LIFE LUPI LYNX

D5.1 - Compilation of good practices for prey abundance for Iberian wolf and Iberian Lynx

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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Prey species abundance is extremely important for the conservation of predators. We present several techniques to increase the number of wild preys to help the conservation of iconic Iberian endemic predators. Iberian Lynx relies almost exclusively on rabbits to survive and reproduce, a species that is threatened and whose population has decreased over 80% in the last decades. The most important tools to restore wild rabbit populations and, in turn, the Iberian Lynx, are habitat restoration and reinforcements with high population densities of locally sourced rabbits, high genetic diversity and natural immunity to several types of diseases. Wolf relies mainly on ungulate species. Roe deer and red deer populations are slowly increasing in the landscape but habitat restoration, like selective bush clearing, reforestation and grassland seeding, needs to be carried out in order to keep sustainable populations and encourage their dispersion. The presence of additional wild prey in the ecosystem diminishes the likelihood of wolves causing damage to livestock.

KEYWORDS

European rabbit; ungulates; reinforcements; habitat restoration; prey species

1. INTRODUCTION

1.1. The importance of wild prey for wolf and lynx

The abundance of wild prey in wolf and lynx territories is perhaps one of the most important factors in reducing the attacks on domestic livestock. The presence of healthy populations of prey for these apex predators also signals a highly functional ecosystem.

Animals like roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), Iberian rabbit (*Oryctolagus cuniculus algirus*) and red legged partridge (*Alectoris rufa*) are intrinsic parts of the food chain in the Iberian Peninsula and develop important ecosystem engineering roles like diversifying forest structure, increasing shelter for other animals by creating burrows, maintaining meadows etc.

Rabbits are directly linked to lynx reproduction success, and despite both male and female lynxes can hunt deer and other prey, expert opinion believes that during breeding season Iberian lynx females are highly dependent on rabbits (P. Sarmento, pers. comm. 2024; C. Carrapato, pers. comm 2024).

Larger herbivores like deer and wild boar also directly affect the size and health of wolf packs, as larger packs with more offspring will require more biomass to sustain their diet. When these larger wild preys are absent, wolves often turn to livestock like sheep and cattle, increasing the human-wildlife conflict (Torres et al. 2015).

Rabbit is the most important prey animal for Iberian lynx (Simón et al., 2008). They reproduce in spring and early summer when food abundance is highest and can be quite prolific, with several litters per year comprising a mean of 3.9 cubs (Gonçalves et al., 2002). They prefer a mosaic type landscape with open grassland for feeding and shrubland for shelter and predator protection, ideally at a rate of 50-50. They spend the day in burrows dug in soft soil or under large rocks and shrubland in rocky soil.

The Iberian rabbit population has faced a decrease of up to 80% in some regions over the last 50 years (Mathias et al., 2023; Alda et al., 2010). Land management has decreased the rabbit's habitat; predation by mesocarnivores has increased due to the dramatic decrease in large predators like lynx, bear and wolf that control the mesocarnivore numbers; hunting pressure is still high and the largest problem rabbits have faced, the introduction of Myxomatosis and Rabbit Haemorrhagic Disease (RHD). These two diseases have decimated rabbit numbers and have gone through many strains and mutations. Rabbits have survived because some populations developed immunity to particular strains while others have managed to not be exposed to the more deadly strains. New mutations are relatively common, and their emergence is associated with population dips in certain areas.

Red deer is an important food source for wolves, especially in the northern part of Portugal where both species occur and are more abundant (Figueiredo et al. 2020). Female and juvenile red deer are taken occasionally by Iberian lynx.
The rutting season starts in September and ends in October, females usually give birth to a single calf in late spring/early summer. Females and young males usually form herds throughout the year while older males form bachelor herds outside of rutting season, splitting up before the rut to fight for female herds they will dominate alone. This species can be found in woodlands, mixed forests and grasslands, preferring areas with cover and open patches for feeding. Red deer are browsers and will feed on young saplings, tree shoots and shrubs as well as a variety of grasses. Throughout the year they can move to higher altitudes in mountainous regions or dense forests to find the most suitable food sources and breeding grounds.
Red deer are making a comeback in Portugal and after going nearly extinct in the early 20^{th} century are recolonizing many areas of their historical range. Besides habitat loss, they face threats like poaching, especially in newly recolonized areas, and diseases like Bovine Tuberculosis. Despite this, red deer are increasing steadily in Portugal (Mathias et al. 2023).

Roe deer are also an important food source for wolves and can be the preferred prey type where both species exist (Figueiredo et al. 2020). It can also be occasional prey for Iberian lynx. Roe deer has a unique reproduction cycle and are the only ruminant that exhibit embryonic diapause, or delayed implantation. Mating occurs in July and August but foetus development only starts 5 months later. Females can have one or two fawns in May or June. This species is significantly more solitary than the red deer and is usually seen alone or in very small family groups. Their diet and habitat preference are similar to that of red deer, while favouring denser cover. Much like the red deer, most of the population was extirpated in the beginning of the 20^{th} century and is now making a comeback with populations and distribution increasing dramatically over the last decades (Mathias et al. 2023).

The species mentioned above are the ones that are the main focus of the project LIFE LUPI LYNX but there are other ungulates that are important prey for wolf and that are also present in the project area, namely **wild boar**, which is the one among the wild ungulates that accounts for a higher percentage in wolf diet (Lino et al. 2023) as it is the only one that is widespread and with high densities in the project area. Other ungulate species present in the project area with more restricted distributions include **Iberian ibex** in Extremadura, Spain, as well as **fallow deer** *(Dama dama)* and **mouflon** *(Ovis aries)*, in Castelo Branco, Portugal.

Restoring populations of these wild prey species, especially when done under game management, often involves a lot of sustained human interference. Artificial feeding and watering systems that need resupplying, constant bush cutting, annual crop sowing, forest management, regular population reinforcements etc. Rewilding practitioners operate under the assumption that focusing on restoring key processes in the ecosystem can provide all of the previous services and allow wildlife populations to reach their natural densities. As an example, for the meadows and clearings created by bush cutting to be maintained long term (without constant human action), large herbivores such as horses and cattle can be introduced into the landscape as semi wild animals. These animals will maintain open areas and prevent the spread of scrubland, while fertilizing the soils and spreading seeds. To increase water availability, instead of maintaining automatic waterers, natural ponds can be restored or created in moist areas or near streams and springs, to retain already occurring water.

This document compiles good practices following the principle of restoring natural processes and habitats avoiding as much as possible recurrent human intervention, in order to **recover functional and sustainable populations of key prey for wolf and lynx.** It is extremely important to follow tried and tested techniques, and for instance many of the guidelines written in this document have come from previous work carried out by other LIFE projects like IBERCONEJO, +IBERLYNX, LYNXCONNECT and WolFlux.

2. WILD UNGULATES

2.1. Functional densities and diversity for wolf and lynx

In landscapes where wild ungulates are available in sufficient diversity and abundance, they constitute the diet basis of the Iberian wolf (Barja et al. 2023; Figueiredo et al. 2020). Prey such as deer and wild boar can be majorly selected, even when domestic livestock is available, reducing conflict with human populations which could lead to direct persecution, the main threat to wolf conservation. Conversely, in areas where wild ungulates are absent, or present only in low abundance and diversity, the diet of the Iberian wolf can be heavily dependent on domestic livestock, as is the case in some areas of central

Portugal (Torres et al. 2015), causing hotspots of conflict with this species. Therefore, identifying adequate values of ungulate diversity and density to sustain an Iberian wolf population can be a valuable guideline for conservation projects. However, it should be considered that many other factors, including ecological and social, may be relevant, such as population structure (both predator and prey), domestic livestock densities, husbandry practices, landscape configuration and seasonal patterns.

In Guadarrama National Park and surrounding regions, in central Spain, Barja et al. (2023) found that wolf diet was composed by 82% wild ungulates, with three species being consumed: roe deer, wild boar and Iberian ibex. Densities of this species in the region are as follows: roe deer 3-6 ind/km2; wild boar 3-5 ind/km^2; Iberian ibex 15-36 ind/km^2 (restricted to high mountain enclaves). The most consumed prey were wild boar (44%) and roe deer (35%).

In Montesinho Natural Park, in northeast Portugal, Figueiredo et al. (2020) found a similar trend. In this area roe deer, red deer and wild boar were the existing wild ungulates. The densities for deer species area as follows: roe deer 1-2 ind/km^2 ; red deer 5-8 ind/km^2. Wild boar density data was not provided in the study, but it occurred in 24% of diet samples, surpassed by red deer (26%) and roe deer (44%). Domestic livestock were only present in 5% of samples, and always goat, despite cattle, sheep and pigs also being available in the landscape. These results contrast with previous studies done in the area (Paixão de Magalhães & Petrucci-Fonseca, 1982), where it was found that domestic livestock composed most of the wolf diet. The shift in diet of the wolves follows the significant increase of wild ungulates in the area, when in 1982 roe deer density was reported as low and red deer was just starting to recolonize the study area. It should be noted that there was also a decrease in livestock densities, a common trend in many areas of Iberian wolf presence.

By analysing the available data, it can be interpreted that in landscapes where the Iberian wolf diet is mostly sustained by wild prey the overall ungulate densities have minimum values of 7 ind/km^2, encompassing two or three main prey species. Both diversity and abundance are key for wolves to choose wild prey over livestock, which happens even in situations where livestock is more abundant (Janeiro-Otero 2020). Several studies support that this selection occurs as wild prey abundances recover, although unattended livestock is a key driver for the consumption of domestic prey (Imbert et al., 2016, Meriggi et al., 2011, Janeiro-Otero, 2020).

Cervids, namely red and roe deer, along with wild boar constitute the main prey, and they also tend to be more widespread than other ungulates such as Iberian ibex. It should be noted that Iberian wolf is also able to bring down larger animals, such as horses and bovids, which used to exist as wildlife in Iberia, and are still taken as prey as extensive livestock or in a semi wild state, as is the case of the Garrano breed in north-western Portugal and Galicia.

Regarding the Iberian lynx, the species is considered a specialist predator, relying mostly on rabbit. However, it is also able to take on larger alternative prey, including wild ungulates. Severino (2022) found a high percentage of ungulate occurrence in Iberian lynx diet at one site in southern Portugal (27,6%), mostly consisting of fallow deer but also red deer and wild boar. This unusual proportion might be explained by the high densities of wild ungulates in the area and the fact that these nuclei of lynx were established following a soft release process, where many individuals had contact with deer grazing outside of their fenced enclosures, potentially noticing them as a potential food source. One individual lynx was observed hunting a fallow deer every 10 days (P. Sarmento, pers. comm. 2024). Most of the prey taken are juveniles, but adult females were also taken. Furthermore, Iberian lynx is also able to eat ungulate carrion. Elsewhere in Iberia, diet of the Iberian lynx has also been shown to include wild ungulates (Beltran Gala et al., 1985, Delibes, 1980) but with lesser frequencies of occurrence.

Therefore, high densities of wild ungulates can lead to more variety in the Iberian lynx diet, with the main potential benefit of being an alternative food source when rabbit availability is lower. Availability of wild ungulates can also reduce predation on domestic livestock, which while apparently rare, has been documented both in Portugal and Spain (Garrote et al 2013, Severino 2022).

2.2. Habitat restoration

Habitat quality is a determinant factor for recovering wildlife populations. In the case of wild ungulates, refuge areas, food and water sources are all key habitat components (Storms et al 2008, Torres et al. 2016, Wallach et al. 2007). The natural recovery of these habitat components can be assisted and accelerated through active restoration actions in ecologically degraded landscapes. Planning such interventions should be carefully done taking into account potential benefits and impacts, land ownership and use, and applicable laws and regulations. All relevant stakeholders involved in land management and local communities should be involved and informed during the process to ensure its long-term success.

During LIFE WolFlux extensive habitat restoration actions were carried out in central Portugal, namely in Guarda district and northern Viseu district. These actions were focused mainly on roe deer and to a lesser extent red deer, a species which is absent and distant from most of the intervention areas. Regarding other wild ungulates, wild boar is widespread throughout the landscape, and others such as Iberian Ibex are regionally extinct. Habitat restoration actions in the LIFE LUPI LYNX project will follow this template, building on the knowledge and experience obtained during LIFE WolFlux. The next sub-sections briefly explain methods for key habitat restoration actions for deer. Note that the provided information should not be seen as a detailed guide and many context specific factors can determine the best approach for habitat restoration in different landscapes.

2.2.1. Water sources

In Mediterranean ecosystems water sources are often an important factor that can influence distribution and densities of wildlife, including deer (Wallach et al. 2007). In drier landscapes aquatic habitats can be scarce and not be available throughout the year. Many water features, both lotic and lentic, have also been degraded due to human influence, including drainage, pollution, overexploitation of water, and artificialization of margins reducing accessibility to wildlife. Regular and intense fires can also lead to oversilting due to increased soil erosion in slopes, and lack of herbivory in the landscape can result in pond banks becoming inaccessible to large animals due to overgrown thorny vegetation such as brambles. Additionally, climate change is expected to continue to decrease water availability.

Restoring existing ponds or creating new ones in sites with suitable conditions can have a positive effect on recovering deer populations. Knowledge of the landscape is essential to select areas and the type of interventions. Topography and presence of wetland vegetation, such as willows and rushes can be used to identify damper areas, and knowledge for local people familiar with the terrain and its history (ex: shepherds and hunters) can be very valuable.

Any intervention on existing ponds should be done at the end of summer, just before the rainy season. Drier soil or lower water levels make digging work easier, and potential impacts on groups such as aquatic invertebrates, amphibians and nesting birds are lower. Ponds can be dug with heavy machinery or manually. Using machinery makes it possible to create bigger ponds and is much quicker. However, costs and potential impacts on surrounding areas can be higher. Using an excavator instead of a digger is usually preferable, as the former's mobility can result in more precise work and less surrounding impact. Digging with hand tools such as pickaxes, hoes and shovels is limited to smaller ponds, is much more time consuming and requires the work of more people. However, this can be a good option for volunteering activities, reducing costs and creating engagement, and to work with less impact on already existing aquatic habitats where the restoration might require only some softening of the profile, desilting, or removal of blocking vegetation such as brambles with manual tools or motorized scrub cutters.

When digging to create a new pond, expand or soften the banks of an existing one, the resulting profile, size and depth will depend on the conditions of the soil and other natural or human related constraints, for example topography and presence of paths. The slope of the margins should be kept as soft as possible (less than 35º in the majority of the pond) to allow easy access to wildlife, reduce erosion and facilitate the establishment of wetland vegetation (Figure 1). Having a deeper central part facilitates water retention during drier periods of the year. It is common to dig an efficient, approximately circular pond with a vertical profile resembling a "soup plate", however more irregular wiggly shapes (or presence of small islands in larger ponds) can also provide interesting microhabitats for other biodiversity.

Nevertheless, unnecessary soil and machine movements and other sources of impact should be avoided as much as possible. Particular attention should be given to preserving existing trees, less abundant shrubs and other sensitive vegetation in the surroundings of each pond. If possible, considering the natural capacities of the site to accumulate water, it's recommended not to use artificial impermeabilization. Besides saving costs, this allows the pond to naturalize quicker and creates less disturbance. It might also result in a temporary hydroperiod at some ponds, which can be beneficial to biodiversity associated with these types of habitats but will result in less water availability throughout the year. If artificial impermeabilization is considered necessary to sustain permanent ponds we recommend the use of clay, as it provides more natural conditions compared to other materials such as plastic liners or concrete.


Figure 1 - Ponds created in LIFE WolFlux,after a recent excavation (left) and after one year post earthworks (right). Note the soft profile of the margins, and preservation of existing trees. Photo credits: André Couto

2.2.2. Selective bush clearing

In landscapes dominated by homogenous scrubland vegetation, caused by the effects of regular fires or lack of herbivory, selective bush clearing can be an important habitat restoration measure. Mechanical cutting of dominant and easily flammable shrubs, such as brooms (ex: *Cytisus sp*) or brambles *(Rubus sp.)* can significantly lower available fuel in case of fire and thus limit the impact on regenerating forest and the seed bank (Figure 2). It can also increase feeding habitats, in the form of grasslands, for deer and other herbivores. However, excessive clearing, especially if no scrubland patches are preserved and slower growing woody plants are also removed can have detrimental effects by reducing shelter for deer and potential food sources, such as young shoots, leaves and fruits. Additionally selective bush clearing with manual scrub cutters or heavy machinery such as tractors can be a costly action to implement over large areas and its effects can be short-lived due to the rapid regrowth of this type of vegetation. Therefore, this type of actions is best employed in the following types of scenarios:

1. Reducing shrub density in areas with high native forest regeneration, to reduce tree mortality in case of fire, and to reduce competition for light and nutrients for young saplings.
2. Clear patches of land for active reforestation actions (further explored in next points).
3. Establishing areas of grassland to be maintained by wild herbivores and potentially domestic livestock (such as roaming sheep flocks). This can be achieved by either allowing already existing grasses and other small plants to flourish once shrubs are cut, or by actively seeding biodiverse pastures after bush clearing (further explored in next points).

Selective removal of vegetation can also be applied to areas where invasive plants are present and pose risks for native habitats. In such situations the control or eradication methods for those species should be followed, as mechanical cutting is often not suitable and follow-up actions can be necessary[1].

[1]Examples of adequate protocols for many invasive species in Iberia can be found in: https://invasoras.pt/pt/metodos-de-controlo
https://www.miteco.gob.es/es/biodiversidad/temas/conservacion-de-especies/especies-exoticas-invasoras/ce-eei-estrategia-planes.html
https://www.miteco.gob.es/en/biodiversidad/temas/conservacion-de-especies/especies-exoticas-invasoras/ce_eei_flora.html

Figure 2 - Scrub clearing area made in LIFE WolFlux, maintaining tree regeneration and scrubland patches. Photo credits: André Couto

2.2.3. Reforestation

In landscapes where mature native forests are not present and where the seed bank has been depleted, both in terms of abundance and species diversity, active reforestation can be an important habitat restoration action, although its effects will only take place after several years (likely >5 years even in high vegetation productivity conditions). In other conditions, allowing natural regeneration of woodlands can be the most effective way of restoration.

Native tree species selection should take into account ecological requirements and other factors that can affect suitability for each site, which include soil type, exposure, temperature ranges and humidity. In sites where no forest stands exist or are in very low numbers, the focus for reforestation should be on species with pioneering capacities and/or species that make up the dominant forest typical of the surrounding landscape. In sites where some forest already exists but has low diversity due to past human activities or severe fires, a higher diversity of species can be considered that include trees or bushes typical from later succession stages that can increase the quality of refuge habitat and food sources.

For the mesomediterranean and termomediterranean landscapes of the project area, the adequate season for reforestation usually goes from November to February, but there can be exceptions depending on specific environmental conditions (ex: high altitude or very dry landscapes, years with atypical temperature and rain patterns). Reforestation can be done either by seeding or using young plants (normally around 1 year old). In areas of dense scrubland, reforestation usually requires previous bush clearing.

For planting, a hole should be dug with manual tools or a motorized drill that fits the whole root system of the plant both in length and width, and the base of the stem should be covered in approximately 3 cm of soil and have a cup shaped pit around it to increase water retention. If the soil is very compact it's recommended to dig a deeper and wider hole, and then place some of the loose soil back in, which will facilitate root growth. Once the tree is planted, step around the base to lightly tighten the soil and then pull lightly on the stem to make sure it is adequately snugged in.

When using seeds, follow specific procedures for each species, as seed size, seeding depth and other factors are highly variable. For instance, some seeds require previous treatment to germinate at an adequate rate, such as exposure to acidity to partially break down the outer layer as it would happen in a bird's digestive system.

Tree spacing on plantation can vary depending on the species or restraints of the site, such as presence of rocks, paths or other obstacles. A common spacing length for most trees is around 5 m., but trees can also be planted at random distances to better mimic natural regeneration forest. When using seeds, the spacing is also species dependent, but usually much shorter, expecting that part of the seeds will not germinate or survive to get to the same size as one year old plants.

For the recovery of seed banks, the size of plantations can be small, patches of woodland of 1-2 hectares can be enough to act as islands of diversity from which seeds can spread through wildlife or abiotic factors to the surrounding landscape. Increasing the diversity of species and restoring communities of species should be prioritized, choosing suitable native species to create diverse woodlands, promoting particularly the ones that have disappeared from the landscape due to human pressure and that will take longer to come back on their own. Examples of species that are part of the community of Pyrenean oak, cork oak and holm oak woodlands present in the project area include *Malus sylvestrys, Frangula alnus, Sorbus latifolia, Sorbus torminalis, Betula celtiberica, Prunus mahaleb, Pyrus bourgeana, Acer monspesulanum, Celtis australis, Olea europaea subsp. sylvestris* and *Quercus faginea.* These correspond to the communities described for priority habitats 9230 and 9340. Plantations can be accompanied by shrubs like *Crataegus monogyna* or *Pistacia sp.* that often are also depleted of seed banks in areas of high fire frequency where *Cytissus sp*. and *Cistus sp*. dominate and simplify the landscape.

In drier soils it’s frequent to water the plantation site during the summer if resources are available. Usually this is only done for the first one or two years. Besides abiotic factors, young plantations can also be affected by wildlife. In areas where wild boar is common, seed patches can be revolved and eaten, and young plants can be uprooted to chew on the root system. Young trees come from the nursery with rich and nutritious soil around the roots, which boars can smell and find appealing. For this reason, it is also not recommended to use any kind of fertilizer when planting or seeding in areas where boar is present. Deer can also eat all leaves of young trees and kill them, but if deer are present in high enough numbers to have a significant impact, habitat restoration to promote their presence is likely not needed. Rabbits and rodents can also have an impact by chewing the base of the plants. Rodents, much like boar, will have a bigger impact on seeding areas, which can also be affected by birds. Finally, if present, domestic livestock can probably have a bigger impact than any wildlife due to their higher numbers, therefore it is important to factor their presence and potential impact when selecting intervention sites.

To avoid damage by animals, temporary protection can be placed in the form of electric or metallic fences or individual tree protectors. These measures can be costly and time consuming to employ, and their effectiveness varies depending on materials and the animals that are present. It is also important to remove them once the plants are big enough, as they can constraint plant growth and have environmental impacts on the landscape.

2.2.4. Grassland seeding

Grassland areas are important feeding habitat for deer (Storms et al. 2008). In most landscapes grasslands are maintained either by the action of wild or domestic herbivores, or by mechanical intervention by people. In areas without enough herbivore pressure or where land abandonment has taken place, open habitats quickly become encroached with shrub vegetation. Over time this will lead to decreased diversity of herbaceous plants, and simple bush clearing actions might not be sufficient to restore diverse meadows, as the available seed bank no longer contains many species.

Active native grassland seeding can be a relevant action when it’s expected that this type of habitat will be maintained by herbivores. These can be either recovering wild populations or low intensity domestic livestock, considering that overgrazing will also lead to impoverished meadows and nullify the benefits of this action. As with reforestation, the seeds used should take into account the species typical from that region and ecological requirements.

Grassland seeding in Iberia is usually done in early autumn. The soil is lightly prepared with a tractor equipped with a disk arrow, and the seeds are spread manually or with specialized equipment. Once the seeds are on the ground any further soil intervention should be very light, as many grassland seeds will not germinate if they are buried too deep.

During the first year of the new grassland, it's ideal to have no intense herbivory, to allow a large quantity of seeds to be produced. Temporary electric or metallic fences can be installed during this period. Afterwards, if domestic livestock is present, grazing should not happen in spring and before seeds are released, in order to renew the seed bank.

Among the native species to choose for the pastures, some that are readily available in suppliers and typical of dry grasslands of the project area include *Trifolum subterraneum*, *Trifolum hirtum*, *Trifolium arvense*, *Ortithopus sp.*, *Vicia sp.*, *Lupinus sp.*, *Avena barbata*, *Festuca sp*. and, *Bromus sp*. and *Lolium sp*. For more humid areas *Dactylis glomerata*, *Medicago sp*. And *Trifolium repens* adapt well and are very palatable for wildlife.

2.3. Population restoration (reinforcements and translocations)

In some parts of the project area, native wild ungulates have become locally extinct or are only present in low densities that prevent these species to fulfil their ecological functions and threaten the long-term survival of their populations. In some regions, natural expansion from surrounding populations may not be possible due to ecological or social barriers, or issues such as lack of wild prey for predators or lack of herbivory in the landscape might require active reintroduction or population reinforcement. In Iberia, several ungulate reintroductions have been carried out since the beginning of the 20th century, and those have been a major factor in the recovery and current distributions of native wild ungulates, including roe deer, red deer, and Iberian ibex (Galarza et al. 2015, Fonseca et al. 2017, Torres et al. 2016, Valente et al. 2017).

Planning a reintroduction or population reinforcement involves a detailed knowledge of the environmental, social and economic reality of the territory. In order to increase the probability of success of the initiative, the guidelines for reintroductions of the International Union for the Conservation of Nature (IUCN/SSC, 2013) (Figure 3) should be followed, which, despite not being a legal imposition, are valuable tools to increase the success of such processes.

As is the case with other wildlife, an ungulate translocation feasibility study must consider not only ecological factors, such as habitat suitability, but also social factors such as human activities in the landscape, including agriculture and game management, to avoid potential conflicts. Early engagement with relevant stakeholders can be crucial for the long-term success of the population. Wild ungulates in particular can be subject to game management practices, and also have a higher risk of being affected by poaching or being disturbed by hunting activities targeting other species, making entities that are involved in hunting, as practitioners or regulators, highly relevant stakeholders. The planning of the reintroduction or reinforcement project should also take into account potential impacts that an ungulate can have on economic activities and the local communities, for example, in the form of crop damage by herbivory. As such it is recommended that the project's budget includes the potential implementation of damage prevention measures, such as crop fencing or wildlife deterrents, and/or compensation for damages. The potential socioeconomic and ecological benefits of the species return should also be assessed and divulged to the stakeholders and general public.

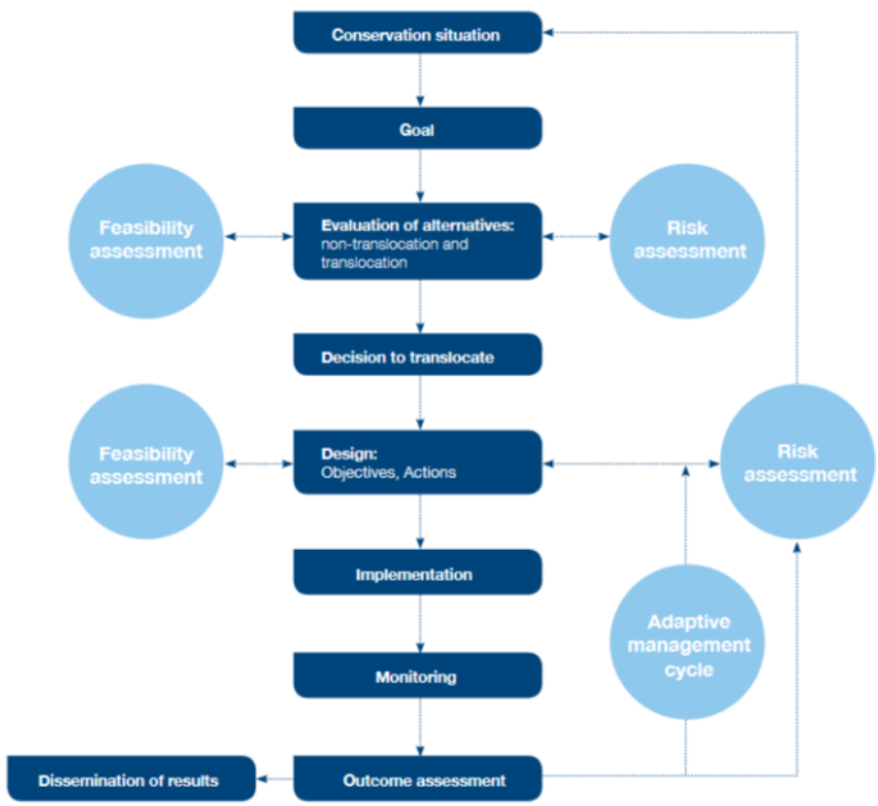

Figure 3 - The conservation translocation cycle. Source: (IUCN/SSC, 2013)

Source populations should be identified and selected according to relevant genetic, health and population structure parameters. All wildlife handling, transport and release is subject to numerous national and international laws and regulations which vary depending on species and country.

Individuals can be subject to a "hard release", being introduced into the landscape directly after transport, or "soft release" which usually involves a temporary stay in acclimation fenced areas at or near the release site. After release, monitoring of the reintroduction process usually involves telemetry, such as the use of GPS tracking collars which have been fitted in part of or all of the animals, and provide regular timed individual locations and possibly other parameters such as body temperature and heart rate. Other less direct or complementary methods can be employed such as camera trapping and sign surveys. Species reintroductions or population reinforcements are often structured in several release events spread out through time, which allows for adaptive management based on lessons learned after the first release.

3. EUROPEAN RABBIT AND RED-LEGGED PARTRIDGE

3.1. Functional densities for Iberian lynx

While Iberian lynx can feed on other animals such as red legged partridge and ungulates, they are highly specialized in rabbits and depend on it for their reproduction success (P. Sarmento, pers. comm. 2024, Simón et al., 2008). Vagrant individuals can sustain themselves with densities as low as 0 to 2 rabbits per hectare, but in order to reproduce successfully, females need territories with 4.5 – 10 rabbits/ha (Sarmento et.al, 2004).

3.2. Habitat restoration (food and shelter)

Rabbits and partridges need mosaic habitats with grasslands and shrubland and will benefit from most of the techniques described in section 2.1, except for 2.2.3 as rabbits do not use forest habitats.

Increasing quantity and quality of grassland to serve as feeding grounds is essential for this species, bush clearing should be made uneven, with irregular contours to minimize the distance from feeding areas to shelter (Figure 4), increasing rabbit survival and willingness to forage. Shrubland cover should be about 50% of the area.

Grasslands can be fertilized (ideally with natural components such as manure without traces of livestock medicine) depending on existing quality of plants and soil. To further increase shelter and reproductive success and to encourage rabbit expansion within a landscape it is vital to build a network of artificial rabbit burrows in ecotones (transition zones between shelter and food, i.e. shrubland and grassland) while avoiding North and Northeast facing slopes (Godinho et al., 2013). Areas with tall and thick shrubs should be prioritized as it has been shown to provide as much security against predation as metal fencing. Burrows must not be in potential flooding areas as flooding is an important cause of mortality in kits. At least 7 burrows of per hectare should be built, less than 150m. from water and food sources and spaced no more than 100 m from each other and 300-500m from existing wild rabbit colonies (if they are present) (Agudín. et al., 2011, Godinho et al., 2013, Soria et al., 2024).

Artificial burrows must be constructed in such a way that ensures total darkness, protection against temperature swings and impermeability. This can be achieved with thick walls covered by large amounts of dirt. The internal structure should be large and as complex as possible, with several chambers, entrances and connection tunnels. Recommended area is 10-40 m^2. This size and complexity will safely harbour more litters of rabbits and avoid single dominant females from controlling the entire burrow.

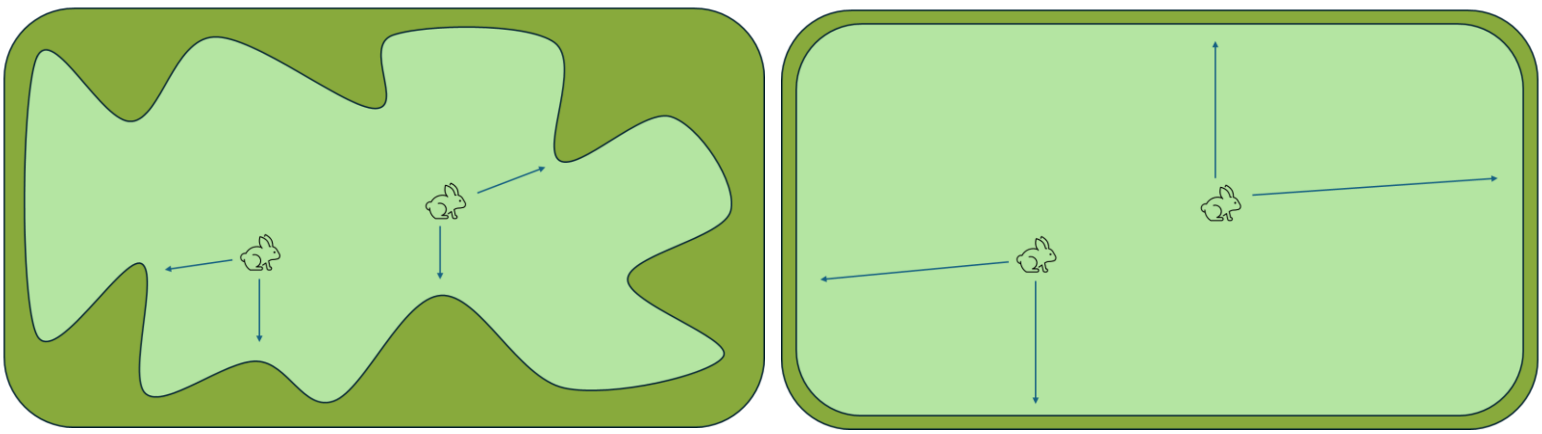

Figure 4 - Differences between correct (left) and incorrect (right) debushing techniques for rabbits. Dark green - shelter (shrubs); light green – food (grasslands); arrows - closest escape path from predators. Area size and rabbit position is the same between images.

To avoid predation inside the burrows, entrances should measure 7-10 cm wide and the internal tunnels should have several tight turns (Agudín. et al., 2011). There are countless methods and styles of artificial burrows but all of them must follow the aforementioned guidelines (Mariana Fernández-Olalla et al., 2010).

When soil is loose and sandy, underground chambers and tunnels can be dug directly on the ground or special concrete pieces that mimic natural burrows can be assembled and buried.

In rocky or hard soil, artificial burrows can be built above ground. Wooden pallets, tree stumps, concrete tunnels, rocks and more, can all serve as rabbit burrows as long as they are well covered by a thick layer of dirt (Mariana Fernández-Olalla et al., 2010) (Figure 5 and Figure 6).

As a complement to burrows which serve as reproduction sites, shelters can also be made available by simply piling together large amounts of branches, twigs or bushes (Figure 7).

Figure 5 - Several types of artificial warrens their building process. Photo credits: CBD habitat and Noctula

Figure 6 - Several types of artificial warrens their building process. Photo credits:CBD habitat and Noctula

Figure 7 - Artificial rabbit shelter made from tree branches. Photo credits:CBD habitat

3.3. Rabbit population restoration (reinforcements and reintroductions)

Rabbit reinforcements and reintroductions are common practice in conservation and hunting management, they are used to quickly boost population numbers but usually require constant releases of animals. Population restoration alone does not guarantee a sustainable increase in individuals and there are mixed results when releasing animals. Mortality is high and reproduction is usually low and new populations cannot maintain themselves. It is extremely important to focus on the techniques described in section 3.2 before deciding to release animals.

Extreme care must be taken when deciding whether to introduce rabbits to a landscape. It is ill advised to introduce new animals to an existing population (reinforcement) as described by Ruiz-Aizpurua & Tortosa (2018) but also because they may carry new disease strains the local rabbits have not been exposed to, increasing their risk of mortality.

When doing reinforcements, one should test the new animals for diseases, strain immunities and genetic traits, in order to introduce the most similar animals to the ones present. The easiest way to achieve this is to source animals from local wild rabbits or local breeders (if their reproduction stock originated from local wild rabbits) (San Miguel, 2014.).

In rabbit reintroductions, similar care should be taken regarding genetic variability and immunity to diseases. When starting a new population, it is of utmost importance to guarantee a high genetic variability to decrease inbreeding which leads to problems with reproduction and fitness. New populations should have targeted releases in later years to continue increasing genetic variability. This variability not only produces a healthier population, but it protects it from total collapse when faced with diseases, as the chance of some rabbits being immune is higher.

When possible, soft releases ought to be chosen over hard releases, this will fixate the rabbits to the new burrow and prevent them from running away in the first few days which would lead to their death. In reintroductions, special attention must be given to the protection of release sites from predators, particularly from terrestrial mesocarnivores. Rabbits must be given the chance to adapt to their new surroundings with low predation risk (San Miguel, 2014.). The soft release fencing can be adapted for this, a C shaped fence (at least 1.5 m. tall) will prevent predators from digging/jumping into the enclosure but allow rabbits to dig out of it naturally (Figure 8). This type of fence is also easier and faster to build than others that require burying parts of the fence. Metal/electric fencing can be used to surround the burrows until the end of the first reproduction cycle after the release, before being removed.

For each artificial burrow 3 males and 7 females should be released, depending on the size of the burrow.

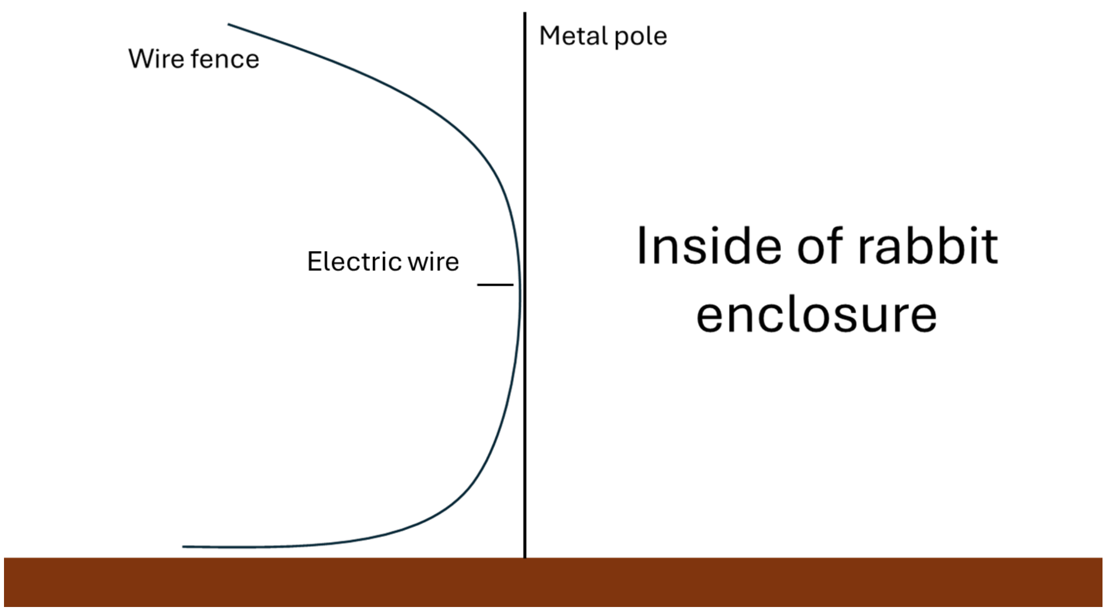

Figure 8 - "C" shaped fence for rabbit enclosures

3.4. Dealing with rabbit diseases

As discussed in the previous sections, diseases are one of the most important causes for local rabbit extinctions. Rabbit expansion in low density areas is also severely limited.

The goal with rabbit conservation should be to improve fitness (by increasing genetic diversity) and encourage immunity to the most severe diseases like Myxomatosis and RHD, allowing larger populations to thrive without major disease outbreaks. Immunity to these diseases has been shown to be polygenetic and population dependent, having high genetic diversity is necessary to have rabbit populations with higher chances of developing resistance over the generations (Alves et al., 2019).

Several vaccinations are available and all rabbits that are introduced into a landscape that don't already have natural immunity should be vaccinated (Alda et al., 2006). Individuals that show natural immunity to any of the diseases mentioned above should be used in reproduction programs and the offspring used for releases (the latter should always be preferential to vaccinations).

It seems that the way to avoid constant reinforcements to keep populations viable, is by reintroducing or reinforcing with high population densities, high genetic diversity and natural immunity to several types of diseases, while making sure the rabbits used are sourced as locally as possible.

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