain without a territory and are unable to reproduce, which limits the rate of population growth. The highest density of lynx reported is around four per 100 km^2, but around one to two lynx per 100 km^2 is more normal at our latitude.

What if the lynx decide to go south into England (instead of north)?

- From what we know about lynx and from our feasibility modelling, it is likely that some of the lynx will travel south. However, there is much less suitable habitat for lynx to the south of Northumberland and in this area the landscape becomes much more fragmented by infrastructure.
- The habitats south of Northumberland might be sufficient for a lynx to be able to travel through the landscape, but there are not many suitable areas for lynx to settle down in a territory. If the lynx find no suitable space to settle down, it is very unlikely that they will breed. This will likely limit the spread of lynx to the south.
- If lynx do manage to reach large suitable areas of habitat in England, it is possible that territories could be settled by these animals. However, it is normally male lynx that are able to travel longer distances in search of suitable territories to settle in, while the females tend to stay much closer to where they were born. The absence of females in any new areas further

afield will prevent a population being established and eventually any solitary male lynx in those southerly areas will leave or die out.

GENETICS

What is genetic health and why is it important?

- All living things have genes, these are the bits of information encoded in our DNA that describe how our bodies are built and work. In large populations there are plenty of different genes – including a few bad ones.
- Normally these occasional bad genes have no big effect on individuals or populations because they are either rare or are counteracted by other dominant genes. In small populations there is a greater risk of individuals carrying similar genes, and when they mate this can increase the prevalence of bad genes among the population.
- If an individual lynx has enough bad genes in its DNA, this can have physical health implications. When enough lynx suffer these physical health issues this may be detected as higher mortality rates and reduced breeding success across the population, hindering the long term survival of the lynx population.
- A genetically healthy lynx population has plenty of different genes and is large enough that inbreeding is avoided (mating between closely related lynx), which reduces the risk of bad genes being expressed as physical health issues. This is why it is important to use genetically healthy lynx for the reintroduction and to ensure the new population grows to establish itself as quickly as possible in the first instance.

How do we prevent genetic decline in an isolated lynx population in the UK?

- The best way to prevent genetic decline in a UK lynx population is to ensure that good numbers of lynx with good genetic health are released in the beginning. This will help the population to expand quickly after reintroduction and help to achieve a large enough population to contain a good diversity of genes. Releasing lynx across more than one reintroduction site can also help.
- When a population is small, over time the genetic diversity declines. For a UK lynx population this could be counteracted by releasing additional lynx from Europe as ‘reinforcements’ to bring in new genes and boost diversity.

Alternatively, lynx from a separate lynx population elsewhere in the UK, if one exists, could be moved over for the same effect.

- These kinds of lynx translocations are becoming quite common in Europe because many of the lynx populations there are isolated from each other by roads and cities and are experiencing this problem of gradual genetic decline.

How do we ensure a good genetic start for a new lynx population in UK?

It is crucial to release sufficient numbers of lynx (our modelling suggests at least 20 of equal numbers males and females or ideally more females) that are from genetically healthy wild populations, or are planned to be genetically healthy by the managed pairing of adult lynx in a captive breeding programme.

THE MODELLING

Why was this modelling approach chosen?

- Real animal populations are very complicated because they have many individuals, making it difficult to predict how the population might develop. The growth or decline of a population in any particular location depends on so many different factors and an element of random chance. For lynx, some examples of different factors are the amount and arrangement of areas of suitable habitat, the presence of roads and other built infrastructure (which tend to be barriers to lynx movement), the size of the territory of each lynx, their mating behaviour, their risk of death, and the individual daily choices made by every lynx in the population.
- The modelling approach we have chosen to use allows us to account for all these factors as well as the choices made by the individual lynx (where they go, how they use the landscape, and how they interact with each other), in each simulation. This allows us to predict how the whole population of lynx will develop over time.
- Information about the resulting lynx population, such as the number of lynx it contains, where it extends to, and how quickly it grows or declines, all depends on the decisions these simulated individual lynxes make.

Is there any proof that what the computer model shows will really happen?

- The model we have used has already been used to simulate other lynx populations. This has included tests to compare whether the development of the lynx populations in real life matches the predictions from the computer simulations.
- The different processes the model describes have been observed in real wild lynx populations, so we know that the information that the model is based on reflects reality.
- This being said, there can be no guarantee that the simulations describe what will definitely happen. This is because the simulation provides us with the best prediction based on the best knowledge available on lynx. These predictions are based on lots of simulations for every set of conditions, and each simulation contains a certain level of randomness (for example, should a lynx turn left, or right? does a lynx die on the road, or cross successfully?). By taking the average result of many simulations, we can predict the most likely outcome. But as in real life, the actual outcome may not necessarily be the most likely one, because chance still plays a role in life.

What is the difference between the global and local models?

- The real British landscape was converted into a simplistic digital map for the simulated lynx to live in. In this simplified world, the land was either suitable or unsuitable for lynx, or lay somewhere in between on a spectrum of habitat suitability. This map of habitat suitability could be generated two ways, which we called either the 'global' model, or the 'local' model.
- The two models would individually each be perfectly valid to apply to Britain. They each have slightly different strengths and weaknesses and generate slightly different maps. Rather than choose just one model and discard the other, we decided to test reintroductions with both to check that both conditions were feasible. It means the results are more conservative (that is, have stricter criteria for defining what is considered a feasible reintroduction) than if we had used either one of the maps generated by the global or local model alone.
- The 'global' model combined data from across all European lynx populations together in one model to create a habitat suitability map for lynx.
- The local model (technically a 'metamodel') did the same thing, but first models were created for each single ('local') lynx population thereby

generating lots of local habitat suitability maps. An extra step was added to generate one combined, or meta, habitat suitability map from all these local maps, by weighting each one based on how representative the environment of each lynx population was for the place being mapped. Local models that were more representative were more strongly weighted than those that were less representative.

- We always examined the results from each of the global and the local model habitat suitability maps. This acts as sensitivity testing of the range of potential lynx behavioural responses to the British landscape.

Was stochasticity (chance behaviour or events) accounted for in the model?

- Stochasticity is a helpful attribute in simulation models because it allows for chance events to occur and be factored into the overall outcome, which is more representative of real life.
- The model we used includes several stochastic elements, all related to lynx life histories. The chance of the random events occurring is pre-specified in the model as a probability, such as the probability that a lynx crossing a road will die in a vehicle collision.
- Other elements that were subject to chance included the movement and territorialism of the lynx (e.g. selection of poor habitats, movement direction, the distance they travel each day, the size of their territory), birth and death rates (e.g. is there a successful reproduction, how many kittens, how many kittens survive, does the lynx die on a road, does the lynx die of natural causes).
- We did not include any stochastic scenarios (that is, freak scenarios) such as major disease outbreaks or things that would suddenly reduce the prey or habitat for lynx such as extreme weather events. These scenarios are too uncertain and difficult to model sensibly. Instead, the management plan for any future reintroduced lynx population would need to account for such eventualities and be able to adapt the management accordingly.

Which 10 release points were tested across Britain?

- These were: Cairngorms, Galloway, Kielder Forest, Kintyre, New Forest, North Wales, North York Moors, Peak District, Southeast England, South Wales.

Why were the others unsuitable?

- For the Scottish regions, these were chosen to align with what earlier modelling approaches had been done. This helps us to be able to directly compare our results with the modelling work on lynx that has been done in the past.
- For England and Wales there had not been any equivalent previous modelling on whether lynx populations could establish and persist, so we decided to select regions based on some areas that had the largest patches of suitable habitat (we used a minimum cut-off of 130 km^2). As this is relatively small for a lynx territory, we were confident that anything smaller than this would not be suitable, and that this therefore made a good choice of cut-off. In any event, the release locations we tested that had smaller and more fragmented habitat patches were not able to accommodate lynx populations in our simulations.
- In Scotland, our testing of just three locations based on previous modelling choices means there may be other suitable release locations that we did not test initially and could be good candidates.

Explain again why the Kielder Forest habitat patch is better than the Galloway patch?

- The population starting in Kielder Forest is predicted to expand more quickly in the first few years, which retains genetics better. Genetic diversity is of paramount importance in the long-term persistence of wild populations. Some gradual loss of genetic diversity is inevitable with an isolated population and needs to be addressed with the planned management of any future reintroduced lynx population, but sometimes even management interventions can be insufficient to secure the survival of the population. Therefore giving the population the best possible starting point is a key decision in any reintroduction programme.
- The habitat patch starting at Kielder Forest has better connectivity via suitable habitat to expand northward and into southern Scotland. This is at least partly because the M74 motorway, which runs north-south in-between the Galloway and Kielder Forest patches, is a likely barrier impeding access to this habitat 'corridor' from the Galloway patch.

Explain again what the central belt barrier is and how it affects lynx reintroduction?

- The 'central belt barrier' is the area of urban land use and concentrated built infrastructure that includes Glasgow and Edinburgh and the area in-between.
- The model predicts this region to be a major barrier to lynx movement because there is less suitable habitat for them, and there are many roads and other land uses that act as physical barriers to lynx movement and survival.
- This means that any reintroduced lynx population south of the belt would be very unlikely to merge into one continuous population with any reintroduced lynx population north of the belt, and vice versa, although there may be the occasional lynx successfully making the journey between. For management purposes if there are two reintroductions, one north and one south of the central belt, these would likely be treated as separate, isolated lynx populations.
- Eventually, many decades into the future, there may be sufficient lynx dispersal between the two reintroduced populations, which would help both populations to retain more genetic diversity and collectively have a better chance of persisting long-term.

What makes a habitat patch large enough to be suitable for lynx?

- In reality this depends on the quality of the habitats and availability of prey and refuge. In resource-poor regions, such as northern Scandinavia, lynx must maintain very large home ranges to acquire all the prey and refuges they need. Female lynx tend to need less space than male lynx because males range more widely in an attempt to monopolise more females to mate with.
- In the model each simulated individual lynx tries to make a territory in a patch of suitable habitat. For females, there is a minimum area they need. If this is not met, they will move onto a different patch. If it is large enough, they might occupy it. Male lynx will only occupy a territory if there is already a female to mate with, but they can also have territories that cover up to 3 female home ranges. (This is a simple answer; there is more nuance to do with stochasticity of the female home ranges).

Did the model compare different staggered releases, as well as releasing altogether?

- We tested 3 different staggered releases where the total released lynx were divided into releases across i) two years, ii) three years, and iii) six years.

How big an area is needed for 20 released lynx?

- This depends on the density at which lynx live in the landscape, but for example, at a density of 2 lynx per 100 km^2 (which would be quite a high density for this elusive animal), then roughly 1000 km^2 would be needed for 20 lynx. This is roughly equivalent to the total area of Northumberland National Park.
- However, lynx do not necessarily stay where they are released. Lynx are highly mobile animals that can travel tens of km per day in search of a territory to settle down, and even when settled down they regularly move around within their large territories. These large territories will include mostly habitats that lynx prefer but there will also be some amount of less preferred habitat that lynx might sometimes travel through.
- Releasing 20 lynx also does not assume that all will remain part of a population. Indeed, some might die before they settle down. Some might die before they reproduce. Introducing more individuals ensures that sufficient genetic diversity is maintained and increases the chance that a wild lynx population will successfully establish.

What was the 'green future' scenario (how many years into the future does it predict) and how realistic is it?

- The 'green future' is a hypothetical future scenario in which there is more woodland cover overall and better connectivity between woodland patches throughout Britain. It could be one result of current and likely future policies that promote tree planting, woodland creation, and better woodland management as a way of storing more carbon and helping to achieve 'net zero' goals.
- The mapped scenario of this is taken directly from research conducted by RSPB scientists and published in a scientific paper here https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.14003. They mapped the places where new woodland could arise, excluding land that is high quality farmland, priority habitat, existing

woodland, and soils where tree cover would not necessarily increase the amount of carbon stored in the land. The resulting total increase in woodland would be somewhere in the region of 2Mha across the UK.

- We originally included this scenario as 'back up' in the event that the model of current habitat showed that lynx would not be able to exist anywhere in Britain as a viable population. Therefore we do not place too much emphasis on the green future scenario as the present day levels of habitat coverage are sufficient for lynx as they are currently.

Did you also test a future 'deforestation' scenario (e.g. of declining carrying capacity)? (why not)

- We did not test such a scenario since this goes against the current long-term policies of the British Governments.

Why might lynx in the UK fare better than in Europe? (what is wrong in Europe?)

- If a reintroduced population is founded with genetically healthy individuals, increases in size, and eventually contains enough lynx, then the population could be large enough to maintain high genetic diversity. This is especially true if multiple habitat patches are occupied and well-connected.
- In Europe many of the historically reintroduced and some of the autochthonous populations (meaning the original wild populations that were never lost), were either initiated with few lynx and low genetic diversity, or they experienced a 'bottleneck' (when the population shrinks rapidly to a few remaining individuals before increasing in size again), or they are completely isolated with no gene flow between them to maintain the health of their gene pools.
- Extensive work is being undertaken across Europe to rescue and reinforce the many isolated lynx populations. This is generating huge amounts of knowledge about how to manage individual lynx, undertake translocations safely and successfully, and how to live well alongside these animals allowing both lynx and people to thrive together.

LYNX REINTRODUCTION – GENERAL

Where will the founder lynx come from?

- We have prepared a separate briefing note on 'Sourcing lynx for reintroduction'.

How many lynx are needed in 100 years for the project to be a success?

- Our modelling tested population success against the likelihood of extinction, rather than the size of the lynx population. The population must have more than a 95% chance of surviving for 100 years for it to be considered 'ecologically viable' (i.e. successful). The number of lynx that the model predicts will be present in the population gives us an indication that the population is on course for success.

Is any conservation management needed to maintain the right conditions for the lynx? (e.g. woodland management)

- Lynx are shy animals that avoid human disturbance. Although they prefer tree cover as this provides the concealment they need to hunt deer, they will most likely avoid live forestry operations or locations where woodland management is in progress such as thinning or coppicing. That said, lynx can persist in all types of landscapes including economic forests. Therefore, if disturbances can be distributed in space and time this will allow lynx to find refuges.

Isn't 50 lynx too low for a long-term sustainable population without ongoing management?

- Our model results indicate that a lynx population originating in the Kielder Forest patch that eventually numbers around 50 individuals would be viable over 100 years. This assumes the conditions for lynx remain as they are today, with no improvement in habitat. So yes, our model indicates 50 lynx is sufficient.
- In the very long term (beyond 100 years) if nothing else has changed (e.g. the population remains isolated) there would probably be a need to

boost the genetic diversity of the population with further lynx translocations into the population. In practice, doing this form of reinforcement would probably happen much sooner to pre-empt any genetic decline. Management of lynx populations of a similar size in Europe is becoming normal practise to aid their long-term conservation.

- In truth, much can happen over 100 years, and it is quite possible that there will be substantially more tree cover and hopefully safe crossing points for wildlife over major roads, both of which would support a larger lynx population and connectivity between lynx in the north and the south of Scotland.